New York Supreme Court
Appellate Division – Second Department

Docket No. 2021-01543

In the Matter of the Application of

DEBORAH KOPALD,
Petitioner-Appellant

For a Judgment pursuant to Article 78

-against-

THE TOWN OF HIGHLANDS, NEW YORK,
THE NEW YORK POWER AUTHORITY
Respondents-Respondents

ORANGE AND ROCKLAND UTILITIES, INC.
Respondent

RECORD ON APPEAL VOL. 1 of 2 (Pages 1-809)

Deborah Kopald
Petitioner-Appellant pro se
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Orange County Clerk's Index No. EF004088-2020

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New York Supreme Court
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In the Matter of the Application of

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THE NEW YORK POWER AUTHORITY,
Respondents-Respondents

ORANGE AND ROCKLAND UTILITIES, INC.,
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Statement Pursuant to CPLR section § 5531

1. The index number of this case in the court below is EF004088-2020. The Docket number of this case is 2021-01543
2. The full names of the original parties to this special proceeding are set forth in the caption above. There has been no change.
3. This special proceeding was commenced in Supreme Court, Orange County.
4. This special proceeding was initiated by the filing of a Petition and Notice of Petition on July 31, 2020. Respondents-Respondents, THE TOWN OF HIGHLANDS, NEW YORK and ORANGE answered around September 29, 2020 AND THE NEW YORK POWER AUTHORITY answered on or about October 2, 2020. ORANGE AND ROCKLAND UTILITIES, INC. never answered the petition.
5. This special proceeding was filed to overturn a Type II designation for the purchase of light fixtures. The decision and order denying same was entered on or about January 26, 2021
6. This appeal is made on a full record.

SUPREME COURT OF THE STATE OF NEW YORK
ORANGE COUNTY

Index No: EF004088-2020

---X

In the Matter of the Application of Deborah Kopald,
Petitioner

For a Judgment pursuant to CPLR Article 78

NOTICE OF APPEAL

-against-

The Town of Highlands New York,
Orange and Rockland Utilities, Inc.,
The New York Power Authority
Respondents

---X

PLEASE TAKE NOTICE, that the Petitioner Deborah Kopald hereby appeals to the Appellate Division of the Supreme Court of the State of New York, Second Department, at the Courthouse thereof located at 45 Monroe Place, Brooklyn, NY, 11201, from each and every part of the attached Decision and Order of the Honorable Maria S. Vazquez-Doles, J.S.C., of the Supreme Court of the State of New York, Orange County dated January 22, 2021 and entered in the Orange County Clerk's Office via NYSCEF on January 26, 2021.

Dated: February 26, 2020
Fort Montgomery, NY

Yours, Deborah Kopald
Deborah Kopald, Petitioner
P.O. Box 998
Fort Montgomery, NY 10922

To:

Michael Matsler
Counsel for the Town
Of Highlands
Rider, Weiner, Frankel
655 Little Britain Rd.
New Windsor, NY 12553

Justin Driscoll/Eileen Flynn
Counsel for The New York
Power Authority
NYPA
123 Main Street
White Plains, NY 10601

Grace Su
Counsel for Orange and
Rockland Utilities, Inc.
c/o Consolidated Edison Corp.
4 Irving Place
New York, NY10003

Supreme Court of the State of New York
Appellate Division: Second Judicial Department

Informational Statement (Pursuant to 22 NYCRR 1250.3 [a]) - Civil

Case Title: Set forth the title of the case as it appears on the summons, notice of petition or order to show cause by which the matter was or is to be commenced, or as amended.

In the Matter of the Application of Deborah Kopald, Petitioner
For a Judgment Pursuant to CPLR Article 78

- against -

The Town of Highlands, New York,
Orange and Rockland Utilities, Inc.
The New York Power Authority

For Court of Original Instance

Date Notice of Appeal Filed

For Appellate Division

Case Type

- ☐ Civil Action
- ☐ CPLR article 75 Arbitration
- ☐ Action Commenced under CPLR 214-g
- ■ CPLR article 78 Proceeding
- ☐ Special Proceeding Other
- ☐ Habeas Corpus Proceeding

Filing Type

- ☐ Appeal
- ☐ Original Proceedings
  - ☐ CPLR Article 78
  - ☐ Eminent Domain
  - ☐ Labor Law 220 or 220-b
  - ☐ Public Officers Law § 36
  - ☐ Real Property Tax Law § 1278
- ☐ Transferred Proceeding
  - ☐ CPLR Article 78
  - ☐ Executive Law § 298
- ☐ CPLR 5704 Review

Nature of Suit: Check up to three of the following categories which best reflect the nature of the case.

■ Administrative Review	☐ Business Relationships	☐ Commercial	☐ Contracts
☐ Declaratory Judgment	☐ Domestic Relations	☐ Election Law	☐ Estate Matters
☐ Family Court	☐ Mortgage Foreclosure	☐ Miscellaneous	☐ Prisoner Discipline & Parole
☐ Real Property (other than foreclosure)	☐ Statutory	☐ Taxation	☐ Torts

Appeal	
Paper Appealed From (Check one only):	If an appeal has been taken from more than one order or judgment by the filing of this notice of appeal, please indicate the below information for each such order or judgment appealed from on a separate sheet of paper.

☐ Amended Decree	☐ Determination	☐ Order	☐ Resettled Order
☐ Amended Judgement	☐ Finding	☐ Order & Judgment	☐ Ruling
☐ Amended Order	☐ Interlocutory Decree	☐ Partial Decree	☑ Other (specify): "Decision + Order"
☐ Decision	☐ Interlocutory Judgment	☐ Resettled Decree	
☐ Decree	☐ Judgment	☐ Resettled Judgment	

Court: Supreme Court	County: Orange
Dated: 01/22/2021	Entered: January 26, 2021
Judge (name in full): Maria S. Vazquez-Doles	Index No.: EF004088-2020
Stage: ☐ Interlocutory ■ Final ☐ Post-Final	Trial: ☐ Yes ■ No If Yes: ☐ Jury ☐ Non-Jury

Prior Unperfected Appeal and Related Case Information

Are any appeals arising in the same action or proceeding currently pending in the court? ☐ Yes ■ No
If Yes, please set forth the Appellate Division Case Number assigned to each such appeal.

Where appropriate, indicate whether there is any related action or proceeding now in any court of this or any other jurisdiction, and if so, the status of the case:

Original Proceeding

Commenced by: ☐ Order to Show Cause ☐ Notice of Petition ☐ Writ of Habeas Corpus	Date Filed:
Statute authorizing commencement of proceeding in the Appellate Division:	

Proceeding Transferred Pursuant to CPLR 7804(g)

Court: Choose Court	County: Choose County
Judge (name in full):	Order of Transfer Date:

CPLR 5704 Review of Ex Parte Order:

Court: Choose Court	County: Choose County
Judge (name in full):	Dated:

Description of Appeal, Proceeding or Application and Statement of Issues

Description: If an appeal, briefly describe the paper appealed from. If the appeal is from an order, specify the relief requested and whether the motion was granted or denied. If an original proceeding commenced in this court or transferred pursuant to CPLR 7804(g), briefly describe the object of proceeding. If an application under CPLR 5704, briefly describe the nature of the ex parte order to be reviewed.

This is one "Decision and Order" that disposed of two different motions (the Order to Show Cause and a Discovery Motion as well as the Petition.)

Issues: Specify the issues proposed to be raised on the appeal, proceeding, or application for CPLR 5704 review, the grounds for reversal, or modification to be advanced and the specific relief sought on appeal.

The Court was wrong that I did not have standing and the harm was speculative; I explained how I was affected because I walk at night on illuminated and LED lights are irritating while the lights they are replacing are safe and not irritating. I clearly articulated the harm with scientific studies and statements by doctors.

Furthermore, the Court misapprehended a contract that had been previously signed; the Town of Highlands New York never had voted to approve LED lights previous to the contract I sought to overturn; they only voted to sign a contract to have NYPA engage in a non-binding consulting arrangement to provide them a list of lighting options. Even NYPA admitted that the contract was not a contract to purchase any specific lighting scheme and the minutes supported both mine and NYPA's contention.

At no point did any of the documents proferred show that the O&R contract I sought to overturn was something that the Town of Highlands had previously voted to approve or that NYPA had offered this option in its consulting arrangement to the Town (even if they had shown it to the Town it was not voted on at any time before my Statute of Limitations to bring this action expired).

Party Information

Instructions: Fill in the name of each party to the action or proceeding, one name per line. If this form is to be filed for an appeal, indicate the status of the party in the court of original instance and his, her, or its status in this court, if any. If this form is to be filed for a proceeding commenced in this court, fill in only the party's name and his, her, or its status in this court.

No.	Party Name	Original Status	Appellate Division Status
1	Deborah Kopald	Petitioner	Appellant
2	The Town of Highlands New York	Respondent	Respondent
3	Orange and Rockland Utilities, Inc.	Respondent	None
4	The New York Power Authority	Respondent	Respondent
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Attorney Information

Instructions: Fill in the names of the attorneys or firms for the respective parties. If this form is to be filed with the notice of petition or order to show cause by which a special proceeding is to be commenced in the Appellate Division, only the name of the attorney for the petitioner need be provided. In the event that a litigant represents herself or himself, the box marked "Pro Se" must be checked and the appropriate information for that litigant must be supplied in the spaces provided.

Attorney/Firm Name: Deborah Kopald			
Address: PO Box 998			
City: Fort Montgomery	State: New York	Zip: 10922	Telephone No: 845 446 9531
E-mail Address: Deborah_Kopald@ymail.com or Deborah_Kopald@post.harvard.edu			
Attorney Type: ☐ Retained ☐ Assigned ☐ Government ☒ Pro Se ☐ Pro Hac Vice			
Party or Parties Represented (set forth party number(s) from table above):1			
Attorney/Firm Name: Michael Matsler, Rider, Weiner, Frankel			
Address: 655 Little Britain Road			
City: New Windsor	State: New York	Zip: 12553	Telephone No: 12553
E-mail Address: mmatsler@riderweiner.com			
Attorney Type: ☒ Retained ☐ Assigned ☐ Government ☐ Pro Se ☐ Pro Hac Vice			
Party or Parties Represented (set forth party number(s) from table above):2			
Attorney/Firm Name: Justin Driscoll/Eileen Flynn, New York Power Authority			
Address: 123 Main Street			
City: White Plains	State: New York	Zip: 10601	Telephone No: (914) 681-6200
E-mail Address: justin.driscoll@nypa.gov			
Attorney Type: ☐ Retained ☒ Assigned ☐ Government ☐ Pro Se ☐ Pro Hac Vice			
Party or Parties Represented (set forth party number(s) from table above):4			
Attorney/Firm Name: Grace Su, Orange and Rockland Utilities, Inc.			
Address: 4 Irving Place			
City: New York	State: NY	Zip: 10003	Telephone No:
E-mail Address:			
Attorney Type: ☐ Retained ☒ Assigned ☐ Government ☐ Pro Se ☐ Pro Hac Vice			
Party or Parties Represented (set forth party number(s) from table above):3			
Attorney/Firm Name:			
Address:			
City:	State:	Zip:	Telephone No:
E-mail Address:			
Attorney Type: ☐ Retained ☐ Assigned ☐ Government ☐ Pro Se ☐ Pro Hac Vice			
Party or Parties Represented (set forth party number(s) from table above):			
Attorney/Firm Name:			
Address:			
City:	State:	Zip:	Telephone No:
E-mail Address:			
Attorney Type: ☐ Retained ☐ Assigned ☐ Government ☐ Pro Se ☐ Pro Hac Vice			
Party or Parties Represented (set forth party number(s) from table above):			

FILED: ORANGE COUNTY CLERK 01/26/2021 12:45 PM INDEX NO. EF004088-2020
NYSCEF DOC. NO. 138 RECEIVED NYSCEF: 01/26/2021

At a term of the IAS Part of the Supreme Court of the State of New York, held in and for the County of Orange, at 285 Main Street, Goshen, New York 10924 on the 22day of January, 2021.

SUPREME COURT OF THE STATE OF NEW YORK
COUNTY OF ORANGE
---X

To commence the statutory time for appeals as of right (CPLR 5513 [a]), you are advised to serve a copy of this order, with notice of entry, upon all parties.

In the Matter of the Application of:

DEBORAH KOPALD,

Petitioner,

For a Judgment Pursuant to Article 78 of the Civil Practice Law and Rules

-against-

THE TOWN OF HIGHLANDS NEW YORK, ORANGE AND ROCKLAND UTILITIES, INC., and THE NEW YORK POWER AUTHORITY,

Respondents.
---X

DECISION AND ORDER
Index No.: EF004088/2020
Motion Date: 11/03/20
Sequence No. 1&2

VAZQUEZ-DOLES, J.

The following papers numbered 1 to 16 were read on the application (Seq. #1) by pro-se petitioner, Deborah Kopald, brought by Notice of Petition/Order to Show Cause and Petition seeking a judgment: 1) to annul the Town of Highlands New York's ("the Town") contract to purchase existing street lighting fixtures from Orange and Rockland Utilities, Inc. ("O&R") and annul the Town Resolution of April 27, 2020 authorizing the purchase, 2) to overturn the Town's contract with the New York Power Authority ("NYPA") executed on September 24, 2019, to design and implement the Town's conversion of its street lighting to LED lighting, and 3) for a Temporary Restraining Order enjoining the defendants from taking any action in furtherance of the street-lighting project:

Filed in Orange County 01/26/2021 12:45:53 PM $0.00 Bk: 5140 Pg: 1089 Index: # EF004088-2020 Clerk: DK

Pro Se Notice of Petition/Order to Show Cause (Seq. #1)/ Verified Petition/ Exhibits 1-17/ Memo of Law	1 - 5
Verified Answer (Town of Highlands)/Exhibits A-E	6 - 7
Affirmation in Opposition (Matsler)/Supporting Affidavits	8 - 9
Verified Answer (NYPA)/Exhibits A-F	10 - 11
Affirmation in Opposition (Flynn)/Supporting Affidavits/Memo of Law	12 - 14
Reply Affidavit (Pro-se Petitioner)/Exhibits 18-23	15 - 16

Pro-se petitioner, Deborah Kopald, commenced this Article 78 to challenge the April 27, 2020 Resolution and the O&R Agreement of June 15, 2020 on the ground that the Town purportedly violated SEQRA in declaring the purchase of existing light fixtures to be a Type II action and therefore exempt from environmental review under SEQRA. Petitioner is also challenging the Town's decision to covert the street lighting to LED lamps, made on September 24, 2019. Both the Town of Highland and NYPA challenge Petitioner's standing to bring this Article 78 proceeding on the ground that she did not adequately allege and demonstrate a single injury-in-fact different in kind or degree from that which would inure to the public at large. Here, petitioner has failed to demonstrate that she has suffered an injury-in-fact distinct from the public at large *(see Tilcon New York Inc. v Town of New Windsor*, 172 AD3 942, 945 [2d Dept 2019]).

"Standing requirements 'are not mere pleading requirements but rather an indispensable part of the plaintiff's case' and therefore "each element must be supported in the same way as any other matter on which the plaintiff bears the burden of proof"" (*Matter of Save the Pine Bush, Inc. v Common Council of City of Albany*, 13 NY3d 297, 306 [2009], *quoting Lujan v Defenders of Wildlife*, 504 US 555, 561 [1992]; *see Society of Plastics Indus. v County of Suffolk*, 77 NY2d 761, 769 [1991]). Thus, "a court can act only when the rights of the party requesting relief are affected" and that party has "an actual legal stake in the matter being adjudicated" *(Society of Plastics Indus. v County of Suffolk*, 77 NY2d at 772; *see Matter of Save the Pine Bush, Inc. v Common Council of*

City of Albany, 13 NY3d at 304-305; *New York State Assn. of Nurse Anesthetists v Novello*, 2 NY3d 207, 211 [2004]).

Generally, to establish standing to challenge governmental action, a party must show that it will "suffer direct harm, injury that is in some way different from that of the public at large" (*Society of Plastics Indus. v County of Suffolk*, 77 NY2d at 774), and that "the in-fact injury of which it complains . . . falls within the 'zone of interests,' or concerns, sought to be promoted or protected by the statutory provision under which the agency has acted" (*Id.* at 773, *quoting Lujan v National Wildlife Federation*, 497 US 871, 883 [1990]; *see Matter of Colella v Board of Assessors of County of Nassau*, 95 NY2d 401, 409-410 [2000]; *Matter of Mobil Oil Corp. v Syracuse Indus. Dev. Agency*, 76 NY2d 428, 433 [1990]; *Matter of Sun-Brite Car Wash v Board of Zoning & Appeals of Town of N. Hempstead*, 69 NY2d 406, 413 [1987]). "Thus, a private citizen who does not show any special rights or interests in the matter in controversy, other than those common to all taxpayers and citizens, has no standing to sue." (*Diederich v Rockland County Police Chiefs' Assn.*, 33 AD3d 653, 654 [2d Dept 2006]) Indeed, even the fact that "an issue may be one of vital public concern does not entitle a party to standing." (*Society of Plastics Indus. v County of Suffolk*, 77 NY2d at 769 [internal quotation marks omitted])

In her Petition, the petitioner argues that the health of both humans and animals will be effected by continued exposure to blue light including increased cancer risk, unpleasant glare and intensity, and damaging effects on the eye's retina, sleep quality, hormones and the well-being of wildlife. Being in the habit of taking walks at night or having an electromagnetic sensitivity is not enough to establish standing. Furthermore, the petitioners' alleged environmentally related injuries are too speculative and conjectural to demonstrate an actual and specific injury-in-fact (*see Matter* *of Kindred v Monroe County*, 119 AD3d 1347, 1348 [4th Dept 2014]).

The basis of petitioner's complaint is respondents' noncompliance with SEQRA, and accordingly, the four-month Statute of Limitations applicable to allegations of SEQRA violations applies (*Matter of Save the Pine Bush v City of Albany*, 70 NY2d 193, 202-203 [1987]; CPLR 217). To determine when the statute was triggered, the Court must ascertain what actions petitioner seeks to review (*see, Matter of Monteiro v Town of Colonie*, 158 AD2d 246, 249 [3d Dept 1990]). Here, petitioner contends in their petition that the Town of Highlands violated SEQRA twice--when it entered into a contract with NYPA as of September 24, 2019 to install LED lights without any SEQRA review, and again when it resolved to enter into an Agreement with O&R to purchase street lighting facilities. The petitioner demands nullification of the separate actions taken by the Town on September 24, 2019 and April 27, 2020.

Clearly, petitioner is attacking the Town's decision to install LED lights which was made on September 24, 2019 when the Town and NYPA signed the contract which was ten months before she filed this Article 78 Petition. The Town's April 27, 2020 Resolution specifically allows the Town to enter into a contract with O&R to purchase street lighting facilities and nothing to do with LED lighting. Petitioner also seeks to challenge the propriety of NYPA's bid for the streetlight fixtures themselves in her fifth and sixth causes of action. As NYPA issued a Request of Proposal for the Furnishing and Delivering of Street light material for its Smart Street Lighting Program in 2017 and executed a contract in March and April 2018, petitioner's application is untimely.

The Petition also alleges that the respondents' determination of the project as a Type II action was arbitrary and capricious. Judicial review of an agency's determination is limited to ascertaining whether the action was illegal, arbitrary and capricious, or an abuse of discretion (*see* CPLR 7803[3];

Birch Tree Partners, LLC v Town of East Hampton, 78 AD3d 693 [2d Dept 2010]; *Matter of Brancato v. Zoning Bd. of Appeals of City of Yonkers*, N.Y., 30 A.D.3d 515, 515 [2d Dept 2006]; *Matter of 1215 N. Blvd., LLC v. Board of Zoning Appeals of Town of N. Hempstead*, 63 A.D.3d 1071, 1072 [2d Dept 2009]; *Matter of Conti v. Zoning Bd. of Appeals of Vil. of Ardsley*, 53 A.D.3d 545, 547 [2d Dept 2008]). "In applying the arbitrary and capricious standard, a court inquires whether the determination under review had a rational basis. Under this standard, a determination should not be disturbed unless the record shows that the agency's action was arbitrary, unreasonable, irrational or indicative of bad faith" (*Matter of Halperin v. City of New Rochelle*, 24 A.D.3d 768, 770 [2d Dept 2010] [internal quotation marks omitted]). Here, petitioner seeks to challenge the determination that the Town of Highland's Street Lighting Replacement Project and the purchase of existing light fixtures from O&R to be a Type II action exempt from environmental review under SEQRA.

The NYS Department of Environmental Conservation ("DEC") has specifically listed Type II actions in 6 NYCRR §617.5(c) and provides in pertinent part that replacement of a structure or facility, in kind, on the same site, including upgrading buildings to meet building, energy or fire codes or the purchase or sale of furnishings, equipment or supplies, including surplus government property, other than the following: land, radioactive material, pesticides herbicides or other hazardous material is not subject to environmental review (*see* 6 NYCRR §617.5 [c][1][2] & [31]).

In their opposition, NYPA submits the affidavit of Charles Hermann, Lead Project Engineer. Mr. Hermann oversees and manages NYPA's individual projects under its Smart Street Lighting Program which seeks to replace at least 500,000 streetlights with energy-efficient LED technology by 2025. The project is consistent with NYPA's thirty-year history in the replacement of inefficient light fixtures first with fluorescent lights and now, as technology has evolved, with LED lights. He states that NYPA has replaced inefficient streetlights under this Program with LED lights throughout New York State with no deleterious health effects.

The Town submits the affidavit of Supervisor, Mervin Livsey, who explains that the Board has a duty to the residents to explore ways to reduce energy consumption and to control, if not reduce, the costs of providing services including ways to reduce the cost of providing adequate road illumination with energy efficient and cost-effective LED lighting. To that end, the Town Board adopted the resolution referred to in the Petition to allow the Town to enter into a purchase agreement with O&R for 168 existing street lighting fixtures and equipment which is a Type II action pursuant to 6 NYCRR 617.5(c)(31) not subject to SEQRA review. The physical work for the project will consist of replacing existing fixtures and hardware and adding new pieces of equipment such as control boxes, wiring and LED lights. The conversion to LED lighting is an energy and cost-saving measure for the benefit of the public. Consequently, the determination that this project is a Type II action was not arbitrary and capricious.

To be entitled to a preliminary injunction, a movant must establish (1) a likelihood of success on the merits, (2) irreparable injury absent granting the preliminary injunction, and (3) a balancing of the equities in the movant's favor (*see 306 Rutledge, LLC v. City of New York*, 90 A.D.3d 1026, 1028 [2d Dept 2011]). The purpose of a preliminary injunction is to maintain the status quo and prevent the dissipation of property that could render a judgment ineffectual (*see Board of Mgrs. of the Britton Condominium v. C.H.P.Y. Realty Assoc.*, 101 A.D.3d 917, 918 [2d Dept 2012]; *Dixon v. Malouf*, 61 A.D.3d 630 [2d Dept 2009]). A movant must satisfy each requirement with "clear and convincing evidence" (*Apa Sec., Inc. v. Apa*, 37 A.D.3d 502, 503 [2d Dept 2007]). "The decision to grant or deny a preliminary injunction lies within the sound discretion of the Supreme Court" (*Arcamone–Makinano v. Britton Prop., Inc.*, 83 A.D.3d 623, 625 [2d Dept 2011]; *County of Suffolk v Givens*, 106 AD3d 943 [2d Dept 2013]).

Here, petitioner has failed to meet the high burden to warrant a preliminary injunction. As determined above, petitioner lacks standing, some of her claims are time-barred and the determinations she challenges were neither arbitrary nor capricious. Further, petitioner has not proven that she will suffer irreparable injury if the injunctive relief is withheld. Any further delay could result in a substantial cost increase for the Town.

In light of the above it is hereby,

ORDERED that the temporary restraining order (Mot. Seq. #1) dated August 24, 2020 is vacated; and it is further

ORDERED that the petition is dismissed; and it is further

ORDERED that in light of this decision, petitioner's discovery motion (Mot. Seq. #2) is denied as moot.

This decision constitutes the order of the Court.

ENTER

Dated: January 22nd , 2021
Goshen, New York

HON. MARIA S. VAZQUEZ-DOLES, J.S.C.

TO: Counsel of Record via NYSCEF

AFFIDAVIT OF SERVICE

STATE OF NEW YORK)
) SS:
COUNTY OF ORANGE)

I, Deborah Kopald. being duly sworn, deposes and states:

1. I am over the age of eighteen years.

2. That on the 26th day of February 2021, I caused to be served by email copies of the Notice of Appeal with Informational Statement and the Decision and Order of the Hon. Maria S. Vazquez Doles, J.S.C. entered on January 26, 2021 (Index Number EF004088-2020)

TO:

Grace Su, Attorney for Orange and Rockland Utilities, Inc.
sug@coned.com

John Carley, Attorney for Orange and Rockland Utilities, Inc.
Carleyj@coned.com

Justin Rider and Michael Matsler, Attorneys for the Town of Highlands, New York
mmatsler@riderweiner.com
jrider@riderweiner.com

Justin Driscoll, Eileen Flynn, and Michael McCarthy, Attorneys for the New York Power Authority
Justin.Driscoll@nypa.gov
Michael.McCarthy@nypa.gov
Eileen.Flynn@nypa.gov

Deborah Kopald

Sworn to before me this
26th day of February 2021

Notary Public

Notarization made pursuant to NY Governor's executive order 202.7, as extended.

Joseph Douglas Barics
Notary Public, State of NewYork
No. 02BA5034853
Qualified in Suffolk County
Commission Expires ~~October 17, 20~~ 3/3/23

SUPREME COURT OF THE STATE OF NEW YORK
ORANGE COUNTY

Index No: ____________

---X

In the Matter of the Application of Deborah Kopald,
Petitioner

For a Judgment pursuant to CPLR Article 78

NOTICE OF PETITION

-against-

Return Date: October 27, 2020

The Town of Highlands New York,
Orange and Rockland Utilities, Inc.,
The New York Power Authority
Respondents

---X

PLEASE TAKE NOTICE that this is an action and proceeding commenced pursuant to Article 78 and Article 30 of the Civil Practice Law and Rules (CPLR) and upon the annexed Petition, verified on the 27th day of July, 2020 an application will be made to the Supreme Court of the State of New York, County of Orange, at the County Courthouse located at 285 Main Street, Goshen NY 10924 on the 27th day of October 2020 at 9:15 in the forenoon or as soon thereafter as the parties can be heard for a judgment pursuant to CPLR §§ 7803(1), 7803(2), CPLR §§ 7803(3), CPLR §§ 7805 and CPLR §§ 7806 to annul, vacate and void

- A resolution ("the Resolution") dated April 27, 2020 of the Town of Highlands "to authorize the Town of Highlands to Enter into an Agreement for Purchase and Sale of Street Lighting Facilities with O&R
- The assertion by the Town of Highlands in the Resolution that the Street Lighting Agreement with Orange and Rockland Utilities, Inc. ("O&R") constitutes "a legislative action pertaining to routine or continuing agency administration and management, not including new programs or major reordering of priorities that may affect the environment, and accordingly is a Type II Action under the State Environmental Quality Review Act"; (that is to say I am asking the Court to declare that the project authorized by the Resolution does not constitute a so-called "Type II" action.
- Any contract related to the Resolution that was signed by the Town of Highlands and O&R since December 9, 2019 or whatever date is deemed four months ago plus the tolling from the Governor's Executive Orders ("the control date").
- Any contract and/or agreement that was signed between the Town of Highlands and the New York Power Authority ("NYPA") since the

control date related to and/or pertaining to the project described in the Resolution that operationalizes this project, that is to say, has to do with the financing of the project and/or the maintenance of the project

- Any contract and/or agreement related to the project described in the Resolution that was signed between NYPA and O&R since the control date.
- Any contract and/or agreement related to the Resolution that was signed by NYPA, O&R and the Town of Highlands") since the control date.

and to order

- the New York Power Authority to put out any future project from the Town of Highlands to competitive bidding that includes not just price considerations, but the color-temperature of the lights, specifically yellow-orange color temperature lights.
- Any other relief that the Honorable Court deems just and proper.

PLEASE TAKE FURTHER NOTICE that pursuant to CPLR §7804(c), Respondents' answer and supporting affidavits, if any, shall be served upon the Petitioner at least five (5) days prior to the return date of this matter.

Dated: July 27, 2020
Fort Montgomery, NY

Deborah Kopald
P.O. Box 998
Fort Montgomery, NY 10922
(845) 446-3768

Town of Highlands
Town Hall
254 Main Street
Highland Falls, NY 10928

Orange and Rockland Utilities
c/o Consolidated Edison Corp.
4 Irving Place,
New York, NY 10003

New York Power Authority
123 Main Street Mail Stop 10B
Corporate Communications
White Plains, NY 10601-3170

SUPREME COURT OF THE STATE OF NEW YORK
ORANGE COUNTY Index No: _____________
---X
In the Matter of the Application of Deborah Kopald,
Petitioner

For a Judgment pursuant to CPLR Article 78 PETITION

-against-

The Town of Highlands New York,
Orange and Rockland Utilities, Inc.,
The New York Power Authority
Respondents
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I, Deborah Kopald, the Petitioner, respectfully alleges to be true upon my own knowledge or upon information and belief as demonstrated by my verification and exhibits submitted with my Order to Show Cause affidavit herewith as follows:

PRELIMINARY STATEMENT

1. This is a petition for a special proceeding in Orange County Supreme Court pursuant to Article 78 of the Civil Practice Law and Rules (CPLR) to annul, vacate and void

- A resolution ("the Resolution") dated April 27, 2020 of the Town of Highlands "to authorize the Town of Highlands to Enter into an Agreement for Purchase and Sale of Street Lighting Facilities with O&R
- The assertion by the Town of Highlands in the Resolution that the Street Lighting Agreement with Orange and Rockland Utilities, Inc. ("O&R") constitutes "a legislative action pertaining to routine or continuing agency administration and management, not including new programs or major reordering of priorities that may affect the environment, and accordingly is a Type II Action under the State Environmental Quality Review Act"; (that is to say I am asking the Court to declare that the project authorized by the Resolution does not constitute a so-called "Type II" action.
- Any contract related to the Resolution that was signed by the Town of Highlands and O&R since December 9, 2019 or whatever date is deemed four months ago plus the tolling from the Governor's Executive Orders ("the control date").
- Any contract and/or agreement that was signed between the Town of Highlands and the New York Power Authority ("NYPA") since the control date related to and/or pertaining to the project described in the

Resolution that operationalizes this project, that is to say, has to do with the financing of the project and/or the maintenance of the project

- Any contract and/or agreement related to the project described in the Resolution that was signed between NYPA and O&R since the control date.
- Any contract and/or agreement related to the Resolution that was signed by NYPA, O&R and the Town of Highlands") since the control date.

In addition, I am asking for the following relief

- That the New York Power Authority be ordered to put out any future project from the Town of Highlands to competitive bidding that includes not just price considerations, but the color-temperature of the lights, specifically yellow-orange color temperature lights.

THE PARTIES

2. I, Deborah Kopald, am a taxpayer and resident of Fort Montgomery, N.Y. in the Town of Highlands who is challenging the Resolution and related contracts in this special proceeding. I am an independent environmental consultant with an undergraduate degree from Harvard College and a Master of Business Administration from the MIT Sloan School of Management. I circulated a petition for a few weeks in the summer of 2019 when the Town was discussing putting LED lights in the portion of the Town that comprises the census-designated place ("CDE") of Fort Montgomery, NY. (On information and belief there are 890 other registered voters in this CDE). Virtually everyone I approached signed my petition that requested the maintenance of Sodium Vapor/Mercury Vapor Lighting and if a switch to LED's was contemplated, to use an Orange color-temperature LED streetlight (such as is in use in Flagstaff AZ, as well as parts of Florida[1] and Yellowstone National Park), as opposed to the Blue-White color temperature LED lights that were then under consideration and effectively already decided upon as a *fait* accompli as evidenced by emails produced in response to Freedom of Information Law ("FOIL") requests. After I collected 110 petition signatures, I was effectively forced out of

[1] Florida has strict ordinances protecting nesting turtles with some jurisdictions mandating red color-temperature lights to protect these animals from light pollution so they are able to reproduce.

my home by a construction project that I assert was illegal and is the subject of another Article 78 in which the Town of Highlands was a Respondent[2]. This made it impossible for me to do any more work informing people of what is going on. My life was upended by the ongoing illegal project that is the subject of litigation in the Appellate Division, Second Department. From past experience, I know that people generally do not go to Town Board meetings, do not read the paper and do not know what is going on; they find out from the post office or when someone circulates a petition. This is a tiny Town that has a combination of people scraping by to make ends meet including people who live in the multiple trailer parks in the Town, many blue collar workers, many people with administrative jobs at West Point, people who commute to other Counties like Westchester as well as New Jersey and New York City who get home long after Town Board meetings, who could be described as "professionals", and one Fortune 500 family who spend some weekends in the Town.

3. The first Respondent, the Town of Highlands, is the municipality in question

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[2] The noise and diesel exhaust fumes from this project forced me out of my home. When I started to complain, I assert the Town started to retaliate against me in various ways resulting in a letter by noted civil rights attorney Michael H. Sussman on my behalf, an appearance by Mr. Sussman at a hearing and at a private meeting with Town officials and in a subsequent phone conversation with the Town Attorney. The Town note-ably retaliated by extending the time for construction by the other respondents in that special proceeding to 9 p.m. at night (the police used to enforce the building department recommendation of 6 p.m.). Noise is presumed to be harmful and there is no jurisdiction that allows construction noise in a residential area at night; this ordinance is likely to be overturned on a declaratory judgment. The point is I was subjected to a taking. Furthermore, given some personal environmental sensitivities, I can't work in most indoor environments, was dependent upon my home and had nowhere to go work. That said, I put all parties on notice in late May and early June that they proceeded at their own peril (Exhibit 13). This was after I received FOIL response documents from the Town showing how far this project had proceeded.

The point, is between the noise, the retaliation and harassment by the Respondents in that case, I have been made virtually homeless and office-less since last summer and had to stop collecting petition signatures. Virtually no one I had approached with my petition was aware that the Town was even contemplating a project; very few people go to Town Board meetings or apparently read the newspaper. **I assert it is therefore relevant that I was able to get 150 signatures or 17% of the registered voters in Fort Montgomery for the few days in July 2019 before I was forced to stop collecting signatures.**

It is open and notorious to at least two of the parties, the Town of Highlands and O&R that I allege electromagnetic sensitivities- so the implications of being forced out of my home/office for upwards of 14 hours a day was a particular problem because I could not find another place to work during the day that did not have Wi-Fi, something I must avoid due to this electromagnetic sensitivity. The noise problem is ongoing.

that passed the Resolution on April 27, 2020 to install Light Emitting Diode ("LED") Streetlights that appear to also have a wireless transmissibility component and declared the project to be a Type II action. The Town of Highlands Supervisor is Mervin Livsey, a/k/a Bob Livsey. The Streetlighting Project has been shepherded by Town Councilman Richard Sullivan, who on information and belief is a member of the Operating Engineer's Union and acknowledged in correspondence that he was employed by the third Respondent, NYPA while pushing the Street lighting project. (This correspondence was provided in an appeal of a Freedom of Information Law ("FOIL") request I made to NYPA. It was not provided by the Town of Highlands in response to substantially the same FOIL request. Mr. Sullivan's failure to provide me this information in response to FOIL was willful and done to cover up impropriety.

4. The second Respondent, Orange and Rockland Utilities, Inc. ("O&R") is the utility serving the Town of Highlands referenced in the Resolution which has, on information and belief, negotiated a contract with the Town of Highlands pursuant to the Resolution.

5. The third Respondent, the New York Power Authority ("NYPA") had previously signed agreements with the Town of Highlands to research LED light projects to present to the Town of Highlands for its consideration. On December 9, 2020, they emailed the Town of Highlands, NY that they were engaging in a kick-off of the project to discuss specifications.

JURISDICTION

6. The Court has subject matter jurisdiction over this matter and may exercise personal jurisdiction over the respondents. Pursuant to CPLR 506(b), venue is proper because the challenged determinations were made in Orange County. O&R has offices therein and the Town of Highlands is located therein. NYPA serves the entire state. The Resolution in Question was made on April 27, 2020. In addition, the statute of limitations was tolled on March 20, 2020 until July 6, 2020 by the Governor of the State of New York. Pursuant to the Governor's

Executive Orders and NY GEN CONSTR § 25-a, I assert that this application is timely made to cover all claims.

STATEMENT OF FACTS

7. Exhibit 5 includes correspondence to the News of the Highlands (local paper) and articles mentioning LED lights from 2015-2019 that I could find. Initially, the Village of Highland Falls which lies within the Town of Highlands and has a separate government, had discussed Light-Emitting Diode "LED" street lighting for a number of years before the Town did. Some of the earlier plans involved dimmable LED's lights and public Wi-Fi systems. The earlier correspondence regarding same speaks to these problematic aspects (including high-frequency transients which create line pollution and degrade power quality) as well as the inherent problems with the LED lights themselves[3]. The Town eventually discussed putting in LED streetlights.. My and other residents' letters, including Dr. Janet Wilkie, and Steven Walker, a new resident from Brooklyn are included in Exhibit 5. These letters include discussion of studies demonstrating disruption to sleep and circadian rhythms from the lights via depleted melatonin, which is also linked to breast cancer development, people complaining their neighborhood was lit up like a run-way by these too-bright, sharp, irritating lights, evidence of retinal toxicity, the hazmat situation created when the lights break, the fact that Davis, CA had to remove them after residents complained- having spent $350,000 to install them, (as well as the lights bleaching out the works of the great Masters in museums).

8. I gave a presentation in to the Town Board on June 24, 2019 (See Exhibit 2 for briefing book). In it I discussed some of the aforementioned topics as well as the issue of color-temperature. The current non-LED lights are either yellow color temperature sodium vapor

[3] It is not clear that the Town is pursuing these types of options, although I note that page 105 of Exhibit 11, which is a document presented at the December 9th "kick-off" meeting, "Smart Streetlighting NY" suggests they might be doing something like this.

lights or orange color-temperature mercury vapor lights. People often confuse the issue of color-temperature with brightness (which is measured in lumens); they are two different things. Lower color temperature lights block out more of the blue-white daylight frequencies which people are not naturally exposed to at night, and which are linked with the aforementioned sleep problems, melatonin depletion and cancer increases. I explained how Flagstaff, AZ, had opted for an orange color-temperature LED streetlights as well as the Federal Government in Yellowstone Park and showed examples of same (see photos at bottom of page 13 of the Briefing Book in Exhibit 5) as well as a particularly extreme blue-white light that had been installed in Eagle Valley Road in Highland Falls. (See discussion on pages 1-4 in the Briefing Book in Exhibit 5). In fact, it was Supervisor Bob Livsey's son, Mervin, who emailed me the photo, which can be seen on page 12 of the briefing book.

9. On pages 5 and 6 of the Briefing Book, I discussed the toxic substances in the LED lights; the Agency for Toxic Substances and Disease Registry ("ATSDR") speaks to the toxicity of nickel and copper that are present in high amounts in these lights, which create a hazmat situation when they break. I also cited to the French Agency for Food, Environmental, and Occupational Health and Safety ("ANSES") Reports on LED lights. With regard to the April 5, 2019 report, I wrote:

> The report cites the scientific evidence on the "phototoxic effects" of short-term exposures to high-intensity blue light, as well as an increased risk of age-related macular degeneration after chronic exposure. Age related macular degeneration causes vision loss in those over 50 by damaging a spot in the center of the retina.
> The press release for the report states:
>
> > .....the expert appraisal showed that even very low levels of exposure to blue light in the evening or at night disrupt biological rhythms and therefore sleep. ANSES stresses that the screens of computers, smartphones and tablets are major sources of blue-rich light, and children and adolescents, whose eyes do not fully filter blue light, are a particularly susceptible population.
>
> The Agency confirms the toxicity of blue light on the retina and highlights the biological

rhythm and sleep disruption associated with exposure to blue light in the evening or at night, particularly via screens and especially for children. The Agency therefore recommends limiting the use of LED devices with the highest blue-light content, especially for children, and reducing light pollution as much as possible to preserve the environment.

Their previous report on the topic was issued in 2010 and called "Lighting systems using light emitting diodes (LEDs): health issues to be considered"ıIt stated:

> The issues of most concern identified by the Agency concern the eye due to the toxic effect of blue light and the risk of glare… Blue light is…recognized as being harmful and dangerous for the retina, as a result of cellular oxidative stress

adding that the blue light necessary to obtain white LEDs causes "toxic stress" to the retina. Blue light causes a photochemical risk to the eye, says the report, the level of which depends on the accumulated dose of blue light to which the person has been exposed, which is generally the result of low-intensity exposure repeated over long periods. In other words, cumulative effect as well as intensity matter.

The report also indicated that three groups are particularly at risk; children, populations which are already light sensitive and workers likely to be exposed to high-intensity lighting. The report cited glare and pointed out that because the emission surfaces of LEDs are highly concentrated point sources, the luminance of each individual source can be 1000 times higher than the discomfort level. In particular, the report refers to the glare risk and says that previous lighting standards should not be adapted to systems using LEDs. Any systems should have optics and diffusers to avoid glare and are more appropriate for industrial settings, not residential ones.

(Footnotes omitted herein; See report for footnotes)

On page 8, I showed differences in plasma melatonin in the blood from night time versus day time and artificial night light.

10. On pages 9 and 10, I went on to cite other studies showing harm:

According to a 2015 Harvard Medical School ("HMS") advisory, night shift work and exposure to light at night are related to several types of cancer, diabetes, heart disease and obesity. The updated advisory it was based upon goes on to state the following:

> …while any kind of light can suppress the secretion of melatonin, blue light does so more powerfully
>
> Even dim light can interfere with a person's circadian rhythm and melatonin secretion. A mere eight lux—a level of brightness exceeded by most table lamps and about twice that of a night light—has an effect, notes Stephen Lockley, a Harvard sleep researcher.

> While light of any kind can suppress the secretion of melatonin, blue light at night does so more powerfully. Harvard researchers and their colleagues conducted an experiment comparing the effects of 6.5 hours of exposure to blue light to exposure to green light of comparable brightness. The blue light suppressed melatonin for about twice as long as the green light and shifted circadian rhythms by twice as much (3 hours vs. 1.5 hours)
>
> .

A 2017 study, "Outdoor Light at Night and Breast Cancer Incidence in the Nurses' Health Study II" conducted by researchers at the Harvard School of Public Health found that

> exposure to residential outdoor light at night may contribute to invasive breast cancer risk.

The Harvard nurses study came to the same type of conclusion as a 2009 study done in Israel which stated:

> …the analysis yielded an estimated 73% higher breast cancer incidence in the highest LAN [light at night] exposed communities compared to the lowest LAN exposed communities.

Another study, "Melatonin, environmental light and breast cancer" dating to that time from an international team of researchers including a doctor at Columbia University in New York, NY came to the same conclusion in regard to female shift workers who were exposed to light at night.

In addition to cancer risk, there is the risk of retinal toxicity. One recent study published in Spain in 2012 found that blue LED light can irreparably damage the cells in the eye's retina specifically the retinal pigment epithelial cells. The study comes to the disturbing conclusion that once damaged, the retina cannot be regenerated and thus LED light exposure can cause blindness.

In 2018, a group from the University of Toledo, Ohio found, as ANSES reported, that that LED light exposure can lead to macular degeneration. The authors recommend not using cell phones in the dark because LED blue light dilates pupils and causes the harmful blue light to enter the eyes, triggering the production of a toxic chemical that interacts with oxygen to kill photoreceptor cells.

Finally, a 2016 article, "Effects of blue light on the circadian system and eye physiology" speaks to the disruption to sleep and blue-light induced damage to the retina. The graph in this paper makes the point that lights can appear similar intensity to a person, but the LED will have much more of the dangerous blue-spectrum light in it….

(Footnotes omitted herein; See report in Exhbiit 5 for footnotes)

The referenced graph on the subsequent page (11) show that the blue-white LED lights have proportionately more of the dangerous wavelengths of the light spectrum than fluorescents and incandescents, which most mimic natural light. The next graph shows that circadian sensitivity (sensitivity of sleep rhythms) is most pronounced at these blue-white wavelengths.

11. In addition to findings by the American Medical Association (glare, sleep problems and other biological effects) and the International Agency for Research on Cancer (shift-work disrupts circadian rhythms, and such shifts, which are also accompanied by light during normal sleeping hours lead to an increase in cancer), I included letters written by New York practicing doctors on the topic of the dangers of blue-white light: one from an otolaryngologist, Joshua Rosenthal, MD and an optometrist, Joel N. Kestenbaum, OD, who directed his letter to the Nassau County legislature. Dr. Rosenbaum shows graphs of increased stress levels from exposure to artificial blue-white light. Dr. Kestenbaum writes:

> It is very important to note that although a lower color temperature (3000K and below) (see figure below) is better for glare, all LED street lamps emit a certain amount of HEV light. Most municipalities who have already installed LED street lamps have installed the higher color temperature lighting, a cheaper alternative but more glare producing and higher HEV exposing bluewhite light. Residents in these areas are up in arms. After public outcry, the city of Davis, CA spent hundreds of thousands of dollars installing warmer LED fixtures just a month after installing white LED lamps. Phoenix residents are also complaining and they are also considering retrofitting to a lower color temperature light. Locally, LED street lamp installations in NYC and Brooklyn are being seen as a disaster by residents. They feel as if there is a film crew outside their windows and the light is spilling into their homes, disrupting their lives. Most don't even realize that they are being exposed to additional HEV light that has potential to lead to health issues.
>
> ..... Based on current research and best practices for reducing light pollution, it is just a matter of time that lawsuits are filed for either installing the wrong LED lamps or improperly shielding them in public areas. Technology is wonderful but can also be dangerous. There needs to be a balance between public benefits, health concerns, and cost savings. With what I have learned in the past few years about health issues and LED exposure and from the complaints that patients reveal in my eye care practice, my vote is for public safety.

He also references a number of articles including "Are LED streetlights disrupting your sleep", "LED streetlights may contribute to serious health conditions, says AMA, prompting cities to re-evaluate" and "AMA report affirms human health impacts from LEDs." (See exhibits 2w, 2x and 2y).

12. As stated in the Parties section under my description of myself, I circulated a petition fewer than half a dozen times (see Exhibit 3) that was signed by 110 people (only 890 live in Fort Montgomery, where these lights were slated to go (the Town does not have jurisdiction over the lighting in the Village of Highland Falls, only in the CDE of Fort Montgomery). This petition reads:

TOWN OF HIGHLANDS STREETLIGHT PETITION

> Blue-white LED streetlights will not save very much money. Compared to the cost to health, and well-being they may wind up costing money. Humans and animals are not designed to be exposed to daylight frequencies at night.
>
> The town's lighting choices should be based on existing and emerging science about the negative effects of blue light on human health and the environment. This includes increased cancer risk, unpleasant glare and intensity, and damaging effects on the eye's retina, sleep quality, hormones and the well-being of wildlife.
>
> The town should maintain our yellow sodium lights and replace broken mercury lights with them as the town did before. The yellow sodium lights provide clear visibility in all weather without being too bright and cohtain no harmful daylight frequencies.
>
> Right now, when a light breaks, O&R replaces it with a blue-white LED light. Individuals should have the right to tell O&R they want the same yellow light if their streetlight breaks.
>
> Meanwhile, the Town should commit to investigating the less harmful orange-amber LED lights (less harmful than blue-white LED lights) as this technology improves over time. Then we can consider whether they are a better solution than the existing yellow sodium vapor lights.

As explained in the Parties Section, it was not possible for me to circulate any more petitions due to the noise nuisance from what I assert has been an ongoing illegal construction project that the Town allowed to go on (the Town also allowed the illegal constructors to work until 9 p.m. at night, something which is not allowed in any other jurisdiction, and appears to be retaliation for suing the Town for this project). But for these realities, I would have been continuing to get petition signatures. While my Zoning Board of Appeals ("ZBA") attorney, Rick Golden has assisted me with the ZBA, I do all of the litigation. Even with that time commitment, the noise has largely been the problem flushing me out of my home. The point is that when I was able to, and I explained what was going on to people, they overwhelmingly supported my petition; most had not known what was being proposed or about the color-temperature light issues. People approached me with comments such as "I can't stand the LED headlights on cars nowadays, they are too bright and irritate me at night" and "I work in New York City and the lights in Brooklyn and on the highways are like an airport runway" and "my across-the-way neighbor has an LED floodlight, and when forget to turn it off before they go to bed, it shines right into our bedroom and is really, really annoying" and "I have one of the O&R replacement lights outside my window and it is horrible".

13. Along the way, this project has been shepherded and evangelized by Town Board member Richard Sullivan who has stubbornly ignored people saying they do not want these lights. Going back to Exhibit 5, The article in the November 30, 2018 News of the Highlands states,

> Supervisor Bob Livsey added that he's not even completely sure that people in Fort Montgomery want the bright LED lights….they are significantly brighter than traditional street lights. "Maybe we like our "country roads" the way they are", the supervisor said.

Exhibit 6 shows email correspondence from July 22, 2019 from Town Attorney Justin Rider with a copy of an agreement that did not bind the Town to the a deal with the New York Power Authority, but that enabled them to look into purchasing options for the Town:

> Deborah, attached is the Master Agreement. It does not contain the particulars for moving forward on LED
> M. Justin Rider, Esq.

Exhibit 12 documents the Town's subsequent deception. When I filed a Freedom of Information Request to see if the Town had signed any contracts or was planning on voting on any at the September 23, 2019 meeting, I was told on September 18th that no such document existed. When I got the agenda on Friday September 20th at 4:45 p.m, nothing about the LED streetlighting scheme was listed. Shortly before the meeting on Monday September 23rd, an amended agenda was produced, and the Town voted to sign this contract which did not bind the Town to any purchase of lights. I can be heard at the beginning of the meeting asking during public comment (I was sitting in the back of the room off camera) trying to determine why the Town had committed a penal code violation (NY Penal Law section 10) by not honestly fulfilling my FOIL, and the Town attorney can be seen covering for the Supervisor- saying there had been some kind of error or misunderstanding: https://www.youtube.com/watch?v=lJJWVF-T2J0&t=660s. In fact, the correspondence from September 10th on the last page of Exhibit 15 showed that the Supervisor knew full well he was going to be voting on September 23rd on a document that would allow NYPA to look for LED solutions for the Town and intended to put it on the agenda. However, he gave the Clerk an agenda to give me the previous Friday without it and when I inquired 15 minutes before the Monday meeting if there were any changes to the agenda, the Deputy Clerk told me that there were changes and in fact the contract was added to the agenda.

14. Richard Sullivan, the board member shepherding this project had been plowing full steam ahead; later when I FOIL'ed more emails, he neglected to give me ones that the New York Power Authority ("NYPA") subsequently produced (and only after an Appeal by me to NYPA). (See Exhibit 11). Note-ably is one from Mr. Sullivan to Jeffrey Laino (of NYPA) stating the following:

> From: Richard Sullivan Sent: Friday, September 6, 2019 5:57 AM
> To: Laino, Jeffrey

> Subject: Re: [EXTERNAL]Town of Highlands_ES_MCRA_2019 between New York Power Authority , mERVIN R. LIVSEY and John Canale is Signed and Filed!
>
> *Hi Jeff, I'm swamped at work, a NYPA project in Yonkers actually*, I'll call today and get things worked out. thanks for patience, Richie Sent from my iPhone
>
> (Emphasis added)
>
> On Sep 4, 2019, at 4:15 PM, Laino, Jeffrey wrote:
>
> Hey Richie, I hope all is well, any news on getting the authorization to proceed signed? Regards, Jeff

(See page 306 of Exhibit 11). So, in other words, the Town was fully intending to proceed with signing an agreements to have NYPA look into the streetlighting. Also of note is the fact that Mr. Sullivan, who is, on information and belief, a member of the Operator's Engineer Union, was actually working for NYPA at the time. I assert that he has a conflict of interest pursuant to NY Gen Muni § 801. Even if he were to claim he does not financially benefit from the underlying contract, he is entitled to no exception, because he isn't merely voting on it, but had been actively evangelizing it, negotiating, preparing, authorizing, etc. as can be seen in the email chain in Exhibit 11 (again, page 306).

15. Meanwhile, in correspondence, NYPA told me that they only had a few options they were upselling to various Towns in the Hudson Valley and that they did not have an orange color-temperature light option (or any non-blue-white color temperature light). See Exhibit 4. During the fall, I sent more emails to the Town. See Exhibits 7, 8 and 9. Exhibit 7 included a new study published in *Experimental Neurology*, that LED lighting leads to neuroinflammation in people who have recently had a heart incident and increases the potential for mortality. One of the study's authors, Dr. Laura Fonken weighed in by email stating:

> I absolutely agree with you that blue-white LED lights are not the optimal design for streetlights.

Exhibit 8 includes an email about and abstracts from papers given at a conference in San Jose, CA: "Predicting Sound and Light levels at Large Spatial Scales"; "Going Global: Individual to Community-Level Responses to Noise and Light" and "Social Science and Citizen Science to Inform Sound and Light Management. The gist of these abstracts was that communities should work closely with the citizens to mitigate these impacts and protect the environment. That is not what was going on in the Town of Highlands. Exhibit 15 show emails from Richard Sullivan that showed up in response to a FOIL request referring to me as "the dissenter", treating Mr. Laino of NYPA to lunch, and warning Town Board members that Steven Walker and I "would be watching". He also talks about populated cities that bear no resemblance to the Town of Highlands as being good examples of LED lights. In an April 5th email, he states,

> I am working in Mt. Pleasant on water improvements, and on my commute going through New Castle (Chappaqua), I see LED going on, and called New Castle, Nyack, Kingston, Rhonebeck and Clarkstown for real time input on satisfaction with the respective upgrades they are implementing, all seem content, and with no dispute, many localities are pursuing these upgrades.

Exhibit 9 was an article in the November 22, 2019 edition of The Daily Mail entitled, "Light pollution is driving the insect apocalypse, scientists claim – from luring moths to their deaths to making bugs more visible to predators". The bullet points under the title read:

- Experts reviewed over 200 studies into the impacts of artificial light on bugs
- Light pollution has diverse impacts on insects that can shake entire food webs
- It is feared that 40 per cent of creepy-crawlies could go extinct within decades
- Researchers encourage people to reduce their use of artificial light at night

Articles on the perils of light pollution continue to crop up; CNN had one on July 8, 2020 (Exhibit 10a) titled: "Light pollution ruins teen sleep and may contribute to mental disorders, study says. Exhibit 10b is the study itself, entitled, "Association of Outdoor Artificial Light at Night with Mental Disorders and Sleep Patterns Among U.S. Adolescents" published in *JAMA Psychiatry*. The literature and the testimonials continue not to support taking a safe color-temperature light and swapping it out for something less safe- to say nothing of doing it in a Town nestled in a State Park with a Historic Revolutionary War Battle Site, nestled up against the Hudson River.

16. During the Pandemic when meetings were not physically attended by the public, the Town voted on a resolution dated April 27, 2020, declaring the LED lighting scheme a Type II Action and voting to sign contracts. They don't explain how they arrived at the decision that the LED streetlights are a Type II action given the controversy, the health and environmental concerns. Exhibit 14 includes the documents released in June to me by FOIL. It appears the Town will buy lights from O&R and have NYPA service them.

FIRST CAUSE OF ACTION

The Town of Highlands failed to perform a duty enjoined upon it by law in violation of CPLR §7803(1) by failing to have a proper SEQR review and by incorrectly issuing a negative declaration without going through the SEQR review process before passing a resolution authorizing contracts for the LED streetlighting scheme.

SECOND CAUSE OF ACTION

NYPA failed to perform a duty enjoined upon it by law in violation of CPLR §7803(1) by failing to have a SEQR review process for the LED lights and/ or by improperly declaring them to be a Type II action.

THIRD CAUSE OF ACTION

The Town of Highlands proceeded in excess of jurisdiction in violation of §7803(2) by issuing a resolution allowing for the signing of contracts for LED lights without having a proper SEQR review.

FOURTH CAUSE OF ACTION

The Town of Highlands Type II designation of the LED streetlighting scheme as well as its Resolution authorizing contracting for same were in violation of lawful procedure, arbitrary and capricious and an abuse of discretion in violation of §7803(3).

FIFTH CAUSE OF ACTION

NYPA proceeded in excess of jurisdiction in violation of §7803(2) by putting lights out to bid without engaging in a SEQR review process or by improperly declaring the lights to be a Type II action.

SIXTH CAUSE OF ACTION

NYPA acted arbitrarily and capriciously and in an abuse of discretion and in violation of lawful procedure in violation of §7803(3) by refusing to put out bids for non blue-white LED lights or by doing so without engaging in a SEQR review process or by improperly declaring the lights to be a Type II action.

WHEREFORE, I as Petitioner respectfully request that this Court enter judgment against Respondents pursuant to CPLR §§ 7803 (1), 7803(2), CPLR 7803(3), CPLR 7805 and CPLR 7806 as follows to annul, vacate and void

- A resolution ("the Resolution") dated April 27, 2020 of the Town of Highlands "to authorize the Town of Highlands to Enter into an Agreement for Purchase and Sale of Street Lighting Facilities with O&R
- The assertion by the Town of Highlands in the Resolution that the Street Lighting Agreement with Orange and Rockland Utilities, Inc. ("O&R") constitutes "a legislative action pertaining to routine or continuing agency administration and management, not including new programs or major reordering of priorities that may affect the environment, and accordingly is a Type II Action under the State Environmental Quality Review Act"; (that is to say I am asking the Court to declare that the project authorized by the Resolution does not constitute a so-called "Type II" action.
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and to order

- the New York Power Authority to put out any future project from the Town of Highlands to competitive bidding that includes not just price considerations, but the color-temperature of the lights, specifically yellow-orange color temperature lights.
- Any other relief that the Honorable Court deems just and proper.

Dated: July 27, 2020

Respectfully submitted,

Deborah Kopald, Petitioner pro se
P.O. Box 998
Fort Montgomery, NY 10922
(845) 446-9531

SUPREME COURT OF THE STATE OF NEW YORK
ORANGE COUNTY Index. No: ___________

--X

In the Matter of the Application of Deborah Kopald,
Petitioner

For a Judgment pursuant to CPLR Article 78 VERIFICATION

-against-

The Town of Highlands New York,
Orange and Rockland Utilities, Inc.,
The New York Power Authority
Respondents

--X

STATE OF NEW YORK)
) SS:
COUNTY OF ORANGE)

I, Deborah Kopald, being duly sworn deposes and states that I am the Petitioner in this Special Proceeding, and that I drafted, read and signed the foregoing Petition and the allegations contained therein are true to my knowledge, except as to matters therein stated to be on information and belief, and as to those matters, I believe them to be true.

Deborah Kopald
P.O. Box 998
Fort Montgomery, NY 10922
(845) 446-3768

Sworn to before me this 27th day of July 2020

RICHARD B. GOLDEN
Notary Public, State of New York
No. 02GO4766376
Qualified in Orange County
Commission Expires November 17, 2022

Notary Public
NOTARIZATION WAS MADE PURSUANT TO GOV. EXEC. ORDER 202.7, AS EXTENDED

Town of Highlands
Town Hall
254 Main Street
Highland Falls, NY 10928

Orange and Rockland Utilities
c/o Consolidated Edison Corp.
4 Irving Place,
New York, NY 10003

New York Power Authority
123 Main Street Mail Stop 10B
Corporate Communications
White Plains, NY 10601-3170

RESOLUTION

OF

APRIL 27, 2020

A RESOLUTION TO AUTHORIZE
THE TOWN OF HIGHLANDS TO
ENTER INTO AN AGREEMENT
FOR PURCHASE AND SALE OF STREET LIGHTING
FACILITIES WITH O&R

Council Member Sullivan moved the following resolution which was seconded by Council Member Parry.

WHEREAS, the Town of Highlands has negotiated an Agreement for Purchase and Sale of Street Lighting Facilities with Orange and Rockland Utilities, Inc. ("O&R) to purchase plus or minus 168 street lighting facilities in Town (the "Agreement"); and

WHEREAS, the Agreement has an approximate cost of Thirty Thousand Nine Hundred Twenty Two ($30,922.00) Dollars; and

WHEREAS, the Agreement constitutes a legislative action pertaining to routine or continuing agency administration and management, not including new programs or major reordering of priorities that may affect the environment, and accordingly is a Type II Action under the State Environmental Quality Review Act; and

WHEREAS, the Town Board deems it to be in the public interest for the Town of Highlands to enter into the Agreement.

NOW, THEREFORE, BE IT RESOLVED; that the Supervisor be and he hereby is authorized and directed to execute the Agreement substantially in the form of Exhibit A annexed hereto; and

BE IT FURTHER RESOLVED, that the Supervisor and officers of the Town are hereby authorized and empowered to make, execute and deliver, or cause to be made, executed and delivered, in the name of and on behalf of the Town, all such certificates, documents and papers as may be necessary to effectuate and carry out the contents of the foregoing resolutions and the terms and conditions of the Agreement; and

BE IT FURTHER RESOLVED, that the aforesaid resolutions shall take effect immediately.

The question of the adoption of the foregoing resolution was duly put to a vote on roll call which resulted as follows:

Tyrone King, Councilman ____________voting **Aye**

Richard Parry, Councilman ___________voting **Aye**_

Richard Sullivan, Councilman _________voting **Aye**_

Mervin R. Livsey, Supervisor _________voting **Aye**_

The foregoing constitutes a true and complete copy of a resolution duty made, seconded and adopted at a meeting of the Town Board, Town of Highlands, on April 27, 2020.

____

June Patterson, Town Clerk

LED LIGHT INFORMATION
Town of Highlands – Town Board
Deborah Kopald
6/24/19

Pages

Sodium vapor lights do NOT emit any blue light, which is implicated with disturbed circadian rhythms, breast cancer and retinal toxicity. **ALL LED lights, even so-called amber (orange) LEDs, also emit this blue light that is of concern.** This is true even if the amber bulb theoretically has a lower color temperature than a sodium vapor bulb.

Amber lights are comparable in efficiency to sodium vapor; both are less efficient than LED white/blue lights. Sodium vapor produce a pure yellow light, more akin to candlelight. They also distribute the light more evenly and are the best option in mist and fog.

No LED light by definition can be as safe as what it is replacing and safe for all residents. On information and belief, nobody in town has expressed that they suffer an irritation from existing Sodium Vapor and/or Mercury Vapor Lights which emit a light in the yellow-orange range only.

Typical high pressure sodium bulb[1], yellow color, best to cut through mist and fog
50 watts, 4,000 lumen, color-temperature- 1900-2200 Kelvin yellow light only
80 lumens/watt efficiency (higher wattage can go up to 106 lumens/watt efficiency)

Some LED blue lights used in Eastern MA[1]
13-15 Watts, 1,600 lumen 3000 Kelvin, contains blue light (2,700 is lowest blue light)
110 lumens/watt energy efficiency
These blue lights may look brighter for many than the sodium bulb, even w/ lower lumen.
Other LED blue lights[2]
25-40 Watts, 2770-3650 lumen (color temperature can vary 2,700-5,000 and above).
90-110 lumens/watt efficiency- up to and past 120
(they can get past 120 lumens/watt efficiency and are several-fold brighter due to blue)
Lowest color-temperature LED light
20 Watts, 2,800 lumen- 2200 Kelvin, *Lumican*-small chassis[3]
140 lumen/watts (dimmable- not a desirable feature)

Amber/orange LED lights
16-42 Watts, 1150-3300 lumen[2], 2200 Kelvin, still contain blue light
40-80 lumens/watt efficiency (on par with sodium vapor lights in terms of efficiency)
Even if lower lumens, still may appear brighter because of residual blue light.
30-228 Watts, 2500-10,000 lumens- 1750 Kelvin *Osram*[4]
43-77 lumens/watt 1750K

Incandescent bulb (*not an option for streetlights*)
7.25-14 lumens/watt efficiency 2700 Kelvin
Candlelight (*not an option for streetlights*), yellow light-ideal for humans
1800Kelvin

[1] Data from J. Kelly Beatty, Sky and Telescope Magazine
[2] This Data from National Optical Astronomy Observatory (Kitt Peak National Observatory): https://www.noao.edu/education/QLTkit/ACTIVITY_Documents/Energy/TypesofLights.pdf
[3] http://lumican.com/wp-content/uploads/2018/10/Lumicana-Cobrahead-Small-Chassis-V14.pdf
[4] https://www.osram.com/ls/news/amber/index.jsp

Correlated Color Temperature: indicates a light's overall color or hue:

Effects on brightness include (1) existence of any blue light, (2) relative color temperature (3) lumens. (Lower color-temperature will not appear less bright if there is any blue in it and possibly, but not definitely if it emits more lumens). Humans have used orange lights at night with no blue for years- candlelight and fire. They also used incandescents indoors- which are more white.

All bulbs have a wattage (power) and intensity measured in lumens (these numbers are related to each other and together (lumens/watt) represent energy efficiency); color-temperature in Kelvin as well as a glare rating- lower glare makes a smaller puddle of light. Yellow is the best color for mist and fog because white and blue light reflect off of water molecules more and visibility is lessened. LED also has residual flicker while sodium vapor does not and also creates high frequency transients. High pressure Sodium vapor is effectively as efficient as an LED bulb of the same color-temperature (amber). (Some amber lights may be more efficient, but this needs to be investigated further.) LED's can create too bright pools of light with more blackness in between the areas as opposed to a more distributed, natural yellow light that is less of an irritant.

Individuals have different reactions to such light and no LED lights can be guaranteed not to irritate peoples' eyes and cause the other aforementioned reactions with cumulative exposure.

To date, at least three people have communicated that they are irritated by LED's- including LED lights on a computer. Dr. Janet Wilkie wrote letter to the News of the Highlands printed on June 7th, I have expressed same, and Merv Livsey has provided a picture of an irritating LED light on Eagle Valley Road. A fourth resident, Jason Taylor has expressed that there are too many streetlights in existence now that create too much light pollution. (These are the only people I surveyed; a demonstration would give a fuller picture).

The American Medical Association ("AMA") states,

> It is estimated that a "white" LED lamp is at least 5 times more powerful in influencing circadian physiology than a high pressure sodium light based on melatonin suppression"[5].

They go on to state the following:

> Many early designs of white LED lighting generated a color spectrum with excessive blue wavelength. This feature further contributes to disability glare, i.e., visual impairment due to stray light, as blue wavelengths are associated with more scattering in the human eye, and sufficiently intense blue spectrum damages retinas[6][7]. The excessive blue spectrum also is environmentally disruptive for many nocturnal species. Accordingly, significant human and environmental concerns are associated with short wavelength (blue) LED emission.

Backlit LED technologies, room lights affect sleep. The AMA reports:

> A number of controlled laboratory studies have shown delays in the normal transition to nighttime physiology from evening exposure to tablet computer screens, backlit e-readers, and room light typical of residential settings.[8][9][10] These effects are wavelength and intensity dependent, implicating bright, short wavelength (blue) electric light sources as disrupting transition. These effects are not seen with dimmer, longer wavelength light (as from wood fires or low wattage incandescent bulbs). In human studies, a short-term

[5] Falchi F, Cinzano P, Elvidge CD, Keith DM, Haim A. Limiting the impact of light pollution on human health, environment and stellar visibility. J Environ Manage. 2011;92:2714-22.,
also reported in the Report of the Council on Science and Public Health, "Human and Environmental Effects of Light Emitting Diode (LED) Community Lighting" http://darksky.org/wp-content/uploads/bsk-pdf-manager/AMA_Report_2016_60.pdf (Report to the American Medical Association ("AMA"))
[6] Shang YM, Wang GS, Sliney D, Yang CH, Lee LL. White light–emitting diodes (LEDs) at domestic lighting levels and retinal injury in a rat model. Environ Health Perspect. 2014:122(3):269-76.
[7] Lougheed T. Hidden blue hazard? LED lighting and retinal damage in rats, Environ Health Perspect. 2014;122(3):A81.
[8] Cajochen C, Frey S, Anders D, et al. Evening exposure to a light-emitting diodes (LED)- backlit computer screen affects circadian physiology and cognitive performance. J Appl Physiol. 2011;110:1432-8.
[9] Chang AM, Aeschbach D, Duffy JF, Czeisler CA. Evening use of light-emitting eReaders negatively affects sleep, circadian timing, and next-morning alertness. Proc Natl Acad Sci USA. 2015;112:1232-7.
[10] Gooley JJ, Chamberlain K, Smith KA, et al. Exposure to room light before bedtime suppresses melatonin onset and shortens melatonin duration in humans. J Clin Endocrinol Metab. 2011;96:E463-72.

detriment in sleep quality has been observed after exposure to short wavelength light before bedtime. Although data are still emerging, some evidence supports a long-term increase in the risk for cancer, diabetes, cardiovascular disease and obesity from chronic sleep disruption or shiftwork and associated with exposure to brighter light sources in the evening or night.[11][12]

No change in technology should be considered at all in the absence of putting up a few next to each other in one location in a demonstration project (not a permanent fixed pilot project) so that people can look at them and report their experiences and compare and contrast. Again, the irritation of the light is one issue- the long term ramifications of blue-light exposure are another. Companies hawking these lights are not able to and not interested in proving safety (this is not the only industry that rolls out things ubiquitously that are unsafe or not yet proven safe (violation of the precautionary principle)- this includes drugs, an assortment of chemicals, products emitting wireless radiation, nanotechnology, synthetic biology, artificial intelligence.

It is up to elected officials to make conservative decisions that do not roll things out ubiquitously that can have adverse effects and to way the potential costs versus the so-called benefits. A solution for a Long Island town may not be appropriate for the Hudson Valley, especially for a town nestled in a state park. The cost savings on a yearly basis are not that great and this should not be entertained lightly given the possibility for the need to remove them. As Merv Livsey mentioned to me, many of us choose to live here and not New York City for a reason, and New York City is increasingly being lit up like a runway. There are other ways to save more meaningful amounts of money and/or reduce global warming if that is a goal (for example, offices could be made to comply with recycling rules that residents must comply with).

Ultimately, anyone who does not want such a light should have the option of opting out within view of their home if new lights were installed (and having O&R re-install a sodium-vapor light or at least some narrow band amber light selected by the Town). Sodium vapor emit no blue, are best for mist and fog, which are conditions we have; we are not a city and don't need blue to illuminate colors of car you are seeing, and anything with any blue will affect humans and animals to varying degrees. Amber LED lights have the least amount of blue light and are at least comparable in energy efficiency to sodium vapor lights.

[11] . Council on Science and Public Health Report 4. Light pollution. Adverse effects of nighttime lighting. American Medical Association, Annual Meeting, Chicago, IL. 2012.

[12] Koo YS, Song JY, Joo EY, et al. Outdoor artificial light at night, obesity, and sleep health: Cross-sectional analysis in the KoGES study. Chronobiol Int. 2016;33(3):301-14.

Breakage of LED diodes

A 2012 Scientific American article, "The Dark Side of LED lightbulbs[13] refers to release of copper and nickel due to LED bulbs breaking on the concrete, absorbed through air, water and soil In the Common House, the bulbs would fall on a concrete floor where children and adults congregate. This article and another article on metal toxicity health dangers follow:

The U.S. CDC Agency for Toxic Substances and Disease Registry defines nickel and copper as toxic substances and the potential for adverse health effects is dose dependent. Twenty percent of the population is allergic to nickel and would have a stronger reaction to a nickel spill from a broken LED bulb.

> Nickel: http://www.atsdr.cdc.gov/toxfaqs/tf.asp?id=244&tid=44
> Copper: http://www.atsdr.cdc.gov/toxfaqs/tf.asp?id=205&tid=37

The French Agency for Food, Environmental and Occupational Health and Safety ("ANSES") Reports

On April 5, 2019, the French Agency for Food, Environmental, and Occupational Health and Safety, ANSES, put out its latest "Opinion on the effects of human health and the environment (fauna and flora) of systems using light-emitting diodes": The report cites the scientific evidence on the "phototoxic effects" of short-term exposures to high-intensity blue light, as well as an increased risk of age-related macular degeneration after chronic exposure. Age related macular degeneration causes vision loss in those over 50 by damaging a spot in the center of the retina. The press release[14] for the report[15] states:

> …..the expert appraisal showed that even very low levels of exposure to blue light in the evening or at night disrupt biological rhythms and therefore sleep. ANSES stresses that the screens of computers, smartphones and tablets are major sources of blue-rich light, and children and adolescents, whose eyes do not fully filter blue light, are a particularly susceptible population.

[13] The Dark Side of LED Lightbulbs, *Scientific American*, 2012:https://webcache.googleusercontent.com/search?q=cache:59DGs7rBqVoJ:https://www.scientificamerican.com/article/led-lightbulb-concerns/+&cd=1&hl=en&ct=clnk&gl=us

http://www.globalhealingcenter.com/natural-health/metal-toxicity-health-dangersnickel/

[14] French Agency for Food, Environmental, and Occupational Health and Safety . *Recommendations for limiting exposure to blue light.* https://www.anses.fr/en/content/leds-anses%E2%80%99s-recommendations-limiting-exposure-blue-light

[15] French Agency for Food, Environmental, and Occupational Health and Safety. *Opinion on the effects of human health and the environment (fauna and flora) of systems using light-emitting diodes*. April 5, 2019 https://www.anses.fr/en/system/files/AP2014SA0253EN.pdf

> The Agency confirms the toxicity of blue light on the retina and highlights the biological rhythm and sleep disruption associated with exposure to blue light in the evening or at night, particularly via screens and especially for children. The Agency therefore recommends limiting the use of LED devices with the highest blue-light content, especially for children, and reducing light pollution as much as possible to preserve the environment.

Their previous report on the topic was issued in 2010 and called "Lighting systems using light emitting diodes (LEDs): health issues to be considered"[16] It stated:

> The issues of most concern identified by the Agency concern the eye due to the toxic effect of blue light and the risk of glare… Blue light is…recognized as being harmful and dangerous for the retina, as a result of cellular oxidative stress

adding that the blue light necessary to obtain white LEDs causes "toxic stress" to the retina. Blue light causes a photochemical risk to the eye, says the report, the level of which depends on the accumulated dose of blue light to which the person has been exposed, which is generally the result of low-intensity exposure repeated over long periods. In other words, cumulative effect as well as intensity matter.

The report also indicated that three groups are particularly at risk; children, populations which are already light sensitive and workers likely to be exposed to high-intensity lighting. The report cited glare and pointed out that because the emission surfaces of LEDs are highly concentrated point sources, the luminance of each individual source can be 1000 times higher than the discomfort level. In particular, the report refers to the glare risk and says that previous lighting standards should not be adapted to systems using LEDs. Any systems should have optics and diffusers to avoid glare and are more appropriate for industrial settings, not residential ones.

Dirty Electricity Involves High frequency voltage transients

LED diodes jack up sine wave- create high frequency transients (also known as "dirty electricity" on the wiring, which are understood to be electrical pollutants. These should not be added into the grid and most sodium vapor lamps do not create them. The nation's expert on this topic is David Stetzer and Stetzer Electric in Wisconsin. His 2013 study, "Dirty Electricity, chronic stress, neurotransmitters and disease[17]" states the following:

> Dirty electricity, also called electrical pollution, is high-frequency voltage transients riding along the 50 or 60 Hz electricity provided by the electric utilities. It is generated by arcing, by sparking and by any device that interrupts current flow, especially switching

[16] French Agency for Food, Environmental, and Occupational Health and Safety. *Lighting systems using light emitting diodes (LEDs): health issues to be considered*, October 19, 2010. https://www.anses.fr/fr/system/files/AP2008sa0408EN.pdf

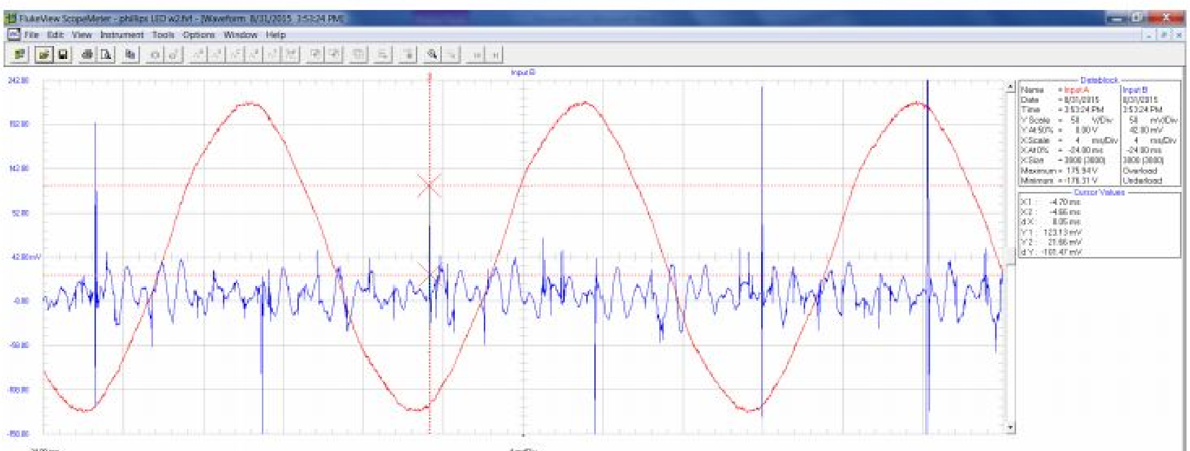
[17] Stetzer D, Milham S. Dirty Electricity, chronic stress, neurotransmitters and disease. Electromagn Biol Med. 2013 Dec; 32(4):500-7.

power supplies. It has been associated with cancer, diabetes and attention deficit hyperactivity disorder in humans.

Stetzer also presented a paper with toxicologist Magda Havas in 2004 at a World Health Organization workshop in which they stated:

> Deteriorating power quality is becoming increasingly common in developed countries. Poor power quality, also known as dirty electricity, refers primarily to a combination of harmonics and transients generated primarily by electronic devices and by non-linear loads. We have assumed, until recently, that this form of energy is not biologically active….. These results are dramatic and warrant further investigation. If they are representative of what is happening worldwide, then dirty electricity is adversely affecting the lives of millions of people.[18]

Dimmable LED lights create even greater line pollution and are to be avoided. The below graphical depiction shows the irregular wave forms created upon dimming:



The above waveforms were collected at the Stetzer Electric offices in Blair, WI using a Fluke 190-202 Scopemeter. Channel A was connected to the 120V receptacle. Channel B was connected at the same potential, except through the Graham Ubiquitous Filter (removes the 60 cycle). A Phillips 12.5-watt dimmable LED light bulb on a dimmer switch (at half brightness) was in use at the time. The area between the cursors represents a frequency of 20 kHz. The reading on the Stetzerizer Microsurge meter increased from 30 GS Units to 132 GS Units.

Stetzer and Havas' report ends by stating the following:

> ….the body recognizes EMF as a foreign invader and mounts an acute stress response to it. With chronic exposure and stress, neuroendocrine and immune system dysregulation results in a wide spectrum of human morbidity and mortality. Our work shows that lowering of dirty

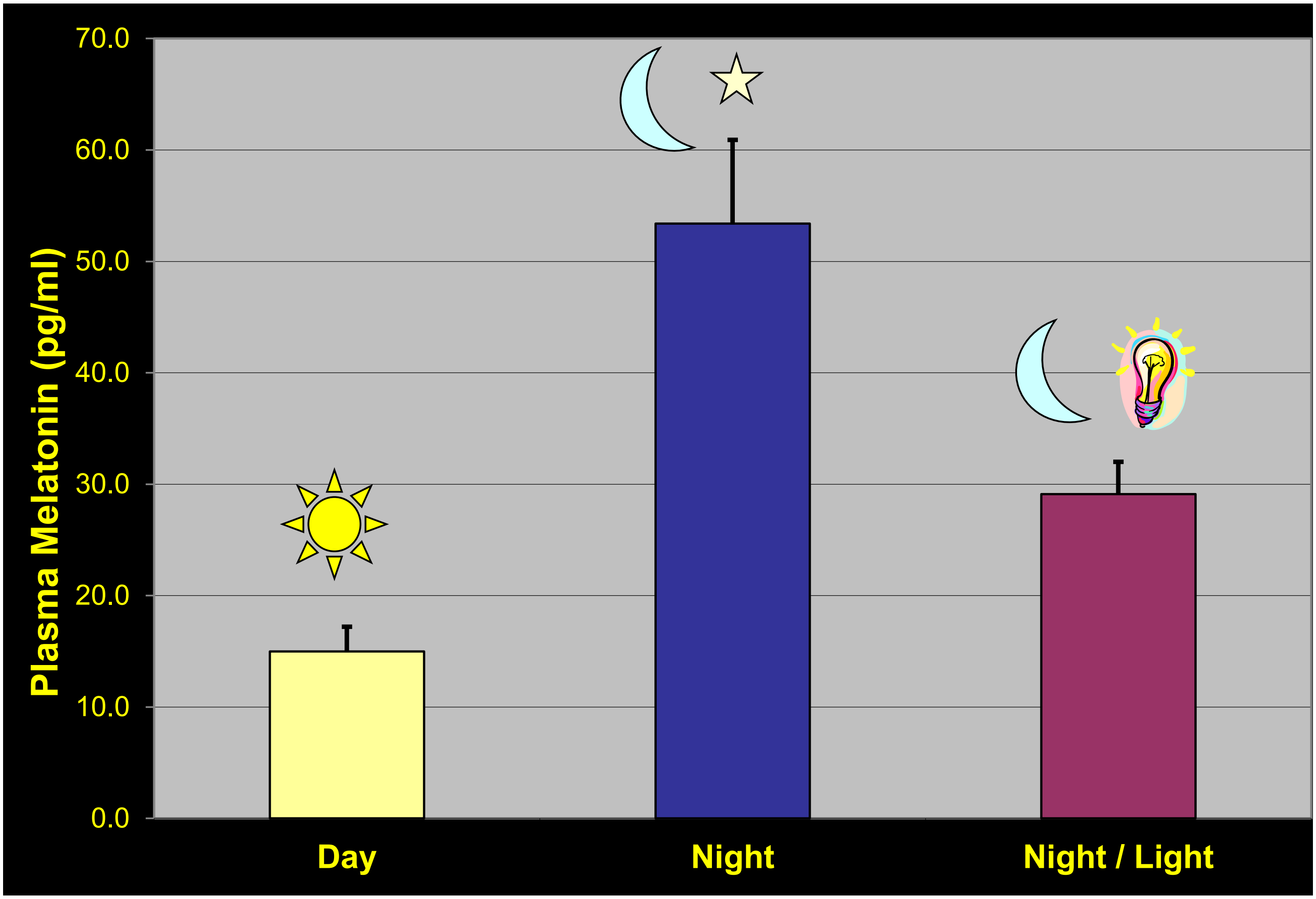
[18] Stetzer D, Havas M. World Health Organization Workshop on Electrical Hypersensitivity, 25-26 October, 2004, Prague, Czech Republic. 1 Dirty Electricity and Electrical Hypersensitivity: Five Case Studies

electricity in an office environment results in increased urinary levels of dopamine and PEA in exposed persons. This is evidence that dirty electricity and probably other types of EMF exposure act as chronic stressors, causing neurotransmitter changes and disease. Neurotransmitters may be biomarkers of dirty electricity and EMF exposures.

Negative Effects of Blue Light

Getting back to the issue of hormone suppression, the artificial blue light from LEDs creates these effects as well as the high frequency transients:

Human Blood Plasma Melatonin Levels (courtesy of the International Dark Sky Association):



Blue light suppresses the production of melatonin, which is the hormone that the sleep-wake cycle. Melatonin has also been shown to be closely related to the development and promotion of breast and prostate cancer. Breast cancer is well known to be caused by high estrogen levels, and melatonin happens to be an aromatase inhibitor, which means it lowers estrogen.

Chronic exposure to blue light, which reaches deep into the eye, is also associated with retinal cell damage and age-related macular degeneration (AMD). According to a 2015 Harvard Medical School ("HMS") advisory[19], night shift work and exposure to light at night are related to several types of cancer, diabetes, heart disease and obesity. The updated advisory it was based upon[20] goes on to state the following:

> …while any kind of light can suppress the secretion of melatonin, blue light does so more powerfully
>
> Even dim light can interfere with a person's circadian rhythm and melatonin secretion. A mere eight lux—a level of brightness exceeded by most table lamps and about twice that of a night light—has an effect, notes Stephen Lockley, a Harvard sleep researcher.
>
> While light of any kind can suppress the secretion of melatonin, blue light at night does so more powerfully. Harvard researchers and their colleagues conducted an experiment comparing the effects of 6.5 hours of exposure to blue light to exposure to green light of comparable brightness. The blue light suppressed melatonin for about twice as long as the green light and shifted circadian rhythms by twice as much (3 hours vs. 1.5 hours).

A 2017 study, "Outdoor Light at Night and Breast Cancer Incidence in the Nurses' Health Study II" conducted by researchers at the Harvard School of Public Health[21] found that

> exposure to residential outdoor light at night may contribute to invasive breast cancer risk.

The Harvard nurses study came to the same type of conclusion as a 2009 study done in Israel[22] which stated:

> …the analysis yielded an estimated 73% higher breast cancer incidence in the highest LAN [light at night] exposed communities compared to the lowest LAN exposed communities.

Another study, "Melatonin, environmental light and breast cancer" dating to that time from an international team of researchers including a doctor at Columbia University in New York, NY

[19] "Using these lights at night may harm your health". Harvard Medical School Advisory 2015. https://www.health.harvard.edu/healthbeat/using-these-lights-at-night-may-harm-your-health

[20] "Blue light has a dark side". Harvard Medical School Advisory May 2012, updated, August 13, 2018 https://www.health.harvard.edu/staying-healthy/blue-light-has-a-dark-side

[21] Bertrand K. James P. et al. *Environmental Health Perspectives* Outdoor Light at Night and Breast Cancer Incidence in the Nurses' Health Study II. 2017: 0817

[22] Kloog I, Haim A, Stevens RG, Barchana M, Portnov BA. Light at Night Co-Distributes with Incident Brast but not Lung Cancer in the Female Population in Israel. *The Journal of Biological and Medical Rhythm Research.* 2008: Vol 25: Issue 1.

came to the same conclusion in regard to female shift workers who were exposed to light at night[23].

In addition to cancer risk, there is the risk of retinal toxicity. One recent study published in Spain in 2012[24] found that blue LED light can irreparably damage the cells in the eye's retina-specifically the retinal pigment epithelial cells. The study comes to the disturbing conclusion that once damaged, the retina cannot be regenerated and thus LED light exposure can cause blindness.

In 2018, a group from the University of Toledo, Ohio found, as ANSES reported, that that LED light exposure can lead to macular degeneration[25]. The authors recommend not using cell phones in the dark because LED blue light dilates pupils and causes the harmful blue light to enter the eyes, triggering the production of a toxic chemical that interacts with oxygen to kill photoreceptor cells.

LED lights are also inadvertently having a bleaching effect on the works of Van Gogh and Cezanne in art galleries according to Professor Koen Janssens at the University of Antwerp[26].

Finally, a 2016 article, "Effects of blue light on the circadian system and eye physiology"[27] speaks to the disruption to sleep and blue-light induced damage to the retina The graph in this paper makes the point that lights can appear similar intensity to a person, but the LED will have much more of the dangerous blue-spectrum light in it:

[23] Srinivasan V, Spence DW, Pandi-Perumal et al. Melatonin, environmental light and breast cancer. *Breast Cancer Res. Treat* 2008: 108: 339-350

[24] Tejedor JV, Marchena M, Ramirez L, Garica-Ayuso D, Gomez-Vicente V, Sanchez-Ramos C, dela Villa P, Germain F. Removal of the blue component of light significantly decreases retinal damage after high-intensity exposure. *PLOS One*, 2018:0315.

[25] Ratnayake, K. Payton JL, Lakmal OH, Karunarathne A. Blue light excited retinal intercepts cellular signaling. *Scientific reports. 2019: July 5.*

[26] Smith L. Will we have to look at Sunflowers in the dark? Scientists discover museum lights are damaging valuable masterpieces by Van Gogh and Cezanne. *Daily Mail* January 7, 2013 https://www.dailymail.co.uk/sciencetech/article-2258344/Scientists-discover-LED-lights-damaging-valuable-masterpieces-artists-including-Van-Gogh-C-zanne.html

[27] Tosini G, Ferguson I, Tsubota K. Effects of blue light on the circadian system and eye physiology. *Molecular Vision Biology and Genetics in Vision Research.* Mol Vis. 2016; 22: 61–72.

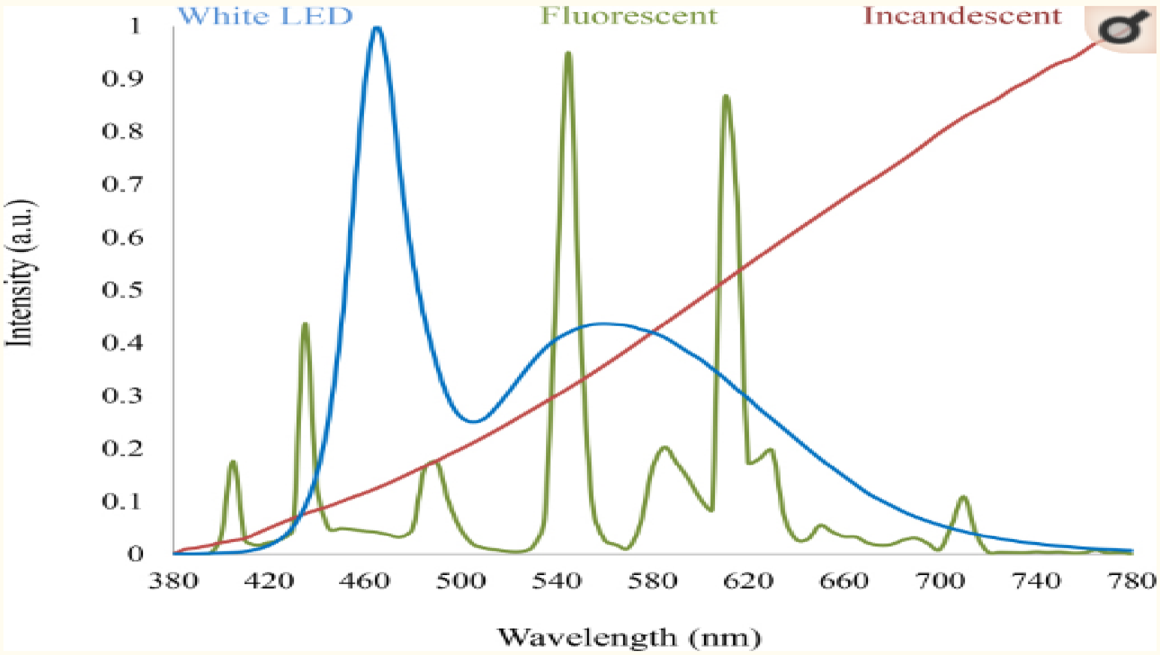
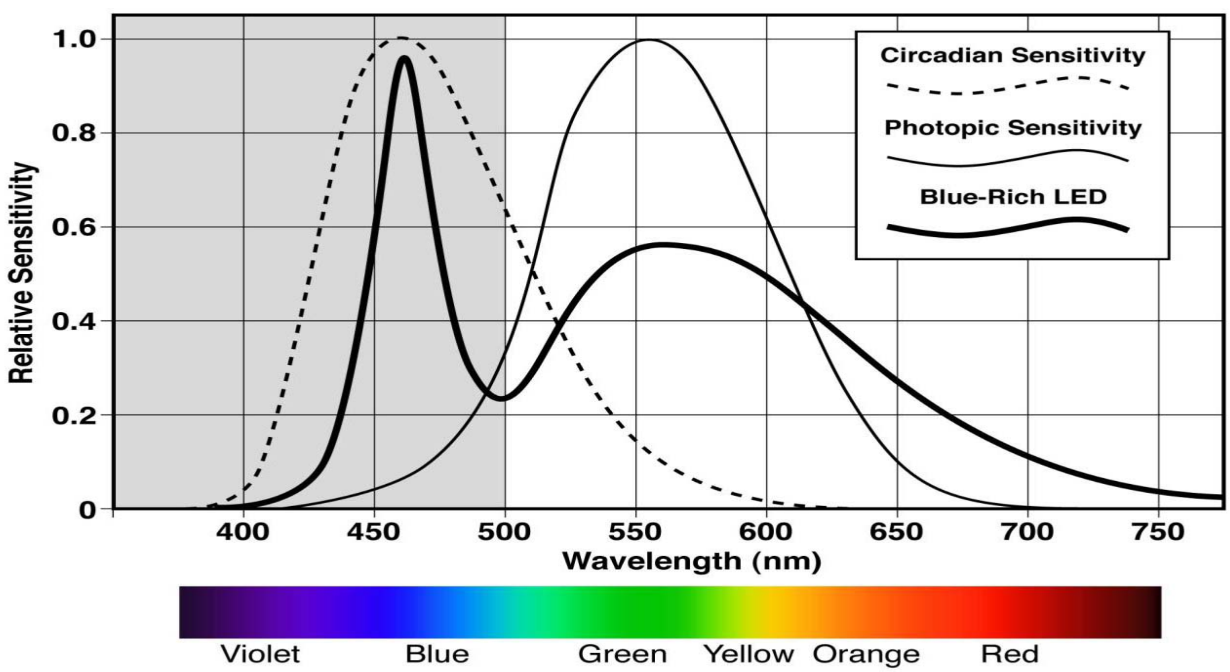


Figure 1

A comparison of the power spectrum of a standard white-light LED, a tricolor fluorescent lamp, and an incandescent source. The radically different power spectrums can look similar when viewed directly by the eye, irrespective of how much blue emission is present.

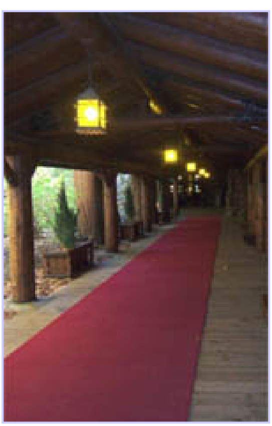
A graph from the International Dark Sky Association shows how the excess blue light emitted by LED's corresponds with peak sensitivity of sleep (circadian) rhythms:

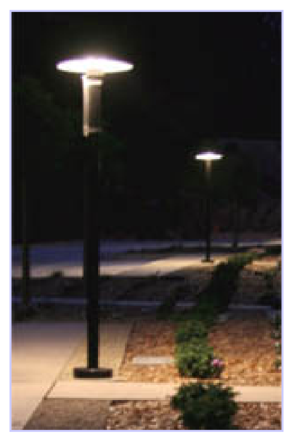


An LED light on Eagle Valley Road, Highland Falls, NY

An LED light courtesy of the International Dark Sky Association:

Yosemite National Park:






American Medical Association (June 2012):
"Pervasive use of nighttime lighting
disrupts various biological processes,
creating potentially harmful health effects
related to disability glare and sleep disturbance."


International Agency for Research on Cancer (May 2007):
"Shiftwork that involves circadian disruption is
probably carcinogenic to humans."

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Tel. 631.923.1900
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Tuesday, March 21, 2017

To Whom It May Concern:

This letter is in support of preventing conversion to LED street lamps. As a physician board certified in sleep medicine, I am very able to state that blue light is one of the biggest threats to the human circadian rhythm and health. For patients with sleep issues (and quite frankly nearly everyone), proper avoidance of blue light is necessary to maintain physiologic melatonin production and appropriate circadian rhythms. Circadian biologic disruption has been linked to disease across the board including but not limited to diabetes and metabolic disorders , neurodegenerative disorders, mental illness, and likely many forms of cancer. Unfortunately, the emitted spectrum of LED lighting is high in the most disruptive frequency for melatonin secretion.

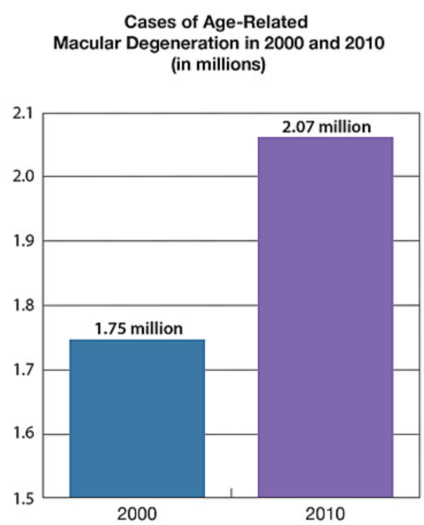
The blue light hazard is not complex and is well studied with scientific rigor, despite arguments to the contrary. In fact, I would say the scientific literature is packed with such support; however, the general medical community and public awareness of this fact is poor, likely due to the inconvenient truth. Whilst most artificial lighting is damaging in such regard, homeowners have a personal choice for the lighting environment they allow in their home, and take ownership of the health consequences. However, street lighting is especially important, since it is on all night and is unchangeable. Such a choice will not only open up liability for the town, but also limit revenues as the community and public at large come to realize the impact of such lighting on human physiology and thus will stay home at night.

Color temperature is not enough of a measure to determine the safety of artificial lighting, although it would suggest that lower color temperature is less damaging than higher color temperature.   With that being said, it has been shown that at 3500 Kelvin cool white artificial light increased stress hormone release during illumination. During the day the sun's color temperature changes from 1,800 Kelvin at sunrise to 16,000 Kelvin at sun down. It does so with a relatively flat frequency response and much closer ratios of red and blue in the spectrum. The main problem with LED lighting is the paucity of purple and red visible spectrum as well as the heavy blue spike as compared to the spectrum of the very natural sun we evolved under.

Stating that the research on melatonin suppression by blue light is not sufficient is not accurate. Very clear suppression of melatonin has been found, and this finding has been upheld by research studies. What has been controversial is the physiologic mechanism in the eye responsible for it. The lighting industry's response of lack of research on the "temporal-spatial-spectral distribution of optical radiation" seems like a semantic diversion to me as I've seen no clinical data on such measures. In fact, searching for these terms on pubmed did not reveal any medical/clinical research, instead revealing articles on "benchtop" optical and biochemical research. Melanopsin is the photopigment responsible for the circadian rhythm in the intrinsically photosensitive retinal ganglion cells (ipRGC) and responds to blue light from ~430-465nm in wavelength. This is the retinal controller of our circadian rhythm. It is well known that when melanopsin is excited by such blue light, it suppresses melatonin secretion.   There should be no doubt in anyone's mind that light stimulating the eye with this frequency at night is deleterious to the circadian rhythm and melatonin expression.

To say the causal relationship between melatonin suppression and circadian disruption is not proven is inaccurate. Melatonin is the gatekeeper hormonal conductor of sleep. Without it your sleep quality suffers. It is also an anticancer hormone. Studies have already demonstrated melatonin to suppress tumor growth, and the lack of melatonin's estrogen suppression may be one of the possible causes to its link to breast cancer. Regardless of the actual pathophysiology, the link is clear and reproducible. Further research is needed on the pathophysiology to reveal possible new treatments, not to further the already clear relationship in the literature. This situation is not "stimulation" of the circadian system. Creating a hormonal imbalance changes the functioning of the whole human adversely. Ask any woman who has low thyroid levels before discovered upon laboratory testing how her body felt and you will understand more clearly how this works. Based on the current state of research, it is clear that the stimulus (artificial light of which LED is included) creates a clear response (melatonin suppression) which is responsible for downstream effects (many already described but likely many more to be elucidated) which create disease.

Additionally, the heavy amounts of blue light in LED fixtures have been shown to cause photochemical damage to the retina. Research has shown photochemical, photomechanical and photothermal damage of retinal cells caused by light. In rod dominant mammals, blue light has been shown to cause apoptosis and necrosis of photoreceptors and retinal pigment epithelium. While human studies are lacking, one thing is clear: the incidence of retinal diseases is rising. While a clear answer has not been identified, our increased usage of blue heavy lighting is likely to blame.



I acquiesce that unfortunately the subclass of "street lamp LED" has not been studied. While unfortunate, this should not preclude our common sense judgment that there is an effect. Also, the study of such effect would be difficult based on the possibility of so many different exposures based on location of the lamps. It should be noted that residents may all have different lifestyles that would create differing exposures to such lamp light. It is obvious that this would make such research difficult, and further study is going on in clinical areas that may create more therapeutic options. I can't currently see much need for any such study with the current evidence in the literature.

The AMA's warning on these lights should be heard. I can see the difficulty for the AMA to advise completely against this money-saving change to LED lights, when there doesn't appear to be a clear option to recommend in its stead. A lack of a better option should not influence a decision for planning which will adversely affect the public's health. Even GE has acknowledged these issues in their own position paper on light and sleep from 2014. The industry's lack of immediate response should not encourage our use of already made products that have ill effects on the human condition.

I strongly urge public health be considered in this decision making. The cost savings of LED lamps may be surpassed by health costs and legal bills in the near future.

Sincerely,

Joshua Rosenthal, MD

431 S Oyster Bay Rd, Plainview, NY 11803
Tel: 516.931.6330 | Fax: 516.931.6352 | www.optixeyecare.com
Your Vision, Your Look, Our Focus

October 17, 2016

Dear Nassau County Government Leaders,

I am writing to inform you of the hazards imposed by the installation of LED (light emitting diode) street lamps in our towns. The potential devastating effect on public health should be further explored before moving forward and finalizing these plans. Most people do not realize how LED lights affect health, both short and long term. This letter should provide a good basic understanding of this very important issue. Along with many of my colleagues, the American Medical Association, and researchers and health scientists, it is my opinion that installing LED lighting in street lamps represents a threat to public health.

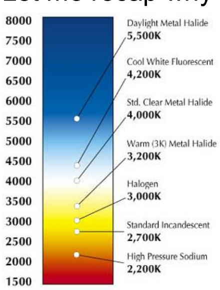
The typical visible spectrum encompasses wavelengths between 390 to 700nm. Blue light, including violet, encompasses light wavelengths between 390 and 500nm. Scientific studies worldwide are pointing to the fact that the shorter wavelengths or high energy visible (HEV) “blue light” are harmful to human health. These shorter wavelengths are between 390 and 450nm. Another short wavelength and higher energy emitter than blue is UV (ultraviolet light). UV is invisible to the human eye. We all know that UV light is harmful to our skin and our eyes. We have developed ways to protect ourselves, reducing damaging effects from UV wavelengths, with sunscreen and sunglasses. Do we need to wait for 100 percent public awareness to protect ourselves from HEV?

To put it simply, overexposure to blue light presents a major health issue to which the public is unaware. Years ago, the only exposure we had to HEV light was the sun. I would consider this short-term exposure. Outdoors we were exposed, indoors we were not. Today we are also exposed to HEV via LED bulbs, smart phones, tablets, television screens, computer screens and CFL (compact fluorescent) bulbs. This creates issues for long term exposure. Studies have shown that it is the cumulative or total exposure to HEV light over time that causes both short and long term medical problems. The high cost of medical care is also highly associated with our exposure to blue light as will be explained below.

The public should know that HEV light is not all bad and a certain amount of HEV light exposure is needed to enhance vitamin D production in our body. Vitamin D is responsible for strong bones and protects in a host of other health problems. Photo-therapeutic benefits or blue light have also been demonstrated to help with jaundice and SAD (seasonal affective disorder). That being said, anyone who reads the newspapers or watches the news has read or heard about increases in obesity, cardiovascular disease, cancer, and ADHD (attention deficit hyperactivity disorder), just to name a few medical issues affecting this country and others. Many of these issues are directly linked to sleep disruption; one of the major causative factors being overexposure to HEV light. In order for our bodies to get ready for sleep, our brain secretes the hormone melatonin. Melatonin production is suppressed when we are exposed to HEV light (smart phone/tablets/computer screens/TV/LED and CFL bulbs in our home). If we cannot sleep, we tend to eat, increasing our risk for diabetes, and heart disease. Our children cannot concentrate in school and sometimes are falsely labeled with ADHD. And to top it off, schools are installing LED lights in the classroom, further exposing our children to HEV light. Everyone should also know that certain cancers have been directly linked to HEV exposure.

Short term and long term effects on vision and eye health have also been well documented by optometrists, ophthalmologists and researchers. In my vision care practice, my associates and I have seen the short term effects include glare, eye strain, headaches, red eyes, dry and burning eyes, irritability, and reduced workplace productivity. The long term effects of HEV exposure that we see are more devastating. People are getting cataracts at an earlier age. Adult onset macular degeneration (AMD) has historically been considered to be a disease of people over age sixty-five. Based on today's overexposure to HEV, scientists are concluding that AMD will soon be a disease of people in their forties. AMD, for those who are not familiar, causes a loss of central vision, severely diminishing a person's ability to read, perceive colors, and walk without bumping into objects or tripping off a curb. Reduced mobility is one of the major causes of falls and injury in the elderly. We are very fortunate that eyeglass lens companies have developed and are constantly improving lens products that block much of the HEV wavelengths to which we are exposed. Some of these lenses have a champagne color, softening the visible "blue" in HEV blue lights. Your eye doctor must be consulted before wearing these lenses or any other tinted lens at night.

Let me recap why we are overexposed? LED or CFL lights in our home and workplace, flat screen computer monitors used by 90% of the public, smart phones and tablets used at least 4-5 hours per day or more, and then another 3 to 4 hours or more of watching our flat screen TVs. There is no getting away from HEV exposure.



Choosing to save money on energy, businesses and government offices like those in Nassau County are installing LED lighting in many of their offices and parking lots, exposing their employees to HEV light. Locally, public works projects in Great Neck and other municipalities are proposing to install LED street lamps adding to our exposure. Indeed, LED lights are less expensive to maintain, but are they worth negatively affecting public health? It is very important to note that although a lower color temperature (3000K and below) (see figure below) is better for glare, all LED street lamps emit a certain amount of HEV light. Most municipalities who have already installed LED street lamps have installed the higher color temperature lighting, a cheaper alternative but more glare producing and higher HEV exposing blue-white light. Residents in these areas are up in arms. After public outcry, the city of Davis, CA spent hundreds of thousands of dollars installing warmer LED fixtures just a month after installing white LED lamps. Phoenix residents are also complaining and they are also considering retrofitting to a lower color temperature light. Locally, LED street lamp installations in NYC and Brooklyn are being seen as a disaster by residents. They feel as if there is a film crew outside their windows and the light is spilling into their homes, disrupting their lives. Most don't even realize that they are being exposed to additional HEV light that has potential to lead to health issues.

In June, 2016, the American Medical Association declared that LED lights are a public health risk. The AMA states, *"As a result of a potential risk to public health from excess blue light exposure, the AMA report encourages attention to optimal design and engineering features when converting from existing lighting technologies to LED. These include requiring properly shielded outdoor lighting, considering adaptive controls that can dim or extinguish light at night, and limiting the correlated color temperature (CCT) of outdoor lighting to 3000 Kelvin (K) or lower. Color temperature is a measure of the spectral content of light, and higher CCT values indicate a greater amount of blue light that a fixture emits."*

It is my opinion that a municipality should be 100 percent certain that the installation of LED lights is in the best interest of the residents. Based on current research and best practices for reducing light pollution, it is just a matter of time that lawsuits are filed for either installing the wrong LED lamps or improperly shielding them in public areas. Technology is wonderful but can also be dangerous. There needs to be a balance between public benefits, health concerns, and cost savings. With what I have learned in the past few years about health issues and LED exposure and from the complaints that patients reveal in my eye care practice, my vote is for public safety.

Feel free to contact me with any questions.

Sincerely,

Joel N. Kestenbaum, OD
drkestenbaum@optixeyecare.com

References:

http://www.govtech.com/health/Are-LED-Streetlights-Disrupting-Your-Sleep.html

http://archinect.com/news/article/149970641/led-streetlights-may-contribute-to-serious-health-conditions-says-ama-prompting-cities-to-re-evaluate

http://darksky.org/ama-report-affirms-human-health-impacts-from-leds/

http://www.longislandeyedoctor.com/2016/09/re-hitting-the-laptops-published-in-newsday-on-page-a2-8312016/

http://www.bluelightexposed.com/#bluelightexposed

Dear Mary Jane

Many people have said that LED lights are energy efficient. The problem is, they are not people efficient.

A cheap light that causes eye damage, disrupts people's sleep patterns, contributes to rising rates of breast cancer (because it stimulates too much estrogen production), and is damaging to the health of people in our town who are sensitive to it, is not cheap, and is not efficient.

For myself, even looking at the little LED lights in electronic equipment feels like suddenly being stabbed in the eye with a laser.

I do not understand why, in this time of economic stress for so many people, we need to spend all this money on the latest thing, when the lights we have now work very well, and do not cause people health problems.

Consider that Montsanto was just successfully sued for billions of dollars for their product (Glyphosate) that caused cancer. Do we want lawsuits here from the women who live here who suddenly find that the town has an increased rate of breast cancer?

A lot of new technology ideas are terrific. LED lights are a new technology that looks good up front, and is terribly costly to our eyes, our bodies and our lives. It's a high price to pay for a few kilowatts of electricity. And the resulting medical costs will be brutally expensive.

Furthermore, it is absurd to think that the equivalent intensity/temperature of an LED streetlight is similar to the existing light, some people will still be affected by the LED's unnatural effects on the human eye and body.

Janet Wilkie

ATSDR Agency for Toxic Substances & Disease Registry

ToxFAQs™ for Copper

(*Cobre* (/es/toxfaqs/es_tfacts132.html))

September 2004

CAS#: 7440-50-8

(tfacts132.pdf) **PDF Version, 29 KB** (tfacts132.pdf)

This fact sheet answers the most frequently asked health questions about copper. For more information, you may call the ATSDR Information Center at 1-888-422-8737. This fact sheet is one in a series of summaries about hazardous substances and their health effects. This information is important because this substance may harm you. The effects of exposure to any hazardous substance depend on the dose, the duration, how you are exposed, personal traits and habits, and whether other chemicals are present.

Highlights

Copper is a metal that occurs naturally in the environment, and also in plants and animals. Low levels of copper are essential for maintaining good health. High levels can cause harmful effects such as irritation of the nose, mouth and eyes, vomiting, diarrhea, stomach cramps, nausea, and even death. Copper has been found in at least 906 of the 1,647 National Priority Sites identified by the Environmental Protection Agency (EPA).

What is copper?

Copper is a metal that occurs naturally throughout the environment, in rocks, soil, water, and air. Copper is an essential element in plants and animals (including humans), which means it is necessary for us to live. Therefore, plants and animals must absorb some copper from eating, drinking, and breathing.

Copper is used to make many different kinds of products like wire, plumbing pipes, and sheet metal. U.S. pennies made before 1982 are made of copper, while those made after 1982 are only coated with copper. Copper is also combined with other metals to make brass and bronze pipes and faucets.

Copper compounds are commonly used in agriculture to treat plant diseases like mildew, for water treatment and, as preservatives for wood, leather, and fabrics.

What happens to copper when it enters the environment?

- Copper is released into the environment by mining, farming, and manufacturing operations and through waste water releases into rivers and lakes. Copper is also released from natural sources, like volcanoes, windblown dusts, decaying vegetation, and forest fires.
- Copper released into the environment usually attaches to particles made of organic matter, clay, soil, or sand.
- Copper does not break down in the environment. Copper compounds can break down and release free copper into the air, water, and foods.

How might I be exposed to copper?

- You may be exposed to copper from breathing air, drinking water, eating foods, or having skin contact with copper, particulates attached to copper, or copper-containing compounds.
- Drinking water may have high levels of copper if your house has copper pipes and acidic water.
- Lakes and rivers that have been treated with copper compounds to control algae, or that receive cooling water from power plants, can have high levels of copper. Soils can also contain high levels of copper, especially if they are near copper smelting plants.
- You may be exposed to copper by ingesting copper-containing fungicides, or if you live near a copper mine or where copper is processed into bronze or brass.
- You may be exposed to copper if you work in copper mines or if you grind metals containing copper.

How can copper affect my health?

Everyone must absorb small amounts of copper every day because copper is essential for good health. High levels of copper can be harmful. Breathing high levels of copper can cause irritation of your nose and throat. Ingesting high levels of copper can cause nausea, vomiting, and diarrhea. Very-high doses of copper can cause damage to your liver and kidneys, and can even cause death.

How likely is copper to cause cancer?

We do not know whether copper can cause cancer in humans. The EPA has determined that copper is not classifiable as to human carcinogenicity.

How can copper affect children?

Exposure to high levels of copper will result in the same type of effects in children and adults. We do not know if these effects would occur at the same dose level in children and adults. Studies in animals suggest that the young children may have more severe effects than adults, but we don't know if this would also be true in humans. There is a very small percentage of infants and children who are unusually sensitive to copper.

We do not know if copper can cause birth defects or other developmental effects in humans. Studies in animals suggest that high levels of copper may cause a decrease in fetal growth.

How can families reduce the risk of exposure to copper?

The most likely place to be exposed to copper is through drinking water, especially if your water is corrosive and you have copper pipes in your house. The best way to lower the level of copper in your drinking water is to let the water run for at least 15 seconds first thing in the morning before drinking or using it. This reduces the levels of copper in tap water dramatically.

If you work with copper, wear the necessary protective clothing and equipment, and always follow safety procedures. Shower and change your clothes before going home each day.

Is there a medical test to show whether I've been exposed to Copper?

Copper is found throughout the body; in hair, nails, blood, urine, and other tissues. High levels of copper in these samples can show that you have been exposed to higher- than normal levels of copper. These tests cannot tell whether you will experience harmful effects. Tests to measure copper levels in the body are not usually available at a doctor's office because they require special equipment, but the doctor can send samples to a specialty laboratory.

Has the federal government made recommendations to protect human health?

The EPA requires that levels of copper in drinking water be less than 1.3 mg of copper per one liter of drinking water (1.3 mg/L).

The U.S. Department of Agriculture has set the recommended daily allowance for copper at 900 micrograms of copper per day (ìg/day) for people older than eight years old.

The Occupational Safety and Health Administration (OSHA) requires that levels of copper in the air in workplaces not exceed 0.1 mg of copper fumes per cubic meter of air (0.1 mg/m3) and 1.0 mg/m^3 for copper dusts.

References

Agency for Toxic Substances and Disease Registry (ATSDR). 2004. Toxicological Profile for Copper (/toxprofiles/TP.asp?id=206&tid=37) . Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

Where can I get more information?

If you have questions or concerns, please contact your community or state health or environmental quality department or:

For more information, contact:
Agency for Toxic Substances and Disease Registry
Division of Toxicology and Human Health Sciences
1600 Clifton Road NE, Mailstop S102-1
Atlanta, GA 30333
Phone: 1-800-CDC-INFO · 888-232-6348 (TTY)
Email: Contact CDC-INFO (http://www.cdc.gov/cdc-info/requestform.html)

ATSDR can also tell you the location of occupational and environmental health clinics. These clinics specialize in recognizing, evaluating, and treating illnesses resulting from exposure to hazardous substances.

- Page last reviewed: March 3, 2011
- Page last updated: October 24, 2011
- Content source: Agency for Toxic Substances and Disease Registry (http://www.atsdr.cdc.gov/)

ATSDR Agency for Toxic Substances & Disease Registry

ToxFAQs^{TM} for Nickel

(*Níquel* (/es/toxfaqs/es_tfacts15.html))

August 2005

CAS#: 7440-02-0

(/tfacts15.pdf) **PDF Version, 33 KB** (/tfacts15.pdf)

This fact sheet answers the most frequently asked health questions about nickel. For more information, you may call the ATSDR Information Center at 1-800-232-4636. This fact sheet is one in a series of summaries about hazardous substances and their health effects. This information is important because this substance may harm you. The effects of exposure to any hazardous substance depend on the dose, the duration, how you are exposed, personal traits and habits, and whether other chemicals are present.

Highlights

Nickel is a naturally occurring element. Pure nickel is a hard, silvery-white metal used to make stainless steel and other metal alloys. Skin effects are the most common effects in people who are sensitive to nickel. Workers who breathed very large amounts of nickel compounds developed chronic bronchitis and lung and nasal sinus cancers. Nickel has been found in at least 882 of the 1,662 National Priority List sites identified by the Environmental Protection Agency (EPA).

What is nickel?

Nickel is a very abundant natural element. Pure nickel is a hard, silvery-white metal. Nickel can be combined with other metals, such as iron, copper, chromium, and zinc, to form alloys. These alloys are used to make coins, jewelry, and items such as valves and heat exchangers. Most nickel is used to make stainless steel.

Nickel can combine with other elements such as chlorine, sulfur, and oxygen to form nickel compounds. Many nickel compounds dissolve fairly easy in water and have a green color. Nickel compounds are used for nickel plating, to color ceramics, to make some batteries, and as substances known as catalysts that increase the rate of chemical reactions.

Nickel is found in all soil and is emitted from volcanoes. Nickel is also found in meteorites and on the ocean floor. Nickel and its compounds have no characteristic odor or taste.

What happens to nickel when it enters the environment?

- Nickel is released into the atmosphere by industries that make or use nickel, nickel alloys, or nickel compounds. It is also released into the atmosphere by oil-burning power plants, coal-burning power plants, and trash incinerators.
- In the air, it attaches to small particles of dust that settle to the ground or are taken out of the air in rain or snow; this usually takes many days.
- Nickel released in industrial waste-water ends up in soil or sediment where it strongly attaches to particles containing iron or manganese.
- Nickel does not appear to accumulate in fish or in other animals used as food.

How might I be exposed to nickel?

- By eating food containing nickel, which is the major source of exposure for most people.
- By skin contact with soil, bath or shower water, or metals containing nickel, as well as by handling coins or touching jewelry containing nickel.
- By drinking water that contains small amounts of nickel.
- By breathing air or smoking tobacco containing nickel.
- Higher exposure may occur if you work in industries that process or use nickel.

How can nickel affect my health?

The most common harmful health effect of nickel in humans is an allergic reaction. Approximately 10-20% of the population is sensitive to nickel. People can become sensitive to nickel when jewelry or other things containing it are in direct contact with the skin for a long time. Once a person is sensitized to nickel, further contact with the metal may produce a reaction. The most common reaction is a skin rash at the site of contact. The skin rash may also occur at a site away from the site of contact. Less frequently, some people who are sensitive to nickel have asthma attacks following exposure to nickel. Some sensitized people react when they consume food or water containing nickel or breathe dust containing it.

People working in nickel refineries or nickel-processing plants have experienced chronic bronchitis and reduced lung function. These persons breathed amounts of nickel much higher than levels found normally in the environment. Workers who drank water containing high amounts of nickel had stomach ache and suffered adverse effects to their blood and kidneys.

Damage to the lung and nasal cavity has been observed in rats and mice breathing nickel compounds. Eating or drinking large amounts of nickel has caused lung disease in dogs and rats and has affected the stomach, blood, liver, kidneys, and immune system in rats and mice, as well as their reproduction and development.

How likely is nickel to cause cancer?

Cancers of the lung and nasal sinus have resulted when workers breathed dust containing high levels of nickel compounds while working in nickel refineries or nickel processing plants. The Department of Health and Human Services (DHHS) has determined that nickel metal may reasonably be anticipated to be a carcinogen and that nickel compounds are known human carcinogens. The International Agency for Research on Cancer (IARC) has determined that some nickel compounds are carcinogenic to humans and that metallic nickel may possibly be carcinogenic to humans. The EPA has determined that nickel refinery dust and nickel subsulfide are human carcinogens.

How can nickel affect children?

It is likely that the health effects seen in children exposed to nickel will be similar to those seen in adults. We do not know whether children differ from adults in their susceptibility to nickel. Human studies that examined whether nickel can harm the fetus are inconclusive. Animal studies have found increases in newborn deaths and decreased newborn weight after ingesting very high amounts of nickel. Nickel can be transferred from the mother to an infant in breast milk and can cross the placenta.

How can families reduce the risks of exposure to nickel?

- Avoiding jewelry containing nickel will eliminate risks of exposure to this source of the metal.
- Exposures of the general population from other sources, such as foods and drinking water, are almost always too low to be of concern.

Is there a medical test to show whether I've been exposed to nickel?

There are tests available to measure nickel in your blood, feces, and urine. More nickel was measured in the urine of workers who were exposed to nickel compounds that dissolve easily in water than in the urine of workers exposed to nickel compounds that are hard to dissolve. This means that it is easier to tell if you have been exposed to soluble nickel compounds than less-soluble compounds. The nickel measurements do not accurately predict potential health effects from exposure to nickel.

Has the federal government made recommendations to protect human health?

The EPA recommends that drinking water should contain no more than 0.1 milligrams of nickel per liter of water (0.1 mg/L).

To protect workers, the Occupational Safety and Health Administration (OSHA) has set a limit of 1 mg of nickel per cubic meter of air (1 mg/m^3) for metallic nickel and nickel compounds in workplace air during an 8-hour workday, 40-hour workweek

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References

Agency for Toxic Substances and Disease Registry (ATSDR). 2005. Toxicological Profile for Nickel (/ToxProfiles/TP.asp?id=245&tid=44) (Update). Atlanta, GA: U.S. Department of Public Health and Human Services, Public Health Service.

Where can I get more information?

If you have questions or concerns, please contact your community or state health or environmental quality department or:

For more information, contact:
Agency for Toxic Substances and Disease Registry
Division of Toxicology and Human Health Sciences
1600 Clifton Road NE, Mailstop S102-1
Atlanta, GA 30333
Phone: 1-800-CDC-INFO · 888-232-6348 (TTY)
Email: Contact CDC-INFO (http://www.cdc.gov/cdc-info/requestform.html)

ATSDR can also tell you the location of occupational and environmental health clinics. These clinics specialize in recognizing, evaluating, and treating illnesses resulting from exposure to hazardous substances.

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- Content source: Agency for Toxic Substances and Disease Registry (http://www.atsdr.cdc.gov/)

Types of Lights

  

Energy conservation is becoming more and more of a concern. One solution is to use more energy efficient bulbs at home, schools, businesses and public places. This document will introduce key terms to use when talking about lighting as well as types of light bulbs in use.

Key Terms:

- **Watt** (abbreviated W) is the unit corresponding to the rate of energy consumption (or power) in an electric circuit needed in this case to light a light bulb.
- **Lumens** are the unit describing the amount of light (energy) as seen by the human eye that is given off by the light bulb.
- **Lux** is defined as being equivalent to one lumen spread over an area of one square meter. To put it another way, a measurement of lux (light intensity) tells you how many lumens are needed for the area being illuminated.
- **Efficiency** is the amount of light that comes out of a light bulb compared to the electrical energy that goes into it. Energy efficient bulbs waste less energy in producing light than less efficient bulbs. Efficiency is an output over an input.
- **Efficacy** is related to the efficiency of the light bulb. It is also an output over an input. The output is the lumens of light and the input in power in watts. So, the expression we use to describe the efficacy of our light is "Lumens Per Watt" or lumens divided by watts. Keep in mind, the bigger the efficacy, the more efficient the bulb.
- Some bulbs make things they are illuminating look a different color than they really are. This property is called **Color Rendition**. Generally, bulbs with good color rendition are used. Color rendition can be measured by the Color Rendering Index[1] (CRI), which is a scale ranging from 0 (very poor color rendition) to 100 (nearly perfect color rendition). In cases of extremely poor color rendition, that bulb's CRI value can be negative. Incandescent bulbs are defined to have perfect color rendition.

[1] http://www.nature.com/lsa/journal/v3/n2/fig_tab/lsa201422t1.html#figure-title

Types of Lights

Indoor Lighting

Some of the most common indoor light bulbs are incandescent bulbs, which look like a traditional light bulb. Generally, the input for these bulbs is either 40W or 60W. But there are other kinds of indoor light bulbs as well, such as CFLs and LEDs. Keep in mind that the wattages listed for the CFLs and LEDs correspond to the 40W and 60W incandescent bulbs. This means that for a lamp that takes a 40W incandescent, you could also use a 9W CFL or a 6W LED. This will allow you to easily compare the bulbs to one another.

Incandescent Bulbs:

The incandescent light bulb has had the same design for over 100 years since Thomas Edison invented it! It produces light when a thin wire called a tungsten filament is heated by electricity running through it making it so hot that it starts to glow brightly. This releases a lot of heat and the bulbs get hot to the touch, meaning this bulb is very inefficient. Many countries, including the United States, are currently passing legislation banning the sale of these light bulbs because they are so inefficient.

CRI: 100

Wattage	40	60
Lumens	290	840

Compact Fluorescent Light Bulbs (CFL):

These spiraled light bulbs are far more efficient than the standard incandescent bulb. Compact Fluorescent Light bulbs (CFLs) work by running electricity through gas inside the coils, exciting that gas, and producing light. There is a coating on the spirals, which makes this light white. These bulbs do not get nearly as hot as the incandescent bulbs.

CRI: 50-80

Wattage	9	13
Lumens	550	810

Types of Lights

Light Emitting Diode (LED):

Unlike incandescent and CFL bulbs, LED bulbs have moved into the technological age. LEDs that produce white light work in a rather complicated way, and their invention won a Nobel Prize in Physics in 2014! While these are the most efficient bulbs to date, they are not without problems. Although the light they produce looks white, remember that white light contains all the colors of the rainbow. LEDs contain a lot of blue light, too much of which can have negative effects on human health and wildlife.

CRI: 80-98

Wattage	6	9.5
Lumens	450	800

Outdoor Lighting

Outdoor lights are usually different from those bulbs used indoors because they need to be much brighter and last longer. There are many different kinds of light bulbs used outdoors, and they each have pros and cons.

Halogen Bulbs:

Halogen bulbs are often found in homes as spotlights or floodlights, in cars as headlights, or at sports fields as stadium lights. These bulbs work in a similar way to an incandescent bulb by running electricity through a tungsten filament. Unlike the incandescent, there is halogen gas inside the bulb. When the tungsten burns off the filament, the gas re-deposits it back onto the filament to be reused. Halogen bulbs last much longer than incandescent, but these bulbs are much brighter and burn much hotter than traditional incandescent bulbs.

CRI: 100

Wattage	53	72	75
Lumens	940	1350	1500

Types of Lights

Metal Halide:

Metal halide lamps are commonly used in streetlights, parking lot lights, and stadium lights. They are very bright and contribute to a lot of light pollution. They are fairly efficient. They produce very white light and have good color rendition, meaning that objects under these lights look their true color.

CRI: 85-94

Wattage	250	400	1000
Lumens	22,000	36,000	110,000

High Pressure Sodium (HPS):

The high pressure sodium lamp (HPS) is the most commonly used street light throughout the world. It produces light by running electricity through a mixture of gases, which produces light. The lamp itself is preferred because it requires little maintenance. These lamps are fairly efficient. They take a while to turn on completely and produce a yellow-orange glow.

CRI: 20-24

Wattage	150	250	400
Lumens	16,000	24,000	50,000

Types of Lights

Low Pressure Sodium (LPS):

The low pressure sodium (LPS) lamp works similarly to the HPS light. Instead of producing white light (all the colors of the rainbow), LPS lamps produce almost exclusively yellow light. While this light is fairly efficient, it takes several minutes for the bulb to turn on. The light is very yellow-orange. This yellow light makes objects it is illuminating look a different color or gray.

CRI: -44

Wattage	18	35	55
Lumens	1800	4550	7800

LED Street Lamps:

LED technologies have developed rapidly in recent years and these bulbs are now being integrated into outdoor lighting solutions. While the energy savings are significant, LEDs produce a lot of blue light, too much of which can have negative effects on human health and wildlife.

CRI: 80-98

Wattage	25	42	146	202
Lumens	2772	3648	12,642	13,620

Types of Lights

Phosphor-Converted Amber (PCA) LED Street Lamps:

PCALEDs have only been on the market for the past few years. They use very little energy and have good color rendition, but are still rather expensive. Some cities have already installed these lights on their streets.

CRI: >80

Wattage	0.9	1.8
Lumens	140	77

Narrow-Band Amber (NBA) LED Street Lamps:

Narrow-band amber (NBA) LED street lights are a brand new technology. Rather than emitting all the colors of the rainbow and a lot of blue light, they emit mostly in the yellow. They still have good color rendition, meaning that they do not make things look grey like LPS lamps do. Because this technology is so new, these bulbs are not widely available and as such, are still expensive. They are very efficient.

CRI: 67

Wattage	16.4	20.6	42.3
Lumens	1147	1460	3311

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Limiting the impact of light pollution on human health, environment and stellar visibility

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Abstract

Light pollution is one of the most rapidly increasing types of environmental degradation. Its levels have been growing exponentially over the natural nocturnal lighting levels provided by starlight and moonlight. To limit this pollution several effective practices have been defined: the use of shielding on lighting fixture to prevent direct upward light, particularly at low angles above the horizon; no over lighting, i.e. avoid using higher lighting levels than strictly needed for the task, constraining illumination to the area where it is needed and the time it will be used. Nevertheless, even after the best control of the light distribution is reached and when the proper quantity of light is used, some upward light emission remains, due to reflections from the lit surfaces and atmospheric scatter. The environmental impact of this "residual light pollution", cannot be neglected and should be limited too. Here we propose a new way to limit the effects of this residual light pollution on wildlife, human health and stellar visibility. We performed analysis of the spectra of common types of lamps for external use, including the new LEDs. We evaluated their emissions relative to the spectral response functions of human eye photoreceptors, in the photopic, scotopic and the 'meltopic' melatonin suppressing bands. We found that the amount of pollution is strongly dependent on the spectral characteristics of the lamps, with the more environmentally friendly lamps being low pressure sodium, followed by high pressure sodium. Most polluting are the lamps with a strong blue emission, like Metal Halide and white LEDs. Migration from the now widely used sodium lamps to white lamps (MH and LEDs) would produce an increase of pollution in the scotopic and melatonin suppression bands of more than five times the present levels, supposing the same photopic installed flux. This increase will exacerbate known and possible unknown effects of light pollution on human health, environment and on visual perception of the Universe by humans. We present quantitative criteria to evaluate the lamps based on their spectral emissions and we suggest regulatory limits for future lighting.

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REPORT OF THE COUNCIL ON SCIENCE AND PUBLIC HEALTH

CSAPH Report 2-A-16

Subject: Human and Environmental Effects of Light Emitting Diode (LED) Community Lighting

Presented by: Louis J. Kraus, MD, Chair

Referred to: Reference Committee E
(Theodore Zanker, MD, Chair)

INTRODUCTION

With the advent of highly efficient and bright light emitting diode (LED) lighting, strong economic arguments exist to overhaul the street lighting of U.S. roadways.[1-3] Valid and compelling reasons driving the conversion from conventional lighting include the inherent energy efficiency and longer lamp life of LED lighting, leading to savings in energy use and reduced operating costs, including taxes and maintenance, as well as lower air pollution burden from reduced reliance on fossil-based carbon fuels.

Not all LED light is optimal, however, when used as street lighting. Improper design of the lighting fixture can result in glare, creating a road hazard condition.[4,5] LED lighting also is available in various color correlated temperatures. Many early designs of white LED lighting generated a color spectrum with excessive blue wavelength. This feature further contributes to disability glare, i.e., visual impairment due to stray light, as blue wavelengths are associated with more scattering in the human eye, and sufficiently intense blue spectrum damages retinas.[6,7] The excessive blue spectrum also is environmentally disruptive for many nocturnal species. Accordingly, significant human and environmental concerns are associated with short wavelength (blue) LED emission. Currently, approximately 10% of existing U.S. street lighting has been converted to solid state LED technology, with efforts underway to accelerate this conversion. The Council is undertaking this report to assist in advising communities on selecting among LED lighting options in order to minimize potentially harmful human health and environmental effects.

METHODS

English language reports published between 2005 and 2016 were selected from a search of the PubMed and Google Scholar databases using the MeSH terms "light," "lighting methods," "color," "photic stimulation," and "adverse effects," in combination with "circadian rhythm/physiology/radiation effects," "radiation dosage/effects," "sleep/physiology," "ecosystem," "environment," and "environmental monitoring." Additional searches using the text terms "LED" and "community," "street," and "roadway lighting" were conducted. Additional information and perspective were supplied by recognized experts in the field.

ADVANTAGES AND DISADVANTAGES OF LED STREET LIGHTS

The main reason for converting to LED street lighting is energy efficiency; LED lighting can reduce energy consumption by up to 50% compared with conventional high pressure sodium (HPS) lighting. LED lighting has no warm up requirement with a rapid "turn on and off" at full intensity. In the event of a power outage, LED lights can turn on instantly when power is restored, as opposed to sodium-based lighting requiring prolonged warm up periods. LED lighting also has the inherent capability to be dimmed or tuned, so that during off peak usage times (e.g., 1 to 5 AM), further energy savings can be achieved by reducing illumination levels. LED lighting also has a much longer lifetime (15 to 20 years, or 50,000 hours), reducing maintenance costs by decreasing the frequency of fixture or bulb replacement. That lifespan exceeds that of conventional HPS lighting by 2-4 times. Also, LED lighting has no mercury or lead, and does not release any toxic substances if damaged, unlike mercury or HPS lighting. The light output is very consistent across cold or warm temperature gradients. LED lights also do not require any internal reflectors or glass covers, allowing higher efficiency as well, if designed properly.[8,9]

Despite the benefits of LED lighting, some potential disadvantages are apparent. The initial cost is higher than conventional lighting; several years of energy savings may be required to recoup that initial expense.[10] The spectral characteristics of LED lighting also can be problematic. LED lighting is inherently narrow bandwidth, with "white" being obtained by adding phosphor coating layers to a high energy (such as blue) LED. These phosphor layers can wear with time leading to a higher spectral response than was designed or intended. Manufacturers address this problem with more resistant coatings, blocking filters, or use of lower color temperature LEDs. With proper design, higher spectral responses can be minimized. LED lighting does not tend to abruptly "burn out," rather it dims slowly over many years. An LED fixture generally needs to be replaced after it has dimmed by 30% from initial specifications, usually after about 15 to 20 years.[1,11]

Depending on the design, a large amount blue light is emitted from some LEDs that appear white to the naked eye. The excess blue and green emissions from some LEDs lead to increased light pollution, as these wavelengths scatter more within the eye and have detrimental environmental and glare effects. LED's light emissions are characterized by their correlated color temperature (CCT) index.[12,13] The first generation of LED outdoor lighting and units that are still widely being installed are "4000K" LED units. This nomenclature (Kelvin scale) reflects the equivalent color of a heated metal object to that temperature. The LEDs are cool to the touch and the nomenclature has nothing to do with the operating temperature of the LED itself. By comparison, the CCT associated with daylight light levels is equivalent to 6500K, and high pressure sodium lighting (the current standard) has a CCT of 2100K. Twenty-nine percent of the spectrum of 4000K LED lighting is emitted as blue light, which the human eye perceives as a harsh white color. Due to the point-source nature of LED lighting, studies have shown that this intense blue point source leads to discomfort and disability glare.[14]

More recently engineered LED lighting is now available at 3000K or lower. At 3000K, the human eye still perceives the light as "white," but it is slightly warmer in tone, and has about 21% of its emission in the blue-appearing part of the spectrum. This emission is still very blue for the nighttime environment, but is a significant improvement over the 4000K lighting because it reduces discomfort and disability glare. Because of different coatings, the energy efficiency of 3000K lighting is only 3% less than 4000K, but the light is more pleasing to humans and has less of an impact on wildlife.

Glare

Disability glare is defined by the Department of Transportation (DOT) as the following:

> "Disability glare occurs when the introduction of stray light into the eye reduces the ability to resolve spatial detail. It is an objective impairment in visual performance."

Classic models of this type of glare attribute the deleterious effects to intraocular light scatter in the eye. Scattering produces a veiling luminance over the retina, which effectively reduces the contrast of stimulus images formed on the retina. The disabling effect of the veiling luminance has serious implications for nighttime driving visibility.[15]

Although LED lighting is cost efficient and inherently directional, it paradoxically can lead to worse glare than conventional lighting. This glare can be greatly minimized by proper lighting design and engineering. Glare can be magnified by improper color temperature of the LED, such as blue-rich LED lighting. LEDs are very intense point sources that cause vision discomfort when viewed by the human eye, especially by older drivers. This effect is magnified by higher color temperature LEDs, because blue light scatters more within the human eye, leading to increased disability glare.[16]

In addition to disability glare and its impact on drivers, many residents are unhappy with bright LED lights. In many localities where 4000K and higher lighting has been installed, community complaints of glare and a “prison atmosphere” by the high intensity blue-rich lighting are common. Residents in Seattle, WA have demanded shielding, complaining they need heavy drapes to be comfortable in their own homes at night.[17] Residents in Davis, CA demanded and succeeded in getting a complete replacement of the originally installed 4000K LED lights with the 3000K version throughout the town at great expense.[18] In Cambridge, MA, 4000K lighting with dimming controls was installed to mitigate the harsh blue-rich lighting late at night. Even in places with a high level of ambient nighttime lighting, such as Queens in New York City, many complaints were made about the harshness and glare from 4000K lighting.[19] In contrast, 3000K lighting has been much better received by citizens in general.

Unshielded LED Lighting

Unshielded LED lighting causes significant discomfort from glare. A French government report published in 2013 stated that due to the point source nature of LED lighting, the luminance level of unshielded LED lighting is sufficiently high to cause visual discomfort regardless of the position, as long as it is in the field of vision. As the emission surfaces of LEDs are highly concentrated point sources, the luminance of each individual source easily exceeds the level of visual discomfort, in some cases by a factor of 1000.[17]

Discomfort and disability glare can decrease visual acuity, decreasing safety and creating a road hazard. Various testing measures have been devised to determine and quantify the level of glare and vision impairment by poorly designed LED lighting.[20] Lighting installations are typically tested by measuring foot-candles per square meter on the ground. This is useful for determining the efficiency and evenness of lighting installations. This method, however, does not take into account the human biological response to the point source. It is well known that unshielded light sources cause pupillary constriction, leading to worse nighttime vision between lighting fixtures and causing a “veil of illuminance” beyond the lighting fixture. This leads to worse vision than if the light never existed at all, defeating the purpose of the lighting fixture. Ideally LED lighting installations should be tested in real life scenarios with effects on visual acuity evaluated in order to ascertain the best designs for public safety.

Proper Shielding

With any LED lighting, proper attention should be paid to the design and engineering features. LED lighting is inherently a bright point source and can cause eye fatigue and disability glare if it is allowed to directly shine into human eyes from roadway lighting. This is mitigated by proper design, shielding and installation ensuring that no light shines above 80 degrees from the horizontal. Proper shielding also should be used to prevent light trespass into homes alongside the road, a common cause of citizen complaints. Unlike current HPS street lighting, LEDs have the ability to be controlled electronically and dimmed from a central location. Providing this additional control increases the installation cost, but may be worthwhile because it increases long term energy savings and minimizes detrimental human and environmental lighting effects. In environmentally sensitive or rural areas where wildlife can be especially affected (e.g., near national parks or bio-rich zones where nocturnal animals need such protection), strong consideration should be made for lower emission LEDs (e.g., 3000K or lower lighting with effective shielding). Strong consideration also should be given to the use of filters to block blue wavelengths (as used in Hawaii), or to the use of inherent amber LEDs, such as those deployed in Quebec. Blue light scatters more widely (the reason the daytime sky is "blue"), and unshielded blue-rich lighting that travels along the horizontal plane increases glare and dramatically increases the nighttime sky glow caused by excessive light pollution.

POTENTIAL HEALTH EFFECTS OF "WHITE" LED STREET LIGHTING

Much has been learned over the past decade about the potential adverse health effects of electric light exposure, particularly at night.[21-25] The core concern is disruption of circadian rhythmicity. With waning ambient light, and in the absence of electric lighting, humans begin the transition to nighttime physiology at about dusk; melatonin blood concentrations rise, body temperature drops, sleepiness grows, and hunger abates, along with several other responses.

A number of controlled laboratory studies have shown delays in the normal transition to nighttime physiology from evening exposure to tablet computer screens, backlit e-readers, and room light typical of residential settings.[26-28] These effects are wavelength and intensity dependent, implicating bright, short wavelength (blue) electric light sources as disrupting transition. These effects are not seen with dimmer, longer wavelength light (as from wood fires or low wattage incandescent bulbs). In human studies, a short-term detriment in sleep quality has been observed after exposure to short wavelength light before bedtime. Although data are still emerging, some evidence supports a long-term increase in the risk for cancer, diabetes, cardiovascular disease and obesity from chronic sleep disruption or shiftwork and associated with exposure to brighter light sources in the evening or night.[25,29]

Electric lights differ in terms of their circadian impact.[30] Understanding the neuroscience of circadian light perception can help optimize the design of electric lighting to minimize circadian disruption and improve visual effectiveness. White LED streetlights are currently being marketed to cities and towns throughout the country in the name of energy efficiency and long term cost savings, but such lights have a spectrum containing a strong spike at the wavelength that most effectively suppresses melatonin during the night. It is estimated that a "white" LED lamp is at least 5 times more powerful in influencing circadian physiology than a high pressure sodium light based on melatonin suppression.[31] Recent large surveys found that brighter residential nighttime lighting is associated with reduced sleep time, dissatisfaction with sleep quality, nighttime awakenings, excessive sleepiness, impaired daytime functioning, and obesity.[29,32] Thus, white LED street lighting patterns also could contribute to the risk of chronic disease in the populations of cities in which they have been installed. Measurements at street level from white LED street lamps are needed to more accurately assess the potential circadian impact of evening/nighttime exposure to these lights.

ENVIRONMENTAL EFFECTS OF LED LIGHTING

The detrimental effects of inefficient lighting are not limited to humans; 60% of animals are nocturnal and are potentially adversely affected by exposure to nighttime electrical lighting. Many birds navigate by the moon and star reflections at night; excessive nighttime lighting can lead to reflections on glass high rise towers and other objects, leading to confusion, collisions and death.[33] Many insects need a dark environment to procreate, the most obvious example being lightning bugs that cannot "see" each other when light pollution is pronounced. Other environmentally beneficial insects are attracted to blue-rich lighting, circling under them until they are exhausted and die.[34,35] Unshielded lighting on beach areas has led to a massive drop in turtle populations as hatchlings are disoriented by electrical light and sky glow, preventing them from reaching the water safely.[35-37] Excessive outdoor lighting diverts the hatchlings inland to their demise. Even bridge lighting that is "too blue" has been shown to inhibit upstream migration of certain fish species such as salmon returning to spawn. One such overly lit bridge in Washington State now is shut off during salmon spawning season.

Recognizing the detrimental effects of light pollution on nocturnal species, U.S. national parks have adopted best lighting practices and now require minimal and shielded lighting. Light pollution along the borders of national parks leads to detrimental effects on the local bio-environment. For example, the glow of Miami, FL extends throughout the Everglades National Park. Proper shielding and proper color temperature of the lighting installations can greatly minimize these types of harmful effects on our environment.

CONCLUSION

Current AMA Policy supports efforts to reduce light pollution. Specific to street lighting, Policy H-135.932 supports the implementation of technologies to reduce glare from roadway lighting. Thus, the Council recommends that communities considering conversion to energy efficient LED street lighting use lower CCT lights that will minimize potential health and environmental effects. The Council previously reviewed the adverse health effects of nighttime lighting, and concluded that pervasive use of nighttime lighting disrupts various biological processes, creating potentially harmful health effects related to disability glare and sleep disturbance.[25]

RECOMMENDATIONS

The Council on Science and Public Health recommends that the following statements be adopted, and the remainder of the report filed.

1. That our American Medical Association (AMA) support the proper conversion to community-based Light Emitting Diode (LED) lighting, which reduces energy consumption and decreases the use of fossil fuels. (New HOD Policy)

2. That our AMA encourage minimizing and controlling blue-rich environmental lighting by using the lowest emission of blue light possible to reduce glare. (New HOD Policy)

3. That our AMA encourage the use of 3000K or lower lighting for outdoor installations such as roadways. All LED lighting should be properly shielded to minimize glare and detrimental human and environmental effects, and consideration should be given to utilize the ability of LED lighting to be dimmed for off-peak time periods. (New HOD Policy)

Fiscal Note: Less than $500

REFERENCES

1. Municipal Solid State Street Lighting Consortium. http://www1.eere.energy.gov/buildings/ssl/consortium.html. Accessed April 4, 2016.

2. Illuminating Engineering Society RP-8 – Guide to Roadway Lighting. http://www.ies.org/? 2014. Accessed April 4, 2016.

3. LED Lighting Facts–A Program of the United States Department of Energy. http://www.lightingfacts.com. Accessed April 5, 2016.

4. Lin Y, Liu Y, Sun Y, Zhu X, Lai J, Heynderickz I. Model predicting discomfort glare caused by LED road lights. *Opt Express*. 2014;22(15):18056-71.

5. Gibbons RB, Edwards CJ. A review of disability and discomfort glare research and future direction. 18th Biennial TRB Visibility Symposium, College Station TX, United States, April 17-19, 2007.

6. Shang YM, Wang GS, Sliney D, Yang CH, Lee LL. White light–emitting diodes (LEDs) at domestic lighting levels and retinal injury in a rat model. *Environ Health Perspect.* 2014:122(3):269-76.

7. Lougheed T. Hidden blue hazard? LED lighting and retinal damage in rats, *Environ Health Perspect*. 2014;122(3):A81.

8. A Municipal Guide for Converting to LED Street Lighting, (http://www1.eere.energy.gov/buildings/ssl/consortium.html) 10/13/2013.

9. In depth: Advantages of LED Lighting. http://energy.ltgovernors.com/in-depth-advantages-of-led-lighting.html. Accessed April 5, 2016.

10. Silverman H. How LED Streetlights Work. HowStuffWorks.com. June 22, 2009. http://science.howstuffworks.com/environmental/green-tech/sustainable/led-streetlight.htm. Accessed April 7, 2016.

11. Jin H, Jin S, Chen L, Cen S, Yuan K. Research on the lighting performance of LED street lights with different color temperatures. *IEEE Photonics Journal*. 2015;24(6):975-78. http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=7328247. Accessed April 7, 2016.

12. Morris N. LED there be light. Nick Morris predicts a bright future for LEDs. *Electrooptics.com*. http://www.electrooptics.com/features/junjul06/junjul06leds.html. Accessed April 7, 2016.

13. Mills MP. The LED illumination revolution. *Forbes Magazine*. February 27, 2008. http://www.forbes.com/2008/02/27/incandescent-led-cfl-pf-guru_in_mm_0227energy_inl.html. Accessed April 5, 2016.

14. Opinion of the French Agency for Food, Environmental and Occupational Health & Safety, October 19, 2010. https://web.archive.org/web/20140429161553/http:/www.anses.fr/Documents/AP2008sa0408EN.pdf

15. U.S. Department of Transportation, Federal Highway Administration, 2005.

16. Sweater-Hickcox K, Narendran N, Bullough JD, Freyssinier JP. Effect of different coloured luminous surrounds on LED discomfort glare perception. *Lighting Research Technology*. 2013;45(4):464-75. http://lrt.sagepub.com/content/45/4/464. Accessed April 5, 2016.

17. Scigliano E. Seattle's new LED-lit streets Blinded by the lights. *Crosscut*. March 18, 2013. http://crosscut.com/2013/03/streetlights-seattle-led/. Accessed April 6, 2016.

18. Davis will spend $350,000 to replace LED lights after neighbor complaints. CBS Local, Sacramento;October 21, 2014. http://sacramento.suntimes.com/sac-news/7/138/6000/davis-will-spend-350000-to-replace-led-lights-after-neighbor-complaints.

19. Chaban M. LED streetlights in Brooklyn are saving energy but exhausting residents. *NY Times*; March 23, 2015. http://www.nytimes.com/2015/03/24/nyregion/new-led-streetlights-shine-too-brightly-for-some-in-brooklyn.html?_r=0. Accessed April 5, 2016.

20. Vos JJ. On the cause of disability glare and its dependence on glare angle, age and ocular pigmentation. *Clin Exp Optom*. 2003;86(6):363-70.

21. Stevens RG, Brainard GC, Blask DE, Lockley, SW, Motta, ME. Breast cancer and circadian disruption from electric lighting in the modern world. *CA Cancer J Clin*. 2014;64:207-18.

22. Evans JA, Davidson AJ. Health consequences of circadian disruption in humans and animal models. *Prog Mol Biol Transl Sci*. 2013;119:283-323.

23. Wright KP Jr, McHill AW, Birks BR, Griffin BR, Rusterholz T, Chinoy ED. Entrainment of the human circadian clock to the natural light-dark cycle. *Curr Biol*. 2013;23:1554-8.

24. Energy Savings Estimates of Light Emitting Diodes in Niche Lighting Applications. Building Technologies Program, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy. January 2011. http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/nichefinalreport_january2011.pdf.Accessed April 7, 2016.

25. Council on Science and Public Health Report 4. Light pollution. Adverse effects of nighttime lighting. American Medical Association, Annual Meeting, Chicago, IL. 2012.

26. Cajochen C, Frey S, Anders D, et al. Evening exposure to a light-emitting diodes (LED)-backlit computer screen affects circadian physiology and cognitive performance. *J Appl Physiol*. 2011;110:1432-8.

27. Chang AM, Aeschbach D, Duffy JF, Czeisler CA. Evening use of light-emitting eReaders negatively affects sleep, circadian timing, and next-morning alertness. *Proc Natl Acad Sci USA*. 2015;112:1232-7.

28. Gooley JJ, Chamberlain K, Smith KA, et al. Exposure to room light before bedtime suppresses melatonin onset and shortens melatonin duration in humans. *J Clin Endocrinol Metab*. 2011;96:E463-72.

29. Koo YS, Song JY, Joo EY, et al. Outdoor artificial light at night, obesity, and sleep health: Cross-sectional analysis in the KoGES study. *Chronobiol Int*. 2016;33(3):301-14.

30. Lucas RJ, Peirson SN, Berson DM, et al. Measuring and using light in the melanopsin age. *Trends Neurosci*. 2014;37:1-9.

31. Falchi F, Cinzano P, Elvidge CD, Keith DM, Haim A. Limiting the impact of light pollution on human health, environment and stellar visibility. *J Environ Manage*. 2011;92:2714-22.

32. Ohayon M, Milesi C. Sleep deprivation/insomnia and exposure to street lights in the American general population. American Academy of Neurology Annual Meeting. April 15-21, 2016. Vancouver, BC.

33. Pawson SM, Bader MK. Led lighting increases the ecological impact of light pollution irrespective of color temperature. *Ecological Applications*. 2014;24:1561-68.

34. Gaston K, Davies T, Bennie J, Hopkins J. Reducing the ecological consequences of night-time light pollution: Options and developments. *J Appl Ecol*. 2012;49(6):1256–66.

35. Salmon M. Protecting sea turtles from artificial night lighting at Florida's oceanic beaches. In-Rich C, Longcore T (eds.). *Ecological Consequences of Artificial Night Lighting.* 2006:141-68. Island Press, Washington, DC.

36. Rusenko KW, Mann JL, Albury R, Moriarty JE, Carter HL. Is the wavelength of city glow getting shorter? Parks with no beachfront lights record adult aversion and hatchling disorientations in 2004. Kalb H, Rohde A, Gayheart K, Shanker, K, compilers. 2008. *Proceedings of the Twenty-fifth Annual Symposium on Sea Turtle Biology and Conservation,* NOAA Technical Memorandum NMFS-SEFSC-582, 204pp. http://www.nmfs.noaa.gov/pr/pdfs/species/turtlesymposium2005.pdf

37. Rusenko KW, Newman R, Mott C, et al. Using GIS to determine the effect of sky glow on nesting sea turtles over a ten year period. Jones TT, Wallace BP, compilers. 2012. *Proceedings of the Thirty-first Annual Symposium on Sea Turtle Biology and Conservation*. NOAA Technical Memorandum NOAA NMFS-SEFSC-631:32p.

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Research

White Light–Emitting Diodes (LEDs) at Domestic Lighting Levels and Retinal Injury in a Rat Model

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Abstract

Background: Light-emitting diodes (LEDs) deliver higher levels of blue light to the retina than do conventional domestic light sources. Chronic exposure to high-intensity light (2,000–10,000 lux) has previously been found to result in light-induced retinal injury, but chronic exposure to relatively low-intensity (750 lux) light has not been previously assessed with LEDs in a rodent model.

Objective: We examined LED-induced retinal neuronal cell damage in the Sprague-Dawley rat using functional, histological, and biochemical measurements.

Methods: We used blue LEDs (460 nm) and full-spectrum white LEDs, coupled with matching compact fluorescent lights, for exposures. Pathological examinations included electroretinogram, hematoxylin and eosin (H&E) staining, immunohistochemistry (IHC), and transmission electron microscopy (TEM). We also measured free radical production in the retina to determine the oxidative stress level.

Results: H&E staining and TEM revealed apoptosis and necrosis of photoreceptors, which indicated blue-light induced photochemical injury of the retina. Free radical production in the retina was increased in LED-exposed groups. IHC staining demonstrated that oxidative stress was associated with retinal injury. Although we found serious retinal light injury in LED groups, the compact fluorescent lamp (CFL) groups showed moderate to mild injury.

Conclusion: Our results raise questions about adverse effects on the retina from chronic exposure to LED light compared with other light sources that have less blue light. Thus, we suggest a precautionary approach with regard to the use of blue-rich "white" LEDs for general lighting.

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Introduction

Artificial lighting is a basic element in modern society; however, the potential health risks caused by light pollution have increased with the development of more sophisticated lighting technology (Chepesiuk 2009). Among the wide variety of artificial lighting selections, light-emitting diodes (LEDs) emit higher levels of blue light than conventional light sources. These LEDs provide humans with their first exposure to such extensive blue light (Behar-Cohen et al. 2011). From an environmental health perspective, retinal light injury and the potential risks for chronic exposure from using LEDs as a domestic light source require assessment before further development of this important, energy-saving technology.

LED (or solid-state) lighting sources are designed to emit all energy within the wavelength range of human vision, making LEDs the most energy-efficient commercially manufactured light. However, many current "white-light" LED designs emit much more blue light than conventional lamps, which has a number of health implications, including disruption of circadian rhythms (Holzman 2010). The most popular LED lighting product, a phosphor-conversion (PC) LED, is an LED chip that emits blue light, which passes through a yellow phosphor-coating layer to generate the ultimate white light (Spivey 2011). Although the white light generated from LEDs appears normal to human vision, a strong peak of blue light ranging from 460 to 500 nm is also emitted within the white light spectrum; this blue light corresponds to a known spectrum for retinal hazards (Behar-Cohen et al. 2011). Some epidemiological studies have suggested that short-wavelength light exposure is a predisposing cause for age-related macular degeneration (AMD) (Wu et al. 2006). Animal models have also been used to determine that excessive exposure to blue light is a critical factor in photochemical retinal injury targeting photoreceptors and the retinal pigment epithelium (RPE) (Hafezi et al. 1997).

Photochemical retinal injury resulting from a cumulative effect is caused by free radicals generated from retinal tissue through continuous light exposure (Dong et al. 2006). When exposure surpasses the protective capability, unfavorable free radicals and reactive oxygen species may form (Wu et al. 2006). This enhances the oxygenated products and provides conditions favorable for photodynamic damage of photoreceptors and other retinal tissues (Beatty et al. 2000). However, the wavelength-dependent effect and its influences on white LED light-induced retinal degenerations remain unknown.

Retinal light injury was studied intensively after Noell et al. (1966) first described retinal damage caused by environmental exposure to fluorescent light, and numerous studies have reported that high-intensity blue light causes acute retinal injury (Ham et al. 1976). However, few studies have focused on retinal injury caused by exposure to relatively low-intensity blue light under chronic exposure conditions (Peng et al. 2012). The composition of the white-light spectrum differs among LED products, and their light qualities change over time. Although it is robust in the beginning, a PC LED progressively releases more short-wavelengths (blue light) when LED lumen depreciation occurs because of phosphor degradation. The quality of the light deteriorates after the lights pass the 70% lumen maintenance level (U.S. Department of Energy 2009). These characteristics suggest that a white LED can cause more blue light exposure than other domestic lighting sources. Cumulative exposure to blue light has been argued to accelerate aging of the retina and possibly play an etiological role in AMD (Behar-Cohen et al. 2011); thus, further study is needed to determine the potential retinal effects of domestic lighting with high blue light.

We hypothesized that chronic LED exposure may induce retinal photochemical injury. This study was performed in a rat model and the retinal neuronal cell damage caused by oxidative stress was examined. Functional, histological, and biochemical measurements were applied to identify the biomarkers for retinal light injury.

Materials and Methods

Animals and rearing conditions. We purchased a total of 120 adult (8-week-old) male Sprague-Dawley rats from BioLasco Taiwan Co. Ltd. (Taipei, Taiwan). Animals were housed in a dark environment for 14 days to clear the effect of light exposure from their previous rearing environment. Unexposed rats (remained in darkness) served as controls (n = 3 for each time point); the other 108 rats were separated into groups and received programmed light exposure from one of four light sources (n = 8 per exposure per time point) (Figure 1). All animals received food and water *ad libitum*. The use of rats in this study conformed to the *Statement for the Use of Animals in Ophthalmic and Vision Researc*h (ARVO 2013). The animals were treated humanely and with regard for alleviation of suffering. See Supplemental Material, p. 2 and Figure S1, for additional details.

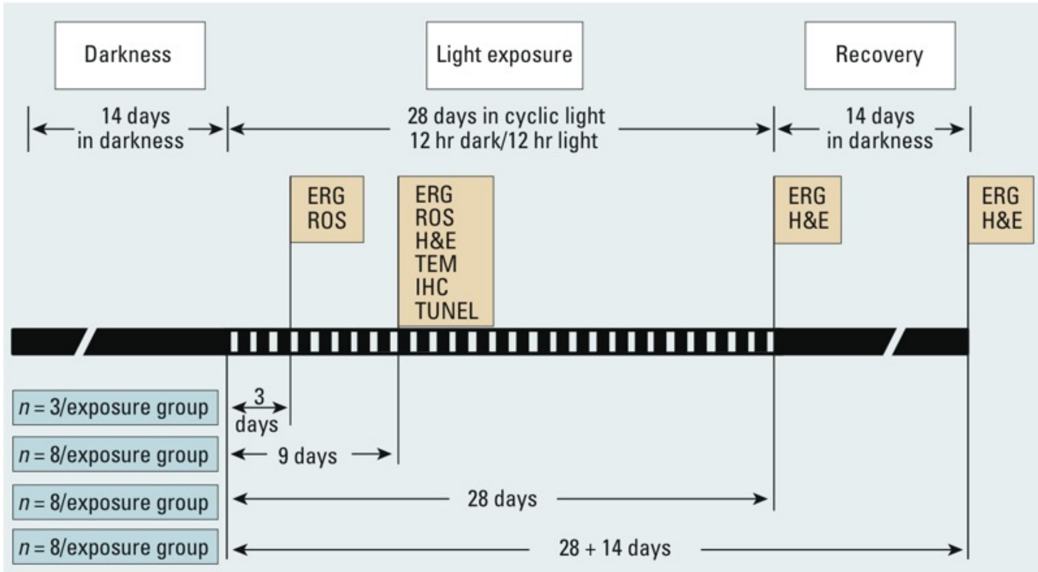

Figure 1

Timeline and experimental design. Abbreviations: CFL, compact fluorescent lamp; ERG, electroretinography; H&E, hematoxylin and eosin staining; IHC, immunohistochemistry; ROS, reactive oxygen species; TEM, transmission electron microscopy; TUNEL, terminal deoxynucleotidyl transferase dUTP nick end labeling. After 14 days of dark maintenance, the rats were divided into four groups and exposed to different light sources (blue LED, white LED, white CFL, or yellow CFL). Specific analytical techniques were performed at the end of exposure periods.

Light sources. Single-wavelength blue LEDs (460 ± 10 nm) and PC white LEDs were custom made for the exposure experiments (BlueDog Technology Corporation Ltd., Taipei, Taiwan). The PC LED had a correlated color temperature (CCT) of 6,500 K. The CCT of the white compact fluorescent lamps (CFLs) (ESE27D-EX; Chuan Shih Industrial Corporation Ltd., Chuang-Hua, Taiwan) was also 6,500 K; whereas the CCT of the yellow CFLs (ESE27L-EX; Chuan Shih Industrial Corporation Ltd.) was 3,000 K. Each light source was programed for 40 measurements in an integrating sphere. The spectrum power distributions (SPDs) and total intensities for all light sources were tested by the Industrial Technology Research Institute (Hsinchu, Taiwan), a Certification Body Testing Laboratory, and are shown in Figure 2.

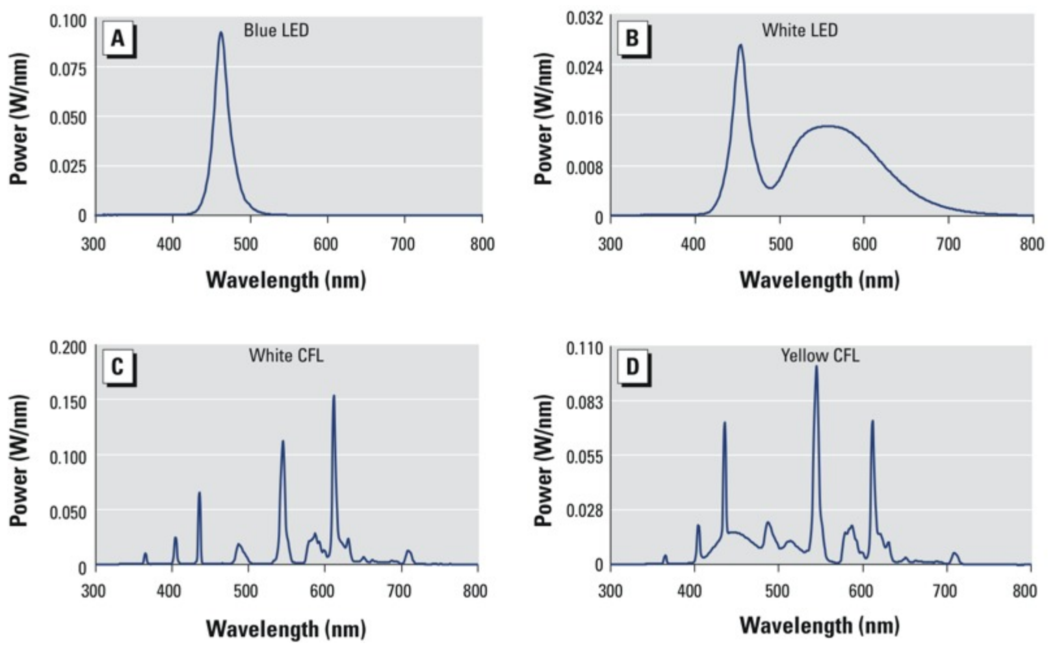

Figure 2

Light source SPD curves for (*A*) blue LED, (*B*) white LED, (*C*) white CFL, and (*D*) yellow CFL. The single-wavelength blue LED light (*A*) peaked at 460 nm (power of near 0.1 W/nm). White LED light (*B*) exhibited a CCT of 6,500 K. The first peak, which appeared at 460 nm with power of 0.028 W/nm, shows blue content; the bell shape of the second peak indicates higher yellow content. The SPD curve of white CFL light (*C*), with a CCT of 6,500 K, shows several sharp peaks across the spectrum; the blue peak is relatively shorter than the yellow or red peaks, and the full width at half maximum (FWHM) is smaller than that in (*A*) or (*B*). The SPD curve of yellow CFL light (*D*) is similar to that of white CFL (*C*), but with a CCT of 3,000 K; the highest peak represents yellow light. Although all of the light sources tested contain blue light peaks, the area under the curve variation leads to a difference in total intensity. Note the different scales for each light source.

Light exposure. For light exposure, the animals were divided into four groups. Each rat was housed in an individual transparent cage (45 cm × 25 cm × 20 cm), and each cage was placed in the center of a rack shelf (75 cm × 45 cm × 35 cm). The light sources were set on the top of each shelf and were measured 20 cm away from each source to acquire the common domestic luminance level of 750 lux. After 14 days of dark maintenance, the light exposure started at 1800 hours on day 15, with total exposure duration of 3, 9, or 28 days under 12-hr dark/12-hr light cyclic routines. The animals were sacrificed at the end of light exposure, except for 32 animals (8 from each exposure group) that were exposed to light for 28 days and then returned to a dark environment for 14 days of recovery (28+14 group) to allow for possible removal of necrotic photoreceptor cell debris.

Electroretinography (ERG). ERG was performed as described previously by Schatz et al. (2012) with some modification. Briefly, retinal electrical responses were recorded immediately before exposure began and after light exposure (allowing 18-hr dark adaptation for each rat before each ERG measurement) using ERG (RETIport ERG/VEP and RETIport software, version 4.7.2.8; Acrivet, Hennigsdorf, Germany). Alcaine (0.5%) (proxymetacaine hydrochloride; Alcon Pharmaceuticals Ltd., Puurs, Belgium) was applied for local anesthesia. Each 20-msec flash was provided by a 4 W LED (1 mV), and the illumination was set at 2.5 log cd·sec/m^2 (candela-seconds per meter squared) for Scotopic ERG response. The final detection values presented are the weighted average of 10 stimulations as computed by the software program. See Supplemental Material, pp. 4–5, for additional details.

Tissue collection. Immediately after the ERG scans, animals were sacrificed with pentobarbital sodium (> 60 mg/kg, intraperitoneal) and eyes were enucleated. For hematoxylin and eosin (H&E) staining and terminal deoxynucleotidyl transferase dUTP nick end labeling (TUNEL), eyes were immersion-fixed overnight in 4% paraformaldehyde in 0.1 M phosphate-buffered saline (PBS), pH 7.4, and then embedded in paraffin. For immunohistochemical (IHC) staining, eyes were frozen immediately in liquid nitrogen; 4-µm cryosections were placed on glass slides and maintained at –80°C until analysis. For the reactive oxygen species (ROS) assay, enucleated eyes were frozen immediately in liquid nitrogen; each eye was homogenized in 500 µL saline for extraction. For transmission electron microscopy (TEM) analysis, eyeballs were immersion-fixed in 2.5% glutaraldehyde in PBS for 2 hr before processing.

Hematoxylin and eosin (H&E) staining. Briefly, tissues embedded in paraffin were cut in 5-µm sections and placed on glass slides; after deparaffinization, tissues were stained with H&E. Retinal histology was performed for the 9-, 28-, and 28+14-day light-exposure groups as described previously by Collier et al. (2011), with some modifications. We examined the midsuperior aspect of the retina for all histological analyses. We quantifid the outer nuclear layer (ONL) and examined alterations in retina morphology using a light microscope.

TUNEL assay. To detect apoptotic cells in eyes after 9 days of light exposure, the TUNEL assay was performed using a FragEL™ DNA fragmentation detection kit (Calbiochem, Darmstadt, Germany) following the manufacturer's protocol for paraffin sections, with some modifications. Tissues were counterstained with DAPI (4′,6-diamidino-2-phenylindole). We used FITC (fluorescein isothiocyanate)-avidin D to label DNA strand breaks. Sections (the entire retina excluding the RPE layer) were visualized on a fluorescent microscope (Nikon Instruments Inc., Melville, NY, USA). The number of TUNEL-positive cells for each section was counted by Image-Pro Plus software (version 6.0; Media Cybernetics Inc., Rockville, MD, USA). See Supplemental Material, pp. 5–6, for additional details.

IHC. IHC was performed on eye tissue from the 9-day light-exposure group, as described previously (Collier et al. 2011; Fang et al. 2013). Briefly, cryosections of the retina samples were incubated overnight at 48°C with one of three primary antibodies: anti-8-hydroxy-2′-deoxyguanosine [8-OHdG; 1:50; JaICA (Japan Institute for the Control of Aging), Shizuoka, Japan] to detect DNA; anti-acrolein (1:200; Advanced Targeting Systems, San Diego, CA, USA) to detect lipids; and anti-nitrotyrosine (1:200; Abcam, Cambridge, MA, USA) to detect proteins. We used biotinylated anti-rabbit IgG as the secondary antibody, and FITC-avidin D to amplify the signal. The number of positive cells in each section was counted using Image-Pro Plus software.

Transmission electron microscopy (TEM) analysis. TEM of retinal tissues from the 9-day light-exposure group was performed at the Electron Microscopy Facility at the Department of Pathology at National Taiwan University Hospital, as described previously (Hafezi et al. 1997). Briefly, 1-mm retina slices were processed for TEM (for details, see Supplemental Material, pp. 6–7), and sections were examined using a high-resolution TEM instrument (JEM-1400; JEOL, Tokyo, Japan) at 80 kV.

Free radical assay (ROS). ROS were measured after 3 or 9 days of light exposure, as described previously (Fang et al. 2013). Briefly, ROS in retinas were quantified in the 3-day and 9-day light-exposure groups after adding the enhancer, lucigenin (bis-*N*-methylacridiniumnitrate), to the chemiluminescence analyzer (CLA-FS1; Tohoku, Tokyo, Japan). The stimulated superoxide anion ($O_2^{\bullet-}$) and total oxidative products were captured every 10 sec and computed for 7 min after 1 min of baseline detection. See Supplemental Material, p. 7, for additional details.

Statistical analysis. Data are presented as the mean ± SD unless otherwise stated. Data were evaluated using analysis of variance (ANOVA), with Tukey post hoc tests to show differences between the groups. A *p*-value < 0.05 was considered to be statistically significant.

Results

Electrophysiological response (ERG). Representative ERG response curves of rats are shown in Figure 3A. After 14, 23, or 42 days of dark maintenance, the control retina showed a high b-wave peak, but the retinas from LED- and CFL-exposed animals had a low b-wave peak, indicating cell function loss. As shown in Figure 3B, the two LED groups and the white CFL group all demonstrated a significant decrease of b-wave amplitude at days 9 and 28 of light exposure ($p < 0.001$, by ANOVA followed by Tukey post hoc test). The b-wave amplitude of the yellow CFL group was not significantly decreased at day 9; however, it had decreased 21% at day 28. The data from each of the four exposure groups was not statistically different at 28+14 days compared with 28 days of exposure; this trend was also present in the H&E staining results (data not shown). Because we found no significant development after 3 days of light exposure, these data are not shown.

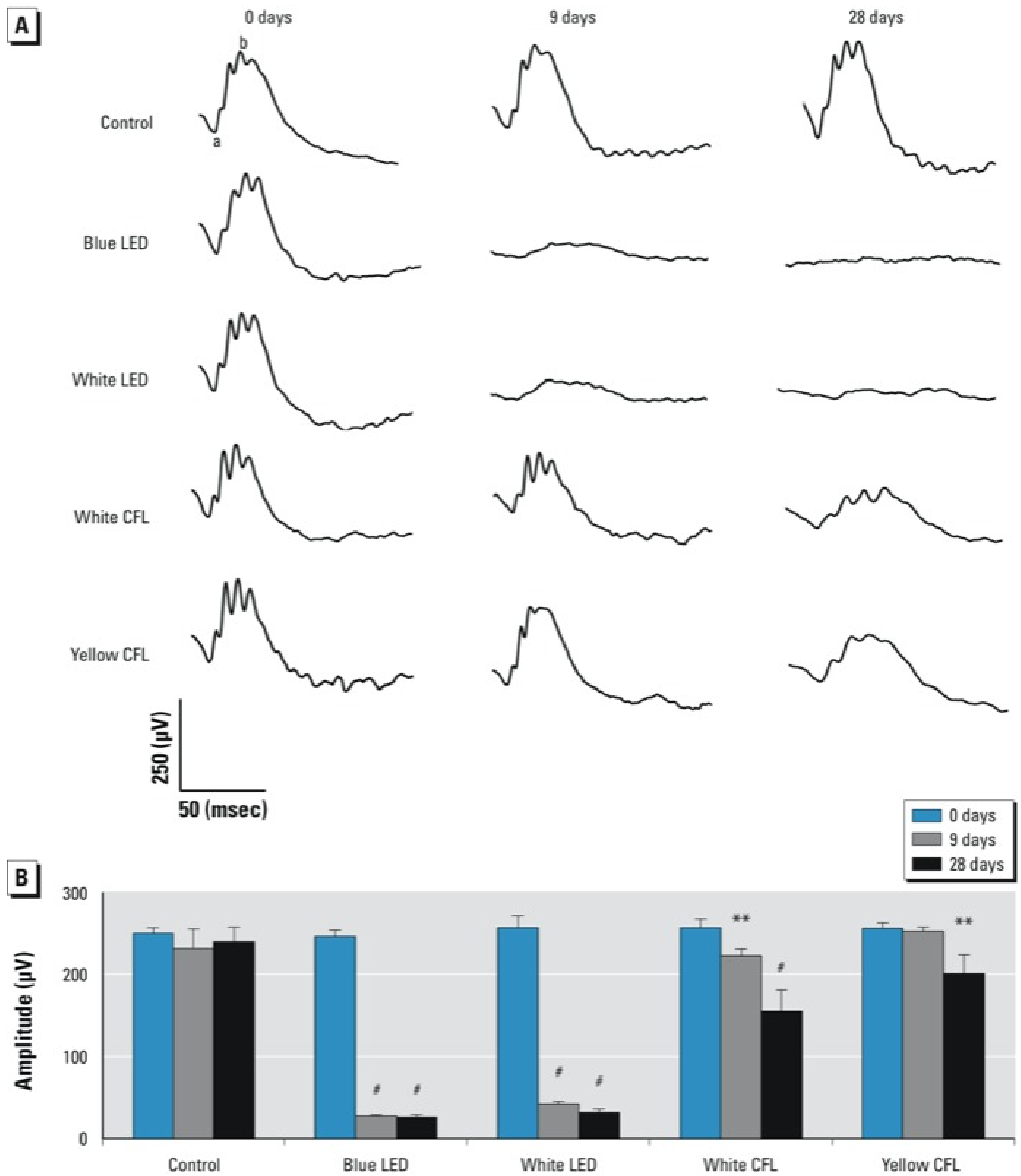

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Figure 3

Representative ERG responses (*A*) and ERG b-wave amplitude (*B*) in unexposed (control) rats or rats exposed to blue LED, white LED, white CFL, or yellow CFL at 0 (baseline), 9, or 28 days of light exposure. Values shown in (*B*) are mean ± SD (for each time point, $n = 3$ controls and 8 for each light-exposure group at each time point. $^{**}p < 0.01$, and $^{\#}p < 0.001$, compared with the control group by ANOVA and Tukey post hoc test.

Retinal histology. Exposure to white LED light exposure can lead to morphologic alterations in the rat retina. Compared with the control group (Figure 4A), the white LED group exposed to 750 lux white LED light for 28 days (Figure 4B) exhibited pyknotic photoreceptor nuclei, swelling of the inner segment, and a disorganized outer segment. ONL thickness was significantly decreased at day 9 and day 28 in the white and blue LED groups (Figure 4C,D) ($p < 0.01$, by ANOVA followed by Tukey post hoc test; Figure 4G), whereas we observed no significant change in ONL thickness in the white and yellow CFL groups at day 9 (Figure 4E,F,G).

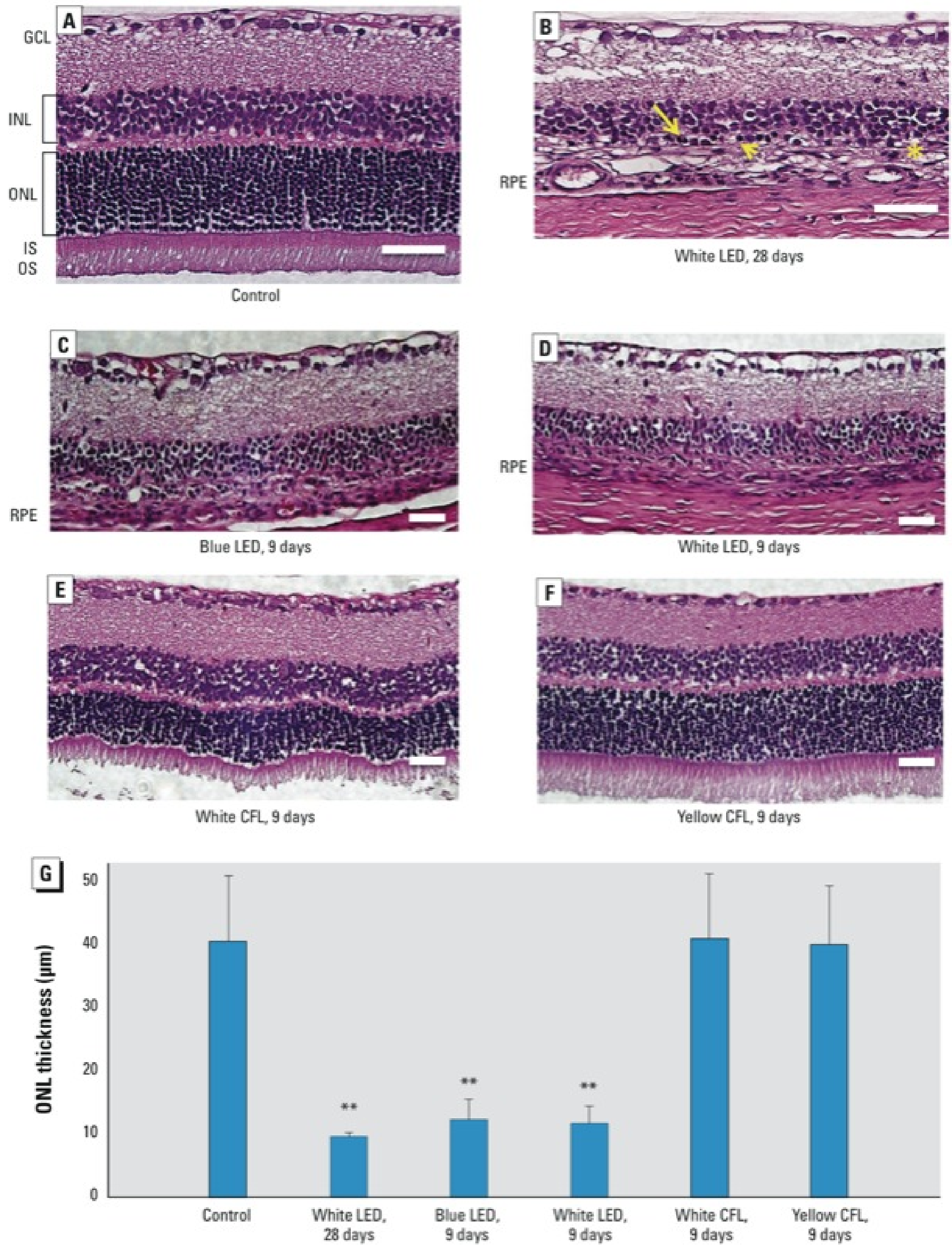

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Figure 4

H&E staining of representative retinal tissue sections from control rats (*A*) and from rats exposed to white LED for 28 days (*B*) or to blue LED (*C*), white LED (*D*), white CFL (*E*), or yellow CFL (*F*) for 9 days. (*G*) ONL thickness (mean ± SD) measured in retinas (n = 3 controls, n = 8 for each light-exposure group at either time point). Abbreviations: GCL, ganglion cell layer; INL, inner nuclear layer; IS, inner segment; ONL, outer nuclear layer; OS, outer segment; RPE, retinal pigment epithelium (usually next to the OS layer but is detached and cannot be found within this scope). (*A*) Control tissue shows normal retinal layers. (*B*) After exposure to white LED for 28 days, retinal injury included pyknotic photoreceptor nuclei (arrow), swelling of the inner segment (arrow head), a disorganized outer segment with no visable RPE [asterisk (*)], and INL degeneration. Photoreceptors were not present in retinals from rats exposed to blue LED (*C*) or white LED (*D*) light; the white CFL group (*E*) exhibited distortion of the OS and ONL, and the yellow CFL group (*F*) exhibited less movement in each layer. In (*A*–*F*), bar = 50 µm. (*G*) ONL thickness was significantly decreased in the LED groups at days 9 and 28, whereas the ONL thickness in white and yellow CFL groups was not significantly altered at day 9. ***$p < 0.01$, compared with the control group by ANOVA and the Tukey post hoc test.

Apoptosis detected by TUNEL staining. Light exposure induced significant retinal cell apoptosis in all light-exposed groups (Figure 5A,B). However, more apoptotic cells were observed in the retina of the LED-exposed groups than in that of CFL-exposed groups after 9 days of exposure ($p < 0.001$ for LED groups and $p < 0.01$ for CFL groups, by ANOVA followed by the Tukey post hoc test) (Figure 5B).

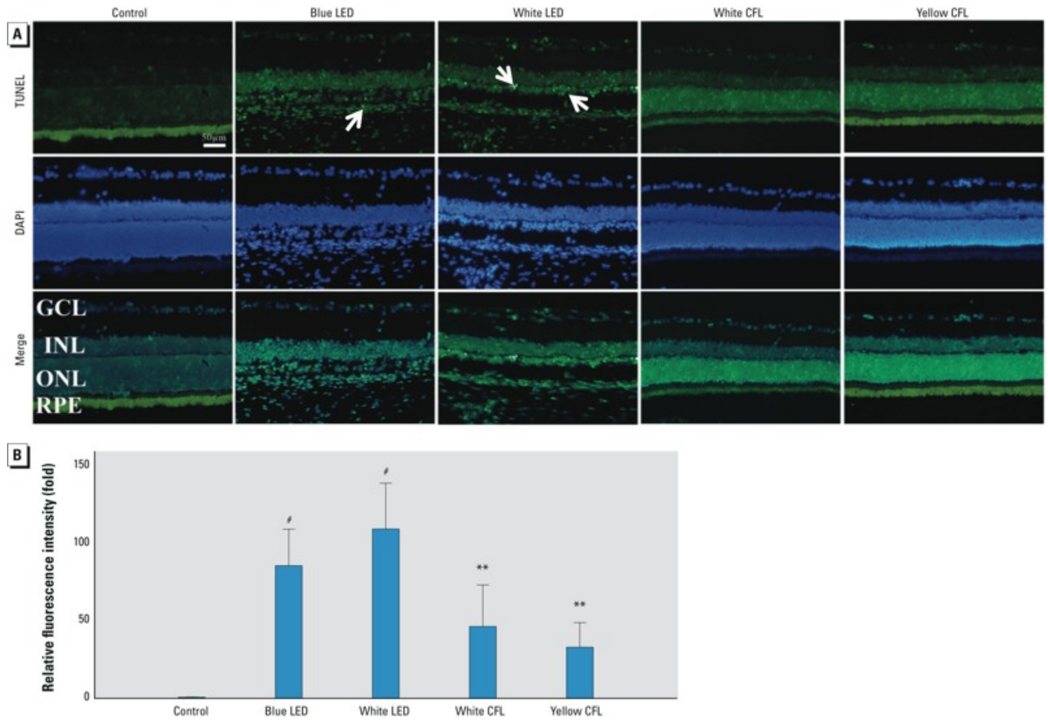
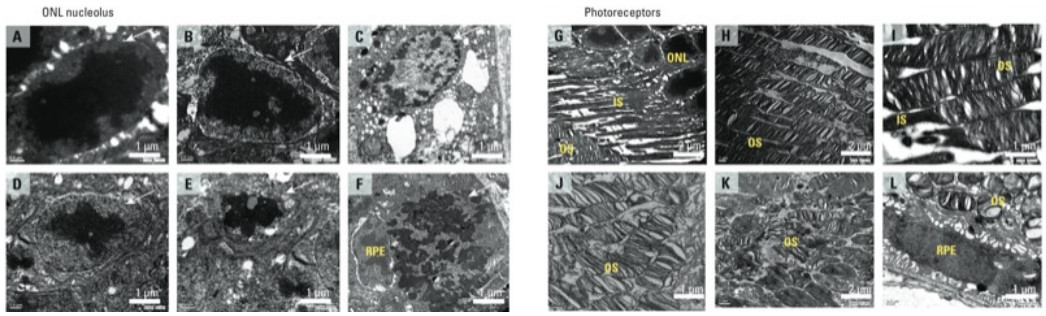


Figure 5

Retinal cell apoptosis detected by TUNEL labeling (damaged retinal cells show positive labeling). (*A*) Representative images of retinal cell apoptosis in control rats and in rats exposed to blue LED, white LED, white CFL, or yellow CFL for 9 days (bar = 50 μm); more apoptotic cells (arrows) appear in the retina of LED-exposed groups than that of CFL-exposed groups. Abbreviations: GCL, ganglion cell layer; INL, inner nuclear layer; ONL, outer nuclear layer; RPE, retinal pigment epithelium. (*B*) Fluorescence intensity of apoptosis in light exposure groups shown as the mean ± SD fold of the control value ($n = 3$ controls and 8 for each exposure group). The LED-exposed groups exhibit higher fluorescence intensity than that of CFL-exposed groups. $^{**}p < 0.01$, and $^{\#}p < 0.001$, compared with the control group by ANOVA and the Tukey post hoc test.

TEM analysis. Figure 6 shows nucleolar damage of photoreceptors in control tissue and in samples collected after 9 days of exposure to white LED light. Nucleolar damage of photoreceptors that occurred after exposure include an early stage of nucleolar condensation (Figure 6B), karyolysis (Figure 6C), pyknosis (Figure 6D–E), and karyorrhexis (Figure 6F). We also observed disruption of the inner and outer segments (Figure 6G–L).



[Figure 6](#)

Representative TEM photomicrographs showing retinal cellular injury of the ONL nucleolus (*A*–*F*) and photoreceptors (*G*–*L*) in control rats (*A*,*G*) and those exposed to white LED light (*B*–*F*, *H*–*L*) at day 9. Abbreviations: INL, inner nuclear layer; IS, inner segment; ONL, outer nuclear layer; OS, outer segment; RPE, retinal pigment epithelium. ONL nuclear deformations (arrows) were observed in (*A*) control ONL nucleus and as (*B*) nucleolus condensation, (*C*) karyolysis, (*D*,*E*) pyknosis, and (*F*) karyorrhexis. (*G*–*L*) Normal photoreceptor, IS, and OS from a control rat (*G*); photoreceptor deformations showing minor disruption (*H*,*I*); and IS disappearance followed by OS shrinkage and the formation of several small round shapes (*J*,*K*,*L*). For (*A*–*F*) and (*I*,*J*,*L*), bar = 1 μm; for (*G*,*H*,*K*), bar = 2 μm. Each photomicrograph is from a different sample.

Immunohistochemistry. Oxidative damage results in adducts on macromolecules that can be detected by immunohistochemistry. We used three antibodies to detect cell conditions in retinas of rats at the 9-day time point: acrolein for lipid recognition (Figure 7A), 8-OHdG for DNA detection (Figure 7B), and nitrotyrosine for protein identification (Figure 7C). LED-exposed groups exhibited higher fluorescence intensity with acrolein, 8-OHdG, and nitrotyrosine in ONL and CFL induced lower fluorescence intensity of these three proteins in ONL.

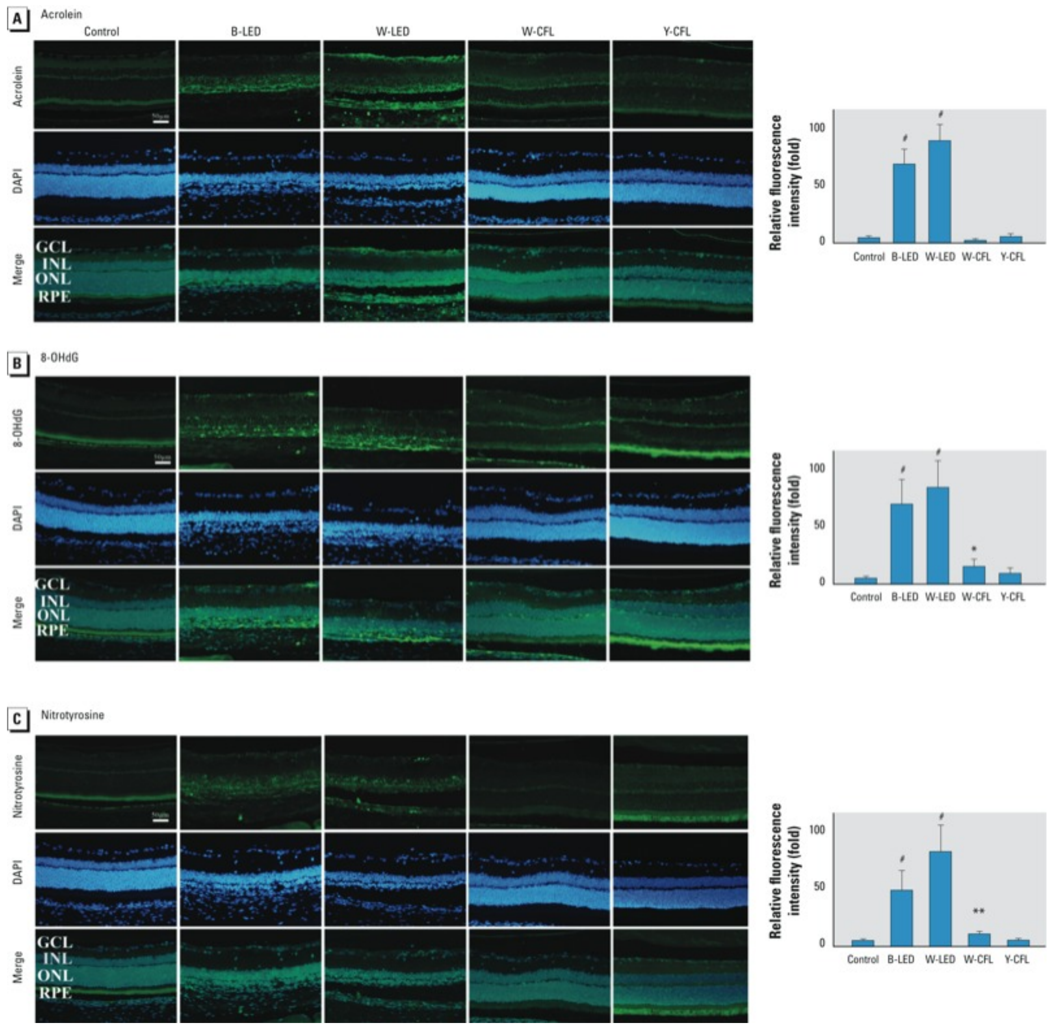


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Figure 7

Retinal light injury shown by IHC staining for acrolein to detect lipid adducts on macromolecules (*A*), 8-OHdG to detect DNA adducts (*B*), and nitrotyrosine to recognize protein adducts (*C*) in the retina of unexposed rats or rats exposed to blue LED, white LED, white CFL, or yellow CFL for 9 days. Abbreviations: B, blue; W, white; Y, yellow. Left, representative photomicrographs (bar = 50 μm). Right, mean ± SD fluorescence of protein-positive cells relative to the control group ($n = 3$ controls, $n = 8$ for each light-exposure group). LED-exposed groups exhibited higher fluorescence intensity on ONL, and the CFL groups had lower fluorescence intensity. $^{*}p < 0.05$, $^{**}p < 0.01$, and $^{\#}p < 0.001$, compared with the control group by ANOVA and the Tukey post hoc test.

Oxidative stress. As shown in Figure 8A, lucigenin-stimulated superoxide anion ($O_2^{\bullet-}$) and total oxidative products were computed for all groups. After 3 days of exposure to blue LED light, retinal $O_2^{\bullet-}$ measured 8 min after stimulation exceeded 60,000; the white-LED group exhibited a high total count close to 40,000, and the CFL groups accumulated smaller total counts, from 20,000 to 30,000.

However, the plot exhibited an opposite trend when the exposure duration was increased to 9 days (Figure 8B). This result suggests that retinal oxidative stress may be induced by light exposure in the early stage of exposure.

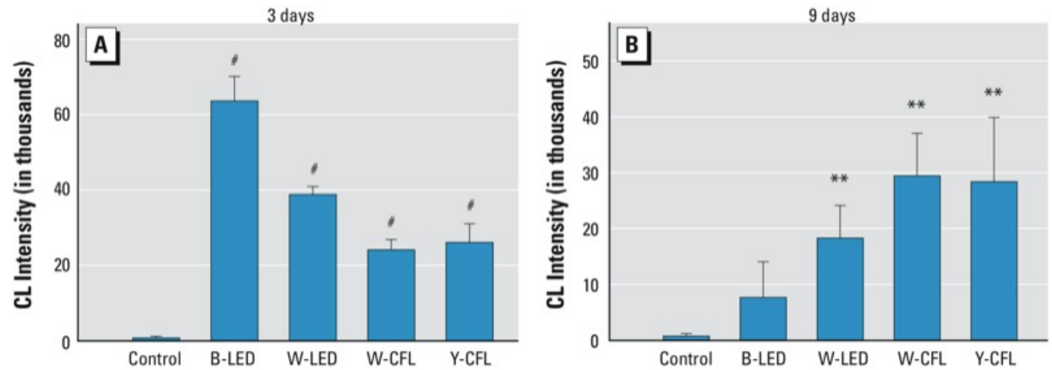

Figure 8

ROS assay performed in control rats and rats exposed to blue LED, white LED, white CFL, or yellow CFL for 3 days (*A*) or 9 days (*B*). Values are presented as mean ± SD chemiluminescence (CL) intensity. Abbreviations: B, blue; W, white; Y, yellow. (*A*) After 3 days of exposure to blue LED light, lucigenin-stimulated $O_2^{\bullet -}$ exceeded 60,000 in total count, the white LED group had a high total count near 40,000, and the CFL groups had total counts of 20,000–30,000; At this time point, control rats exhibited a count of approximately 1,000. $n = 3$ controls, and $n = 3$ for each exposure group. (*B*) After 9 days of exposure, the $O_2^{\bullet -}$ total count for the blue LED light group decreased to 8,000, that for the white LED light group decreased to 18,000, and that for both fluorescent light groups remained at the same level. $n = 3$ controls, and $n = 8$ for each exposure group. $^{**}p < 0.01$, and $^{\#}p < 0.001$, compared with the control group by ANOVA and the Tukey post hoc test.

Discussion

Retinal light damage depends on the duration of exposure and the light level reaching the retina (retinal irradiance). The pathological process is also wavelength dependent (Organisciak and Vaughan 2010). The results of the present study indicate that exposure to LED light in this albino rat model can induce retinal damage as evidenced by the functional ERG study, IHC, TUNEL, and TEM examinations. Our results also suggest that this retinal damage could be related to blue light–induced oxidative stress within the retinal tissues, as evidenced by the ROS generated in the retina after LED light exposure.

The ERG results show functional loss in the retina after LED light exposure. The white and blue LED groups demonstrated a significant decrease in the b-wave amplitude at days 9 and 28 after light exposure. The morphological results show that exposure to cyclic white LED light may induce outer retinal damage within 9 days and may be responsible for further deterioration when the exposure duration is extended. The ONL, which is usually 12–14 rows of nuclei in unexposed Sprague-Dawley rats at 2–3 month of age, was reduced to approximately 4–5 rows. OS and IS were absent, and the RPE appeared to be damaged or missing. However, we observed less damage within the photoreceptor after exposure to yellow CFL, as shown in Figure 4F. Our functional and morphological results indicate that the wavelength and the SPD, rather than total light irradiance, are crucial risk factors that contribute to photochemical retinal injury. The results also suggest that LED light–induced cell death may occur through the intrinsic apoptotic pathway under oxidative stress. Sliney (1984) calculated that for the same lamp brightness, the retinal irradiance in the rat eye would be at least 60% greater than experienced in the human retina. The light exposure in the present study began at 1800 hours to match the nocturnal activity pattern, but this exposure time may also enhance susceptibility to light damage in rats. Therefore, the careful development of an action spectrum for LED light damage remains an important research goal.

The retina has one of the highest oxygen consumption levels of tissues in the body, and it is sensitive to oxidative stress (Yu and Cringle 2005). Oxidative stress is the crucial risk factor for photoreceptor degeneration, which is caused by the generation of toxic ROS within retinal tissue. The retina contains enzymes involved in detoxification or synthesis, particularly in the OS or RPE (Newsome et al. 1990). In the present study, we compared the phototoxicity of CFLs with that of typical white LEDs. The white LED lights carry higher energy that exceeds the threshold of the enzymes that serve as a stress-induced protection mechanism (Behar-Cohen et al. 2011); thus, exposure to these white LEDs may result in severe damage to the outer retina. To prevent or decrease this potential retinal damage, some companies are increasing the market segments of lower color-temperature LEDs for domestic lighting (U.S. Department of Energy 2012).

Photochemical damage is the major cause of low-intensity chronic exposure light-induced injury. Noell (1980) indicated that the direct action of light on photoreactive molecules within the damaged cell causes primary damage. Secondary damage, which follows the primary event, can either continue the damaging process in the same cell or expand to other cells (Noell 1980). The main concern is that light damage involves oxidative events (Lohr et al. 2006). In the present study, we used several exposure durations to analyze cause and effect in a temporal manner (Figure 1). We found that LED lights carry energy that is strong enough to generate oxidative stress (Figure 8). Our results are consistent with the observation by Noell (1980); that is, retinal neuronal cell DNA levels are correlated with ERG b-wave estimates of photoreceptor cell loss in light-exposed retinals of rats. Oxidative stress is responsible for pathogenesis of light injury, especially when light is sufficient to damage > 80% of photoreceptor cells detected by nonrecoverable ERG b-waves. Furthermore, our histological analysis showed that most cell death does not occur immediately after light exposure; the damaged retinal neuronal cells may lose function but are still present on the retinal layers with oxidative modified lipids, nucleic acids, and proteins.

Conclusions

LEDs are expected to become the primary domestic light sources in the near future. Certain amounts of LED light exposure may induce retinal damage, and this animal model provides comparative measures of damage from different commercial light sources. Albino rats are commonly used for retinal light injury experiments (Collier et al. 2011). Retinas from rats maintained in the dark for 14 days are more susceptible to light-induced damage than normal pigmented retinas (Organisciak and Vaughan 2010). Our results show that the SPDs of bluish-white (high CCT) LEDs contain a major fraction of short-wavelength light that causes irreversible retinal neuronal cell death in rats. Furthermore, this model shows that the SPD of white LEDs now being introduced for domestic lighting pose a theoretical risk compared to CFLs (or incandescent lamps that have little blue light). When analyzing blue-light hazards, we cannot exclude the risk of chronic effects from daily exposure because photochemical damage may not induce an acute syndrome; instead, blue light exposure may cumulatively induce photoreceptor loss.

Regardless of whether the initial damage is caused by a photochemical effect, LED light damage is dependent on wavelength and duration. The entire retinal neuronal cell is affected, regardless of whether the injury is localized in the outer segment, mitochondria, or other subcellular organelles. Because illuminance levels of LED domestic light sources may induce retinal degeneration in experimental albino rats, the exact risks for the pigmented human retina require further investigation.

Supplemental Material

(152 KB) PDF

Click here for additional data file.(147K, pdf)

Acknowledgments

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Footnotes

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The authors declare they have no actual or potential competing financial interests.

References

ARVO (Association for Research in Vision and Ophthalmology). Statement for the Use of Animals in Ophthalmic and Vision Research. 2013. Available: http://www.arvo.org/About_ARVO/Policies/Statement_for_the_Use_of_Animals_in_Ophthalmic_and_Visual_Research/ [accessed 21 January 2014]

Beatty S, Koh H, Phil M, Henson D, Boulton M. The role of oxidative stress in the pathogenesis of age-related macular degeneration. Surv Ophthalmol. 2000;45:115–134. [PubMed] [Google Scholar]

Behar-Cohen F, Martinsons C, Vienot F, Zissis G, Barlier-Salsi A, Cesarini JP, et al. Light-emitting diodes (LED) for domestic lighting: any risks for the eye? Prog Retin Eye Res. 2011;30:239–257. [PubMed] [Google Scholar]

Chepesiuk R. Missing the dark: health effects of light pollution. Environ Health Perspect. 2009;117:A20–A27. [PMC free article] [PubMed] [Google Scholar]

Collier RJ, Wang Y, Smith SS, Martin E, Ornberg R, Rhoades K, et al. Complement deposition and microglial activation in the outer retina in light-induced retinopathy: inhibition by a 5-HT_{1A} agonist. Invest Ophthalmol Vis Sci. 2011;52:8108–8116. [PubMed] [Google Scholar]

Dong A, Shen J, Krause M, Akiyama H, Hackett SF, Lai H, et al. Superoxide dismutase 1 protects retinal cells from oxidative damage. J Cell Physiol. 2006;208:516–526. [PubMed] [Google Scholar]

Fang IM, Yang CM, Yang CH, Chiou SH, Chen MS. Transplantation of induced pluripotent stem cells without C-Myc attenuates retinal ischemia and reperfusion injury in rats. Exp Eye Res. 2013;113:49–59. [PubMed] [Google Scholar]

Hafezi F, Marti A, Munz K, Reme CE. Light-induced apoptosis: differential timing in the retina and pigment epithelium. Exp Cell Res. 1997;64:963–970. [PubMed] [Google Scholar]

Ham WT, Jr, Mueller HA, Sliney DH. Retinal sensitivity to damage from short wavelength light. Nature. 1976;260:153–155. [PubMed] [Google Scholar]

Holzman DC.2010What's in a color? The unique human health effect of blue light. Environ Health Perspect 118A22–A27.; 10.1289/ehp.118-a22 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

Lohr HR, Kuntchithapautham K, Sharma AK, Rohrer B. Multiple, parallel cellular suicide mechanisms participate in photoreceptor cell death. Exp Cell Res. 2006;83:380–389. [PubMed] [Google Scholar]

Newsome DA, Dobard EP, Liles MR, Oliver PD. Human retinal pigment epithelium contains two distinct species of superoxide dismutase. Invest Ophthalmol Vis Sci. 1990;31:2508–2513. [PubMed] [Google Scholar]

Noell WK. Possible mechanisms of photoreceptor damage by light in mammalian eyes. Vision Res. 1980;20:1163–1171. [PubMed] [Google Scholar]

Noell WK, Walker VS, Kang BS, Berman S. Retinal damage by light in rats. Invest Ophthalmol. 1966;5:450–473. [PubMed] [Google Scholar]

Organisciak DT, Vaughan DK. Retinal light damage: mechanisms and protection. Prog Retin Eye Res. 2010;29:113–134. [PMC free article] [PubMed] [Google Scholar]

Peng ML, Tsai CY, Chien CL, Hsiao JCJ, Huang SY, Lee CJ. The influence of low-powered family LED lighting on eyes in mice experimental model. Life Sci J 9:477–482. 2012. Available: http://www.lifesciencesite.com/lsj/life0901/072_8366life0901_477_482.pdf [accessed 21 January 2014]

Schatz A, Arango-Gonzalez B, Fischer D, Enderle H, Bolz S, Röck T, et al. Transcorneal electrical stimulation shows neuroprotective effects in retinas of light-exposed rats. Invest Ophthalmol Vis Sci. 2012;53:5552–5561. [PubMed] [Google Scholar]

Sliney DH. Quantifying retinal irradiance levels in light damage experiments. Curr Eye Res. 1984;3:175–179. [PubMed] [Google Scholar]

Spivey A. 2011The mixed blessing of phosphor-based white LEDs. Environ Health Perspect 119A472–A473.; 10.1289/ehp.119-a472 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

U.S. Department of Energy. Lifetime of White LEDs. PNNL-SA-50957. Washington, DC:U.S. Department of Energy. 2009. Available: http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/lifetime_white_leds.pdf [accessed 4 February 2014]

U.S. Department of Energy. Solid-State Lighting Research and Development: Manufacturing Roadmap. Washington DC:U.S. Department of Energy. 2012. Available: http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/ssl_manuf-roadmap_august2012.pdf [accessed 6 February 2014]

Wu J, Seregard S, Algvere PV. Photochemical damage of the retina. Surv Ophthalmol. 2006;51:461–481. [PubMed] [Google Scholar]

Yu DY, Cringle SJ. Retinal degeneration and local oxygen metabolism. Exp Eye Res. 2005;80:745–751. [PubMed] [Google Scholar]

Exhb 2g Footnote 7 Hidden Blue Hazard? (100-102)

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Hidden Blue Hazard? LED Lighting and Retinal Damage in Rats

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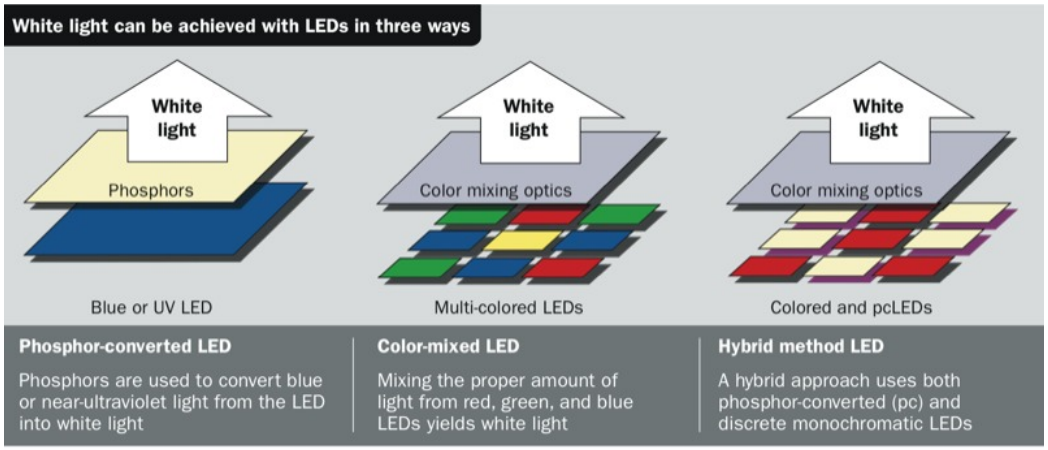
The Canadian government greeted 2014 with the first tier of its new energy-efficiency standards for light bulbs,[1] which will effectively ban incandescent light bulbs by next year.[2] But efficient lighting can have its own drawbacks. For instance, although devoid of the mercury used in compact fluorescent lamps (CFLs), some white light-emitting diodes (LEDs) emit a wavelength of light associated with adverse human health effects. In this issue of *EHP*, researchers study retinal changes in rats exposed to white LEDs like those sometimes used in household lighting.[3]

Among the most popular household LEDs are products that employ a chip emitting blue light, which is surrounded by a yellow phosphor coating. Although the resulting light looks white to the naked eye, it can feature a spike in the blue end of the spectrum, at wavelengths of 460–500 nm.

Light of this wavelength has been shown to have unique physiological effects, some positive, some negative.[4,5,6] White LEDs, as a new source of exposure to blue light, initially prompted concerns about potential changes in melatonin production and disruption of human sleep cycles.[7] More recent research considers the direct effect of this light on the eye, including the risk of ongoing damage to retinal cells.[8]

In the current study, the researchers wanted to accurately simulate exposure to indoor lighting, says corresponding author Chang-Ho Yang, a professor and ophthalmologist at National Taiwan University's College of Medicine. He points out that earlier work shone light directly into the eyes of experimental animals, which may induce damage but hardly corresponds to the indirect way in which most people are exposed to artificial lighting.

"We created an exposure environment where rats could run freely in a cage with the light source set on the rack ceiling twenty centimeters above the cage roof," Yang explains. "This mimics the 'domestic lighting' condition as much as possible, which should greatly reduce the injury—theoretically."



White light can be achieved with LEDs in three ways

Source: Office of Energy Efficiency & Renewable Energy, U.S. Department of Energy; https://www1.eere.energy.gov/buildings/ssl/sslbasics_ledbasics.html

However, the retinas of rats exposed to either blue or cool white9 LED light showed evidence of retinal damage and cell death after 9 days of exposure. Although rats exposed to cool or warm white10 CFL lights also showed some evidence of damage relative to unexposed controls, in general differences were much less pronounced than those observed in the LED-exposed rats. The authors suggest the observed injuries may have been a consequence of oxidative stress from reactive oxygen species that were generated in retinal tissue.3

The rats used in these experiments were albino, and their unpigmented eyes were more sensitive to all effects of light. But even in typically pigmented eyes, Yang says, neuronal cells are incapable of repairing themselves or regenerating after damage. This makes it important to pin down mechanisms of injury and link them with clinical studies matching the conditions under which people will ultimately be using LED lighting. Future studies may suggest a spectrum threshold that could help the lighting industry optimize eye-friendly products, he notes.

Blue light is not without its virtues, says Seang Mei Saw, a professor of epidemiology and ophthalmology at the National University of Singapore, whose work deals with the onset of myopia in children. Time outdoors has shown a strong protective effect against myopia,11 and although the reasons are still undetermined, it's possible blue light may play a role, Saw says—a hypothesis supported by evidence from animal studies.12 "Outdoor sunlight has more blue light that may protect for myopia," she explains, "and indoor lighting, with relatively less blue light, may be detrimental for myopia."

References and Notes

1. Natural Resources Canada. General Service Lamps [website]. Brampton, Ontario, Canada:Natural Resources Canada, Government of Canada (modified 15 January 2014). Available: http://www.nrcan.gc.ca/energy/regulations-codes-standards/products/6869 [accessed 14 February 2014].

2. Federal ban ignites rush on old-style light bulbs. CBC News Manitoba, Canada section (2 January 2014). Available: http://goo.gl/boKyKw [accessed 14 February 2014].

3. Shang Y-M, et al. White light–emitting diodes (LEDs) at domestic lighting levels and retinal injury in a rat model. Environ Health Perspect 1223269–276.2014; 10.1289/ehp.1307294 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

4. McDonagh AF, et al. Blue light and bilirubin excretion. Science 2084440145–151.1980; 10.1126/science.7361112 [PubMed] [CrossRef] [Google Scholar]

5. Lockley SW, et al. High sensitivity of the human circadian melatonin. J Clin Endocrinol Metab 8894502–4505.2003; 10.1210/jc.2003-030570 [PubMed] [CrossRef] [Google Scholar]

6. Vandewalle G, et al. Spectral quality of light modulates emotional brain responses in humans. Proc Natl Acad Sci USA 1074519549–19554.2010; 10.1073/pnas.1010180107 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

7. West KE, et al. Blue light from light-emitting diodes elicits a dose-dependent suppression of melatonin in humans. J Appl Physiol. 2011;110(3):619–626. http://jap.physiology.org/content/110/3/619.long [PubMed] [Google Scholar]

8. Behar-Cohen F, et al. Light-emitting diodes (LED) for domestic lighting: any risks for the eye? Prog Retin Eye Res 304239–257.2011; 10.1016/j.preteyeres.2011.04.002 [PubMed] [CrossRef] [Google Scholar]

9. Both LED light sources had a perceived color "temperature" of 6,500 kelvins (K). The higher the kelvin temperature, the cooler the light appears. Typical incandescent bulbs have a color temperature of approximately 3,000 K.

10. The cool and warm CFLs had temperatures of 6,500 K and 3,000 K, respectively.

11. Lougheed T.Myopia: the evidence for environmental factors. Environ Health Perspect 1221A12–A19.2014; 10.1289/ehp.122-A12 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

12. Rucker FJ, Wallman J.Chick eyes compensate for chromatic simulations of hyperopic and myopic defocus: evidence that the eye uses longitudinal chromatic aberration to guide eye-growth. Vision Res 49141775–1783.2009; 10.1016/j.visres.2009.04.014 [PMC free article] [PubMed] [CrossRef] [Google Scholar]

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Exposure to Room Light before Bedtime Suppresses Melatonin Onset and Shortens Melatonin Duration in Humans

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Abstract

Context:

Millions of individuals habitually expose themselves to room light in the hours before bedtime, yet the effects of this behavior on melatonin signaling are not well recognized.

Objective:

We tested the hypothesis that exposure to room light in the late evening suppresses the onset of melatonin synthesis and shortens the duration of melatonin production.

Design:

In a retrospective analysis, we compared daily melatonin profiles in individuals living in room light (<200 lux) *vs*. dim light (<3 lux).

Patients:

Healthy volunteers (n = 116, 18–30 yr) were recruited from the general population to participate in one of two studies.

Setting:

Participants lived in a General Clinical Research Center for at least five consecutive days.

Intervention:

Individuals were exposed to room light or dim light in the 8 h preceding bedtime.

Outcome Measures:

Melatonin duration, onset and offset, suppression, and phase angle of entrainment were determined.

Results:

Compared with dim light, exposure to room light before bedtime suppressed melatonin, resulting in a later melatonin onset in 99.0% of individuals and shortening melatonin duration by about 90 min. Also, exposure to room light during the usual hours of sleep suppressed melatonin by greater than 50% in most (85%) trials.

Conclusions:

These findings indicate that room light exerts a profound suppressive effect on melatonin levels and shortens the body's internal representation of night duration. Hence, chronically exposing oneself to electrical lighting in the late evening disrupts melatonin signaling and could therefore potentially impact sleep, thermoregulation, blood pressure, and glucose homeostasis.

The pineal gland hormone melatonin is released during the biological night and provides the body's internal biological signal of darkness. Exposure to light both resets the circadian rhythm of melatonin and acutely inhibits melatonin synthesis (1, 2). In some mammals, light regulation of melatonin gives rise to photoperiodic responses including patterns of seasonal breeding and changes in pelage (3, 4). The duration of nocturnal melatonin secretion in humans is likewise dependent on photoperiod (5), but effects on the reproductive system remain controversial. Several groups have shown seasonality in births, but few studies have examined the potential link between melatonin duration and reproductive hormones that determine the likelihood of conception (6,–8).

Because the onset of melatonin secretion is associated with an increase in sleep propensity, and exogenous administration of melatonin can facilitate sleep (9,–12), melatonin has long been hypothesized as a sleep-promoting factor in humans. Melatonin treatment reduces sleep onset latency when endogenous levels of melatonin are low during the biological daytime (12). Melatonin receptors are located on circadian clock neurons in the suprachiasmatic nucleus in the anterior hypothalamus (13), suggesting that feedback regulation by melatonin signaling may contribute to circadian regulation, including the timing of sleep. Consistent with this hypothesis, daily ingestion of melatonin has been shown to synchronize circadian rhythms of behavior and physiology in blind individuals (14, 15). In addition to its hypnotic and circadian phase resetting effects, exogenous melatonin has been shown to lower blood pressure and body temperature (16, 17), and recent genome-wide association studies have established a putative link between signaling at the melatonin 1B receptor and risk for type 2 diabetes (18,–20). With melatonin receptors located in several sites of the central nervous system and in peripheral tissues including the heart, kidney, pancreatic islets, adrenal glands, stomach, and gonads (21), melatonin has been explored as a treatment option for various human disease states including insomnia, hypertension, and cancer (22).

Despite the potential therapeutic benefits of melatonin treatment, the physiological consequences of chronically inhibiting melatonin synthesis are unknown. Recent studies have shown that indoor room light (*i.e.* <500 lux) can elicit strong melatonin suppression and phase shift responses (23,–25), suggesting that individuals who habitually expose themselves to light during nighttime hours could have reduced melatonin levels and perturbed rhythms. In a study that examined the dose response for melatonin suppression and phase resetting responses to white light given at night, half-maximal responses were observed at about 100 lux (25), which is substantially dimmer than recommended office lighting (~350–500 lux) (26). In that study, however, participants were kept in relatively dim light (<15 lux) for 3 d preceding the light stimulus, which may have sensitized the circadian system to light (27, 28). Nonetheless, in other studies, exposure to room light suppressed the onset of melatonin secretion even when preceded by room light levels during the daytime (24, 28). Appropriately timed exposure to indoor light (~380 lux) has also been shown to accelerate entrainment to a rapid 5-h advance of the sleep-wake cycle (29). Taken together, these studies indicate that melatonin suppression and phase shift responses are sensitive to ordinary room light levels regardless of previous light history.

These findings suggest that exposure to room light before bedtime, a common practice in modern society, may inhibit melatonin production and, as a result, alter physiological processes regulated by melatonin signaling. To address this possibility, we examined melatonin responses to room light *vs.* dim light in 116 research volunteers studied in the laboratory under a fixed sleep-wake schedule (8 h asleep, 16 h awake). Here, we report that exposure to electrical light between dusk and bedtime strongly suppresses melatonin levels, leading to an artificially shortened melatonin duration and disruption of the body's biological signal of night.

Subjects and Materials

Participants

Healthy research volunteers (n = 116) aged 18–30 yr were enrolled into one of two inpatient studies (see below) at the General Clinical Research Center (GCRC), Brigham and Women's Hospital (BWH) (Boston, MA). Physical health was evaluated by medical history and physical examination, blood biochemistry and hematology, and electrocardiogram. Sleep and circadian rhythm disorders were exclusionary. Mental health was assessed by interview with a staff psychologist or psychiatrist, and normal sight was confirmed by an ophthalmological examination and/or the Ishihara test for color blindness. For at least 2 wk before the inpatient study, participants were required to keep a fixed sleep-wake schedule (8 h asleep, 16 h awake) of their choice, and compliance was verified by continuous actigraphy monitoring (Actiwatch-L; Minimitter, Inc., Bend, OR). To ensure that participants had refrained from the use of drugs, a comprehensive toxicology screen was performed on the day of admission to the GCRC. Informed consent was obtained from all volunteers, and research procedures were approved by the Institutional Review Board at BWH and were in compliance with HIPAA regulations and the Declaration of Helsinki.

General inpatient procedures

Research volunteers lived individually in a laboratory free of time cues. During the first 3 d of each study, participants were scheduled to sleep and wake at their habitual prestudy sleep-wake times (8 h asleep, 16 h awake). Ambient light was provided by ceiling-mounted 4100K fluorescent lamps (Philips Lighting, Eindhoven, The Netherlands) and transmitted through an UV-stable filter (Lexan, General Electric Plastics, Pittsfield, MA). Illuminance was measured with an IL1400 radiometer fitted with an SEL-033/Y/W detector (International Light Inc., Peabody, MA). For the under 200 lux and under 3 lux settings, lighting levels were defined by the maximum illuminance measured in the horizontal plane, with the detector aimed directly at the ceiling lamps at a height of 187 cm. For the under 200 lux light setting, illuminance in the horizontal angle of gaze was less than 150 lux (*i.e.* measured in the vertical plane), and typical illumination at the eyes ranged from 60–130 lux, as reported previously (25, 30). For the approximately 200 lux light setting, overhead lighting was adjusted such that when participants were in bed they received approximately 200 lux of corneal illuminance (28).

On the second baseline day of each study, an indwelling iv catheter was inserted into a forearm vein to allow for continuous collection of blood plasma every 30–60 min for melatonin assay. In the present investigation, melatonin data were analyzed only across study d 2–5. During sleep episodes and the constant routine procedure (see below), blood was drawn from outside the research suite through a porthole in the bedroom wall. Melatonin concentration was determined by standard RIA by laboratories that were blind to the experimental intervention (Pharmasan, Osceola, WI; BWH GCRC Core Laboratory, Boston, MA). Plasma melatonin intraassay and interassay coefficients of variation for each of the studies were cited in the original reports (28, 30,–32).

Protocol design

Study 1

Plasma melatonin was examined in 104 volunteers who participated in a 9- to 10-day research study (31, 32). Participants slept in darkness and were exposed to room light (<200 lux) until midway through study d 3, after which the light was dimmed to under 3 lux. The following morning, participants awoke to a constant routine procedure consisting of wakefulness enforced by technician monitors (30–50 h), semirecumbent bed rest, consumption of hourly equicaloric snacks, and constant exposure to dim light (<3 lux) (33).

Study 2

Twelve volunteers completed a 14-d research protocol (28), including one person who completed the study twice under different lighting conditions (see below). We analyzed a 4-d segment of the protocol that was randomized to occur either on study d 6–9, or study d 10–13. Over the first 3 d, participants slept in darkness and were exposed to room light during the daytime (<200 lux, n = 5; ∼200 lux, n = 8). After 8 h of scheduled sleep in darkness, participants underwent a 40-h constant routine procedure in room light. Melatonin levels in room light during the habitual hours of sleep were compared with melatonin levels during sleep on the previous night. To determine percent suppression of melatonin, the area under the curve (AUC, trapezoidal method) was calculated for exposure to room light (AUC_{RL}), and compared with the AUC for the melatonin rhythm during the preceding sleep episode in darkness (AUC_D) at the same relative clock times. Hence, percent melatonin suppression was calculated as $[1 - (AUC_{RL}) \times (AUC_D)^{-1}] \times 100$, with higher values indicating stronger suppression of the melatonin rhythm.

Determination of melatonin phase, duration, and phase angle

For each subject in study 1, the melatonin rhythm during the constant routine procedure was fit by a three-harmonic regression model to estimate the amplitude. Dim light melatonin onset ($DLMOn_{25\%}$) and offset ($DLMOff_{25\%}$) were defined as the clock times at which the melatonin rhythm crossed a threshold value of 25% of the peak-to-trough fitted amplitude (half the standard amplitude). The same 25% threshold was used for determining melatonin onset and offset on d 2–3, during which individuals were exposed to either room light or dim ambient light. Melatonin duration was defined as the number of consecutive hours that melatonin levels exceeded the 25% threshold between melatonin onset and offset. Phase angle was defined as the difference in timing between melatonin onset or offset *vs*. bedtime, with positive values indicating that the event occurred before each participant's regular bedtime. To determine the percent reduction in melatonin concentration due to exposure to room light before bedtime, the AUC was calculated between melatonin onset and bedtime on d 3 (<3 lux) and compared with the AUC on the preceding day (<200 lux) at the same relative clock times. Local clock times of sleep and wake during inpatient studies were scheduled based on each subject's habitual sleep hours during the prestudy screening procedures. For purposes of illustration, data were aligned by scheduled sleep in Figs. 1–4 and plotted *vs*. relative clock time. We set relative clock times of sleep from 2400 to 0800 h. The distribution of wake times, melatonin onset, and melatonin offset *vs*. local time are shown in Supplemental Fig. 1 (published on The Endocrine Society's Journals Online web site at http://jcem.endojournals.org).

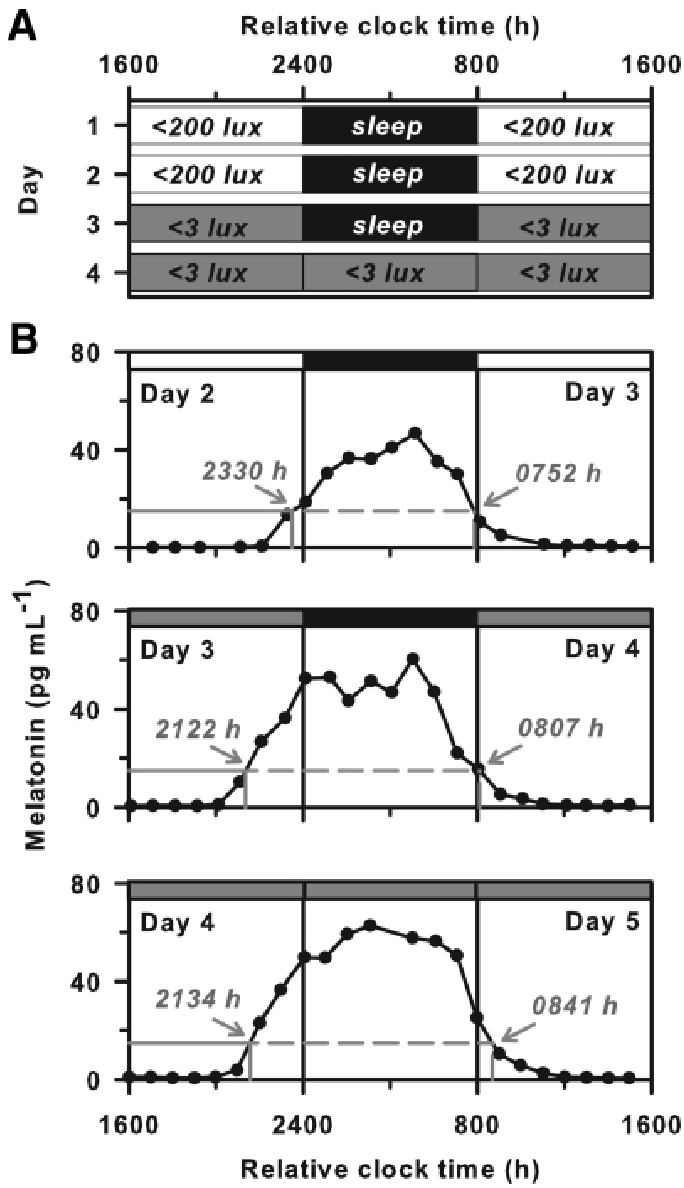

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Fig. 1.

Melatonin onset occurs later in room light than in dim light. A, In study 1, participants lived in room light (<200 lux) and slept in darkness for the first two baseline days. Upon awakening on the morning of d 3, participants were exposed to 8 h of room light, followed by 8 h of dim light (<3 lux) before bedtime. After sleep, individuals underwent a constant routine procedure in dim light. B, The melatonin rhythm is shown for a representative subject over three consecutive cycles (d 2–5). In this subject, melatonin onset occurred about 2 h earlier on d 3 and 4 in dim light, compared with d 2 in room light. The timing of melatonin onset and offset are shown by the *labeled arrows in gray. White and gray bars* at the *top* of each plot indicate exposure to room light and dim light, respectively, and *black bars* indicate sleep in darkness.

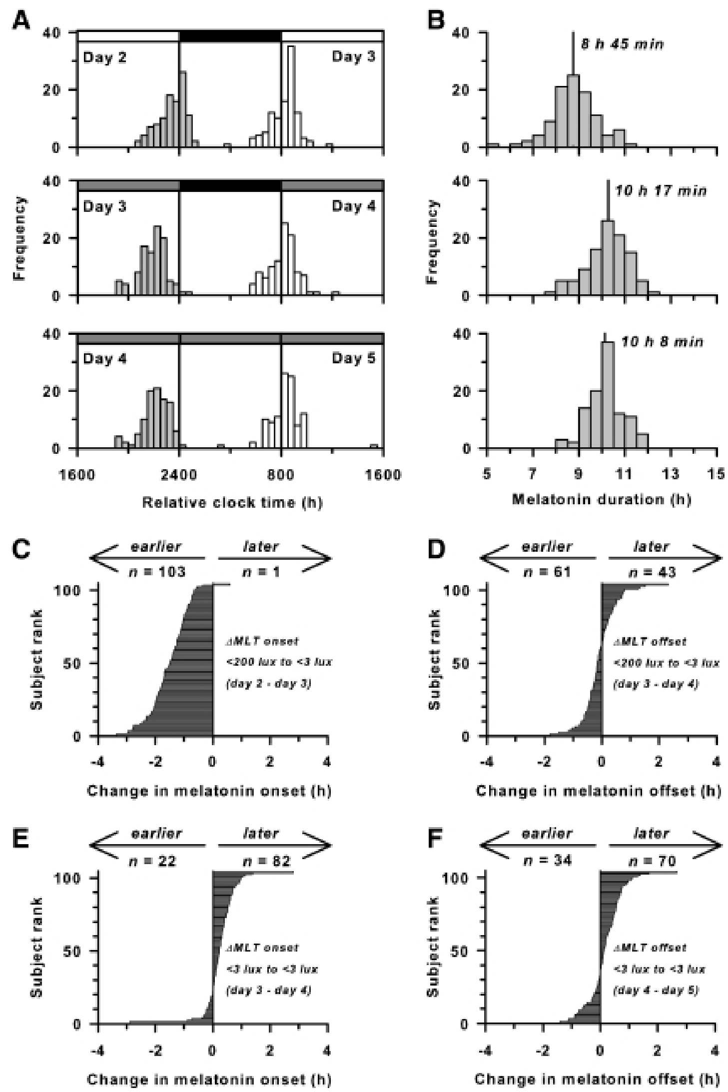

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Fig. 2.

Exposure to room light before bedtime shortens melatonin (MLT) duration. A, Histograms show the timing of melatonin onset (*gray bars*) and offset (*white bars*) in participants (n = 104) living in room light *vs*. dim light. *White and gray bars* at the *top* of each plot indicate exposure to room light (<200 lux) and dim light (<3 lux), respectively, and *black bars* indicate scheduled sleep in darkness. B, Histograms show melatonin duration in the same participants over three consecutive cycles corresponding to A. Median melatonin duration is indicated by the *vertical line with label*. Melatonin duration is longest when the onset and offset occur under dim light. C, Horizontal bar chart showing the change in timing of melatonin onset in individual participants from d 2 in room light to d 3 in dim light. In 99% of individuals, melatonin onset occurred earlier in dim light relative to room light. Data are ranked in ascending order of magnitude. D–F, Similar plots are shown for changes in the timing of melatonin offset from the morning of d 3 in room light to d 4 in dim light (D), melatonin onset from d 3 in dim light to d 4 in dim light (E), and melatonin offset from the morning of d 4–5 in dim light (F).

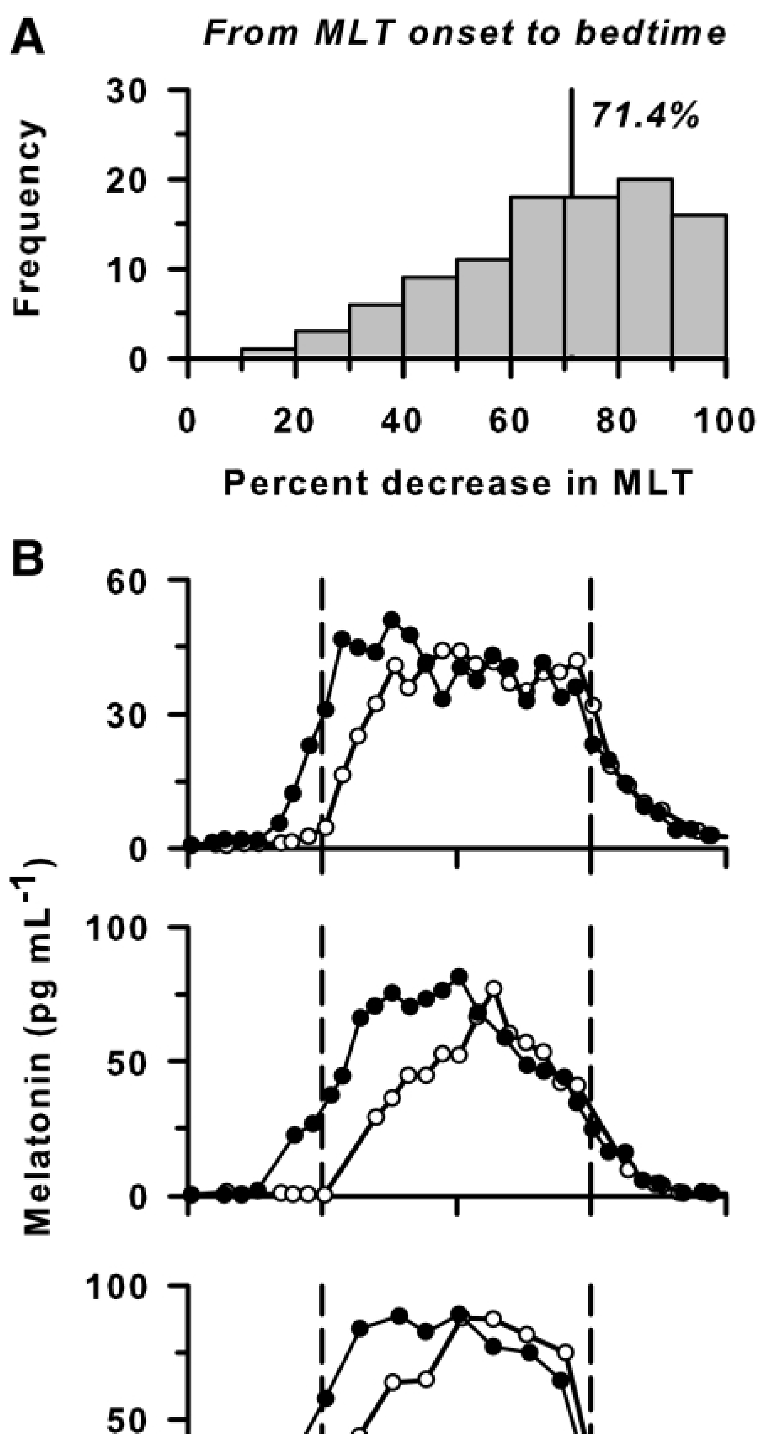

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Fig. 3.

Exposure to room light before bedtime decreases melatonin (MLT) levels. A, Histogram showing the percent decrease in melatonin from melatonin onset to bedtime when participants were exposed to room light (<200 lux) *vs*. dim light (<3 lux) until scheduled sleep. The AUC of the melatonin profile was determined in dim light and compared with the AUC on the preceding day at the same relative clock times.

Median percent decrease in melatonin is indicated by the *vertical line with label*. B, The melatonin rhythm is shown for three representative volunteers exposed to room light (○) before and after scheduled sleep in darkness (enclosed by the *vertical dashed lines*) *vs*. exposure to dim light (●) at the same relative clock times on the following day.

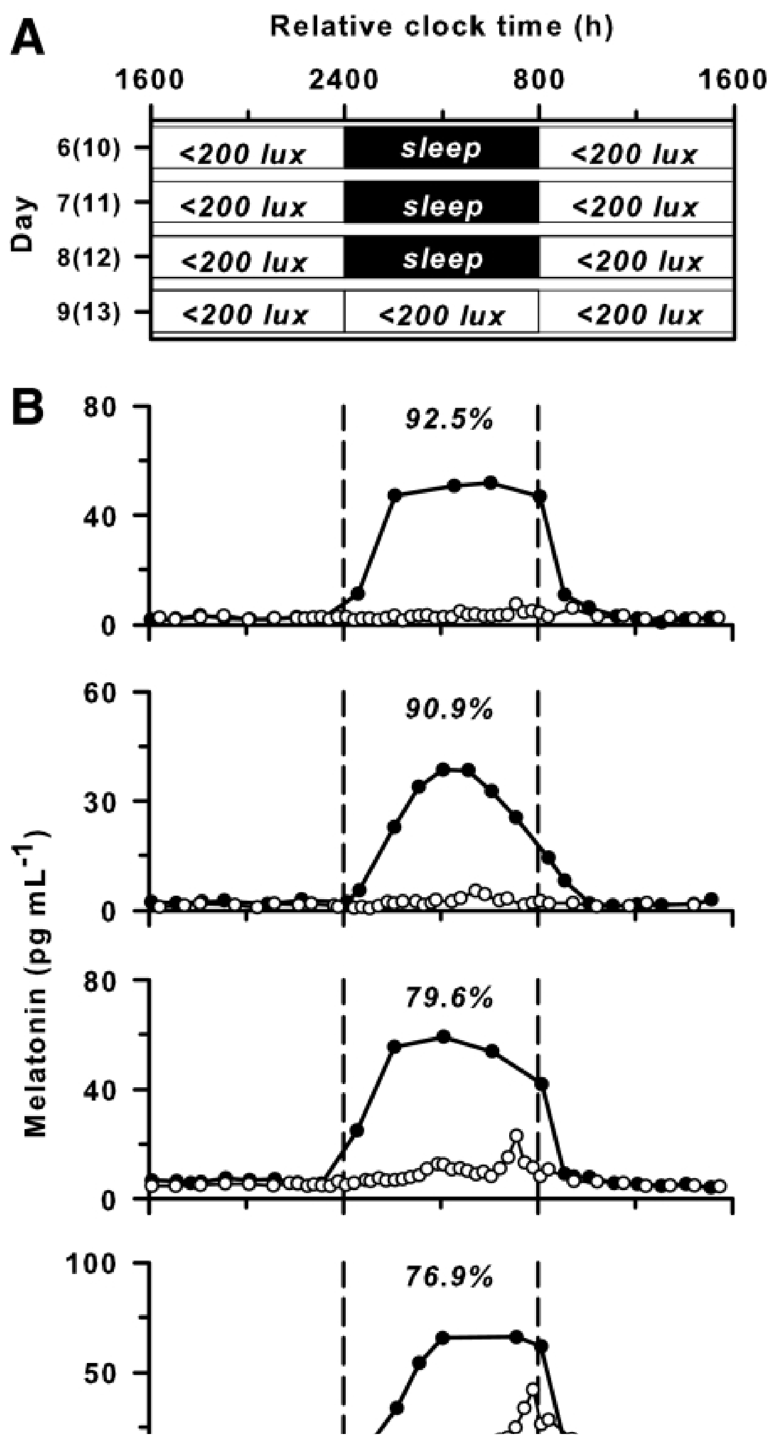

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Fig. 4.

Exposure to room light elicits strong suppression of melatonin during the usual hours of sleep. A, Participants lived in ambient room light (<200 lux) and slept in darkness for 3 baseline days, after which they underwent a constant routine procedure in room light (<200 lux). Data are shown from either d 6–9 or 10–13 of a 14-d research protocol (See *Subjects and Methods*). B, The melatonin rhythm is shown for five individuals exposed to room light (○) during the constant routine *vs*. darkness during sleep (●) on the preceding day. Percent melatonin suppression by room light is indicated at the *top* of each plot for the 8 h corresponding to habitual sleep (enclosed by the *vertical dashed lines*).

Data analysis and statistics

Within-subjects differences in the timing of melatonin onset, offset, duration, and phase angle were compared by Friedman's repeated-measures ANOVA on ranks (SigmaPlot 11; Systat Software, Inc., San Jose, CA). We chose to use nonparametric statistics because the distribution of melatonin onsets and offsets did not always pass the Kolmogorov-Smirnov test for normality ($P < 0.05$). In each comparison, the melatonin outcome (onset, offset, duration, or phase angle) was the dependent variable, and ambient lighting, which varied over three consecutive days, was the repeated factor (*i.e.* the treatment group). For those comparisons in which the difference in median values among the treatment groups was greater than that expected by chance ($P < 0.05$), all pairwise multiple comparisons were tested for significance using Tukey's method ($\alpha = 0.05$). Within-subjects differences in AUC for melatonin levels in dim light (<3 lux) *vs*. room light (<200 lux) were compared using the Wilcoxon signed rank test. Median values for melatonin outcomes are reported in the text with the interquartile range (IQR); the 25th and 75th percentiles are shown in Table 1.

Table 1.

Melatonin responses to room light *vs*. dim light in study 1 (n = 104)

	Median (25%, 75%)		
	Light (<200 lux), d 2-3	Dim (<3 lux), d 3-4	Dim (<3 lux), d 4-5
MLT onset (h min)	23 39 (22 18, 00 55)	21 54 (20 58, 23 14)[a]	22 09 (21 13, 23 21)[a,b]
MLT offset (h min)	08 16 (07 20, 09 34)	08 23 (07 12, 09 22)	08 26 (07 17, 09 30)
MLT duration (h)	8.75 (8.25, 9.42)	10.28 (9.68, 10.85)[a]	10.13 (9.68, 10.60)[a]
Phase angle MLT onset (h)	0.38 (−0.32, 1.22)	1.95 (1.37, 2.63)[a]	1.68 (1.07, 2.45)[a,b]
Phase angle MLT offset (h)	−8.52 (−8.92, −7.55)	−8.33 (−8.87, −7.50)	−8.38 (−8.87, −7.77)

Melatonin (MLT) outcomes are reported for participants over three consecutive days. Individuals lived in room light (<200 lux) and slept in darkness until midway through d 3 (column 2). Over the next 24 h, participants lived in dim light (<3 lux) and slept in darkness (column 3), followed by a constant routine procedure on d 4 and 5 conducted in under 3 lux light (column 4). Phase angle is defined as the relative timing of melatonin onset or offset *vs*. scheduled bedtime. A positive phase angle indicates that the event happened before scheduled sleep, whereas negative values indicate that the event happened after bedtime.

[a]Significant differences for comparisons with the first melatonin cycle (column 2; d 2-3)
[b]Significant differences for comparisons with the second melatonin cycle (column 3; d 3-4).

Results

Melatonin onset and duration are affected by evening exposure to room light

In study 1, changes in the melatonin profile were compared within subjects (n = 104) exposed to either room light or dim light before sleep (Fig. 1). In room light, melatonin onset occurred 23 min (IQR, 1 h 36 min) before scheduled sleep, whereas in dim light, melatonin onset occurred 1 h 57 min (IQR, 1 h 16 min) before scheduled bedtime ($P < 0.05$, Fig. 2A and Table 1). In contrast, the timing of melatonin offset did not differ significantly between room light and dim light conditions. Thus, due to its effect on melatonin onset, exposure to room light before bedtime shortened melatonin duration by 1 h 32 min (IQR, 1 h 6 min) compared with exposure to dim light (8 h 45 min *vs*. 10 h 17 min, $P < 0.05$; Fig. 2B and Table 1).

Next, we examined changes in the timing of melatonin onset and offset in individual participants. We found that 99.0% of participants (103 of 104) exhibited an earlier melatonin onset in dim light (d 3) *vs*. room light (d 2), and 78.6% of these individuals exhibited an earlier onset by more than an hour (Fig. 2 C). In contrast, only 58.6% of participants showed an earlier melatonin offset in dim light *vs*. room light, indicating that melatonin offset was not affected by the difference in lighting conditions (Table 1 and Fig. 2D). During two cycles of exposure to dim light, most participants showed a small daily delay (∼12 min) in the timing of melatonin onset and offset, 78.9 and 67.3% of individuals, respectively (Fig. 2, E and F), which is consistent with the longer-than-24-h intrinsic period of the human circadian system reported in previous studies (34).

To determine the effect of room light exposure on melatonin concentration before sleep, we compared the AUC for melatonin measured on d 2 (<200 lux) *vs*. d 3 (<3 lux). In dim light, the onset of nocturnal melatonin secretion occurred before scheduled sleep in 98% of participants (102 of 104). In these individuals, exposure to room light from the onset of melatonin until bedtime reduced melatonin concentration by 71.4% (IQR, 32.2%) relative to exposure to dim light 24 h later ($P < 0.001$, Fig. 3). In contrast, exposure to room light after awakening did not reduce melatonin levels ($P = 0.802$) in participants whose melatonin offset occurred after scheduled wake time in dim light (n = 64).

Exposure to room light suppresses melatonin during the usual hours of sleep

To test directly whether the later melatonin onset that we observed in room light was due to melatonin suppression, in study 2, we examined the melatonin rhythm under constant routine conditions in room light (n = 5, <200 lux) (Fig. 4). Compared with the melatonin rhythm observed when participants slept in darkness, exposure to room light during the normal hours of sleep suppressed melatonin strongly in four of five individuals (percent suppression: 92.5, 90.9, 79.6, 76.9, and 29.3%). In another group of participants (n = 8) who were exposed to a slightly higher level of ambient light (∼200 lux at the level of the eyes), there was robust melatonin suppression in seven of eight individuals (percent suppression: 87.6, 87.1, 73.7, 62.7, 54.2, 53.0, 51.1, and −1.3%). Hence, in 11 of 13 trials, exposure to room light in participants who were kept awake during the usual hours of sleep suppressed melatonin by more than half the amount measured during sleep in darkness.

Discussion

Our results demonstrate that the melatonin profile is truncated by exposure to room light before bedtime. Specifically, we show that exposure to room light (<200 lux) in the late evening suppresses the onset of melatonin synthesis, thereby shortening melatonin duration by about 90 min compared with exposure to dim light (<3 lux). As a result of this exposure to electrical light between dusk and bedtime, presleep levels of melatonin were reduced by 71.4% and total daily levels of melatonin were reduced by about 12.5%. When room light exposure continues for the entire night, total daily melatonin is suppressed by more than 50% in most individuals, with median suppression of 73.7%. These findings suggest that exposure to electrical room light before bedtime and during the normal hours of sleep (*e.g.* during shift work) may impact physiological processes regulated by melatonin signaling, such as sleepiness, thermoregulation, blood pressure, and perhaps even glucose homeostasis.

Room light suppresses melatonin and shortens melatonin duration

We hypothesize that the later melatonin onset we observed during exposure to room light in the evening was due primarily to melatonin suppression, rather than phase shifting of the circadian system. In study 1, the earlier melatonin onset we observed on d 3 could be attributed, in part, to a net phase advance of the circadian system, because participants were exposed to room light in the morning and early afternoon and dim light in the late afternoon and evening. Hence, individuals were exposed to higher light levels during the predicted phase-advance region of the phase-response curve, compared with the phase-delay region (30) (Fig. 1A). If phase shifting were principally responsible for the change in melatonin onset, we would expect a comparable shift in the timing of melatonin offset in the same direction. Rather, our results show that the timing of melatonin offset was unchanged. To examine this question in greater detail, we examined results from an additional set of 58 participants who completed a similar research protocol under different lighting conditions (see Supplemental Data). In that study, volunteers were exposed to room light until the end of the third baseline day, after which time the circadian system was released into constant conditions. Whereas 70.7% of individuals showed a later melatonin offset (41 of 58 participants) in dim light, consistent with drift of the circadian pacemaker (34), 86.2% of individuals showed an earlier melatonin onset (50 of 58) when exposed to dim light (<15 lux) on d 4, *vs*. room light on d 3 (Supplemental Figs. 2 and 3). These data suggest that the underlying circadian phase of melatonin onset on d 3 was masked by light exposure, presumably due to photic melatonin suppression. Consistent with this interpretation, in study 2, we observed that exposure to room light during the usual hours of sleep resulted in strong melatonin suppression in 84.6% of trials (Fig. 4). Some participants showed partial recovery from melatonin suppression during room light exposure, whereas others showed complete suppression of melatonin such that melatonin onset or offset could not be measured. By comparison, two participants showed weak melatonin suppression responses to room light. This inter-individual variability in melatonin suppression sensitivity is consistent with the dose-response function for melatonin suppression reported previously; room light (100–500 lux) falls on the steep linear part of the dose-response curve, such that small differences in corneal illuminance can result in large differences in melatonin suppression magnitude (25, 32).

A limitation of the present study is that the dim light and room light conditions were not balanced for order of presentation. We obtained similar results in a previous study, however, in which the order of light conditions was reversed, such that participants were exposed to dim light on d 1 (<3 lux), followed by 2 d in room light (<200 lux). In that study, melatonin onset also occurred substantially later in room light compared with dim light (by about 90 min), suggesting that the order of room light *vs*. dim light in the present study did not affect the primary outcomes (35). Another limitation of our study is that participants were exposed to long durations of room light or dim light (16 or 8 h) before sleep, whereas in the real world, individuals often choose to turn on, or turn off, electrical lights closer to bedtime. Also, illumination levels that people are exposed to during the daytime could potentially modulate melatonin suppression responses to electrical light at night (*e.g.* by sensitizing or desensitizing melatonin suppression responses). Previously, we showed that the suppressive effect of room light on melatonin synthesis was reduced by about 15% when participants were exposed to room light, instead of dim light, during the daytime (28). In the present study, participants were also exposed to room light during the day, which may have decreased melatonin suppression sensitivity at night; nonetheless, melatonin levels were strongly suppressed by room light (by about 70%) before bedtime and during the usual hours of sleep (Figs. 2–4).

Potential implications of melatonin suppression by electrical lighting

In modern society, people are routinely exposed to electrical lighting during evening hours, after the onset of melatonin production, to partake in work, recreational, and social activities. Our results demonstrate that this indoor room light profoundly alters the timing, duration, and amount of melatonin synthesis, the health consequences of which are unknown. Melatonin is the body's internal representation of night duration, or scotoperiod, and is sensitive to changes in season in humans (5, 36). Chronic exposure to evening electrical lighting extends the photoperiod and shortens the scotoperiod, which is equivalent to placing modern humans in a continual biological summer. This could, in turn, have effects on metabolic function via alteration of melatonin secretion directly (18,–20) or indirectly via altered sleep duration (37).

The effects of exogenous melatonin on human physiology suggest that this hormone plays a role in regulating body temperature, blood pressure, and sleepiness (12, 17, 38). Given the ability of melatonin to inhibit linoleic acid uptake, melatonin has also been proposed as a treatment option for inhibiting cancer progression (39). In an animal model for human cancer in which nude rats were implanted with breast cancer xenografts, perfusion with blood taken from women exposed to dim light at night, when melatonin is released, reduced tumor growth markedly (40). In contrast, blood taken from women who had been exposed to bright light at night, which drastically reduced levels of plasma melatonin, did not affect growth rate of xenografts. Rates of breast cancer are especially high in chronic shift workers (41,–43), most of whom are exposed to light that is of sufficient intensity to suppress nighttime melatonin levels. This, coupled with the finding that the rate of breast cancer is lower in blind women without light perception (44,–46), raises the possibility that chronic light suppression of melatonin may increase the relative risk for some types of cancer (47), an idea that was proposed nearly 25 yr ago by Richard Stevens as part of his light-at-night theory (48, 49). Chronically exposing oneself to light at night could also increase cancer risk by disrupting circadian clock function; continuous exposure to light disrupts behavioral rhythms and increases tumor malignity in C57BL/6 mice, even though these animals do not secrete melatonin (50). If further research substantiates melatonin suppression as a significant risk factor for breast cancer, our results demonstrating strong suppression of melatonin with evening room light could have important health implications. Moreover, in future studies, it will be important to determine whether small, chronic changes in sleep, melatonin, and circadian phase, as experienced every day in many nonshift workers, might present a health risk in vulnerable individuals (49). Given that melatonin receptor genes have recently been linked to the pathogenesis of type 2 diabetes (18,–20, 51), it is possible that disruption of melatonin signaling by exposure to light at night could contribute to the increased risk for developing metabolic syndrome and type 2 diabetes in shift workers. Hence, future work should focus on determining the mechanisms by which melatonin regulates glucose metabolism and the consequences of inhibiting melatonin receptor signaling on blood glucose and insulin levels (51, 52).

In conclusion, our findings demonstrate that melatonin levels are remarkably sensitive to room light levels, with exposure before bedtime resulting in strong suppression of melatonin synthesis. As a result, exposure to room light into the late evening has the effect of shortening melatonin duration, thereby truncating the body's internal representation of solar night. With growing evidence that melatonin receptor signaling plays an important role in regulating human physiology, in future studies, it will be important to determine the impact of chronic nighttime exposure to electrical lighting on melatonin suppression and morbidity.

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Footnotes

Abbreviations:

AUC Area under the curve

GCRC General Clinical Research Center

IQR interquartile range.

References

1. Lewy AJ, Wehr TA, Goodwin FK, Newsome DA, Markey SP. 1980. Light suppresses melatonin secretion in humans. Science 210:1267–1269 [PubMed] [Google Scholar]

2. Shanahan TL, Czeisler CA. 1991. Light exposure induces equivalent phase shifts of the endogenous circadian rhythms of circulating plasma melatonin and core body temperature in men. J Clin Endocrinol Metab 73:227–235 [PubMed] [Google Scholar]

3. Bittman EL, Karsch FJ, Hopkins JW. 1983. Role of the pineal gland in ovine photoperiodism: regulation of seasonal breeding and negative feedback effects of estradiol upon luteinizing hormone secretion. Endocrinology 113:329–336 [PubMed] [Google Scholar]

4. Reiter RJ. 1980. The pineal and its hormones in the control of reproduction in mammals. Endocr Rev 1:109–131 [PubMed] [Google Scholar]

5. Wehr TA, Moul DE, Barbato G, Giesen HA, Seidel JA, Barker C, Bender C. 1993. Conservation of photoperiod-responsive mechanisms in humans. Am J Physiol 265:R846–R857 [PubMed] [Google Scholar]

6. Kauppila A, Kivelä A, Pakarinen A, Vakkuri O. 1987. Inverse seasonal relationship between melatonin and ovarian activity in humans in a region with a strong seasonal contrast in luminosity. J Clin Endocrinol Metab 65:823–828 [PubMed] [Google Scholar]

7. Roenneberg T, Aschoff J. 1990. Annual rhythm of human reproduction. II. Environmental correlations. J Biol Rhythms 5:217–239 [PubMed] [Google Scholar]

8. Roenneberg T, Aschoff J. 1990. Annual rhythm of human reproduction. I. Biology, sociology, or both? J Biol Rhythms 5:195–216 [PubMed] [Google Scholar]

9. Hughes RJ, Badia P. 1997. Sleep-promoting and hypothermic effects of daytime melatonin administration in humans. Sleep 20:124–131 [PubMed] [Google Scholar]

10. Rajaratnam SM, Middleton B, Stone BM, Arendt J, Dijk DJ. 2004. Melatonin advances the circadian timing of EEG sleep and directly facilitates sleep without altering its duration in extended sleep opportunities in humans. J Physiol 561:339–351 [PMC free article] [PubMed] [Google Scholar]

11. Stone BM, Turner C, Mills SL, Nicholson AN. 2000. Hypnotic activity of melatonin. Sleep 23:663–669 [PubMed] [Google Scholar]

12. Wyatt JK, Dijk DJ, Ritz-de Cecco A, Ronda JM, Czeisler CA. 2006. Sleep-facilitating effect of exogenous melatonin in healthy young men and women is circadian-phase dependent. Sleep 29:609–618 [PubMed] [Google Scholar]

13. Vaněcek J, Pavlík A, Illnerová H. 1987. Hypothalamic melatonin receptor sites revealed by autoradiography. Brain Res 435:359–362 [PubMed] [Google Scholar]

14. Lockley SW, Skene DJ, James K, Thapan K, Wright J, Arendt J. 2000. Melatonin administration can entrain the free-running circadian system of blind subjects. J Endocrinol 164:R1–R6 [PubMed] [Google Scholar]

15. Sack RL, Brandes RW, Kendall AR, Lewy AJ. 2000. Entrainment of free-running circadian rhythms by melatonin in blind people. N Engl J Med 343:1070–1077 [PubMed] [Google Scholar]

16. Arangino S, Cagnacci A, Angiolucci M, Vacca AM, Longu G, Volpe A, Melis GB. 1999. Effects of melatonin on vascular reactivity, catecholamine levels, and blood pressure in healthy men. Am J Cardiol 83:1417–1419 [PubMed] [Google Scholar]

17. Reid K, Van den Heuvel C, Dawson D. 1996. Day-time melatonin administration: effects on core temperature and sleep onset latency. J Sleep Res 5:150–154 [PubMed] [Google Scholar]

18. Bouatia-Naji N, Bonnefond A, Cavalcanti-Proença C, Sparsø T, Holmkvist J, Marchand M, Delplanque J, Lobbens S, Rocheleau G, Durand E, De Graeve F, Chèvre JC, Borch-Johnsen K, Hartikainen AL, Ruokonen A, Tichet J, Marre M, Weill J, Heude B, Tauber M, Lemaire K, Schuit F, Elliott P, Jørgensen T, Charpentier G, Hadjadj S, Cauchi S, Vaxillaire M, Sladek R, Visvikis-Siest S, Balkau B, Lévy-Marchal C, Pattou F, Meyre D, Blakemore AI, Jarvelin MR, Walley AJ, Hansen T, Dina C, Pedersen O, Froguel P. 2009. A variant near MTNR1B is associated with increased fasting plasma glucose levels and type 2 diabetes risk. Nat Genet 41:89–94 [PubMed] [Google Scholar]

19. Lyssenko V, Nagorny CL, Erdos MR, Wierup N, Jonsson A, Spégel P, Bugliani M, Saxena R, Fex M, Pulizzi N, Isomaa B, Tuomi T, Nilsson P, Kuusisto J, Tuomilehto J, Boehnke M, Altshuler D, Sundler F, Eriksson JG, Jackson AU, Laakso M, Marchetti P, Watanabe RM, Mulder H, Groop L. 2009. Common variant in MTNR1B associated with increased risk of type 2 diabetes and impaired early insulin secretion. Nat Genet 41:82–88 [PMC free article] [PubMed] [Google Scholar]

20. Prokopenko I, Langenberg C, Florez JC, Saxena R, Soranzo N, Thorleifsson G, Loos RJ, Manning AK, Jackson AU, Aulchenko Y, Potter SC, Erdos MR, Sanna S, Hottenga JJ, Wheeler E, Kaakinen M, Lyssenko V, Chen WM, Ahmadi K, Beckmann JS, Bergman RN, Bochud M, Bonnycastle LL, Buchanan TA, Cao A, Cervino A, Coin L, Collins FS, Crisponi L, de Geus EJ, Dehghan A, Deloukas P, Doney AS, Elliott P, Freimer N, Gateva V, Herder C, Hofman A, Hughes TE, Hunt S, Illig T, Inouye M, Isomaa B, Johnson T, Kong A, Krestyaninova M, Kuusisto J, Laakso M, Lim N, Lindblad U, Lindgren CM, McCann OT, Mohlke KL, Morris AD, Naitza S, Orrù M, Palmer CN, Pouta A, Randall J, Rathmann W, Saramies J, Scheet P, Scott LJ, Scuteri A, Sharp S, Sijbrands E, Smit JH, Song K, Steinthorsdottir V, Stringham HM, Tuomi T, Tuomilehto J, Uitterlinden AG, Voight BF, Waterworth D, Wichmann HE, Willemsen G, Witteman JC, Yuan X, Zhao JH, Zeggini E, Schlessinger D, Sandhu M, Boomsma DI, Uda M, Spector TD, Penninx BW, Altshuler D, Vollenweider P, Jarvelin MR, Lakatta E, Waeber G, Fox CS, Peltonen L, Groop LC, Mooser V, Cupples LA, Thorsteinsdottir U, Boehnke M, Barroso I, Van Duijn C, Dupuis J, Watanabe RM, Stefansson K, McCarthy MI, Wareham NJ, Meigs JB, Abecasis GR. 2009. Variants in MTNR1B influence fasting glucose levels. Nat Genet 41:77–81 [PMC free article] [PubMed] [Google Scholar]

21. Drew JE, Barrett P, Mercer JG, Moar KM, Canet E, Delagrange P, Morgan PJ. 2001. Localization of the melatonin-related receptor in the rodent brain and peripheral tissues. J Neuroendocrinol 13:453–458 [PubMed] [Google Scholar]

22. Sánchez-Barceló EJ, Mediavilla MD, Tan DX, Reiter RJ. 2010. Clinical uses of melatonin: evaluation of human trials. Curr Med Chem 17:2070–2095 [PubMed] [Google Scholar]

23. Boivin DB, Duffy JF, Kronauer RE, Czeisler CA. 1996. Dose-response relationships for resetting of human circadian clock by light. Nature 379:540–542 [PubMed] [Google Scholar]

24. Laakso ML, Hätönen T, Stenberg D, Alila A, Smith S. 1993. One-hour exposure to moderate illuminance (500 lux) shifts the human melatonin rhythm. J Pineal Res 15:21–26 [PubMed] [Google Scholar]

25. Zeitzer JM, Dijk DJ, Kronauer RE, Brown EN, Czeisler CA. 2000. Sensitivity of the human circadian pacemaker to nocturnal light: Melatonin phase resetting and suppression. J Physiol 526(Pt 3):695–702 [PMC free article] [PubMed] [Google Scholar]

26. Osterhaus W, Office lighting: a review of 80 years of standards and recommendations. IEEE Industry Applications Society Annual Meeting, Toronto, Ontario, Canada, 1993 [Google Scholar]

27. Jasser SA, Hanifin JP, Rollag MD, Brainard GC. 2006. Dim light adaptation attenuates acute melatonin suppression in humans. J Biol Rhythms 21:394–404 [PubMed] [Google Scholar]

28. Smith KA, Schoen MW, Czeisler CA. 2004. Adaptation of human pineal melatonin suppression by recent photic history. J Clin Endocrinol Metab 89:3610–3614 [PubMed] [Google Scholar]

29. Boivin DB, James FO. 2002. Phase-dependent effect of room light exposure in a 5-h advance of the sleep-wake cycle: implications for jet lag. J Biol Rhythms 17:266–276 [PubMed] [Google Scholar]

30. Khalsa SB, Jewett ME, Cajochen C, Czeisler CA. 2003. A phase response curve to single bright light pulses in human subjects. J Physiol 549:945–952 [PMC free article] [PubMed] [Google Scholar]

31. Gooley JJ, Rajaratnam SM, Brainard GC, Kronauer RE, Czeisler CA, Lockley SW. 2010. Spectral responses of the human circadian system depend on the irradiance and duration of exposure to light. Sci Transl Med 2:31ra33 [PMC free article] [PubMed] [Google Scholar]

32. Lockley SW, Brainard GC, Czeisler CA. 2003. High sensitivity of the human circadian melatonin rhythm to resetting by short wavelength light. J Clin Endocrinol Metab 88:4502–4505 [PubMed] [Google Scholar]

33. Duffy JF, Dijk DJ. 2002. Getting through to circadian oscillators: why use constant routines? J Biol Rhythms 17:4–13 [PubMed] [Google Scholar]

34. Czeisler CA, Duffy JF, Shanahan TL, Brown EN, Mitchell JF, Rimmer DW, Ronda JM, Silva EJ, Allan JS, Emens JS, Dijk DJ, Kronauer RE. 1999. Stability, precision, and near-24-hour period of the human circadian pacemaker. Science 284:2177–2181 [PubMed] [Google Scholar]

35. Wright KP, Jr, Gronfier C, Duffy JF, Czeisler CA. 2005. Intrinsic period and light intensity determine the phase relationship between melatonin and sleep in humans. J Biol Rhythms 20:168–177 [PMC free article] [PubMed] [Google Scholar]

36. Owen J, Arendt J. 1992. Melatonin suppression in human subjects by bright and dim light in Antarctica: time and season-dependent effects. Neurosci Lett 137:181–184 [PubMed] [Google Scholar]

37. Spiegel K, Tasali E, Leproult R, Van Cauter E. 2009. Effects of poor and short sleep on glucose metabolism and obesity risk. Nat Rev Endocrinol 5:253–261 [PMC free article] [PubMed] [Google Scholar]

38. Simko F, Paulis L. 2007. Melatonin as a potential antihypertensive treatment. J Pineal Res 42:319–322 [PubMed] [Google Scholar]

39. Blask DE, Sauer LA, Dauchy RT, Holowachuk EW, Ruhoff MS, Kopff HS. 1999. Melatonin inhibition of cancer growth in vivo involves suppression of tumor fatty acid metabolism via melatonin receptor-mediated signal transduction events. Cancer Res 59:4693–4701 [PubMed] [Google Scholar]

40. Blask DE, Brainard GC, Dauchy RT, Hanifin JP, Davidson LK, Krause JA, Sauer LA, Rivera-Bermudez MA, Dubocovich ML, Jasser SA, Lynch DT, Rollag MD, Zalatan F. 2005. Melatonin-depleted blood from premenopausal women exposed to light at night stimulates growth of human breast cancer xenografts in nude rats. Cancer Res 65:11174–11184 [PubMed] [Google Scholar]

41. Hansen J. 2001. Light at night, shiftwork, and breast cancer risk. J Natl Cancer Inst 93:1513–1515 [PubMed] [Google Scholar]

42. Hansen J. 2001. Increased breast cancer risk among women who work predominantly at night. Epidemiology 12:74–77 [PubMed] [Google Scholar]

43. Tokumaru O, Haruki K, Bacal K, Katagiri T, Yamamoto T, Sakurai Y. 2006. Incidence of cancer among female flight attendants: a meta-analysis. J Travel Med 13:127–132 [PubMed] [Google Scholar]

44. Feychting M, Osterlund B, Ahlbom A. 1998. Reduced cancer incidence among the blind. Epidemiology 9:490–494 [PubMed] [Google Scholar]

45. Flynn-Evans EE, Stevens RG, Tabandeh H, Schernhammer ES, Lockley SW. 2009. Total visual blindness is protective against breast cancer. Cancer Causes Control 20:1753–1756 [PubMed] [Google Scholar]

46. Hahn RA. 1991. Profound bilateral blindness and the incidence of breast cancer. Epidemiology 2:208–210 [PubMed] [Google Scholar]

47. Straif K, Baan R, Grosse Y, Secretan B, El Ghissassi F, Bouvard V, Altieri A, Benbrahim-Tallaa L, Cogliano V. 2007. Carcinogenicity of shift-work, painting, and fire-fighting. Lancet Oncol 8:1065–1066 [PubMed] [Google Scholar]

48. Stevens RG. 1987. Electric power use and breast cancer: a hypothesis. Am J Epidemiol 125:556–561 [PubMed] [Google Scholar]

49. Stevens RG. 2009. Light-at-night, circadian disruption and breast cancer: assessment of existing evidence. Int J Epidemiol 38:963–970 [PMC free article] [PubMed] [Google Scholar]

50. Otálora BB, Madrid JA, Alvarez N, Vicente V, Rol MA. 2008. Effects of exogenous melatonin and circadian synchronization on tumor progression in melanoma-bearing C57BL6 mice. J Pineal Res 44:307–315 [PubMed] [Google Scholar]

51. Contreras-Alcantara S, Baba K, Tosini G. 2010. Removal of melatonin receptor type 1 induces insulin resistance in the mouse. Obesity (Silver Spring) 18:1861–1863 [PMC free article] [PubMed] [Google Scholar]

52. Mühlbauer E, Gross E, Labucay K, Wolgast S, Peschke E. 2009. Loss of melatonin signalling and its impact on circadian rhythms in mouse organs regulating blood glucose. Eur J Pharmacol 606:61–71 [PubMed] [Google Scholar]

REPORT 4 OF THE COUNCIL ON SCIENCE AND PUBLIC HEALTH (A-12)
Light Pollution: Adverse Health Effects of Nighttime Lighting

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EXECUTIVE SUMMARY

Objective. To evaluate the impact of artificial lighting on human health, primarily through disruption of circadian biological rhythms or sleep, as well as the impact of headlamps, nighttime lighting schemes, and glare on driving safety. Concerns related to energy cost, effects on wildlife and vegetation, and esthetics also are briefly noted.

Methods. English-language reports in humans were selected from a PubMed search of the literature from 1995 to March 2012 using the MeSH terms "circadian/biological clocks/rhythm," "chronobiology/disorders," "photoperiod," "light/lighting" "sleep," "work schedule," or "adaptation," combined with the terms "physiology," "melatonin," "adverse effects/toxicity," "pathophysiology," "neoplasm," "epidemiology/etiology," "mental disorders," "energy metabolism," and "gene expression." Additional articles were identified by manual review of the references cited in these publications; others were supplied by experts in the field who contributed to this report (see Acknowledgement).

Results. Biological adaptation to the sun has evolved over billions of years. The power to artificially override the natural cycle of light and dark is a recent event and represents a man-made self-experiment on the effects of exposure to increasingly bright light during the night as human societies acquire technology and expand industry. In addition to resetting the circadian pacemaker, light also stimulates additional neuroendocrine and neurobehavioral responses including suppression of melatonin release from the pineal gland improving alertness and performance. Low levels of illuminance in the blue or white fluorescent spectrum disrupt melatonin secretion. The primary human concerns with nighttime lighting include disability glare (which affects driving and pedestrian safety) and various health effects. Among the latter are potential carcinogenic effects related to melatonin suppression, especially breast cancer. Other diseases that may be exacerbated by circadian disruption include obesity, diabetes, depression and mood disorders, and reproductive problems.

Conclusion. The natural 24-hour cycle of light and dark helps maintain precise alignment of circadian biological rhythms, the general activation of the central nervous system and various biological and cellular processes, and entrainment of melatonin release from the pineal gland. Pervasive use of nighttime lighting disrupts these endogenous processes and creates potentially harmful health effects and/or hazardous situations with varying degrees of harm. The latter includes the generation of glare from roadway, property, and other artificial lighting sources that can create unsafe driving conditions, especially for older drivers. More direct health effects of nighttime lighting may be attributable to disruption of the sleep-wake cycle and suppression of melatonin release. Even low intensity nighttime light has the capability of suppressing melatonin release. In various laboratory models of cancer, melatonin serves as a circulating anticancer signal and suppresses tumor growth. Limited epidemiological studies support the hypothesis that nighttime lighting and/or repetitive disruption of circadian rhythms increases cancer risk; most attention in this arena has been devoted to breast cancer. Further information is required to

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evaluate the relative role of sleep versus the period of darkness in certain diseases or on mediators of certain chronic diseases or conditions including obesity. Due to the nearly ubiquitous exposure to light at inappropriate times relative to endogenous circadian rhythms, a need exists for further multidisciplinary research on occupational and environmental exposure to light-at-night, the risk of cancer, and effects on various chronic diseases

REPORT OF THE COUNCIL ON SCIENCE AND PUBLIC HEALTH

CSAPH Report 4-A-12

INTRODUCTION

Current AMA Policy H-135.937 (AMA Policy Database) advocates for light pollution control and reduced glare from (electric) artifical light sources to both protect public safety and conserve energy. Lighting the night has become a necessity in many areas of the world to enhance commerce, promote social activity, and enhance public safety. However, an emerging consensus has come to acknowledge the effects of widespread nighttime artificial lighting, including the: 1) impact of artificial lighting on human health, primarily through disruption of circadian biological rhythms or sleep; 2) intersection of ocular physiology, vehicle headlamps, nighttime lighting schemes, and harmful glare; 3) energy cost of wasted and unnecessary electric light; and 4) impact of novel light at night on wildlife and vegetation. In addition to these health and environmental effects, an esthetic deficit is apparent with the progressive loss of the starry night sky and interference with astronomical observations. With the assistance of experts in the field, this report evaluates the effects of pervasive nighttime lighting on human health and performance. Concerns related to energy cost, effects on wildlife and vegetation, and esthetics are also briefly noted.

METHODS

English-language reports in humans were selected from a PubMed search of the literature from 1995 to March 2012 using the MeSH terms "circadian/biological clocks/rhythm," "chronobiology/disorders," "photoperiod," "light/lighting" "sleep," "work schedule," or "adaptation," combined with the terms "physiology," "melatonin," "adverse effects/toxicity," "pathophysiology," "neoplasm," "epidemiology/etiology," "mental disorders," "energy metabolism," and "gene expression." Additional articles were identified by manual review of the references cited in these publications; others were supplied by experts in the field who contributed to this report (see Acknowledgement).

LIGHT AND HUMAN PHYSIOLOGY

The solar cycle of light and dark provides the essential basis for life on Earth. Adaptation to the solar cycle has resulted in fundamental molecular and genetic endogenous processes in virtually all life forms that are aligned with an approximately 24-hour period (circadian biological rhythm). The circadian genetic clock mechanism is intimately involved in many, if not most, facets of cellular and organismal function.[1] Although the circadian system spontaneously generates near-24-hour rhythms, this master clock must be reset daily by the light-dark cycle to maintain proper temporal alignment with the environment. In humans and other mammals, this daily entrainment is achieved primarily by novel photoreceptors that project directly to the site of the circadian clock (suprachiasmatic nuclei (SCN) of the hypothalamus).[2-5] The tandem development of an endogenous rhythm sensitive to light presumably evolved to allow for precise 24-hour regulation of rest and activity, and for adapting to seasonal changes in night-length, while maintaining the advantages of an underlying physiology that anticipates day and night. Understanding the molecular and

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physiological basis of endogenous rhythms, how light information is communicated, and the health implications of disruptions to this system are topics of intensive study.

ELECTRIC LIGHTING AND HUMAN HEALTH

Biological adaptation to the sun has evolved over billions of years. The power to artificially override the natural cycle of light and dark is a recent event and represents a man-made self-experiment on the effects of exposure to increasingly bright light during the night as human societies acquire technology and expand industry. At the same time, increasing numbers of people work inside buildings under electric lighting both night and day. Artificial lighting is substantially dimmer than sunlight and provides a very different spectral irradiance. Sunlight is strong at all visible wavelengths, peaking in the yellow region, whereas electric lighting has either extreme characteristic wavelength peaks (fluorescent) or exhibits a monotonic increase in irradiance as wavelength lengthens (incandescent). In contrast to outdoor lighting conditions, much of the modern world now lives and works in relatively dim light throughout the day in isolation from the sun, with often poor contrast between night and day, even for those who live and work in sunny environments.[6]

Extensive nighttime lighting is required for contemporary society and commerce. Therefore, it is imperative to evaluate the unintended adverse health consequences of electric lighting practices in the human environment, and determine their physiological bases so that effective interventions can be developed to mitigate harmful effects of suboptimal light exposure. For example, engineers have already developed less disruptive night lighting technologies, and continued progress in this area is anticipated. That such technologies exist, however, does not guarantee that they will be purchased, installed and properly implemented. The medical community and public can take the lead on advocating a healthier environment, as illustrated by recent changes in public smoking policies worldwide. As the research on the biology of circadian rhythms has advanced, the range of potential disease connections due to disrupted circadian rhythms and sleep has expanded.

Biological Impact of Light on Human Physiology

Light is the most powerful stimulus for regulating human circadian rhythms and is the major environmental time cue for synchronizing the circadian clock. In addition to resetting the circadian pacemaker, light also stimulates additional neuroendocrine and neurobehavioral responses, including suppression of melatonin release from the pineal gland, directly alerting the brain, and improving alertness and performance.[7-9] Melatonin is one of the most studied biomarkers of the human physiological response to light.[10] This substance is the biochemical correlate of darkness and is only produced at night, regardless of whether an organism is day-active (diurnal) or night-active (nocturnal). Conceptually, melatonin provides an internal representation of the environmental photoperiod, specifically night-length. The synthesis and timing of melatonin production requires an afferent signal from the SCN. Ablation of this pathway, which occurs in some patients from upper cervical spinal damage, completely abolishes melatonin production. Certain other circadian rhythms (e.g., cortisol, body temperature, sleep-wake cycles) do not depend on this pathway and persist if the SCN pathway is damaged.

Light is not required to generate circadian rhythms or pineal melatonin production. In the absence of a light-dark cycle (e.g., totally blind individuals), the circadian pacemaker generates rhythms close to, but not exactly a 24-hour periodicity, reflecting the timing of processes under SCN control.[2] However, as previously noted, the timing of SCN rhythms and consequently the rhythms controlled by the circadian clock are affected by light, and require daily exposure to the light-dark cycle to be synchronized with the 24-hour day.

When light information fails to reach the SCN to synchronize the clock and its outputs, the pacemaker reverts to its endogenous non-24-hour period (range 23.7-25.0 h). Consequently, the timing of physiology and behavior that is controlled by the circadian system, for example the sleep-wake cycle, alertness and performance patterns, the core body temperature rhythm, and melatonin and cortisol production, becomes desynchronized from the 24-hour day.[2] The resultant clinical disorder is termed "non-24-hour sleep-wake disorder" and is characterized by alternating episodes of restful sleep, followed by poor night-time sleep and excessive day-time napping, as the non-24-hour circadian pacemaker cycles in and out of phase with the 24-hour social day.[11] Another effect of light exposure at night is the immediate suppression of melatonin production. Under natural conditions, organisms would never be exposed to light during the night in substantial amounts and would not experience melatonin suppression. Electric light, however, efficiently suppresses melatonin at intensities commonly experienced in the home at night.[12]

Measures of Illumination

Luminous flux is the measure of the perceived power of light. The lumen is the standard international unit of luminous flux, a measure of the total "amount" of visible light emitted by a source, while illumination is a measure of how much luminous flux is spread over a given area (intensity of illumination). One lux is equal to one lumen/m^2. Luminous flux measurements take into account the fact that the human eye and visual system is more sensitive to some wavelengths than others. The peak luminosity function is in the green spectral region; white light sources produce far fewer lumens. To provide some perspective, the illuminance associated with a full moon is less than 1 lux, versus 50 lux for a typically incandescent lit family room, 80 lux in a narrower hallway, 325-500 lux for office lighting, 1,000 lux for an overcast day, and 32,000-130,000 lux for direct sunlight.

Initially it was thought that bright light of at least 2,500-20,000 lux was needed to suppress nighttime melatonin secretion or phase shift the melatonin rhythm (as in jet lag) in humans.[13-15] It is now established that when exposure of the human eye is carefully controlled, illuminance as low as 5−17 lux of monochromatic green light or 100 lux of broadband white light can significantly suppress melatonin in normal human volunteers.[12,16-18] Similarly, circadian phase shifts of the melatonin rhythm can be evoked with an illuminance of 5 lux of monochromatic blue light or <100 lux of white fluorescent light, however, exposure to red light is not disruptive.[18,19] Typical lighting in bedrooms in the evening after dusk (but before bedtime) can also suppress melatonin and delay its nocturnal surge.[12] Acute enhancement of both subjective and objective measures of alertness can be evoked with as little as 5 lux of monochromatic blue light.[20] Dose-response curves for melatonin suppression by night-time light exposure to fluorescent light show that ~100 lux of light induces 50% of the maximal response observed with 1,000-10,000 lux of light.[18,21]

Ocular Physiology Mediating Photic Effects

Factors that alter the amount and spectral quality of light reaching the retina include gaze behavior relative to a light source, age (of the ocular lens), and pupillary dilation. Once a light stimulus reaches the retina, physiology within the retina and within the nervous system determines the capacity of the stimulus to evoke circadian, neuroendocrine or neurobehavioral responses. This physiology includes: 1) the sensitivity of the operative photopigments and photoreceptors; 2) location of these photoreceptors within the retina; 3) the ability of the nervous system to integrate photic stimuli spatially and temporally; and, 4) the state of photoreceptor adaptation.
In particular, both short and long-term photoreceptor adaptation can significantly modify the biological and behavioral responses to light and acutely suppress melatonin in humans.[22] For

example, a full week of daytime exposure to bright light (by daylight and/or indoor light boxes at ~ 5,000 lux) or a three-day period of exposure to moderate indoor lighting (200 lux) reduces an individual's sensitivity to light suppression of nighttime melatonin compared with exposure to dim indoor lighting (0.5 lux); similar dim light conditions also enhance circadian phase shifting.[23-25] Two hours of exposure to 18 lux of white incandescent light versus full dark exposure in a single evening modifies the sensitivity of an individual for light-induced melatonin suppression later that same night.[26] Hence, photoreceptor adaptation, like the other ocular and neural elements noted above, can significantly modify the biological and behavioral responses to light.[16]

In general, photobiological responses to light are not all-or-none phenomena. In the case of acutely suppressing high nighttime levels of melatonin or phase-shifting the entire melatonin rhythm, light works in a dose-response fashion. Once threshold is exceeded, increasing irradiances of light elicit increasing acute plasma melatonin suppression or longer-term phase-shifts of the melatonin rhythm in healthy individuals.[16,18,27] All humans, however, are not equally sensitive to light; significant individual differences exist in sensitivity to light for both neuroendocrine and circadian regulation.[16,18] For a detailed description of the molecular and cellular basis for how photoreceptive input regulates circadian and neuroendocrine system function, see the Addendum.

HUMAN CONCERNS-DISABILITY AND DISCOMFORT GLARE

Glare from nighttime lighting can create hazards ranging from discomfort to frank visual disability. Disability glare has been fairly well-defined based on the physiology of the human eye and behavior of light as it enters the ocular media. Discomfort glare is less well-defined and more subjective as it is not based on a physical response per se but rather a psychological response. Accordingly, the respective bases of (and research into) these two responses are fundamentally different.

Disability Glare

Disability glare is unwanted and poorly directed light that temporarily blinds, causes poor vision by decreasing contrast, and creates an unsafe viewing condition, especially at night, by limiting the ability of the person to see. There are natural causes of disability glare, such as solar glare at sunset on a dirty windshield which can be lessened by cleaning the windshield. Unfortunately, nighttime glare while driving is not easily remedied. It is caused by the misapplication of luminaires that comprise the lighting design which are generally overly bright and unshielded, and/or sources of poorly directed light that enters the eye and scatters among ocular structures resulting in diminished contrast and impeded vision. Such effects dramatically worsen as the human eye ages, contributing to poor night vision and difficulty in driving at night for older drivers.

Disability glare is caused by light scatter from ocular media.[28] As light enters the eye, it collides with cornea, lens, and vitreous humor, scattering photons and casting a veil of light across the retina[29-31] (see Figure 1). The veil of light reduces the contrast of the object that the driver is trying to see, having the same effect as increasing the background luminance of the object. This veiling light is represented by the term veiling luminance. Veiling luminance is directly related to the illuminance of the light source and inversely related to the square of the angle of eccentricity of the light source with an age dependent multiplier across the entire equation.[28] This means that the disability from a light source is lessened the farther the source is from the line of sight.[α]

[α] As an example, high mast lighting systems where the roadway lighting is over 100 feet in the air have significantly less glare than traditional systems, which are typically located 30−50 feet in the air. Because of

Accordingly, proper design techniques and consideration for the glare caused by lighting systems need to be considered. One of the primary difficulties, especially for roadways, is that the lighting is not governed by a single jurisdiction. Roadway lighting may be designed properly and provide a low level of glare; however lighting can emanate from adjacent properties, spilling out into the roadway thus affecting the driver and overall performance and suitability of a lighting system. Control over all environmental sources of nighttime lighting is therefore critical for the overall control of disability glare.

Discomfort Glare

Discomfort glare is less well defined but emanates from a glare source that causes the observer to feel uncomfortable. The definition of discomfort is not precise, and some research has shown that a person's response to a glare source is based more on his/her emotional state than on the light source itself. Discomfort glare may be based primarily on the observer's light adaptation level, the size, number, luminance and location of the light sources in the scene.[32]

Both overhead roadway lighting and opposing headlamps are involved with discomfort glare in the driver. A numerical rating scale based on the dynamic nature of glare in simulations is available to measure the discomfort level experienced by drivers (Appendix).[33] The overall impact of discomfort glare on fatigue and driver safety remains an issue.

<u>Lighting and Glare</u>. Both discomfort and disability glare have specific impacts on the user in the nighttime environment. Research has shown that both of these glare effects occur simultaneously. Research also shows that the effects of the glare are cumulative, meaning that the glare from two light sources is the sum of the glare from the individual light sources. As a result, every light source within the field of view has an impact on the comfort and visual capability of the driver.

Overhead lighting

For overhead roadway lighting, design standards include a methodology for controlling the disability glare through a ratio of the eye adaptation luminance to the veiling luminance caused by the light source. As the veiling luminance is related to the illuminance the light source produces at the eye, a roadway luminaire that directs light horizontally has a much greater effect on the driver than a light source that cuts off the horizontal light. A trend towards flat glass luminaires, which provide a cut off of light at horizontal angles, provides a lower level of both disability and discomfort glare.

Decorative luminaires (e.g., acorn or drop lens) have a high level of horizontal light and typically are used in areas where pedestrians are the primary roadway users. The horizontal light in this situation is useful for facial recognition of a pedestrian, but it limits the driver's ability to perceive other objects in the roadway. As a result, many cities are designing and installing two lighting systems, one for the pedestrian and one for the roadway.

Luminaires employing solid state technologies and light-emitting diodes (LED) provide light from an array of small sources rather than a single large source. These designs either rely on each small source to provide a component of the light distribution, or the components of the lighting array provide individual luminating fields of the light distribution. In the first instance, the arrays are

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the inverse squared relationship, a high mast system reduces glare by 75% compared with a traditional system.

typically flat and have an optic to provide the light distribution; if a single LED fails, the others still provide the light distribution. In the second method, the components of the array are aimed to different areas of the beam distribution. This approach typically results in light aimed at the driver and pedestrians causing a higher glare impact. The other issue with the multiple sources used in LED luminaires is that each of the sources typically has a very high luminance itself as the source is very small and very bright; in the absence of sufficient diffusion, they cause significant glare. Accordingly, solid state lighting systems typically have a higher glare impact than traditional sources.

The final issue with glare from overhead lighting is the cyclic nature of the impact. As drivers course along a roadway, they pass from one luminaire to another. The glare experience increases as they approach the luminaire and then diminishes as they pass beyond. While typically not an issue for disability glare, this repetitive process can cause discomfort and fatigue.[34]

Opposing vehicle headlamps

Vehicle headlamps are aimed at the opposing driver eye level resulting in very high ocular illuminance and significant disability glare. The impact of opposing headlamps on the ability of the oncoming driver to observe beyond the headlamps is significant. For example, the visibility of a pedestrian standing behind a vehicle can be reduced by as much as 50%.[35]

In order to minimize the glare impact, headlamps are designed with lower left side light intensity than the right side. This reduces the glare to an opposing vehicle but does not eliminate it. New technologies such as turning headlamps and headlamps that hide part of the headlamp beam when a vehicle passes are possible solutions for this issue. With the advent of high intensity discharge Xenon headlamps and LED-based technologies, the glare issue has become more serious. While the intensity towards a driver is limited, the small but brighter source generates a much higher impression of glare than traditional technologies. These “blue” headlamp sources have a higher complaint rate for glare than for any other light source.

Effects of Lighting Design on Traffic Accidents

Adult, and especially elderly drivers, experience increased glare sensitivity, and elderly drivers may not be able to sufficiently fulfill the criteria for night driving ability because of contrast and glare sensitivity.[36] Prospective studies indicate that reduction in the useful field of view, visual field loss, and glare sensitivity increase crash risk in older drivers.[37,38] Crash risk begins to increase around age 50 years of age and continues to increase with aging.[39] No studies have explicitly compared traffic accident rates under different highway lighting conditions.

HEALTH EFFECTS OF DISRUPTED CIRCADIAN RHYTHMS

Epidemiological studies are a critical component of the evidence base required to assess whether or not light exposure at night affects disease risk, including cancer. These studies, however, are necessarily observational and can rarely provide mechanistic understanding of the associations observed. Carefully designed and controlled basic laboratory studies in experimental animal models have the potential to provide the empiric support for a causal nexus between light exposure at night and biological/health effects and to help establish plausible mechanisms. One area of considerable study on the possible effects of nighttime light exposure involves cancer.

CANCER

Light at Night, Melatonin and Circadian Influences on Carcinogenesis

Experimental Evidence. The majority of earlier studies in experimental models of either spontaneous or chemically-induced mammary carcinogenesis in mice and rats demonstrated an accelerated onset of mammary tumor development accompanied by increased tumor incidence and number in animals exposed to constant bright fluorescent light during the night as compared with control animals maintained on a strict 12 hours light/12 hours dark cycle.[40-51]

More recent work has focused on the ability of light at night to promote the growth progression and metabolism in human breast cancer xenografts. Nocturnal melatonin suppresses the growth of both estrogen receptor negative (ER-) and estrogen receptor positive (ER+) human breast cancer xenografts; the essential polyunsaturated fatty acid, linoleic acid is necessary for the growth of such (ER-) tumors, and its metabolism can be used as a biomarker of cellular growth.[52-55] Exposure of rats with such cancer xenografts to increasing intensities of white, fluorescent polychromatic light during the 12 hour dark phase of each daily cycle results in a dose-dependent suppression of peak nocturnal serum melatonin levels and a corresponding marked increase in tumor metabolism of linoleic acid and the rate of tumor growth. Exposure to even the very dimmest intensity of light during the night (0.2 lux) suppressed the nocturnal peak of circulating melatonin by 65% and was associated with marked stimulation in the rates of tumor growth and linoleic acid metabolic activity. In this model, measurable effects on xenograft growth and linoleic acid metabolism were apparent with 15% suppression in nocturnal melatonin levels.

The ability of light exposure at night to stimulate tumor growth (including dim exposures) has been replicated in rat hepatoma models.[54,56-58] The reverse also is true; gradually restoring circulating melatonin by reducing initial exposure to light at night (24.5 lux) is accompanied by a marked reduction in tumor growth and linoleic acid metabolic activity to baseline rates in the breast cancer and hepatoma models.[59]

The important role of melatonin as a nocturnal anticancer signal is further supported by the growth responses of human breast cancer xenografts perfused with human whole blood collected from young, healthy premenopausal female subjects exposed to complete darkness at night (e.g., high melatonin), compared with xenografts that were perfused with blood collected from the same subjects during the daytime (e.g., low melatonin).[54] The growth of xenografts perfused with blood collected during the dark was markedly reduced. Addition of a physiological nocturnal concentration of melatonin to blood collected from light-treated subjects restored the tumor inhibitory activity to a level comparable to that observed in the melatonin-rich blood collected at night during total darkness. Moreover, the addition of a melatonin receptor antagonist to the blood collected during darkness (i.e., high melatonin) eliminated the ability of the blood to inhibit the growth and metabolic activity of perfused tumors. Some evidence also exists that circadian disruption by chronic phase advancement (e.g., simulating jet lag) may increase cancer growth in laboratory animals.[60,61]

Potential Anticancer Mechanisms of Melatonin

The preponderance of experimental evidence supports the hypothesis that under the conditions of complete darkness, high circulating levels of melatonin during the night not only provide a potent circadian anticancer signal to established cancer cells but help protect normal cells from the initiation of the carcinogenic process in the first place.[62,63] It has been postulated that disruption in the phasing/timing of the central circadian pacemaker in the SCN, in general, and the suppression of circadian nocturnal production of melatonin, in particular, by light at night, may be an important biological explanation for the observed epidemiological associations of cancer risk and surrogates for nocturnal light exposure (such as night shift work, blindness, reported hours of sleep, etc.) (see below).[64]

Melatonin exerts several cellular effects that may be relevant in this regard. It exhibits antiproliferative and antioxidant properties, modulates both cellular and humoral responses, and regulates epigenetic responses.[65-67] Melatonin also may play a role in cancer cell apoptosis and in inhibiting tumor angiogenesis.[68,69]

Human Studies

While the experimental evidence from rodent cancer models links disruption of circadian rhythms and circulating melatonin concentrations (inversely) with progression of disease, the human evidence is indirect and based on epidemiological studies. Breast cancer has received the most study.

The hypothesis that the increasing use of electricity to light the night might be related to the high breast cancer risk in the industrialized world, and the increasing incidence and mortality in the developing world was first articulated in 1987.[70] Potential pathways include suppression of the normal nocturnal rise in circulating melatonin and circadian gene function.[54,71,72] Conceptually, this theory would predict that non-day shift work would raise risk, blind women would be at lower risk, reported sleep duration (as a surrogate for hours of dark) would be inversely associated with risk, and population nighttime light level would co-distribute with breast cancer incidence worldwide.[72,73] Only the first hypothesis has been systematically evaluated. Based on studies of non-day shift occupation and cancer (mostly breast cancer) published through 2007, the International Agency for Research on Cancer (IARC) concluded “shift-work that involves circadian disruption is *probably carcinogenic* to humans” (Recommendation Level 2A).[74] A detailed review of the individual studies supporting this conclusion is available.[75]

Since the IARC evaluation was conducted, several new studies of breast cancer and nighttime light have been published with mixed results.[76-79] Two found no significant association between shift work and risk of breast cancer.[76,77] A large case-control study of nurses in Norway[78] found a significantly elevated risk in subjects with a history of regularly working five or more consecutive nights between days off, and another found that as the type of shift (e.g., evening, night, rotating) became more disruptive, the risk increased.[79,80] In the Nurses Health Study cohort, increased urinary excretion of melatonin metabolites also was associated with a lower risk of breast cancer.[81] Each of these studies has strengths and limitations common to epidemiology, particularly in exposure assessment and appropriate comparison groups (e.g., no woman in the modern world is unexposed to light-at-night, but quantifying that exposure is difficult).

Although shiftwork represents the most extreme example of exposure to light at night and circadian disruption, perturbation of circadian rhythms and the melatonin signal is also experienced by non-shift workers with a normal sleep/wake-cycle.[12] Anyone exposing themselves to light after dusk or before dawn is overriding the natural light-dark exposure pattern as noted in the earlier discussion on measures of illumination.

After lights out for bedtime, it is not yet clear whether the ambient background light from weak sources in the bedroom or outside light coming through the window could influence the circadian system; a brief exposure at these levels may not have a detectable impact in a laboratory setting, although long-term chronic exposure might. Four case-control studies have now reported an association of some aspect of nighttime light level in the bedroom with breast cancer risk.[82-85] The elevated risk estimate was statistically significant in two of them.[83,85] As case-control designs, in addition to the limitation of recall error, there is also the potentially significant limitation of recall bias.

Despite the difficulty of gathering reliable information on bedroom light level at night, the possibility that even a very low luminance over a long period of time might have an impact is important. The lower limit of light intensity that could, over a long time period, affect the circadian system is not established. In the modern world few people sleep in total darkness. When eyelids are shut during sleep, only very bright light can penetrate to lower melatonin and only in some individuals.[86] Frequent awakenings with low level light exposure in the bedroom and certain nighttime activities (e.g., bathroom visits) may disrupt the circadian system, but any related health effects are unknown.[87]

Other Cancers

Light-at-night and circadian disruptions have been suggested to play a role in other cancers including endometrial, ovarian, prostate, colorectal, and non-Hodgkins lymphoma but evidence comparable to that obtained for breast cancer has not yet been developed.[88] On the other hand, engaging in night shift work may protect against skin cancer and cutaneous melanoma.[89]

Other Diseases

<u>Obesity, Diabetes, and Metabolic Syndrome.</u> The modern world has an epidemic of obesity and diabetes that may be influenced by lack of sleep, lack of dark, and/or circadian disruption.[90] Non-day shift workers have a higher incidence of diabetes and obesity.[91] Epidemiological studies also show associations of reported sleep duration and risk of obesity and diabetes.[92] Circadian disruption may be a common mechanism for these outcomes and potential links between the circadian rhythm and metabolism.[93-95]

<u>Other Disorders</u>. Although in the early stage of development, emerging evidence suggests that other chronic conditions also may be exacerbated by light at night exposure and ongoing disruption of circadian rhythms, including depression and mood disorders, gastrointestinal and digestive problems, and reproductive functions.[88]

DARK VERSUS SLEEP

The circadian rhythm and sleep are intimately related but not the same thing. Adequate daily sleep is required for maintenance of cognitive function and for a vast array of other capabilities that are only partially understood. Sleep is not required to synchronize the endogenous circadian rhythm, whereas a stable 24-hour light-dark cycle is required. The epidemiological and laboratory research on sleep and health cannot entirely separate effects of sleep duration from duration of exposure to dark, because the sleep-wake cycle partitions light-dark exposure to the SCN and pineal gland.[96] The distinction is important because a requirement for a daily and lengthy period of dark to maintain optimal circadian health has different implications than a requirement that one must be asleep during this entire period of dark; many individuals normally experience a wakeful episode in the middle of a dark night.[87]

Light during the night will disrupt circadian function as well as sleep, and the health consequences of short sleep and of chronic circadian disruption are being intensively investigated.[97] A growing number of observational and clinical studies on sleep and metabolism suggest short sleep periods have substantial harmful effects on health; however, it is not yet clear that sleep and dark have been entirely disentangled in these studies.[97,98] For example, in one study, sleep duration (verified by polysomnography) was associated with morning blood levels of leptin, a hormone that plays a key role in energy expenditure and appetite.[99] However, the duration of typical sleep reported by each subject was more strongly associated with leptin concentrations. Mean verified sleep was 6.2 hours, whereas mean reported sleep was 7.2 hours. Reported "sleep duration" probably reflects the time from when a person turns out their light for bed and falls asleep and when they get up in the morning (i.e., actual hours of dark exposure). An important question is to determine what portion of the health effects of dark disruption is due to sleep disruption and what portion is due directly to circadian impact of electric light intrusion on the dark of night.

Media use at night (i.e., televisions, computer monitors, cell phone screens) negatively affects the sleep patterns of children and adolescents and suppresses melatonin concentrations.[100-102] The American Academy of Pediatrics recommends removing televisions and computers from bedrooms to assist in limiting total "screen time" on a daily basis.[101] This action also may help in improving sleep patterns.

ENERGY COST

Electric lighting accounts for about 19% of electricity consumption worldwide and costs about $360 billion.[103] Much of the light that is produced is wasted, for example, by radiating light into space away from the task or environment intended to be illuminated. Estimates of how much is wasted vary; one estimate from the International Dark-Sky Association is 30% in the United States.[104] Such a percentage worldwide would account for an annual cost of about $100 billion.

ENVIRONMENTAL ISSUES

Although not directly under the purview of human health and disease, the following considerations are indirectly related to human well-being.

Esthetics

The Milky Way is no longer visible to the majority of people in the modern world. As societies have increasingly used electricity to light the night, it has become difficult to see more than a few of the innumerable stars from Earth's surface.[105] This has been carefully documented in a cover story by National Geographic Magazine in November 2008, which includes extensive visual documentation on its website.[106] Though the major impact of electric light at night is in major metropolitan areas, even the once pristine nights of the U.S. National Parks are beginning to be degraded, more rapidly in the East but also in parks in the West as well.[107]

Impact on Wildlife

Life on the planet has evolved to accommodate the 24-hour solar cycle of light and dark. Human imposition of light at night and disruption of the natural dark-light cycle represents a dramatic change to the environment.[108] Study of the effects of light at night on animal and plant life is in the early stages, but the entire spectrum of life, including animal, plant, insect, and aquatic species, may be affected.

About 30% of all vertebrate species and 60% of invertebrate species on Earth are nocturnal and depend on dark for foraging and mating.[108] Documented wildlife destruction by light at night has been evident in bird species, which fly into lit buildings at night in enormous numbers when migrating, and in the disruption of migration and breeding cycles in amphibians.[108-111] The most studied case in reptiles involves sea turtle hatchlings on the coast of Florida, which historically have scurried from their nest directly to the ocean. With increased development along the coast, and attendant increased electric lighting at night, these hatchlings become confused and often migrate away from shore to the lights. Hundreds of thousands of hatchlings are believed to have been lost as a result of this stray electric lighting at night in Florida.[109] Furthermore, many billions of insects are lost to electric light annually, which reduces food availability for other species in addition to unnecessarily reducing living biomass. It is concerning that light at night also may be vector attractant for diseases such as malaria.[112]

The circadian biology of plants is as robust as animals, and the impact of light at night on plant life may also be considerable due to the role of light in photosynthesis and the fact that many plants are pollinated at night.[113,114]

POLICY AND PUBLIC HEALTH IMPLICATIONS OF LIGHT AT NIGHT

Some responses to public health concerns associated with light-at-night exposures are readily apparent, such as developing and implementing technologies to reduce glare from vehicle headlamps and roadway lighting schemes, and developing lighting technologies at home and at work that minimize circadian disruption, while maintaining visual efficiency and aesthetics. Additionally, clinical studies support efforts to reduce child and adolescent night-time exposure from exogenous light derived from various media sources, especially in the bedroom environment. Recommendations to use dim lighting in residences at night raise issues for elderly patients. The American Geriatrics Society recommends ensuring well lit pathways within households to reduce the incidence of falls in elderly patients.[115]

Individuals who are subject to shift work experience disrupted circadian rhythms, fatigue, and cognitive dysfunction. Many industries, including hospitals, require a 24-hour workforce. The American College of Occupational and Environmental Medicine has established guidelines to address fatigue risk management in the workplace.[116] In healthcare workers, such as nurses who experience rapidly rotating shifts, brief morning light exposure improves subjective symptoms and performance.[117] The judicious use of bright light and/or melatonin supplements can improve adaptation to permanent, long-term night work.[118]

SUMMARY AND CONCLUSIONS

The natural 24-hour cycle of light and dark helps maintain precise alignment of circadian biological rhythms, the general activation of the central nervous system and various biological and cellular processes, and entrainment of melatonin release from the pineal gland. Pervasive use of nighttime lighting disrupts these endogenous processes and creates potentially harmful health effects and/or hazardous situations with varying degrees of harm. The latter includes the generation of glare from roadway, property, and other artificial lighting sources that can create unsafe driving conditions, especially for older drivers. Current AMA policy advocates that all future outdoor lighting be of energy efficient designs to reduce energy use and waste. Future streetlights should incorporate fully shielded or similar non-glare design to improve the safety of our roadways for all, but especially vision impaired and older drivers.

More direct health effects of nighttime lighting may be attributable to disruption of the sleep-wake cycle and suppression of melatonin release. Even low intensity nighttime light has the capability of suppressing melatonin release. In various laboratory models of cancer, melatonin serves as a circulating anticancer signal and suppresses tumor growth. Limited epidemiological studies support the hypothesis that nighttime lighting and/or repetitive disruption of circadian rhythms increases cancer risk; most attention in this arena has been devoted to breast cancer. The quality and duration of sleep and/or period of darkness affect many biological processes that are currently under investigation. Further information is required to evaluate the relative role of sleep versus the period of darkness in certain diseases or on mediators of certain chronic diseases or conditions including obesity. Due to the nearly ubiquitous exposure to light at inappropriate times relative to endogenous circadian rhythms, a need exists for further multidisciplinary research on occupational and environmental exposure to light-at-night, the risk of cancer, and exacerbation of chronic diseases.

RECOMMENDATIONS

The Council on Science and Public Health recommends that the following statements be adopted and the remainder of the report be filed:

That our American Medical Association:

1. Supports the need for developing and implementing technologies to reduce glare from vehicle headlamps and roadway lighting schemes, and developing lighting technologies at home and at work that minimize circadian disruption, while maintaining visual efficiency. (New HOD Policy)

2. Recognizes that exposure to excessive light at night, including extended use of various electronic media, can disrupt sleep or exacerbate sleep disorders, especially in children and adolescents. This effect can be minimized by using dim red lighting in the nighttime bedroom environment. (New HOD Policy)

3. Supports the need for further multidisciplinary research on the risks and benefits of occupational and environmental exposure to light-at-night. (New HOD Policy)

4. That work environments operating in a 24/7 hour fashion have an employee fatigue risk management plan in place. (New HOD Policy)

5. That Policy H-135.937 be reaffirmed. (Reaffirm HOD Policy)

Fiscal Note: Less than $500

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REFERENCES

1. Takahashi JS, Hong HK, Ko CH, McDearmon EL. The genetics of mammalian circadian order and disorder: implications for physiology and disease. *Nat Rev Genet*. 2008;9:764-775.

2. Lockley SW, Arendt J, Skene DJ. Visual impairment and circadian rhythm disorders. *Dialogues Clin Neurosci*. 2007;9:301-314.

3. Brainard GC, Hanifin JP, Greeson JM, et al. Action spectrum for melatonin regulation in humans: evidence for a novel circadian photoreceptor. *J Neurosci*. 2001;21:6405-6412.

4. Thapan, K, Arendt J, Skene DJ. An action spectrum for melatonin suppression: evidence for a novel non-rod, non-cone photoreceptor system in humans. *J.Physiol*. 2001;535:261-267.

5. Gooley JJ, Rajaratnam SM, Brainard GC, Kronauer RE, Czeisler CA, Lockley SW. Spectral responses of the human circadian system depend on the irradiance and duration of exposure to light. *Sci Transl Med*. 2010;2:31-33.

6. Cole RJ, Kripke DF, Wisbey J, et al. Seasonal variation in human illumination exposure at two different latitudes. *J Biol Rhythms*. 1995;10:324-334.

7. IESNA (Illuminating Engineering Society of North America). *Light and Human Health: An Overview of the Impact of Optical Radiation on Visual, Circadian, Neuroendocrine, and Neurobehavioral Responses*. IES TM-18-08, Illuminating Engineering Society of North America, New York, 2008.

8. Commission Internationale de l'Eclairage. *Ocular Lighting Effects on Human Physiology and Behaviour*. Commission Internationale de l'Eclairage, Technical Report #158, Vienna, 1-54, 2004.

9. Special Issue: Human circadian rhythms: regulation and impact. *J Biol Rhythms*. 2005;20:279-386.

10. Arendt J. *Melatonin and the Mammalian Pineal Gland.* Chapman and Hall, London 1995.

11. Uchiyama M, Lockley SW. Non-24-hour sleep–wake syndrome in sighted and blind patients. *Sleep Medicine Clinics of North America*. 2009;4: 195-211.

12. Gooley JJ, Chamberlain K, Smith KA, et al. Exposure to Room Light before Bedtime Suppresses Melatonin Onset and Shortens Melatonin Duration in Humans. *Endocrinology.* 2011;152:742.

13. Lewy AJ, Wehr TA, Goodwin FK, Newsome DA, Markey SP. Light suppresses melatonin secretion in humans. *Science.* 1980;210:1267-1269.

14. Lewy AJ, Sack RL, Miller LS, Hoban TM. Antidepressant and circadian phase-shifting effects of light. *Science*. 1987;235:352-354.

15. Czeisler CA, Allan JS, Strogatz SH, et al. Bright light resets the human circadian pacemaker independent of the timing of the sleep-wake cycle. *Science*. 1986;233:667-671.

16. Brainard GC, Lewy AJ, Menaker M, et al. Dose-response relationship between light irradiance and the suppression of melatonin in human volunteers. *Brain Research*. 1988;454:212-218.

17. Gaddy JR, Rollag MD, Brainard GC. Pupil size regulation of threshold of light-induced melatonin suppression. *Journal of Clinical Endocrinology and Metabolism*. 1993;77:1398-1401.

18. Zeitzer JM, Dijk D-J, Kronauer RE, Brown EN, Czeisler CA. Sensitivity of the human circadian pacemaker to nocturnal light: melatonin phase resetting and suppression. *J Physiology*. 2000;526:695-702.

19. Lockley SW, Brainard GC, Czeisler CA. High sensitivity of the human circadian melatonin rhythm to resetting by short wavelength light. *J Clin Endocrinol Metab*. 2003;88:4502-4505.

20. Lockley SW, Evans EE, Scheer FA, Brainard GC, Czeisler CA, and Aeschbach D. Short-wavelength sensitivity for the direct effects of light on alertness, vigilance, and the waking electroencephalogram in humans. *Sleep*. 2006;29:161-168.

21. Cajochen C, Munch M, Kobialka S, Krauchi K, et al. High sensitivity of human melatonin, alertness, thermoregulation, and heart rate to short wavelength light. *J Clin Endocrinol Metab*. 2005;90:1311-1316.

22. Brainard GC, Rollag MD, Hanifin JP. Photic regulation of melatonin in humans: ocular and neural signal transduction. *J Biological Rhythms*. 1997;12:537-546.

23. Hébert M, Martin SK, Lee C, Eastman CI. The effects of prior light history on the suppression of melatonin by light in humans. *J Pineal Res*. 2002;33:198-203.

24. Smith KA, Schoen MW, Czeisler CA. Adaptation of human pineal melatonin suppression by recent photic history. *JCEM*. 2004;89:3610-3614.

25. Chang AM, Scheer FA, Czeisler CA. The human circadian system adapts to prior photic history. *J Physiol*. 2011 Mar 1;589(Pt 5):1095-1102.

26. Jasser SA, Hanifin JP, Rollag MD, Brainard GC. Dim light adaptation attenuates acute melatonin suppression in humans. *J Biol Rhythms*. 2006;21:394-404.

27. McIntyre IM, Norman TR, Burrows GD, Armstrong SM. Human melatonin suppression by light is intensity dependent. *J Pineal Res*. 1989;6:149-156.

28. Holladay SA. Light scatter in ocular media. *Am J Opthalmol* 1927;4:122-129.

29. Vos JJ, Bouman MA. Contribution of the retina to entropic scatter. *J Opt Soc Am.* 1964;54:95-100.

30. Boyton RM, Clark JJ. Sources for entropic scatter in the human eye. *J Opt Soc Am*. 1962; 54:1326.

31. Adrian W, Bhanji A. Fundamentals of disability glare: A formula to describe straylight in the eye as a function of glare angle and age. In W. Adrian (Ed.), *Proceedings of the First International Symposium on Glare*. New York: Lighting Research Institute. 1992;185-193.

32. Van Bommel WJM, JB deBoer. *Road Lighting.* Kluwer Technische Boeken. B.V. Philips Technical Library, Antwerpen, 1980.

33. deBoer J B, Schreuder DA. Glare as a criterion for quality in street lighting. *Trans Illumin Engineer Soc.* 1967;32:117-135.

34. Bennett DW. Repetitive lighting and ocular fatigue. *Opthalmic Res.* 1995;27:34-41.

35. Gibbons RB, Hankey JM. Influence of vertical illuminance on pedestrian visibility in crosswalks. *Trans Res Record.* 2006;No. 1973.

36. Bbizhayev MA. Glare disability and driving safety. *Opthalmic Res.* 2003;35:19-25

37. Owsley C, Ball KB, McGwin G, et al. Visual processing impairment and risk of motor vehicle crash among older adults. *JAMA.* 1998;279:1083-1088.

38. Rubin GS, Ng ES, Bandeen-Roche K, et al. A prospective, population-based study of the role of visual impairment in motor vehicle crashes among older drivers: The SEE study. *Invest Opthalmol Visual Sci.* 2007;48:1483-1491.

39. Straus H, Gu X. The roads ahead: collision risks, trends, and safety of drivers. *Risk Analysis.* 2009;29:900-911.

40. Jöchle W. Trends in photophysiologic concepts. *Ann N Y Acad Sci.* 1964;117: 88-104.

41. Khaetski IK. Effect of hypothalamo-pituitary lesions induced by constant illumination on development of induced mammary tumors in rats. *Vopr Exp Oncol (Kiev)*. 1965;1:87-93.

42. Hamilton T. Influence of environmental light and melatonin upon mammary tumour induction. *Br J Surg.* 1969;56:764-766.

43. Aubert C, Janiaud P, Lecalvez J. Effect of pinealectomy and melatonin on mammary tumor growth in Sprague-Dawley rats under different conditions of lighting. *J Neural Transm.* 1980;47:121-130.

44. Kothari LS, Shah PN, Mhatre MC. Effect of continuous light on the incidence of 9,10-dimethyl-1,2-benzanthracene induced mammary tumors in female Holtzman rats. *Cancer Lett.* 1982;16:313-317.

45. Kothari LS, Shah PN, Mhatre MC. Pineal ablation in varying photoperiods and the incidence of 9,10-dimethyl-1,2-benzanthracene induced mammary cancer in rats. *Cancer Lett.* 1984;22:99-102.

46. Mhatre MC, Shah PN, Juneja HS. Effect of varying photoperiods on mammary morphology, DNA synthesis, and hormone profile in female rats. *J Natl Cancer Inst.* 1984;72:1411-1416.

47. Shah PN, Mhatre MC, Kothari LS. Effect of melatonin on mammary carcinogenesis in intact and pinealectomized rats in varying photoperiods. *Cancer Res.* 1984;44:3403-3407.

48. Van den Heiligenberg S, Deprés-Brummer P, Barbason H, et al. The tumor promoting effect of constant light exposure on diethylnitrosamine-induced hepatocarcinogenesis in rats. *Life Sci*. 1999;64:2523-2534.

49. Travlos GS, Wilson RE, Murrell JA, et al. The effect of short intermittent light exposures on the melatonin circadian rhythm and NMU-induced breast cancer in female F344/N rats. *Toxicol Pathol* . 2001;29: 126-136.

50. Beniashvili DS, Benjamin S, Baturin DA, et al. Effect of light/dark regimen on N-nitrosoethylurea-induced transplacental carcinogenesis in rats. *Cancer Lett.* 2001;163:51-57

51. Anisimov VN, Baturin DA, Popovich IG, et al. Effect of exposure to light-at-night on life span and spontaneous carcinogenesis in female CBA mice. *Int J Cancer*. 2004;111:475-479.

52. Blask DE, Sauer LA, Dauchy RT, et al. Melatonin inhibition of cancer growth in vivo involves suppression of tumor fatty acid metabolism via melatonin receptor-mediated signal transduction events. *Cancer Res.* 1999;59:4693-4701.

53. Blask DE, Dauchy RT, Sauer LA, et al. Growth and fatty acid metabolism of human breast cancer (MCF-7) xenografts in nude rats: impact of constant light-induced nocturnal melatonin suppression. *Breast Cancer Res Treat* . 2003;79:313-320.

54. Blask DE, Brainard GC, Dauchy RT, et al. Melatonin-depleted blood from premenopausal women exposed to light at night stimulates growth of human breast cancer xenografts in nude rats. *Cancer Res*. 2005;65:11174-11184.

55. Wu J, Dauchy RT, Tirrell PC, et al. Light at night activates IGF-1R/PDK1 signaling and accelerates tumor growth in human breast cancer xenografts. *Cancer Res*. 2011;71:2622-2631.

56. Dauchy RT, Sauer LA, Blask DE, et al. Light contamination during the dark phase in "photoperiodically controlled" animal rooms: effect on tumor growth and metabolism in rats. *Lab Anim Sci.* 1997;47:511-518.

57. Dauchy RT, Blask DE, Sauer LA, Brainard GC, Krause, JA. Dim light during darkness stimulates tumor progression by enhancing tumor fatty acid uptake. *Cancer Lett*. 1999;144:131-136.

58. Cos S, Mediavilla D, Martinez-Campa C, et al. Exposure to light-at-night increases the growth of DMBA-induced mammary adenocarcinomas in rats. *Cancer Lett*. 2006;235:266-271.

59. Dauchy RT, Dupepe LM, Ooms TG, et al. Eliminating animal facility light-at-night contamination and its effect on circadian regulation of rodent physiology, tumor growth and metabolism: a challenge in the relocation of a cancer research laboratory. *J Am Assoc Lab Anim Sci*. 2011;50:326-336.

60. Filipski E, Delaunay F, King VM, et al. Effects of chronic jet lag on tumor progression in mice. *Cancer Res.* 2004;64:7879-7885.

61. Filipski E, Innominato PF, Wu M, et al. Effects of light and food schedules on liver and tumor molecular clocks in mice. *J Natl Cancer Inst.* 2005;97:507-517.

62. Blask DE. Melatonin, sleep disturbance and cancer risk. *Sleep Med Rev*. 2009;13:257-264.

63. Blask DE, Hill SM, Dauchy RT, et al. Circadian regulation of molecular, dietary, and metabolic signaling mechanisms of human breast cancer growth by the nocturnal melatonin signal and the consequences of its disruption by light at night. *J Pineal Res*. 2011;51:259-269.

64. Stevens RG, Blask DE, Brainard GC, et al. Meeting Report: The role of environmental lighting and circadian disruption in cancer and other diseases. *Environ Health Perspec*. 2007;115:1357-1362.

65. Brzezinski A. Melatonin in humans. *N Engl J Med* 1997; 336:186-95.

66. Korkmaz A, Topal T, Tan DX, Reiter RJ. Role of melatonin in metabolic regulation. *Rev Endocr Metab Disord.* 2009;10:261-70.

67. Reiter RJ, Tan DX, Fuentes-Broto L. Melatonin: a multitasking molecule. *Prog Brain Res.* 2010;181:127-51.

68. Sainz RM, Mayo JC, Rodriguez C, et al. Melatonin and cell death: differential actions on apoptosis in normal and cancer cells. *Cell Mol Life Sci*. 2003;60:1407-1426.

69. Lissoni P, Rovelli F, Malugani F, Bucovec R, Conti A, Maestroni GJ. Antiangiogenic activity of melatonin in advanced cancer patients. *Neuro Endocrinol Lett*. 2001;22:45-47.

70. Stevens, RG. Review and Commentary: Electric power use and breast cancer: a hypothesis. *Am J Epidemiol.* 1987;125:556-561.

71. Hoffman AE, Yi CH, Zheng T, et al. CLOCK in breast tumorigenesis: genetic, epigenetic, and transcriptional profiling analyses. *Cancer Res.* 2010;70:1459-1468.

72. Stevens RG. Light at night, circadian disruption, and breast cancer: assessment of existing evidence. *Int J Epidemiol*. 2009;38:963-970.

73. Kloog I, Stevens RG, Haim A, Portnov BA. Nighttime light level co-distributes with breast cancer incidence worldwide. *Cancer Causes Control.* 2010;21:2059-2068.

74. Straif K, Baan R, Grosse Y, et al. Carcinogenicity of shift-work, painting, and fire-fighting. *Lancet Oncol*. 2007;8:1065-1066.

75. *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans*. Painting, Firefighting, and Shiftwork. Volume 98, 2010. http://monographs.iarc.fr/ENG/Monographs/vol98/index.php

76. Pronk A, Ji BT, Shu XO, et al. Night-shift work and breast cancer risk in a cohort of Chinese women. *Am J Epidemiol.* 2010;171:953-959.

77. Pesch B, Harth V, Rabstein S, et al. Night work and breast cancer - results from the German GENICA study. *Scand J Work Environ Health*. 2010;36:134-141.

78. Lie JAS, Kjuus H, Haugen A, Zienolddiny S, Stevens RG, Kjærheim K. Night work and breast cancer risk among Norwegian nurses: Assessment by different exposure metrics. *Am J Epidemiol*. 2011;173:1272-1279.

79. Hansen J, Stevens RG. Case–control study of shift-work and breast cancer risk in Danish nurses: Impact of shift systems. *Eur J Cancer*. 2011. Aug 16. [Epub ahead of print]

80. Stevens RG, Hansen J, Costa G, et al. Considerations of circadian impact for defining 'shift work' in cancer studies: IARC Working Group Report. *Occup Environ Med*. 2011;68:154-162.

81. Schernhammer ES, Hankinson SE. Urinary melatonin levels and postmenopausal breast cancer risk in the nurses' health study cohort. *Cancer Epidemiol Biomarkers Prev*. 2009;18:74-79.

82. Davis S, Mirick DK, Stevens RG. Night shift work, light at night, and risk of breast cancer. *J Natl Cancer Inst*. 2001;93:1557-1562.

83. O'Leary ES, Schoenfeld ER, Stevens RG, et al. Electromagnetic Fields and Breast Cancer on Long Island Study Group. Shift work, light at night, and breast cancer on Long Island, New York. *Am J Epidemiol*. 2006;164:358-366.

84. Li Q, Zheng T, Holford TR, Boyle P, Zhang Y, Dai M. Light at night and breast cancer: results from a population-based case-control study in Connecticut, USA. *Cancer Causes Control*. 2010;21:2281-2285.

85. Kloog I, Portnov BA, Rennert HS, Haim A. Does the modern urbanized sleeping habitat pose a breast cancer risk? *Chronobiol Int*. 2011;28:76-80.

86. Hatonen T, Alila-Johansson A, Mustanoja S, Laakso ML. Suppression of melatonin by 2000-lux light in humans with closed eyelids. *Biol Psychiatry*. 1999;46:827-831.

87. Wehr TA. In short photoperiods, human sleep is biphasic. *J Sleep Res*. 1992;1:103-107.

88. European Union. Scientific Committee on Emerging and Newly Identified Health Risks. *Health Effects of Artificial Light*. http://ec.europa.eu/health/scientific_committees/emerging/docs/scenihr_o_033.pdf. Accessed March 4, 2012.

89. Schernhammer ES, Razavi P, Li TY, Qureshi AA, Han J. Rotating night shifts and risk of skin cancer in the nurses health study. *J Natl Cancer Inst*. 2011;103:602-606.

90. Cappuccio FP, Miller MA, Lockley SW, Eds. *Sleep, health and society: From Aetiology to Public Health*, Oxford, UK: Oxford University Press; 2010.

91. Pietroiusti A, Neri A, Somma G, et al. Incidence of metabolic syndrome among night-shift healthcare workers. *Occup Environ Med.* 2010;67:54-57.

92. Gangwisch JE. Epidemiological evidence for the links between sleep, circadian rhythms and metabolism. *Obes Rev.* 2009;10 Suppl 2:37-45.

93. Bass J, Takahashi JS. Circadian integration of metabolism and energetics. *Science*. 2010;330:1349-1354.

94. Schibler U. The daily timing of gene expression and physiology in mammals. *Dialogues Clin Neurosci.* 2007;9:257-272.

95. Bellet MM, Sassone-Corsi P. Mammalian circadian clock and metabolism - the epigenetic link. *J Cell Sci.* 2010;123(Pt 22):3837-3848.

96. Djjk D-J, Lockley SW. Integrations of human sleep-wake regulation and circadian rhythmicity. *Journal of Applied Physiology*. 2002;92(Pt 2):852-862.

97. Van Cauter E, Spiegel K, Tasali E, Leproult R. Metabolic consequences of sleep and sleep loss. *Sleep Med.* 2008;9 Suppl 1:S23-28.

98. Spiegel K, Tasali E, Leproult R, Van Cauter E. Effects of poor and short sleep on glucose metabolism and obesity risk. *Nat Rev Endocrinol.* 2009;5:253-261.

99. Taheri S, Lin L, Austin D, Young T, Mignot E. Short sleep duration is associated with reduced leptin, elevated ghrelin, and increased body mass index. *PLoS Med.* 2004:1(3):e62.

100. Garrison MM, Leikweg K, Christakis DA. Media use and child sleep: the impact of content, timing, and environment. *Pediatrics*. 2011;128:29-35.

101. Owens J, Maxim R, McGuinn M, Nobile C, Msall M, Alario A. Television-viewing habits and sleep disturbances in school children. *Pediatrics.* 1999;104;e27

102. Higuchi S, Motohashi Y, Liu Y, Ahara M, Kaneko Y. Effects of VDT tasks with a bright display at night on melatonin, core temperature, heart rate, and sleepiness. *J Appl Physiol.* 2003;94:1773-1776.

103. Organization for Economic Co-operation and Development (OECD)/International Energy Agency (IEA). Light's labour's lost policies for energy-efficient lighting. *OECD/IEA.* Paris, France, 2006.

104. International Dark-Sky Association (IDA). *Economic Issues in Wasted and Inefficient Outdoor Lighting*. Information Sheet #26.

105. Cinzano P, Falchi F, Elvidge CD. The first world atlas of the artificial night sky brightness. *Monthly Notices of the Royal Astronomical Society*. 2001;328:689-707.

106. Klinkenborg V, Richardson J. Our Vanishing Night. *National Geographic,*. November, 2008. (http://ngm.nationalgeographic.com/geopedia/Light_Pollution)

107. Albers A, Duriscoe D. Modeling light pollution from population data and implications for national park service lands. *The George Wright Forum*. 2001;18:56-68.

108. Hölker F, Moss T, Griefahn B, et al. The dark side of light: A transdisciplinary research agenda for light pollution policy. *Ecology and Society* 2010;15(4): article 13.

109. International Dark-Sky Association (IDA). Effects of artificial light at night on wildlife. *Practical Guide 2*. 2008.

110. Longcore T, Rich C. Ecological light pollution. *Frontiers Ecology Environ.* 2004;2:191-198.

111. Rich and Longcore 2006

112. Barghini A, de Medeiros BA. Artificial Lighting as a Vector Attractant and Cause of Disease Diffusion. *Environ Health Perspect*. 2010;118:1503-1506.

113. McClung, CR. Plant Circadian Rhythms. *Plant Cell.* 2006;18:792–803.

114. Sedbrook J. *The Night Shift*. 2010. http://www.coopext.colostate.edu/4dmg/Flowers/night.htm

115. Panel on Prevention of Falls in Older Persons, American Geriatrics Society and British Geriatrics Society. Summary of the Updated American Geriatrics Society/British Geriatrics Society Clinical Practice Guideline for Prevention of Falls in Older Persons. *J Am Ger Soc.* 2010.

116. American College of Occupational and Environmental Medicine. Guidance Statement. Fatigue risk management in the workplace. *JOEM.* 2012; 54:231-258.

117. Tanaka K, Takahashi M, Tanaka M, et al. Brief morning exposure to bright light improves subjective symptoms and performance in nurses with rapidly rotating shifts. *J Occup Health.* 2011;53:258-266.

118. Palleson S, Bjorvatn B, Mageroy N, Saksvik IB, Waage S, Moen BE. Measures to counteract the negative effects of night work. *Scand J Work Environ Health.* 2010;36:109-121.

119. Brainard GC, Hanifin JP, Rollag MD, et al. Human melatonin regulation is not mediated by the three cone photopic visual system. *J Clin Endocrinol Metab*. 2001;86:433-436.

120. Brainard GC, Hanifin JP. Photons, clocks and consciousness. *J Biol Rhythms.* 2005;20: 314-325.

121. Gamlin PDR, McDougal DH, Pokorny J, et al. Human and macaque pupil responses driven by melanopsin-containing retinal ganglion cells. *Vision Res.* 2007;47:946-954.

122. Zaidi FH, Hull JT, Peirson SN, et al. Short-wavelength light sensitivity of circadian, pupillary, and visual awareness in humans lacking an outer retina. *Curr Biol.* 2007;17:2122-2128.

123. Warman VL, Dijk DJ, Warman GR, Arendt J, Skene DJ. Phase advancing human circadian rhythms with short wavelength light. *Neurosci Lett.* 2003;342:37-40.

124. Cajochen C, Jud C, Munch M, Kobialka S, Wirz-Justice A, Albrecht U. Evening exposure to blue light stimulates the expression of the clock gene PER2 in humans. *Eur J Neurosci*. 2006;23:1082-1086.

125. Revell VL, Arendt J, Terman M, Skene DJ. Short-wavelength sensitivity of the human circadian system to phase-advancing light. *J Biol Rhythms*. 2005;20:270-272.

126. Revell VL, Arendt J, Fogg LF, Skene DJ. Alerting effects of light are sensitive to very short wavelengths. *Neurosci Lett*. 2006;399:96-100.

127. Provencio I, Rodriguez IR, Jiang G, Hayes WP, Moreira EF, Rollag MD. A novel human opsin in the inner retina. *J Neurosci*. 2000;20:600-605.

128. Berson DM, Dunn FA, Takao M. Phototransduction by retinal ganglion cells that set the circadian clock. *Science*. 2002;295:1070-1073.

129. Hattar S, Liao H-W, Takao M, Berson DM, Yau K-W. Melanopsin-containing retinal ganglion cells: Architecture, projections, and intrinsic photosensitivity. *Science*. 2002;295:1065-1070.

130. Gooley JJ, Lu J, Chou TC, Scammell TE, Saper CB. Melanopsin in cell of origin of the retinohypothalamic tract. *Nature Neurosci*. 2001;4:1165.

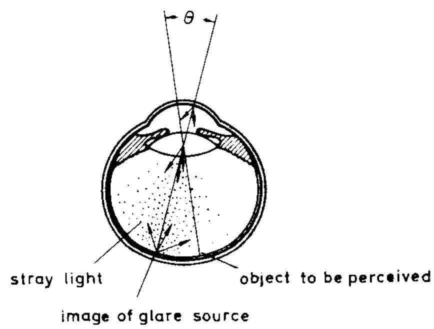
131. Hattar S, Kumar M, Park A, et al. Central projections of melanopsin-expressing retinal ganglion cells in the mouse. *J Comparative Neurology*. 2006;497:326-349.

132. Altimus CM, Guler AD, Alam NM, et al. Rod photoreceptors drive circadian photoentrainment across a wide range of light intensities. *Nature Neuroscience*. 2010;13:1107-1113.

133. Lall GS, Revell VL, Momiji H, et al. Distinct contributions of rod, cone, and melanopsin photoreceptors to encoding irradiance. *Neuron*. 2010;66:417–428

134. Dacey DM, Liao H-W, Peterson BB, et al. Melanopsin expressing ganglion cells in primate retina signal colour and irradiance and project to the LGN. *Nature*. 2005;433:749-754.

Figure 1. Stray light in the ocular media



Appendix

DeBoer Scale

DeBoer Numerical Rating	Glare Intensity
1	Unbearable
3	Disturbing
5	Just Admissible
7	Satisfactory
9	Unnoticeable

Addendum

Molecular and Cellular Basis for Photoreceptive Regulation of Circadian and Neuroendocrine System Function

In the past decade, there has been an upheaval in the understanding of photoreceptive input to the human circadian and neuroendocrine systems. A study on healthy human subjects confirmed that the three-cone system that mediates human vision during the daytime is not the primary photoreceptor system that transduces light stimuli for acute melatonin suppression.[119] That discovery was rapidly followed by the elucidation of two action spectra in healthy human subjects that identified 446-477 nm as the most potent wavelength region for melatonin suppression.[3,4] To date, ten published action spectra have examined neuroendocrine, circadian, and neurobehavioral responses in humans, monkeys, and rodents. The action spectra demonstrate peak sensitivities in the blue region of the visible spectrum, with calculated peak photosensitivities ranging from 459 nm to 484 nm.[120-122] Further, a set of studies has confirmed that shorter wavelength, monochromatic light is more potent than equal photon densities of longer wavelength light for evoking circadian phase shifts, suppressing melatonin, enhancing subjective and objective correlates of alertness, increasing heart rate, increasing body temperature, and inducing expression of the circadian clock gene Per2 in humans.[19,20,123-126]

Studies using both animal and human models are clarifying the neuroanatomy and neurophysiology of the photosensory system that provides input for circadian, neuroendocrine, and neurobehavioral regulation. A recently discovered photopigment, named melanopsin, has been localized both in the retinas of rodents and humans.[127] More specifically, melanopsin is found in a subtype of intrinsically photoreceptive retinal ganglion cells (ipRGCs).[128,129] These light sensitive ganglion cells project to nuclei and regions of the central nervous system that mediate the biological and behavioral effects of light.[130,131] Although ipRGCs provide the strongest input for regulation of biology and behavior, studies on genetically manipulated rodents, normal monkeys, and humans demonstrate that the visual rod and cone photoreceptors integrate into this physiology.[5,132-134] Continued advances in understanding the physiology of this phototransduction will undoubtedly yield further insights into potential health impacts of electric lighting.

Journal

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Original Articles

Outdoor artificial light at night, obesity, and sleep health: Cross-sectional analysis in the KoGES study

Yong Seo Koo, Jin-Young Song, Eun-Yeon Joo, Heon-Jeong Lee, Eunil Lee, Sang-kun Lee & ...show all

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ABSTRACT

Obesity is a common disorder with many complications. Although chronodisruption plays a role in obesity, few epidemiological studies have investigated the association between artificial light at night (ALAN) and obesity. Since sleep health is related to both obesity and ALAN, we investigated the association between outdoor ALAN and obesity after adjusting for sleep health. We also investigated the association between outdoor ALAN and sleep health. This cross-sectional survey included 8526 adults, 39–70 years of age, who participated in the Korean Genome and Epidemiology Study. Outdoor ALAN data were obtained from satellite images provided by the US Defense level, type of residential building, monthly household income, alcohol consumption, smoking status and consumption of caffeine or alcohol before sleep. A logistic regression model was used to investigate the association between outdoor ALAN and obesity. The prevalence of obesity differed significantly according to sex (women 47% versus men 39%, $p < 0.001$) and outdoor ALAN (high 55% versus low 40%, $p < 0.001$). Univariate logistic regression analysis revealed a significant association between high outdoor ALAN and obesity (odds ratio [OR] 1.24, 95% confidence interval [CI] 1.14–1.35, $p < 0.001$). Furthermore, multivariate logistic regression analyses showed that high outdoor ALAN was significantly associated with obesity after adjusting for age and sex (OR 1.25, 95% CI 1.14–1.37, $p < 0.001$) and even after controlling for various other confounding factors including age, sex, educational level, type of residential building, monthly household income, alcohol consumption, smoking, consumption of caffeine or alcohol before sleep, delayed sleep pattern, short sleep duration and habitual snoring (OR 1.20, 95% CI 1.06–1.36, $p = 0.003$). The findings of our study provide epidemiological evidence that outdoor ALAN is significantly related to obesity.

KEYWORDS: Artificial light at night, chronotype, insomnia, obesity, sleep duration, sleep health, snoring

Additional information

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Declaration of interest

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Published online: 16 Sep 2015

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ENVIRONMENT

The Dark Side of LED Lightbulbs

September 15, 2012

Credit: Getty Images

Dear EarthTalk: Are there health or environmental concerns with LED lightbulbs, which may soon replace compact fluorescents as the green-friendly light bulb of choice?—*Mari-Louise, via e-mail*

Indeed, LED (light emitting diode) lighting does seem to be the wave of the future right now, given the mercury content and light quality issues with the current king-of-the-hill of green bulbs, the compact fluorescent (CFL). LEDs use significantly less energy than even CFLs, and do not contain mercury. And they are becoming economically competitive with CFLs at the point of purchase while yielding superior quality lighting and energy bill savings down the line.

But LEDs do have a dark side. A study published in late 2010 in the journal *Environmental Science and Technology* found that LEDs contain lead, arsenic and a dozen other potentially dangerous substances. LEDs are touted as the next generation of lighting," says Oladele Ogunseitan, one of the researchers behind the study and chair of the University of California (UC)-Irvine's Department of Population Health & Disease Prevention. "But as we try to find better products that do not deplete energy resources or contribute to global warming, we have to be vigilant [about] toxicity hazards...."

Ogunseitan and other UC-Irvine researchers tested several types of LEDs, including those used as Christmas lights, traffic lights, car headlights and brake lights. What did they find? Some of the worst offenders were low-intensity red LEDs, which were found to contain up to eight times the amount of lead, a known neurotoxin, allowed by California state law and which, according to researchers, “exhibit significant cancer and noncancer potentials due to the high content of arsenic and lead.” Meanwhile, white LEDs contain the least lead, but still harbor large amounts of nickel, another heavy metal that causes allergic reactions in as many as one in five of us upon exposure. And the copper found in some LEDs can pose an environmental threat if it accumulates in rivers and lakes where it can poison aquatic life.

Lightbulb Frenzy in the 21st Century

Read more from this special report:

Lightbulb Frenzy in the 21st Century

Ogunseitan adds that while breaking open a single LED and breathing in its fumes wouldn’t likely cause cancer, our bodies hardly need more toxic substances floating around, as the combined effects could be a disease trigger. If any LEDs break at home, Ogunseitan recommends sweeping them up while wearing gloves and a mask, and disposing of the debris — and even the broom — as hazardous waste. Furthermore, crews dispatched to clean up car crashes or broken traffic lights (LEDs are used extensively for automotive and traffic lighting) should wear protective clothing and handle material as hazardous waste. LEDs are currently not considered toxic by law and can be disposed of in regular landfills.

According to Ogunseitan, LED makers could easily reduce the concentrations of heavy metals in their products or even redesign them with truly safer materials, especially if state or federal regulators required them to do so. “Every day we don’t have a law that says you cannot replace an unsafe product with another unsafe product, we’re putting people’s lives at risk,” he concludes. “And it’s a preventable risk.”

Of course, we all need some kind of lighting in our lives and, despite their flaws, LEDs may still be the best choice regarding light quality, energy use and environmental footprint. That said, researchers are busy at work on even newer lighting technologies that could render even today’s green choices obsolete.

CONTACT: UC-Irvine study, www.pubs.acs.org/doi/abs/10.1021/es101052q?

prevSearch=irvine%2Bled.

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LEDs: ANSES’s recommendations for limiting exposure to blue light

News of 14/05/2019

Now that the use of LEDs for lighting has become widespread and the number of LED objects has proliferated, ANSES is publishing an update of its 2010 expert appraisal on the health effects of LEDs in light of new scientific knowledge. The Agency confirms the toxicity of blue light on the retina and highlights the biological rhythm and sleep disruption associated with exposure to blue light in the evening or at night, particularly via screens and especially for children. The Agency therefore recommends limiting the use of LED devices with the highest blue-light content, especially for children, and reducing light pollution as much as possible to preserve the environment.

Against a backdrop of energy-saving policies and the phasing-out of traditional lamps (incandescent and halogen lamps), LEDs have seen strong growth due to their energy-efficient performance. In a few decades, therefore, the population's exposure to blue light has increased sharply, especially in the evening with artificial lighting or screens rich in blue light. This is due to the unique technological characteristics of LEDs, which enable them to emit more short-wavelength light, known as "blue-rich". This lighting is more intense than other light sources, and can have effects on human health and the environment.

When this technology was initially deployed, ANSES's first expert appraisal underlined the retinal toxicity of the blue light contained in LED lighting systems and recommended adapting the regulatory and normative framework. As a result, for domestic lighting, only LED lamps in risk groups 0 or 1 (in accordance with the NF-EN-62471 standard on photobiological safety) are currently accessible to the general public. The most at-risk lighting systems (groups 2 and 3) are reserved for professional use under conditions that guarantee worker safety.

Today, ANSES is publishing a new expert appraisal covering all LED systems and taking into account all the scientific data acquired since 2010.

Demonstration of new effects associated with the blue light of LEDs

The new scientific data confirm the 2010 result regarding the toxicity of blue light to the eye, which can lead to failing eyesight. They show short-term phototoxic effects associated with acute exposure and long-term effects associated with chronic exposure, which increase the risk of developing age-related macular degeneration (ARMD). "Warm white" domestic LED lighting is no different from traditional lighting and has a low risk of phototoxicity. On the other hand, other types of LED lighting systems, such as hand-held lamps, vehicle lights, decorations or toys, may emit particularly blue-rich light and belong to risk group 2, and yet they are not covered by the current regulations.

In addition, the expert appraisal showed that even very low levels of exposure to blue light in the evening or at night disrupt biological rhythms and therefore sleep. ANSES stresses that the screens of computers, smartphones and tablets are major sources of blue-rich light, and children and adolescents, whose eyes do not fully filter blue light, are a particularly susceptible population.

The expert appraisal also showed that a high proportion of LED lamps have significant variations in light intensity. Some groups of people, such as children, adolescents and workers, may be more susceptible to the potential effects of this light modulation: headaches, visual fatigue, risk of accidents, etc.

Adapt the regulations and improve the information provided to the public about the risks associated with exposure to blue light

In view of the results of its expert appraisal, ANSES is making a series of recommendations to limit the population's exposure to blue light. The Agency reiterates the importance of favouring "warm white" domestic lighting (colour temperature below 3000 K). To prevent the disruptive effect on biological rhythms, it recommends limiting the exposure of people – children in particular – to the blue-rich light of LED screens (mobile phones, tablets, computers, etc.) before bedtime and at night.

In addition, ANSES recommends adapting the regulatory framework for all LED systems, particularly in order to:

- restrict the sale of LED objects to the general public to those in photobiological risk group 0 or 1;
- limit the light intensity of vehicle lights, while guaranteeing road safety;
- minimise the temporal modulation of the light emitted by all light sources (lighting, screens, other LED objects).

Moreover, with regard to the protective devices available to the general public, such as treated lenses, protective glasses or specific screens, the Agency stresses that their effectiveness against the effects of blue light on the retina varies widely. Moreover, their effectiveness at preserving circadian rhythms has not yet been proven. ANSES encourages the establishment of standards defining performance criteria for protective equipment in relation to blue light.

An impact on biodiversity and the environment

Concerning the environment, the available studies mainly focus on artificial light at night in general and not specifically on LEDs. Regardless of the studied ecosystem, scientific knowledge consistently shows an increase in mortality and a decline in the diversity of the animal and plant species studied in environments lit at night, including by LED lighting systems. The Agency recommends strengthening regulations to limit light pollution, while ensuring public safety.

FOR MORE INFORMATION

ANSES OPINION on the “effects on human health and the environment (fauna and flora) of systems using light-emitting diodes (LEDs)”

Press kit

The Director General

Maisons-Alfort, 5 April 2019

OPINION
of the French Agency for Food, Environmental and Occupational Health & Safety

on the "effects on human health and the environment (fauna and flora) of systems using light-emitting diodes (LEDs)"

ANSES undertakes independent and pluralistic scientific expert assessments.

ANSES primarily ensures environmental, occupational and food safety as well as assessing the potential health risks they may entail.

It also contributes to the protection of the health and welfare of animals, the protection of plant health and the evaluation of the nutritional characteristics of food.

It provides the competent authorities with all necessary information concerning these risks as well as the requisite expertise and scientific and technical support for drafting legislative and statutory provisions and implementing risk management strategies (Article L.1313-1 of the French Public Health Code).

Its opinions are published on its website. This opinion is a translation of the original French version. In the event of any discrepancy or ambiguity the French language text dated 5 April 2019 shall prevail.

On 19 December 2014, ANSES received a formal request from the Directorate General for Health, Directorate General for Labour, Directorate General for Risk Prevention and Directorate General for Competition, Consumer Affairs and Fraud Control to undertake an expert appraisal assessing the effects on human health and the environment (fauna and flora) of systems using light-emitting diodes (LEDs).

1. BACKGROUND AND PURPOSE OF THE REQUEST

The objective of the expert appraisal undertaken by ANSES was to update knowledge on the health effects related to exposure to lighting systems using LEDs. The request focused more specifically on assessing the risks associated with exposure to LED systems for the general population and workers, distinguishing between the different types of applications of LED lighting systems and objects (domestic lighting, professional uses, vehicle lights, toys, screens, etc.) and taking into account real situations of exposure. Moreover, a review of the potential environmental risks associated with these systems throughout their life cycle was requested.

Pursuant to Directive 2005/32/EC on the eco-design of energy-using products, known as the "EuP" Directive, the planned withdrawal of incandescent lamps (spread out between 2009 and 2012) and conventional halogen lamps (set for September 2018) from the lighting market has led to a sharp increase in LED lighting systems on the consumer market, thus increasing the population's exposure to lighting systems using this technology. The scope of LED systems has expanded: it now includes not only a large number of applications for professional use, but also applications for public use including displays and signs, as well as certain objects and devices (toys, decorative objects, etc.), backlighting in screens (mobile telephones, tablets, televisions, etc.) and indoor and outdoor lighting.

When publishing its first Opinion on the health effects associated with LEDs (ANSES's collective expert appraisal report published in 2010[1]), the Agency drew attention to the retinal toxicity of blue light. Indeed, LEDs are unique in that they emit light rich in short wavelengths: this is known as blue-rich light. On this occasion, ANSES issued recommendations relating, among other things, to the placing on the market of LEDs and the provision of information to consumers.

The potential health effects associated with exposure to the light emitted by LEDs are now better documented. Since the Opinion issued by the Agency in 2010, new experimental data, obtained in animals in particular, have been published regarding the phototoxicity associated with long-term exposure to blue light. New data have also been published relating to the disruptive effects of blue light on the biological clock, glare, and the health effects associated with temporal light modulation (light-intensity fluctuations in lighting that may be visually perceived depending on frequency). Regarding the possible effects on the environment, there are data that raise questions about potentially induced imbalances in ecosystems, which may have consequences for fauna and flora as well as for humans and human health.

Adding or substituting artificial light to/for natural sunlight raises the issue of the potential health effects this may cause, due to the accumulation or modification of the lighting environment. Over the past few decades, humans have considerably increased their exposure to blue light in the evening with artificial lighting and backlights rich in blue light. Previously, the lighting systems used had tended to be yellow-orange in colour (candles, incandescent lamps).

The update of the expert appraisal considered all of the effects on human health and the environment (fauna and flora) that could be associated with exposure to the light of LED lamps.

2. Organisation and methodology of the expert appraisal

This expert appraisal falls within the sphere of competence of the Expert Committee (CES) on "Physical agents, new technologies and development areas". The Agency mandated a Working Group of experts, entitled "Health effects of LED systems", to undertake this expert appraisal under the leadership of the CES.

Working Group

The Working Group was formed following a public call for applications issued on 28 April 2015. The experts in this group were selected for their scientific and technical skills in the areas of physics, optical radiation metrology, vision, ophthalmology, chronobiology, biology, the environment and lighting regulations. The Working Group was created in September 2015. It met 25 times in plenary sessions between September 2015 and May 2018.

[1] https://www.anses.fr/fr/system/files/AP2008sa0408.pdf.

External contributions

To make up for the lack of data relating to the characterisation of exposure to LED systems, three studies were financed by the Agency.

Characterisation of the artificial lighting systems available on the French market

First of all, a research and development agreement was drawn up between the Agency and the French National Consumer Institute (INC) in order to conduct an updated comparative study of the technical properties of various lighting systems available on the market.

Documentation of exposure to light in populations

The implementation of a second study was entrusted to the French Scientific and Technical Centre for Building (CSTB), in order to characterise the population's exposure to various artificial lighting and LED systems, in real conditions of exposure. A software program developed to that end enabled light exposure to be assessed for several exposure scenarios (children, workers, elderly people, etc.).

Assessment of blue-light protection systems intended for the general public

A third study was undertaken with the CSTB to assess the blue-light filtration capacities of protective devices intended for the general public (screen filters, treated lenses, blocking glasses, software protection).

Collective expert appraisal

The methodological and scientific aspects of the expert appraisal work were regularly submitted to the CES. The report produced by the Working Group takes account of the observations and additional information discussed with the CES members. This expert appraisal was therefore conducted by a group of experts with complementary skills. It was carried out in accordance with the French Standard NF X 50-110 "Quality in Expertise Activities".

Interests declared by the experts were analysed by ANSES before they were appointed and throughout their work in order to prevent risks of conflicts of interest in relation to the points addressed in the expert appraisal. The experts' declarations of interests have been made public via the ANSES website: http://www.anses.fr

Expert appraisal methodology

Literature search and analysis

The collective expert appraisal was mainly based on a critical analysis and summary of the data published in the scientific literature (articles, reports, etc.). The literature search was thus undertaken for the period from January 2010 to July 2017.

The results of the studies financed by ANSES to supplement knowledge of protective devices and exposure to artificial light in populations were taken into account in the expert appraisal.

The Working Group also interviewed external experts and figures, as well as representatives from the lighting industry and environmental protection associations, inviting them to contribute information and data supplementing the data available for the expert appraisal.

Assessment of the level of evidence for health effects

For each studied health effect, the results of the available studies undertaken in humans on the one hand and animals on the other hand were considered separately to characterise the evidence provided regarding the connection between exposure to LED light, in particular blue-rich light, and the occurrence of the health effect. In the end, the evidence for humans and animals was combined in order to establish an overall assessment of the level of evidence for the health effect of exposure to LED light, classifying it into one of the following categories:

- proven effect;
- probable effect;

- possible effect;
- it is not possible to conclude from the available data as to whether or not there is an effect;
- probably no effect.

Characterisation of exposure

The lack of literature data dealing with the population's exposure to LED technologies led ANSES to finance specific measurement campaigns, in particular to describe the type and quantity of light emitted by LED systems used on a daily basis (e.g. lamps, objects featuring LEDs, vehicle headlamps, and computer, tablet and mobile telephone screens). Exposure to blue-rich light, especially via LED systems, was assessed as part of life scenarios, thanks to measurements taken *in situ* in specific environments.

Table 1 in the Annex summarises the main physical quantities used in particular to quantify emissions and exposure in the area of lighting.

Assessment of risks to human health

By combining the assessment of the level of evidence for health effects obtained from the analysis of the scientific articles and the data from the exposure scenarios, the expert appraisal sought to characterise the potential risks to humans associated with exposure to systems using LEDs. Thus, the Working Group classified risks of occurrence of health effects in humans into four levels as defined below:

- high risk;
- moderate risk;
- low risk;
- no predictable risk.

The collective expert appraisal report describes the methodology used to assess the level of evidence for the studied effects as well as the qualitative assessment of the related risks.

3. Analysis and conclusions of the CES

The Expert Committee on “Physical agents, new technologies and development areas” adopted the collective expert appraisal work and its conclusions and recommendations as described in this summary at its meeting of 23 November 2018 and informed the ANSES General Directorate accordingly.

3.1 Specific characteristics of the light emitted by LED lamps

The specific characteristics of LEDs are related to the type of radiation emitted on the one hand and to the physical properties of the lamps using this technology on the other hand.

Firstly, the light spectrum emitted by LEDs can be richer in blue light (there are lamps with very high colour temperatures[2] of above 6000 K, supplying extremely blue-rich light) and poorer in red light than most other natural and artificial light sources. The additional blue light in the LED spectrum compared to other light sources (spectral imbalance) raises the issue of the effects of light from LED lamps on the retina (phototoxic effects) and on circadian rhythms and sleep (melanopic effects). The lack of red light in LEDs may also deprive individuals of the potential photoprotective effects of this

[2] Colour temperature is a way to characterise light sources in comparison with an ideal material emitting light only under the influence of heat. The temperature of the black body whose visual appearance is closest to that of the light source is expressed in Kelvins (a unit of the international system whose symbol is K).

radiation, especially during the physiological emmetropisation[3] process that takes place during childhood.

Secondly, due to their high luminance[4] and small emission areas, LED lights can produce more glare than light emitted by other technologies (incandescent, compact fluorescent, halogen lamps, etc.). This can especially be the case with LED matrices (small LED aggregates on the same base), LED spotlights, vehicle lights and hand-held lamps.

Lastly, LEDs are highly reactive to current fluctuations. Thus, variations in light intensity can appear depending on the quality of the power supply. These phenomena are grouped under the term "temporal light modulation". Humans can suffer from the negative effects of these variations, whether or not they are visually perceptible.

3.2 Changes in regulations and standards since 2010

3.2.1 Regulations and standards relating to the phototoxicity of light

- *Exposure limits*

Regarding exposure to optical radiation and photobiological safety in particular, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) published new guidelines on exposure to visible and infrared optical radiation in 2013 (ICNIRP, 2013)[5]. The blue-light exposure limits, which remained the same as those proposed in 1997, only involved acute exposure (single, continuous exposure for less than eight hours).

- *Regulatory texts governing uses of devices, lighting products and artificial optical radiation applicable to LEDs in particular*
  - General population

The European "Low Voltage" Directive (2014/35/EU) aims to ensure that the electrical equipment on the European market meets requirements providing a high level of protection of health and safety. Manufacturers can rely on their products' compliance with harmonised standards to meet the essential requirements of this directive.

However, portable lighting systems (hand-held lamps, head torches) do not fall within the scope of the Low Voltage Directive. Nevertheless, they use LED sources that can have very high light intensities.

Similarly, for vehicle lighting (exterior lamps), there are no regulations intended to guarantee photobiological safety, for example by limiting the emission intensities of lamps or human exposure.

The case of toys using LEDs is not adequately covered by the European Directive on the safety of toys (2009/48/EC), since it refers, for health-related risks, to the standard on the safety of laser products (IEC 608251-1), which is not suited to LED lighting. This standard also does not consider the fact that the eyes of children are more sensitive to blue light due to a clearer lens.

  - Workers

European Directive 2006/25/EC of 5 April 2006 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (artificial optical radiation - AOR) includes risk related to blue light. For this specific risk, it relies on the ICNIRP guidelines

3 Emmetropisation is the process of normal ocular development leading to the formation of a sharp image on the retina.

4 Luminance is a quantity corresponding to the perceived brightness of an area. A very bright area has high luminance, while a completely black area has zero luminance.

5 ICNIRP Guidelines on Limits of Exposure to Incoherent Visible and Infrared Radiation, published in: Health Physics 105(1):74-96;2013.

published in 1997. In France, the AOR Directive was transposed into the Labour Code by decree in 2010[6]. A ministerial order from 2016[7] defines risk assessment methods based on European standards relating to human exposure to optical radiation.

- Standards

The standards relating to the assessment of photobiological safety (CIE S009, IEC 62471 and NF EN 62471) refer to the ICNIRP limit values and propose that lamps be classified into risk groups: risk group 0 (no risk), risk group 1 (low risk), risk group 2 (moderate risk) and risk group 3 (high risk).

In 2014, a technical report (IEC TR 62778:2014) accompanying the NF EN 62471 standard was published by the International Electrotechnical Commission (IEC). This report describes a method for assessing the photobiological risk group in the case of blue light. It includes several of ANSES's recommendations, in particular a procedure for transferring the risk group of an individual LED to an LED module and a finished product (luminaire), as well as the specification of a minimum viewing distance for people exposed to light sources in risk group 2 or higher.

Since 2015, harmonised lighting standards have included photobiological safety requirements[8] limiting the possible effects of radiation on eyes and skin. A distinction is made between lamps on the one hand and luminaires[9] powered by the electrical grid (non-portable luminaires) on the other hand. Regarding lamps, the requirements consist in limiting the photobiological risk group to level 0 or 1 in accordance with the NF EN 62471 standard. Regarding non-portable luminaires, there are no limits on the risk group; there is merely an obligation to inform consumers in the event of a risk group of 2 or higher[10].

3.2.2. Regulations and standards relating to other health effects

There are currently no specific regulations dealing with effects related to circadian rhythm disruption, glare, or temporal light modulation.

- *Circadian rhythm disruption*

In 2004, the International Commission on Illumination (CIE) published a document, updated in 2009 (CIE, 2009)[11], defining spectral sensitivity curves for melanopsin[12]-containing retinal ganglion cells.

- *Glare*

The standards relating to glare have not changed since 2010. The lighting industry uses the glare ratings, in particular the Unified Glare Rating (UGR), defined by the CIE. The UGR formula was initially developed for interior luminaires equipped with fluorescent tubes. The validity of extending the use of the UGR to LED lighting systems is questionable. The CIE's 2013 publication, "Review of

6 Decree no. 2010-750 of 2 July 2010 concerning the protection of workers from risks due to artificial optical radiation, JORF no. 0153 of 4 July 2010, page 12149, text no. 11.

7 Ministerial Order of 1 March 2016 concerning methods for assessing risks resulting from occupational exposure to artificial optical radiation, JORF no. 0066 of 18 March 2016, text no. 30.

8 These requirements are specified in Standard NF EN 62560– Self-ballasted LED-lamps for general lighting services by voltage > 50 V – Safety specifications, and Standard NF EN 60598-1 Luminaires – Part 1: General requirements and tests (general part common to all luminaires).

9 A luminaire is a combination of a lamp and a decorative element or a combination of several lamps.

10 For non-portable luminaires belonging to risk group 2, the safety standards (for example, Standard NF EN 60598-1 on general requirements for luminaires) require the labelling of the threshold distance and the following statements: *"the luminaire should be positioned so that prolonged staring into the luminaire at a distance closer than x m is not expected"* and *"do not stare at the light source".*

11 CIE 158:2009: Ocular Lighting Effects on Human Physiology and Behaviour.

12 Melanopsin is a photopigment contained in the retina and photosensitive ganglion cells.

Lighting Quality Measures for Interior Lighting with LED Lighting Systems" (CIE 205:2013), concluded that a new assessment system for glare was necessary for LED lighting.

- *Health effects related to temporal light modulation*

Since 2015, most standardisation organisations have produced new standards and technical documents or updated those already existing to describe phenomena involving temporal light modulation. However, there are no European or French regulations limiting the temporal modulation of the light emitted by lamps and luminaires. The regulations on lighting (in terms of eco-design and labelling) are currently being revised by the European Commission; aspects involving temporal light modulation are expected to appear in the text.

3.3 Human health risks associated with exposure to LED light

The human health risks associated with exposure to LED light are mainly due to the spectral composition of the light on the one hand and temporal light modulation on the other hand.

Of the health effects of LEDs, those related to blue light, such as phototoxicity and circadian rhythm disruption, are highly dependent on the exposed person's age. Indeed, the lens acts as a blue-light filter in the eye and its transmittance changes considerably with age. Children are born with a clear lens, letting through all blue light, and reach an optimum filtration rate around the age of 20. A person over the age of 60 has a blue-light filtration rate around twice that of a 20-year-old.

There is a distinction between light sources (or light objects) emitting blue light and objects that have a blue colour. In the first case, the light spectrum received by the eye is (often) enriched with blue light. The amount of light received by the retina in the blue band can be large and have phototoxic effects on the eye and a disruptive effect on biological rhythms. In the second case, the blue colour of the objects and surrounding materials, with conventional lighting, is due to the reflection of part of the spectrum and ends up absorbing some of the light. The intensity of the light source is diminished overall, and the perception of colour can have soothing effects.

3.3.1. Circadian rhythm disruption, sleep disruption, and effects on cognitive performance and vigilance levels

3.3.1.1 Hazard characterisation

- *Circadian rhythm disruption*

The light received by the retina has two main effects: it enables the formation of images (visual effect) and gives the body an idea of the time of day (non-visual effect). This non-visual effect involves melanopsin-containing retinal ganglion cells (mRGCs) that have specific spectral sensitivity: they are strongly stimulated by blue light, with peak sensitivity around 480 nm. These mRGCs send their messages to the suprachiasmatic nuclei of the hypothalamus, the seat of the central circadian clock. This central clock distributes the message to the rest of the body, in order to synchronise all of its biological functions with the day/night cycle. Thus, the adequate regulation of mRGC activity is essential for keeping the biological rhythms of organisms synchronised with their environment. The "melanopic" wavelength band (turquoise blue, 480-490 nm) is thus related to effects on circadian rhythmicity.

The central biological clock determines the production of a hormone, called melatonin, whose secretion begins in the evening, around two hours before bedtime, and then reaches a peak towards the middle of the night before returning to very low and even undetectable levels in the morning and for the rest of the day. Thus, the daily rhythm of circulating melatonin concentrations is a reliable indicator of the biological clock's activity and disruptions.

The effective synchronisation of the central circadian clock, and thus of the biological functions that depend on it, in particular wake/sleep rhythms, requires high light intensity during the day and total darkness at night. Current lifestyle habits, especially in urban environments, are increasingly tending to disrupt the natural daily light/dark cycle, with time spent indoors during the day (accompanied by a decrease in light intensity) and exposure to multiple light sources (lighting, screens) in the evening and at night.

There have been many different publications studying the disruption of circadian rhythms related to exposure to light in the evening or at night. The results of several experimental studies conducted in humans, during which people were subjected to blue-rich light from artificial lighting or screens (computers, telephones, tablets, etc.), were consistent and indicated that nocturnal melatonin synthesis was delayed or inhibited even by very low exposure to blue-rich light.

The degree of circadian disruption seems to depend on the light intensity, the time and duration of exposure, and the individual's history of exposure to light during the day. However, a value of around 10-40 lux or lower (a very low level that can be largely exceeded with domestic lighting) is sufficient to observe an impact on the circadian clock (illustrated by the suppression of nocturnal melatonin secretion).

In conclusion, in light of the sufficient evidence provided by studies undertaken in humans, circadian rhythm disruption induced by exposure to blue-rich light during the evening or at night is considered as proven.

Furthermore, experimental studies in animals have demonstrated that circulating melatonin in a mother crosses the placental barrier and enters the foetal circulation, which possesses melatonin receptors. Thus, maternal melatonin can impact foetal development, in particular the establishment of the circadian system. At night, maternal exposure to light modifies melatonin levels and induces a prenatal effect that appears to have consequences lasting into adulthood (effects on circadian rhythms, metabolic effects, etc.). It can reasonably be assumed that in humans, the effects of modern lighting at night on maternal melatonin secretion negatively impact *in utero* foetal development.

The disruption of circadian rhythms is also associated with other health effects[13] (disruption of sleep quality and quantity, metabolic disorders, increased risk of cancer - especially breast cancer, cardiovascular diseases, effects on mental health). However, the direct connection between exposure to blue-rich light in the evening or at night and the occurrence of these health effects, while strongly suspected, has not been proven to date in humans.

- *Sleep disruption*

Most of the available scientific studies show that blue light alters sleep regulation via circadian disruptions. The evidence provided by studies undertaken in humans is sufficient to conclude that exposure to blue-rich light during the evening has a proven effect on sleep onset latency and the duration and quality of sleep.

- *Effects on vigilance levels and cognitive performance*

Several studies have shown that exposure to blue light (from LEDs in particular) in the day or at night improves cognitive performance and enhances vigilance levels. A number of studies have focused on the effects of lighting, especially blue light, on the performance of night workers. The objective has been the short-term optimisation of vigilance and the reduction of sleepiness in order to reduce industrial and traffic accidents and enhance performance and productivity. These are major challenges for modern societies. However, the issue of potential health effects, due to a possible increase in the phototoxicity of light at night, has yet to be defined.

[13] Assessment of the health risks associated with night work, ANSES collective expert appraisal report, June 2016.

3.3.1.2 Characterisation of LED light sources and exposure

Exposure to blue light was studied in the “melanopic” band (turquoise blue, 480-490 nm) for effects on melatonin and circadian rhythms.

The quantity of blue light emitted by an LED object can be estimated based on its colour temperature, expressed in Kelvins (K), and its level of illuminance on a surface, expressed in lux (especially at the plane of the eye).

Measurement campaigns undertaken to describe the type and quantity of light emitted by LED systems showed that light emitted by screens of televisions, computers, mobile telephones or tablets had a low level of illuminance but was rich in blue light. LED computer screens had colour temperatures ranging from 4500 K to 6900 K and illuminance values at the plane of the eye ranging from 20 to 60 lux. For the LED screens of smartphones and electronic tablets, colour temperatures ranged from 4100 K to 7000 K and illuminance values at the plane of the eye from 2 to 10 lux. As for domestic lighting, the LED lamps available on the market can offer colour temperatures ranging from 2500 K (low level of blue light) to 6900 K (very high level of blue light).

Regarding human exposure to blue light in the melanopic band, no data were identified in the scientific literature. The light exposure scenarios developed for this expert appraisal, representing typical living conditions for various populations, showed that exposure in the melanopic band was similar with LED lighting with moderate levels of blue light (colour temperatures ranging from 2700 K to 4000 K), compact fluorescent lamps and halogen lamps. Nevertheless, with life scenarios including “worst case” situations (LEDs with very high levels of blue light, colour temperatures of around 6500 K), exposure in the melanopic band was higher compared with other lighting technologies, regardless of the population in question. Moreover, the use of LED screens and objects is likely to increase exposure to blue light in the melanopic band.

3.3.1.3 Health risk assessment

Based on the available data, the risk of circadian rhythm disruption or sleep disruption related to exposure to LEDs cannot be precisely quantified. Nevertheless, in light of the above and based on a qualitative approach, the Working Group's experts consider that the risk of circadian disruption associated with exposure to blue-rich LED lights in the evening or at night is high.

In particular, exposure before bedtime to LED lighting or screens from televisions or communication technologies enriched with blue light is likely to adversely affect sleep duration and quality and impact cognitive functions.

3.3.1.4 Susceptible population groups

The available studies have shown even stronger effects of delayed bedtimes, due to the impairment of non-visual functions, in particular melatonin suppression, in children, adolescents and young adults (before the age of 20). An obvious factor is the higher lens clarity of young people, causing more light to pass through than for adults. In addition to the widespread use of devices with LED screens by adolescents, the behavioural, hormonal and circadian changes occurring in this phase of life (increase in the endogenous period of the circadian cycle) are probably also involved.

More generally, several population groups were identified as being more specifically susceptible to the risk of circadian and sleep disruption associated with exposure to LEDs:

- infants, children, adolescents and young adults (due to a clear lens); aphakic (with no lens) and pseudophakic (with an artificial lens) individuals;
- pregnant women (potential health effects on the unborn child);
- night workers[14];

[14] Night workers are particularly susceptible since their exposure to LED lighting is potentially high.

- people with ocular diseases or anomalies, and people with sleep disorders.

3.3.2 Ocular effects and diseases

3.3.2.1 Hazard characterisation

Phototoxicity is a mechanism of light-induced cellular damage that can lead to cell death. Exposure to intense and acute light is phototoxic since it causes the irreversible loss of retinal cells, which can lead to partial and permanent (scotoma[15], decrease in visual field, reduced resolution) or total (blindness) vision loss. Chronic exposure to low-intensity phototoxic lights speeds up the ageing of retinal tissues, potentially leading to vision loss and degenerative diseases such as age-related macular degeneration (ARMD).

Regarding the toxic effects of blue-rich light on the eye, the available data show that:

- the retinal phototoxicity of acute (for less than eight hours) exposure to blue-rich light is proven;
- the contribution of chronic (for several years) retinal exposure to blue-rich light to the occurrence of ARMD is proven; since the long-term ocular effects of artificial lighting have not been studied to date, these conclusions are based on epidemiological studies taking into account exposure to sunlight (blue-rich light);
- in addition to the received phototoxic dose, the time of exposure plays a major role. Some experimental studies, currently limited to animals, have demonstrated increased retinal vulnerability to phototoxicity at night, due to a daily photosensitivity rhythm and disruptive effects on the endogenous retinal clock.

Numerous studies have shown that the exposure limits (ELs) selected by ICNIRP for the retinal toxicity of light are not sufficiently protective. Some authors (Hunter *et al.*, 2012)[16] have considered that to be protective, these ELs would need to decrease by a factor of 20. In addition, the expert appraisal provided an opportunity to highlight that these ELs are only proposed for acute exposure (for less than eight hours) and ignore the issue of long-term exposure. The experts also mentioned the existence of new UV-LED systems[17] that may pose phototoxic risks.

Furthermore, the review of the scientific literature on myopia and Sjögren syndrome[18] led to the following conclusions:

- the effect of blue-rich light on myopia is possible (whether positive or negative);
- the effect of blue-rich light on the occurrence of Sjögren syndrome is possible.

3.3.2.2 Characterisation of LED light sources and exposure

Exposure to blue light was studied in the “phototoxic” band (deep blue, 450-470 nm).

The physical measurements taken as part of this expert appraisal showed that some of the tested LED lighting devices (hand-held lamps, head torches, toys and certain vehicle lights - especially dipped-beam headlamps, etc.) emit blue-rich light (devices classified in risk group 2, maximum anticipated exposure duration of less than 100 s, according to the exposure limits defined by

15 A break in the field of vision due to insensitive retinal areas.

16 Hunter, Jennifer J., Jessica I. W. Morgan, William H. Merigan, David H. Sliney, Janet R. Sparrow, and David R. Williams. 2012. The Susceptibility of the Retina to Photochemical Damage from Visible Light. Progress in Retinal and Eye Research 31 (1): 28-42.

17 New generation of LEDs whose blue-light peak is shifted to the ultraviolet region (around 410 nm).

18 Sjögren syndrome involves lacrimal system dysfunction causing dryness on the surface of the eye (cornea, conjunctiva, etc.). This syndrome is characterised by ocular discomfort with tingling sensations or an impression of a foreign body in the eye.

ICNIRP). Some telephone screens and electronic tablets using LED technology emit fairly low-intensity but systematically blue-rich light. It should also be noted that decorative blue LEDs have emerged on the market and that LEDs are being used in a growing number of applications (e.g. in agricultural lighting systems, to light up aquariums, etc.).

Adding artificial lighting to natural lighting is likely to modify the ocular doses received by the cornea and retina in the phototoxic band (up to a 50% increase). Comparing the contributions of LED lighting systems and other lighting technologies to overall human exposure according to defined scenarios produced the following results:

- in general, LED lighting systems increase the imbalance in wavelengths in favour of blue light compared to red light, in comparison with other lighting systems, at the same colour temperature;
- exposure in the phototoxic band is even higher when colour temperature is high (blue-rich light), regardless of the lighting technology (LED or otherwise).

Regarding the phototoxic dose received by the retina, the results of the examination of exposure scenarios showed that LEDs were only different from other technologies in the “worst case” scenario, in which the LED lighting systems used had very high levels of blue light (high colour temperatures of around 6500 K). Even so, the experts underline that this “worst case” scenario can correspond to the situations of certain people with very low exposure to natural light who are subjected to blue-rich lighting in their workplace (for example, in the winter, it is dark out in the morning when leaving home and in the evening when returning home, and the daytime is spent in an environment lit exclusively by artificial blue-rich lighting).

The Working Group's experts would like to point out the significant commercial development of small bare decorative LEDs emitting blue light (string lights, ambient lighting, etc.). These LEDs can increase exposure in the phototoxic band, even at low luminance levels. Indeed, the photons of blue light have higher energy than the photons associated with longer wavelengths. They can therefore induce photochemical reactions similar to those caused by ultraviolet radiation. Moreover, human visual perception is less sensitive to blue light. High energy levels in blue light can therefore be received by the retina without creating a strong visual sensation. Since this blue-coloured light does not necessarily create glare, it can be stared at over a long period, especially by children.

3.3.2.3 Health risk assessment

Based on the available data, the risk of ocular diseases occurring in relation to exposure to LEDs cannot be precisely quantified. However, in light of the above and based on a qualitative approach, the experts consider that the risk of acute toxicity associated with “warm white” (low colour temperature) LEDs for domestic use is low.

It should be noted that lighting devices belonging to risk group 2 (hand-held lamps, head torches, toys and certain vehicle lights) are available on the market. The risk of ocular diseases occurring in relation to exposure to these devices is higher, especially for susceptible population groups. Similarly, objects specifically emitting blue light (e.g. decorative LEDs), even at low intensities, can increase exposure in the phototoxic band.

Due to the lack of data on the chronic effects of low-dose exposure to cool light (screens, for example), the risk level associated with chronic exposure to blue-rich LEDs cannot currently be assessed.

3.3.2.4 Susceptible population groups

Regarding the risk of ocular diseases, several susceptible population groups were identified based on the data from the literature:

- infants, children, adolescents and young adults (clear lens); aphakic (no lens) and pseudophakic (artificial lens) individuals;

- people with ocular diseases (dry eye, ARMD, glaucoma, retinopathy, etc.); people with motor or cognitive disorders reducing their avoidance or decision-making capacities in the event of overly intense light; people taking photosensitising medications or exposed to photosensitising pollutants;
- night workers[19] and any other professionals with potentially high exposure to LED lighting (surgeons, dentists, lighting professionals, lighting distributors, performing artists, people working in sport facilities, people working in agri-food facilities using LEDs (greenhouses, aquaculture), etc.).

3.3.3 Glare and visual comfort

3.3.3.1 Hazard characterisation

Glare corresponds to viewing conditions in which a person experiences discomfort or is less capable of perceiving details or objects, due to an unfavourable luminance distribution or an extreme contrast. A distinction should be made between disability glare, which reduces the subject's visual capacities and performance, and discomfort glare, which causes the subject to experience a sensation of discomfort but does not cause a decline in visual performance.

Several factors modulate glare-related disability. These include the quantity of light sent into the eye by the source itself as well as the distance from the glare source and the observer’s age. However, the spectral composition of light does not modify the disability glare phenomenon.

It appears that the multiple visible point sources in luminaires (LED matrices) considerably increase discomfort. All studies have consistently shown that (1) non-uniform sources produce more glare than uniform sources, even with moderate luminance, and (2) the higher the contrast, the greater the sensation of discomfort. Moreover, since the scattering of light in ocular environments increases with age, discomfort also increases. Regarding both LED sources and “conventional” light sources, colour temperature does not seem to be a determinant of visual comfort. However, at the same colour temperature, the spectral composition and especially the blue-light enrichment of the spectrum has probable consequences on visual discomfort.

The long-term effects of repeated glare are not known to date. Furthermore, there is a high level of inter-individual variability in the general population as to the assessment of glare situations.

3.3.3.2 Characterisation of LED light sources and exposure

Luminance (expressed in cd/m^2 [20]), measured when directly viewing a light source from a short distance, enables the level of glare potentially produced by that light source to be assessed. The LED lamps tested for this expert appraisal had disparate luminance levels; some of them, especially those in LED spotlights, produced a very high level of glare.

Another aspect of visual comfort is related to colour rendering. The colour rendering index (CRI) represents a light's capacity to faithfully render a colour. A CRI of 100 refers to an optimum light, and it is recognised that a CRI is deemed acceptable above 80. LED lamps do not yet offer the capacities of halogen lamps, which have CRIs close to 100, but their performance is similar to that of compact fluorescent lamps, sometimes with measured CRIs greater than 80. Compared to the context of ANSES's previous expert appraisal published in 2010, LED technology now offers higher-quality colour rendering.

3.3.3.3 Health risk assessment

Based on the available data, the risk of visual discomfort or disability glare related to exposure to LEDs cannot be precisely quantified. However, in light of the above and based on a qualitative approach, the experts consider that certain lighting devices including LEDs (hand-held lamps,

[19] Night workers are particularly susceptible since their exposure to LED lighting is potentially high.

[20] cd/m^2: candela per square metre.

vehicle lights, LED spotlights, LED matrices, etc.) can pose a high risk of glare. Moreover, while certain LED lamps have better colour rendering than they did a few years ago, this can still be improved.

3.3.3.4 Susceptible population groups

Age is a factor aggravating the risk of glare associated with LEDs, both during the day and at night. Deterioration of vision accelerates after the age of 60, at varying rates depending on the individual. The stray light generated around sources increases considerably with age, lowering the perception of object contrast and therefore visual performance.

Subjects with migraine seem to be specifically susceptible to the glare caused by certain irregularities in the spectral distribution of light energy.

3.3.4 Skin effects

3.3.4.1 Hazard characterisation

Blue light may have adverse effects on the skin, accelerating ageing and delaying healing processes, whereas exposure to wavelengths of 590 to 700 nm (red light) appears to have opposite effects. The experts conclude that the effect of exposure to blue-rich light on the occurrence of skin diseases is possible.

Moreover, the delayed carcinogenic effect (melanoma induction) induced by blue-light LED phototherapy used for the treatment of neonatal jaundice should be given special attention. Of the five studies undertaken to assess the risk of developing benign or malignant melanocytic lesions following blue-light neonatal phototherapy, three showed an increased number of common or atypical naevi in exposed children.

3.3.4.2 Characterisation of LED light sources and exposure

There are no exposure data specifically dealing with the skin effects of blue-light emissions. Nevertheless, the photobiological risk group provides an idea of the quantity of blue light emitted by LED lighting (see § on the characterisation of exposure for ocular diseases).

3.3.4.3 Health risk assessment

Based on the available data, the potential risks to the skin related to exposure to LEDs cannot be quantified. Based on a qualitative approach and considering the exposure levels associated with the domestic use of LED lighting as well as the limited skin penetration depth of blue-light optical radiation, the experts consider that the risk of skin diseases occurring in relation to exposure to blue light from LEDs is low.

3.3.4.5 Susceptible population groups

The experts identified some potentially susceptible population groups:

- newborns in the event of blue-light LED phototherapy prescribed to treat neonatal jaundice;
- people with certain skin diseases (epithelial lesions, wounds, etc.); these people appear to have an increased risk of skin lesions developing or worsening during exposure to blue light.

3.3.5 Other disorders (migraines, headaches, visual fatigue, accidents, epilepsy attacks)

3.3.5.1 Hazard characterisation

The temporal modulation of a lighting system is primarily characterised by its modulation frequency and the corresponding modulation rate, expressed as a percentage of the light intensity (values ranging from 0% to 100%). Depending on its frequency, this modulation may or may not be perceptible by the human visual system. Three separate visual effects (conscious perception of modulation) have been described: flicker, the stroboscopic effect and the phantom array effect. Health effects can be directly induced by these visual effects or occur with no conscious perception of any modulation. The health effects that can result from the conscious or unconscious perception of modulation are epilepsy attacks, traffic accidents, accidents related to the use of machines, migraines, headaches and visual fatigue.

Effects such as headaches, migraines and visual fatigue can be associated with temporal modulation frequencies between 80 and 120 Hz. The related evidence provided by studies is limited for humans.

Phenomena such as the stroboscopic effect (apparent immobility or slowing of a moving object) and the phantom array effect (persistence of an image during a visual saccade) can occur at high modulation frequencies (greater than around 80 Hz). In an industrial or domestic context, it is likely that the stroboscopic effect could affect safety during the use of machines or tools.

Temporal light modulation can also be associated with the triggering of attacks in people with epilepsy. However, the modulation frequencies of the LED lamps and luminaires available on the market are too high to trigger attacks in these individuals. Nevertheless, there is a possibility of attacks being triggered in the population of epileptic subjects during exposure to LED lamps or luminaires with abnormal temporal modulation (defective products or incompatibility with the controller).

Moreover, certain self-contained lighting devices on bicycles (recharged by magnetic induction) are very strongly modulated (100% modulation) at frequencies varying with the cyclist's speed. At certain speeds, the temporal modulations are located around 15 Hz, in the most critical band for the triggering of epilepsy attacks.

In all of these situations, temporal light modulation is associated with visual discomfort and a decrease in visual efficiency, especially at workstations in occupational settings.

3.3.5.2 Characterisation of LED light sources and exposure

Results from the scientific literature dealing with the temporal modulation of LED lamps were aggregated with measurements taken in the context of this expert appraisal; of the 53 tested lamps:

- 18 lamps (around 34%) had very low temporal modulation (of less than 1%);
- 12 lamps (around 23%) had temporal modulation between 1% and 15%, similar to that of halogen and compact fluorescent lamps;
- 14 lamps (around 26%) had modulation between 12% and 70%; their values were significantly higher than those of halogen and compact fluorescent technologies;
- nine lamps (around 17%) had very high modulation, exceeding 70% and even reaching 100%.

It is estimated that around 43% of LED lamps for domestic use have degraded temporal modulation performance (modulation rate greater than 15% at 100 Hz) compared to halogen and compact fluorescent technologies.

The stroboscopic effect is particularly visible with LED lamps and luminaires having high temporal modulation at 100 Hz.

Some LED lamps and luminaires have high enough modulation levels that the phantom array effect is perceptible, especially when driving a car.

3.3.5.3 Health risk assessment

For people with epilepsy, based on the available data, it is not possible to quantify the risk of attacks being triggered in relation to the temporal modulation of an LED lighting system.

Moreover, the experts consider that due to the limited number of exposure data, the risk associated with effects (headaches, migraines, visual fatigue) occurring in the frequency range (80-120 Hz) associated with LED exposure is not known.

Based on the scientific data, it is not possible to conclude as to whether or not the perception of the stroboscopic or phantom array effect has an impact on accidents occurring when handling machines or tools, or on traffic accidents.

3.3.5.4 Susceptible population groups

Studies dealing with the maturation of the visual contrast perception system in humans indicate that maximum temporal contrast sensitivity is reached during adolescence and young adulthood. These are therefore population groups particularly sensitive to modulated light.

Epidemiological studies showing an association between modulated light and the triggering of migraine refer to migraine patients as a population group sensitive to modulated light.

Work undertaken using older-generation fluorescent tubes showed that certain individuals had heightened sensitivity to temporal light modulations at the frequency of 100 Hz. In addition, studies have shown that some individuals visually perceive flicker at 100 Hz.

Thus, with regard to certain health effects related to temporal light modulation, several susceptible population groups were identified:

- regarding headaches, migraine and visual fatigue:
  - children, adolescents and young adults;
  - migraine sufferers;
- regarding the risk of accidents related to the stroboscopic effect or phantom array effect:
  - machine and tool operators and vehicle drivers;
  - people with motor or cognitive disorders reducing their avoidance or decision-making capacities;
  - children, adolescents and young adults;
- regarding the triggering of epilepsy attacks: people with epilepsy.

3.4 Effectiveness of protective devices

There are various solutions claiming to reduce or suppress the effects of blue light: these include filters built into computer screens or into the lenses of prescription glasses, as well as programmable lighting systems that modulate the quantity of melanopic light (wavelength of around 480-490 nm) depending on the time of day.

According to the measurements taken for this expert appraisal:

- specific blue-light-blocking glasses were more effective at filtering than treated ophthalmic lenses. However, neither of these two systems was effective enough to be considered as personal protective equipment[21] (PPE) regarding the risk of acute retinal phototoxicity resulting from prolonged exposure to a very high-intensity LED source;
- depending on the tested protective device, the capacity to filter blue radiation in the melanopic band was highly variable: it was very low or even non-existent for treated lenses, despite the claims made by manufacturers and distributors of these products. It cannot be said that this filtration is sufficient to prevent the decrease in melatonin secretion induced by exposure to light in the evening and the related effects of sleep onset delay;
- for the tested screens claiming to limit blue-light emissions, no real effectiveness was observed. However, reducing the colour temperature (switching to warm white) and brightness of the screens was somewhat effective at reducing the quantity of blue light in the spectrum.

[21] There are currently no standards specifying test methods and performance requirements for PPE with regard to blue light.

3.5 Environmental impact of LEDs

3.5.1 Threat to biodiversity

The diversity of the living world is reflected in the wide variety of metabolic, physiological and behavioural responses to light observed in fauna and flora. Thus, what might be an advantage for a given plant or animal species may prove to be a disadvantage for another. Changes in the (daily and annual) biological rhythms, orientation, geographical distribution and migration of species can thus be observed following exposure to artificial light. There can also be indirect effects (in the medium and long term) on these populations and their ecosystems.

Research into the impact on the living world of the light emitted by LEDs at night still heavily relies on that dealing with artificial light in general. Moreover, it still involves a very limited number of species. Regardless of the studied ecosystem, the general long-term trend as observed in the scientific literature appears to be an increase in mortality and a decline in the diversity of the animal and plant species studied in environments lit at night, including by LED lighting systems.

According to the scientific literature, the effects of light at night, especially from LED lighting, on fauna and flora and ecosystems are proven for all of the species studied. Overall, these effects correspond to those of night-time lighting. It is important to distinguish those that could be specifically related to the particular characteristics of LEDs (intensity, spectral composition). These effects are combined with other anthropogenic pressures (chemical pollution, geographical barriers, shrinking habitats, overexploitation, etc.). The continuous extension of human, industrial and leisure activities in addition to physical and chemical nuisances combined with the effects of climate change are all factors that certain animal and plant populations will probably be incapable of coping with, which will speed up the decline in biodiversity. However, data involving the combined action of these multiple disruptive factors are still extremely scarce.

3.5.2 Light pollution

The collective expert appraisal report associated with this summary includes an assessment of the effects of LED deployment (outdoor display and lighting sources in particular) on light pollution. Various aspects have been considered, such as effects on the sky glow, nuisances for humans (intrusive light, light trespass, glare, circadian rhythms) and nuisances for ecosystems and biodiversity.

According to the Working Group's experts, the change in lighting technologies due to LEDs could either increase or reduce light pollution, depending on the choices made for public and indoor lighting, architectural and landscape enhancement, etc. The categories of LED lighting systems that may be responsible for the greatest increases in light pollution are as follows: illuminated signs, billboards and advertising, as well as lighting for commercial, agricultural (including horticultural greenhouses), aquaculture and industrial zones. This also encompasses lighting for outdoor car parks in these zones. In these categories, the trend is towards an increase in the number and intensity of points of light.

Replacing lamps for street lighting and indoor lamps with LEDs could contribute to reducing light pollution, by better targeting areas to be illuminated (and thus limiting diffusion) and modulating the quality (wavelength) and intensity of the light emitted, as enabled by LED technology, provided that the number of points of LED light is not increased compared to the number of replaced points of light.

Despite the results highlighted above, it is difficult to assess the overall impact of the transition from current lighting systems to LEDs on light pollution.

3.5.3 Impacts related to the life cycle of LED lamps and luminaires

Several categories of environmental impacts are defined when analysing the life cycle of a product: energy consumption, the amount of hazardous waste produced, the amount of water used, the impact on global warming, toxic effects on human health, etc. The results of the life-cycle analyses (LCAs) undertaken for the analysed light sources show that LED lamps and luminaires have the lowest environmental impacts compared to other lighting technologies. This is due to the higher light efficiency of LED lighting compared to other sources. However, the content of the LCA studies dealing with lamps and luminaires varied, especially in terms of the analysed products and chosen methods (the functional unit, impact categories and life-cycle stages included). Despite major differences in the LCA methods, the analyses generally led to very similar results: the LED use phase was primarily (70% to 99%) responsible for the environmental impacts observed, due to the energy consumption of this technology. Manufacturing was responsible for most of the other impacts.

The CES notes that one limitation of the LCAs was the lack of a methodology for assessing the impacts of light on human health and the environment (fauna and flora).

Recommendations of the CES

Based on the Working Group's conclusions and recommendations, the CES is issuing the following recommendations aiming to better protect human health (general population and workers) and the environment from effects related to exposure to LED systems. These recommendations are intended to limit harmful effects related to exposure to LEDs by developing information for the general population and in the workplace and by improving the normative and regulatory frameworks governing the use of LEDs. Lastly, the CES highlights the efforts to be made in terms of research.

Recommendations for the public authorities to protect the population and the environment

The CES recommends developing actions and information regarding:

- the need to limit exposure to blue-rich light (from LEDs and other technologies), by favouring the use of warm-coloured lighting (colour temperature below 3000 K) before going to bed and during the night, especially for certain population groups: children, adolescents and pregnant women (see lists by health effect in Section 3). In particular, the CES recommends not using blue-rich night-lights for infants and children and limiting the exposure of children and adolescents to blue-rich light sources (computer, tablet, mobile telephone screens, etc.) at night and before going to bed;
- the importance of enhancing the light contrast between daytime and night-time by increasing exposure to natural light during the day and limiting exposure to artificial light before bedtime and at night;
- the phototoxic effects of light associated with exposure to certain LED lighting devices (hand-held lamps, head torches, toys, vehicle lights, blue-light decorative string lights) available on the market, especially for the most susceptible population groups such as children;
- the widely varying effectiveness of the protective devices currently proposed with regard to the adverse health effects associated with exposure to LEDs.

In order to protect against the harmful effects of light pollution on humans and their environment, the CES recommends:

- undertaking actions to limit intrusive light in homes and thus reduce the risk of circadian disruption;

- limiting the number of illuminated outdoor facilities, keeping the surface areas of illuminated zones to a minimum, improving control of their directivity and promoting their sound management;
- conducting, wherever lighting is necessary, a study of its impact on the local ecosystem in natural and suburban areas;
- creating protected spaces, without any artificial lighting.

Recommendations for employers and occupational physicians to protect workers

- considering the phototoxic effects of blue light and the potential effects of temporal light modulation, the CES reiterates the obligation to limit the exposure of workers to these light sources and inform them of the related hazards;
- moreover, given the effects observed on foetal development in animals related to maternal exposure to light at night, the CES recommends limiting the exposure of pregnant women to light during the night.

Recommendations regarding the regulatory and normative frameworks with the aim of protecting human health and the environment

At national level:

the CES recommends enforcing the regulations on the switching-off of interior lighting with exterior emission and the illumination of building façades (Ministerial Order[22] of 25 January 2013 on the nocturnal lighting of non-residential buildings in order to limit light pollution and energy consumption) as well as those on the switching-off of advertising signs (Decree no. 2012-118[23] on outdoor advertising and signs).

At European level:

regarding normative changes to be made, the CES recommends:

- revising the exposure limits for optical radiation proposed by ICNIRP, so as to make them sufficiently protective against phototoxic risks. They should take into account chronic exposure and consider other indicators, especially those relating to infra-clinical toxicity[24];
- creating an effectiveness index and requiring its labelling on devices providing protection against blue light (accounting for the attenuation rate);
- developing a metrological standard, at European level, specifying conditions for measuring temporal modulation and calculating the related indices;

regarding regulatory changes to be made, the CES recommends:

[22] "The interior lighting of premises for professional use must be switched off one hour after these premises have been vacated. Building façade lighting must be switched off at 1 am at the latest. Store window lights and window display lights must be switched off at 1 am at the latest or one hour after these premises have been vacated, whichever occurs later".

[23] "Illuminated advertisements must be switched off at night, between 1 am and 6 am, except for airports and urban units with more than 800,000 inhabitants, for which the mayors shall set out the applicable rules. Illuminated signs shall comply with the same rules".

[24] For example, there can be cell death in the retina without this being visible when examining the back of the eye.

- requiring the labelling of the photobiological risk group (assessed according to Standard NF ISO 62471) for domestic lighting as well as for LED objects;
- restricting the sale of LED systems (lamps, luminaires, objects and especially toys) to the general public to those in risk group 1 or lower;
- harmonising the regulatory framework by amending the regulations specific to LED systems other than lamps and luminaires, in order to take into account the photobiological risk, in particular:
    - Directive 2009/48/EC on the safety of toys;
    - UNECE[25] (United Nations Economic Commission for Europe) Regulations R112 and R113 on prescriptions for light sources from vehicles.
- limiting the luminance of vehicle lights (without necessarily reducing the overall flux and therefore the range of vision);
- taking into account, in the regulations, the specific characteristics of bare LED strips and matrices in devices sold to the general public (bare LED aggregates on the same base);
- establishing, at European level, limits for temporal light modulation, in order to limit the biological and health effects associated with the light emitted by LED lamps and luminaires;
- amending the current regulations in order to take into account the risks associated with temporal modulation, in particular:
    - Directive 2006/25/EC of the European Parliament on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (artificial optical radiation);
    - the UNECE regulations, requiring a minimum modulation frequency of around 2 kHz when the lamps (front lamps and rear lamps) of vehicles are used in pulse width modulation[26] (PWM) mode. This recommendation will limit the visibility of the phantom array effect, which is a source of proven visual disturbances;
- introducing the option to automatically lower the colour temperature (switch to warm white) and brightness of mobile telephone and tablet screens before bedtime.

Research recommendations

While numerous data are available on the health effects of light, especially blue light, the scientific data are still incomplete with regard to the specific effects of LEDs depending on their geometry and spectral quality. Therefore, the CES insists on the need to improve the quantitative assessment of the impact of a general shift to LED technology on human health and the environment.

The CES encourages the implementation and intensification of research into light-induced circadian rhythm disruption and the resulting effects on vigilance, sleep, mood, well-being, cognition and health. Two aspects for which there is still little documentation should particularly be taken into account in humans and diurnal animal models:

- the impact of the maternal light environment on foetal development;

[25] The UNECE Sustainable Transport Division provides secretariat services to the World Forum for Harmonization of Vehicle Regulations.

[26] PWM mode is a duty-cycle modulation. Light is modulated at a fixed frequency and the change in the duty cycle modifies the average light intensity.

- for children and adolescents, the impact of the light environment, depending on the period (day, night), on biological rhythm synchronisation and health, particularly considering higher light transmission due to a clearer lens and a more open pupil.

Since potentially beneficial effects of a strong light contrast between daytime and night-time have been described in the scientific literature, it will be necessary to:

- confirm the effects of exposure to sufficient daytime light intensities on quality of life, sleep, well-being and health, especially for people with circadian rhythm disorders (elderly subjects, hospitalised patients, people with dementia, etc.);
- improve knowledge of the ability of exposure to blue light in the morning to correct circadian desynchronisation and assess the associated ocular risks;
- for night workers, study the relevance of favouring exposure to certain wavelengths depending on the time of day, to promote vigilance on the one hand and recovery on the other hand while minimising the negative side effects.

The CES recommends improving the assessment of the risk of eye dryness and ocular diseases occurring in relation to exposure to light in the phototoxic range, especially in the long term. Special attention should be paid to certain susceptible population groups (children, adolescents, people with ocular diseases, aphakic individuals, etc.). The CES also recommends studying the factors that may be involved in the phototoxicity of light, such as the time of exposure, the possible associated temporal modulation, and risk factors related to ocular diseases. It would also be advisable to study to what extent phototoxicity results obtained in rodents can be extrapolated to humans.

Since temporal light modulation appears to be a major flaw of certain LEDs and LED systems, the CES recommends improving knowledge of its visual, biological and health effects. In particular, it recommends conducting:

- studies to better identify inter-individual variations in sensitivity to temporal contrasts and better understand the prevalence and incidence of effects related to temporal light modulation in the general population;
- studies enabling the risk of accidents arising from exposure to a stroboscopic effect or phantom array effect to be quantified.

The various health effects of LEDs mentioned above make it necessary to improve the assessment of exposure in populations. The CES recommends taking precise measurements of luminance distribution, spectral energy distributions and temporal modulation for a wide range of LED devices to which the population is exposed.

The CES recommends better taking account of the environmental impact of a general shift to LED technology, by improving knowledge regarding the effects of light pollution on fauna and flora and the ecosystem as a whole.

Lastly, the CES recommends considering the entire life cycle of LEDs, in particular:

- accessing detailed data on the products used in the manufacture of LEDs (raw materials, manufacturing processes) and those released into the air, water and soil during the manufacture of LEDs;
- documenting end-of-life for LEDs: recovery and sorting of used products, recovery of raw materials, recycling of certain LED components, treatment of final waste.

4. AGENCY CONCLUSIONS AND RECOMMENDATIONS

ANSES endorses the conclusions and recommendations of its Expert Committee on "Physical agents, new technologies and development areas", set out in Section 3 of this Opinion.

An initial expert appraisal on the health effects of exposure to LED lamps was published by ANSES in 2010, when this technology was just starting to be deployed on a large scale and other lighting technologies (incandescent in particular) were beginning to be gradually withdrawn from the market at the same time. This expert appraisal had underlined the retinal toxicity of the blue light contained in LED lighting systems and their high capacity for glare.

Long contained mainly in specific applications (signage, electronic objects, etc.), LED technology is increasingly being used in automotive vehicles (lamps, etc.) and has become essential in domestic and public lighting as well as in light objects and screens (telephones, computers, televisions). The artificial light to which the population and its environment are exposed, which was previously rich in yellow-orange shades, is now richer in blue light than it was 10 years ago due to the now predominant use of LEDs in industrial and consumer applications.

This expert appraisal sought to update the state of knowledge since 2010 on the various health effects likely to be associated with exposure to blue-rich light as well as other characteristics of LED lighting. To do so, it used a methodology for assessing the levels of evidence associated with the health effects in question.

Moreover, due to the lack of literature data dealing with the population's exposure to LED technologies, the Agency financed specific measurement campaigns, in particular to describe the type and quantity of light emitted by LED systems used on a daily basis (lamps, objects featuring LEDs, vehicle headlamps, computer, tablet and mobile telephone screens, etc.).

The new scientific data examined corroborated the findings of 2010 relating to phototoxicity and enabled the experts to establish that the retinal phototoxicity of acute exposure to blue-rich light is proven. The long-term contribution of blue-rich light to the occurrence of age-related macular degeneration (ARMD) is also proven.

The Agency confirms that some of the tested lighting devices (hand-held lamps, vehicle lamps, LED spotlights, LED matrices, etc.) can produce high levels of glare.

In 2010, the Agency had suggested the possibility of biological clock disruption induced by exposure to LEDs. The update of the expert appraisal showed that the disruption of circadian rhythms (biological clocks) induced by exposure to blue-rich LED light in the evening or at night is proven. Children and adolescents, exposed from a very early age to screens in particular (tablets, game consoles, mobile telephones, etc.), constitute a particularly susceptible population group.

Regarding the temporal modulation of the light emitted by LEDs, the data examined showed that a high proportion of the tested LED lamps had degraded performance (high temporal modulation). Although the health risks associated with exposure to this modulation have not been determined, some people (children, adolescents, young adults, machine operators and vehicle drivers, etc.) may be more susceptible to the potential health effects of this light modulation: headaches, visual fatigue, risk of accidents, etc.

Regarding the impacts of light on the environment and biodiversity in particular, the available studies show an increase in mortality and a decline in the diversity of the animal and plant species studied in environments lit at night, including by LED lighting systems.

The Agency's recommendations

Advance knowledge

Regarding the assessment of risks related to exposure to LEDs, ANSES underlines the need to better quantify the risk levels associated with the identified effects. It thus recommends initiating additional research aiming to:

- improve knowledge of exposure for the general population, workers and the environment;
- better characterise the health effects associated with the temporal modulation of the light from LEDs in addition to long-term phototoxicity;
- clarify the exposure-response relationship between exposure and the occurrence of health effects (especially those involving circadian disruption, phototoxicity, etc.).

Lastly, to respond to the potential health effects associated with exposure to LED phototherapy devices, the Agency advises the public authorities to have a risk-benefit assessment of these devices undertaken by a competent organisation.

Adapt the regulations and improve information

In light of the newly available experimental data concerning phototoxicity mechanisms, ANSES underlines the need to update the exposure limits (ELs) for blue light, especially to take into account the specific situation of children, whose eye lens filters blue light much less efficiently than that of adults and elderly people. These ELs are used to verify the compliance of LED systems with the essential health and safety requirements set out in European directives.

Considering the results of the risk assessment undertaken as part of the collective expert appraisal, ANSES recommends adapting the regulatory framework applicable to LED systems, in order to:

- restrict the sale of LED objects to the general public to those in photobiological risk group 0 or 1;
- limit the light intensity of vehicle lamps, while guaranteeing road safety;
- establish, at European level, limits minimising the temporal modulation of the light emitted by all light sources (lighting systems, screens, LED objects), all while improving the characterisation of the related health effects.

Pending changes to the regulations, ANSES recommends raising awareness in the population and encouraging people, children in particular, to limit their exposure to:

- blue-rich light before bedtime and during the night (LED screens: mobile telephones, tablets, computers, etc.);
- blue-rich lighting, i.e. “cool white” lamps and luminaires, by favouring indirect lighting or using diffusers;
- direct light from LED objects in risk group 2 or higher (hand-held lamps, toys, vehicle lamps, etc.).

ANSES also draws attention to the varying levels of effectiveness of the current devices providing protection against the phototoxicity of blue light (treated lenses, protective glasses, specific screens, etc.). It also notes their lack of significant action on the preservation of circadian rhythms for which, in the case of LED screens, exposure can only be limited by reducing the brightness and colour temperature of screens. It encourages the establishment of standards defining performance criteria for personal protective equipment in relation to blue light.

Regarding the environment and biodiversity, although it is difficult to assess the overall health and environmental impacts of the transition from current lighting technologies to LEDs, ANSES recommends strengthening the prevention of light pollution. The Agency thus underlines the need to enforce the current regulations and adapt them, in particular by limiting the number of points of light and reducing light pollution, all while taking care to ensure the safety of people.

Dr Roger Genet

KEYWORDS

Lumière bleue, LED, éclairage artificiel, phototoxicité, rythmes circadiens, modulation temporelle de la lumière, biodiversité, pollution lumineuse.

Blue light, LED, artificial lighting, phototoxicity, circadian rhythms, temporal light modulation, biodiversity, light pollution.

ANNEX

Table 1: Main physical quantities used in the area of lighting

Quantity	Unit	Description
Luminance (*L*)	Candela per square metre (cd/m^2)	Amount of visible light emitted by a light surface or an object, for example the luminance of a computer screen: around 200 cd/m^2
Illuminance *(E)*	Lux (lx)	Amount of light received on a surface. For example: 500 lux on a desk
Colour temperature *(T)*	Kelvin (K)	Specifies the shade of a white light: a “warm” light will have a low temperature (yellowish colour, $T < 3000$ K), while a “cool” light will have a high temperature (bluish colour, $T > 5000$ K)
Colour rendering index (CRI)	No unit	Ability of a light to faithfully render the colour of objects. A highly faithful light will have a CRI of 100, while a moderate-quality light will have a CRI below 80
Luminous efficacy	Lumens per watt (lm/W)	Defines the energy efficiency of a light source

Maisons-Alfort, 19 October 2010

The Director General

OPINION
OF THE FRENCH AGENCY FOR FOOD, ENVIRONMENTAL AND OCCUPATIONAL HEALTH & SAFETY

in response to the internally-solicited request entitled "Health effects of lighting systems using light-emitting diodes (LEDs)"

ANSES's public health mission involves ensuring environmental, occupational and food safety as well as assessing the potential health risks they may entail.

It provides the competent authorities with the necessary information concerning these risks as well as the requisite expertise and technical support for drafting legislative and statutory provisions and implementing risk management strategies (Article L.1313-1 of the French Public Health Code).

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1. PRESENTATION OF THE QUESTION

The European Eco-design Directive (2005/32/EC), known as "EuP" for Energy-using Products, aims to improve the energy efficiency of certain consumer goods. This Directive was transposed into national law by the Member States of the European Union in 2007 and came into force between 2008 and 2010.

On 18 March 2009, in application of the EuP Directive, the European Commission decided in favour of a gradual ban on the sale of the most energy-consuming lamps, scheduled for implementation from 1 September 2009 to 1 September 2016. Compact fluorescent or "low-energy" lamps, or other sources of energy-saving lighting such as light-emitting diodes, are destined to replace them eventually.

Light-emitting diodes are light sources that are currently undergoing rapid technological and financial development. They have been used for several years in electronics as weak, monochromatic light sources for indicator or warning lights and are now commonly used as normal light sources in lighting systems.

The first visible spectrum LED was created in 1962 and emitted only very low intensity light. The blue diode was invented in 1990, followed by the development of the white diode that made it possible for new and important applications to be adopted, mainly for lighting, television and computer screens. The first white LEDs appeared on the market gradually and are now increasingly powerful[1] (consuming from a few Watts to a few tens of Watts). The most widely-used procedure for producing white light couples a blue LED and a yellow phosphor.

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[1] Source – ADEME: "Low-power LEDs (i.e. lower than 1 Watt) are used as indicator lights on domestic appliances, for example. High-power LEDs (i.e. higher than 1 Watt) can withstand stronger currents (up to 1500 mA) and supply more light (135 lm/W)".

The French company OSYRIS[2] expressed concern in a letter addressed to the French Institute for Public Health Surveillance (InVS), dated 27 December 2007, about the possible impact on the retina of light from LEDs. The letter underlined the possible link between exposure of the eye to shortwave radiation, close to ultraviolet light (characteristic of the light spectra of LEDs) and the risk of macular degeneration, an eye disease. The InVS forwarded the OSYRIS letter to the French Agency for Environmental and Occupational Health Safety (AFSSET[3]) in a letter dated 14 January 2008.
Simultaneously, the question of the impact of LEDs on occupational health was raised during informal discussions between AFSSET and the Directorate-General for Labour (DGT), the latter having recently been alerted by projects for the use of indoor LED lighting for buildings. The development of this type of lighting solution is likely to accelerate mainly due to cost considerations, for applications involving both general and professional populations.

2. Scientific context and applicable standards

In France, lighting accounts for 10% of total electricity consumption, or 350 kWh per year and per household[4]. LEDs consume far less energy than other types of lighting and have much longer lifetimes.
The luminous efficacy of incandescent lamps is of the order of 10 to 15 lumens[5] per Watt (lm/W), for halogen lamps it is from 15 to 30 lm/W and for compact fluorescent lamps it is in the range of 50 to 100 lm/W. Some of the latest LEDs achieve an efficacy of up to 100 to 150 lm/W, with predictions in the region of 200 lm/W for 2020[6].
There is as yet no standard definition of the lifetime of an LED. Estimates for current LEDs, however, predict considerable lifetimes, up to 50,000 hours[7], or 50 times longer than incandescent lamps and 3 to 5 times longer than compact fluorescent lamps.
The technology behind LEDs, which have certain advantages over other types of lighting, (energy efficiency and lifetime), is constantly changing. They are used in a wide variety of fields: public, domestic and workplace lighting, sports facilities, as indicator lights (toys, signage, etc.), vehicle lights and light therapy products. However, the quality of the light (colour temperature[8], colour rendering index[9]) emitted by these lamps does not always achieve the same level of performance as other sources of lighting.

There are currently three methods for creating a light-emitting diode that emits white light:

[2] A French company specialising in lasers and their application in medicine and industry.

[3] The French Agency for Environmental and Occupational Health Safety (AFSSET) and the French Food Safety Agency (AFSSA) merged on 1 July 2010 to create the French Agency for Food, Environmental and Occupational Health & Safety (ANSES).

[4] Source: ADEME 2010.

[5] The lumen is the unit used to quantify luminous flux and expresses the total quantity of light emitted by a source. The candela is the unit used to express the quantity of light emitted in a given direction. The quantity of light received on a surface is expressed in lux.

[6] The theoretical limit for the luminous efficacy of light sources is set at 683 lm/W.

[7] Source: ADEME 2010

[8] The colour temperature of a white light is used to define its hue, which can be warm or cold; lights with warm hues tend towards yellow-orange and have colour temperatures below 3000 K. Higher colour temperatures correspond to "colder" hues.

[9] The Colour Rendering Index (CRI) runs from 0 to 100 and defines the aptitude of a light source to reproduce the different colours of the objects on which its light falls, compared to a reference source. Sunlight has a CRI of 100, while some low-pressure sodium-vapour lamps (used in road tunnels, for example) have a CRI of 20. In shops, schools and offices, the CRI should always be greater than 80.

- *1*: by combining a short wavelength-emitting diode (blue) with a yellow luminophore;
- *2*: by using a diode emitting in the near-ultraviolet, coupled with one or more luminophores;
- *3*: by using at least three visible wavelength-emitting diodes that combine to give a white light.

At the moment, the most economic and widely used is Method 1. The conclusions presented in this Opinion concern LEDs using this first method. They cannot therefore be extrapolated to cover LEDs created using other methods for producing white light.

Strong components in the blue part of the spectrum of light emitted by the LEDs, as well as the associated intensity of the radiation, raise the issue of new health risks related to these sources of lighting.
Some scientific studies [Dawson *et al.*, 2001[10], Ueda *et al.*, 2009[11]], based on laboratory experiments with blue LEDs conducted on monkeys, give reason to suspect a danger for the retina related to exposure to light-emitting diodes.
A study by Altkorn [Altkorn *et al.*, 2005] investigated the health impact of LEDs by reviewing the current debate on the position of LEDs with regard to standards: should they be rated, in terms of photobiological risk, according to the same standards as those applied to lasers or according to the standards applied to incoherent light sources? Indeed, until 2008, LEDs were considered in the same way as laser sources. Since January 2008, the NF EN 60825-1 'Lasers' standard has recommended using, for LED devices, the CIE[12] S009:2002 'Photobiological safety of lamps and lamp systems' photobiological safety standard concerning incoherent sources, which became a French standard (NF EN 62471) in December 2008.

3. Organisation of the expert appraisal

At its meeting on 23 September 2008, the AFSSET Expert Committee (CES) on "Physical agents, new technologies and development areas" discussed the impact of LEDs on human health. The CES judged the subject to be a matter of some concern and decided that the Agency should investigate the question on its own initiative.
The Scientific Council issued an Opinion, on 29 September 2008, in favour of AFSSET investigating on its own initiative the health consequences of exposure to lighting systems using light-emitting diodes. The expert appraisal was entrusted to the CES on "Physical agents, new technologies and development areas". At the suggestion of the CES, the Agency set up a Working Group with a mandate to carry out the expert appraisal. After a public call for applications from 12 December 2008 to 12 March 2009, the Working Group was formed with experts in ophthalmology, dermatology, lighting and optical radiation physics.
The Working Group convened ten times in plenary session between 13 May 2009 and 26 March 2010. It also interviewed French and international scientific experts, and representatives of the French Lighting Association (*Association Française de l'Eclairage* – AFE) in order to obtain all relevant information for carrying out the investigation. To conduct its appraisal, the Working Group carried out a broad review of the international

[10] Dawson, *et al*, *Local fundus response to blue (LED and laser) and infrared (LED and laser) sources*, Exp. Eye Res., 73(1):137-47 2001
[11] Ueda *et al*, *Eye damage control by reduced blue illumination*, Exp. Eye Res, 89(6):863-8. 2009
[12] CIE: International Commission on Illumination

scientific literature alongside its interviews with leading scientists. At the group's request, the French Environment and Energy Management Agency (ADEME) submitted a written contribution on the French and European market for lighting systems and the recycling of lamps.

The bibliographical analysis carried out by the 'LED' Working Group was as thorough as possible. The scientific studies taken into account in the report were all published in international, English-language, peer-reviewed journals.

The methodological and scientific aspects of the work were regularly submitted by the Working Group to the CES. The report produced by the Working Group takes account of observations and additional information supplied by the members of the CES.

This expert appraisal was therefore conducted by a group of experts with complementary skills. It was carried out in accordance with the French Standard NF X 50-110 "Quality in Expertise Activities" to ensure compliance with the following points: competence, independence and transparency, while at the same time ensuring traceability.

4. RESULT OF THE COLLECTIVE EXPERT APPRAISAL

The work of the experts was based on five main themes:

- a review of the current situation regarding lighting;
- a presentation of the technology behind LEDs;
- an analysis of the way light interacts with biological systems (the eyes and skin);
- a summary of the standards currently applicable to LEDs;
- an analysis of the potential health effects of LEDs.

A special feature of this study concerned the calculations and measurements conducted by the members of the Working Group in their respective laboratories (CSTB[13], INRS[14], LNE[15]) to assign some examples of LED lighting systems to specific Risk Groups in accordance with the photobiological standard applicable to LEDs (NF EN 62471).

The CES on "Physical agents, new technologies and development areas" adopted the collective expert appraisal together with its conclusions and recommendations at its meeting on 3 June 2010 and informed the Agency's General Directorate.

5. OPINION AND RECOMMENDATIONS

This Opinion is based on the collective expert appraisal of the 'LED' Working Group and the CES on "Physical agents, new technologies and development areas". It restates the conclusions and recommendations in the report and the summary of the collective expert appraisal by the CES, and makes supplementary proposals for risk management.

CONCLUSIONS OF THE COLLECTIVE EXPERT APPRAISAL

As a result of the analysis of the existing scientific literature and the information collected during the additional hearings, potential health issues related to the use of LEDs were identified. Those of greatest concern, due to both the severity of the corresponding

[13] CSTB: *Centre Scientifique et Technique du Bâtiment* (French Scientific and Technical Centre for Construction)

[14] INRS: *Institut National de Recherche et de Sécurité pour la prévention des accidents du travail et des maladies professionnelles* (National Research and Safety Institute)

[15] LNE: *Laboratoire National de Métrologie et d'Essais* (the Metrology Institute and Reference Laboratory for French Industry)

dangers and the probability of their occurring as a result of the increasingly widespread use of LEDs, relate to the photochemical effects of blue light on the eye and the glare phenomenon. They result from:

- the spectral imbalance in LEDs (high proportion of blue light in white LEDs)
- the very high luminance[16] of LEDs (high brightness density per surface unit emitted by these very small sources).

Risks related to blue light

The photochemical risk is associated with blue light, and depends on the accumulated dose to which the person has been exposed, which is generally the result of low intensity exposure repeated over long periods. There is a high level of proof of such a risk.

Evidence from human observation and experimental studies on cell cultures and various animal species has converged to demonstrate the specific toxicity of shortwave (blue) light to the retina. Blue light is therefore recognised as being harmful and dangerous to the retina, as a result of cellular oxidative stress.

There is a strong suspicion that blue light aggravates age-related macular degeneration (ARMD), based on converging observations on experimental models. Epidemiological studies carried out up to now have proved inconclusive as a result of their lack of precision in assessing exposure and the data concerning individual predisposition.

Three population groups have been identified as being either especially sensitive to the risk or highly exposed to blue light:

- children (because of the transparency of their crystalline lens) and both aphakics (with no crystalline lens) and pseudophakics (with artificial crystalline lenses) who consequently either cannot or can only insufficiently filter short wavelengths (particularly blue light);
- population groups which are already light-sensitive: patients suffering from certain eye (e.g. ARMD) and skin diseases, patients taking photosensitising substances, etc., for whom blue light may aggravate their condition;
- population groups highly exposed to LEDs (certain categories of workers: those installing lighting systems, theatre and film industry professionals, etc.) which are subjected to high-intensity lighting, and are therefore likely to be exposed to large quantities of blue light.

Risk related to glare

In indoor lighting, it is generally agreed that luminance higher than 10,000 cd/m²[17] causes visual discomfort irrespective of the position of the lighting unit in the field of vision. Because the emission surfaces of LEDs are highly concentrated point sources, the luminance of each individual source can be 1000 times higher than the discomfort level. The level of direct radiation from this type of source can therefore easily exceed the level of visual discomfort, far more than is the case with "traditional" lighting (halogen and low-energy lamps).

[16] Luminance is the unit used to quantify the light emitted by a non-point source, per surface unit, in other words, the light density. It is expressed in candela per square metre (cd/m^2) and defines the brilliance of a light source as perceived by the human eye. It can therefore be used to measure glare.

[17] This value is generally quoted as being the upper limit beyond which subjects experience discomfort from glare in indoor lighting. The French NF X 35 103 standard: *Principes ergonomiques visuels applicables à l'éclairage des lieux de travail* (Ergonomic principles applicable to the lighting of workplaces for visual comfort) mentions admissible luminance of 2000 cd/m² for a small source on the working surface.

Other risks related to exposure to LEDs
The experts considered other potential risks such as disruption of circadian rhythms (biological clock) and stroboscopic effects (visually imperceptible fluctuation of the intensity of light).
There is very little risk of thermal effects, associated with burns to the retina and generally resulting from short-term exposure to very intense light, from the normal uses of LEDs.

LED technology can lead to the emission of electromagnetic fields insofar as such systems are combined with a power and voltage transformation device. Because of the low levels of exposure generated, the Working Group did not undertake a specific study of potential associated risks.

Assessment of the photochemical risks of LEDs
There is currently little information about human exposure to lighting, whether for systems using LEDs or other types of light sources. The Working Group was only able to present quantified risk assessments for exposure to blue light, under the terms of the NF EN 62471 standard for photobiological safety. This standard, which concerns the photobiological safety of lamps and devices using lamps, recommends exposure limits for radiation from these light sources. It provides a system of classification based on radiance and actual irradiance. The standard considers all of the photobiological hazards that may affect the eye (thermal and photochemical hazards) for ultraviolet to infrared wavelengths and defines four risk groups: Risk Group 0 (no risk), Risk Group 1 (low risk), Risk Group 2 (moderate risk), Risk Group 3 (high risk).

Due to the lack of information on exposure, the Working Group asked certain national laboratories to take radiance measurements. These readings were taken as an exploratory measure and were not intended to be exhaustive. Furthermore, as the standard was not designed to cover LED systems, these experiments are inadequate for a rigorous assessment of the photobiological risks related to LEDs, and are intended simply to determine the risk group of these new lighting systems in comparison to those for traditional lighting.

The radiance[18] measurements show that certain LEDs currently on sale to the general public and potentially used in domestic lighting situations, for signage and guide lights, fall into Risk Group 2, whereas all the other light sources currently on sale to the public fall into either Risk Groups 0 or 1. The safe exposure limit times implied by placing these items in Group 2 vary from a few seconds for certain royal blue LEDs to a few tens of seconds for certain cold white LEDs.

Furthermore, it seems that the NF EN 62 471 standard is unsuited to lighting systems using LEDs:

- the maximum exposure limits defined by the ICNIRP[19] and used to define the Risk Groups are not appropriate for repeated exposure to blue light as they were calculated for exposure of one 8-hour day and do not take into account the possibility of exposure over an entire lifetime;
- it contains ambiguities concerning the measurement protocols for allocating Risk Groups: the same LED could be assigned to different Risk Groups if considered

[18] The readings taken were of the radiance (which depends on the wavelength) weighted by the degree of phototoxicity of the blue light.
[19] ICNIRP: International Commission for Non-Ionising Radiation Protection.

individually or if integrated in a lighting system, as the evaluation distance imposed by the standard could be different;

- it does not take into account the sensitivity of certain specific population groups (children, aphakics, pseudophakics, etc.).

It is important to emphasise that other widely-used sources of lighting, particularly high-pressure gas discharge lamps (metal-halide lamps for outdoor lighting), are also in Risk Group 2. However, this last example is intended for clearly identified uses and can only be installed by professionals who are required to limit the exposure level for the population.
With the arrival on the domestic lighting market of LEDs, light sources falling into Risk Group 2 thus become available to the general public, without details of the risk incurred appearing on the labelling.
The methodology adopted in this report enabled the experts to evaluate the photobiological risks related to LEDs producing a luminous flux close to the mean of LEDs found on the market at the time of writing this document. At present and in the next few years it seems unlikely that technological progress will yield LEDs that can be classified in Risk Group 3. On the other hand, with the increase in both luminous flux and radiance, there is no doubt that more and more LEDs will fall into Risk Group 2.

Compliance with standards concerning glare

With regard to glare-related risks, the standards lay down certain references[20] covering visual ergonomics and safety. In LED lighting systems available on the market, the LEDs are often directly visible in order to avoid attenuating the level of brightness produced. This could lead to non-compliance with the requirements laid down in the standards.

RECOMMENDATIONS

The purpose of the following recommendations is to protect both the general public and working populations exposed to LED lighting in the workplace.

Concerning regulations and standards

Directive 2001/95/EC concerning general product safety applies to all products classified in sectors not covered by specific legislation (toys, etc.). The “EC” label, which is mandatory on all electrical devices sold in Europe, is a ‘self-declaration’, indicating that the manufacturer considers that the product complies with all the EU conditions for use of the label.
Where LED lighting is concerned, EC labelling ensures that the product complies with the essential requirements of the following European Directives: “Low voltage” (2006/95/EC), “Electromagnetic compatibility” (2004/108/EC) and “Eco-design” (for Energy-using Products) (2005/32/EC), concerning product safety, power consumption and emissions (noise, vibrations, radiation, electromagnetic fields), recycling potential, etc.
To satisfy these requirements, products must comply with specific standards, known as harmonised standards, published in the Official Journal of the European Union (e.g. NF EN 62311 concerning electromagnetic fields and NF EN 62471 concerning the photobiological safety of lamps). Furthermore, the Government Decree 2010-750 of 2 July 2010,

[20] The text refers to the French standard NF X 35-103: ‘*Ergonomie : Principes d´ergonomie visuelle applicables à l´éclairage des lieux de travail*’ (Ergonomics: Ergonomic principles applicable to the lighting of workplaces for visual comfort), the European standards NF EN 12464-1: ‘Lighting of workplaces – Part 1: indoor workplaces’, NF EN 12464-2: ‘Lighting of workplaces – Part 2: outdoor workplaces’, and the series of standards NF EN 13201: ‘Street Lighting’ and NF EN 12193: ‘Sports Lighting’.

transposing Directive 2006/25/EC into French law, stipulates the measures to be applied to ensure that workers are protected against the risks of exposure to artificial optical radiation.

Considering:

- the health risks related to blue light emitted by LED lighting systems falling into Risk Groups higher than 1 (according to the NF EN 62 471 standard);
- the significant risks of glare induced by LED lighting systems;
- the need to protect the general and working population from excessive radiance produced by LED systems and any risk of glare associated with the different uses of these new lighting systems;
- the marketing of LED products intended for light therapy, comfort or well-being purposes;

ANSES recommends:

- limiting the sale of LEDs for domestic use or for the general public to LEDs falling into Risk Groups equal to or less than 1 (when assessed at an observation distance of 200 mm);
- regulating the installation of LED lighting systems falling into Risk Groups greater than 1, by limiting them to professional uses, under conditions in which risks can be prevented;
- encouraging manufacturers and integrators of LED lighting systems to:
  - design lighting systems in which beams of light emitted by LEDs cannot be seen directly, to avoid glare. In particular, ANSES recommends the use of optical devices that reduce the intensity of light perceived directly or by reflection and to make the sources of LED light more diffuse;
  - take account of the progressive wear of phosphor layers in white LEDs, which in time could lead to devices moving to a higher photobiological risk group.
- assessing the safety and compliance of devices for light therapy, comfort or well-being and regulating their use.

Considering:

- that the standards in force for designing LED-based lighting installations are not always applied by professionals (electricians, lighting technicians and designers);
- that current photobiological safety standards seem unsuited to lighting systems using LEDs;

ANSES recommends:

- obliging professionals designing lighting systems using LEDs to apply all standards concerning the quality of lighting:
  - NF X 35-103 ('Ergonomics: Ergonomic principles applicable to the lighting of workplaces for visual comfort');
  - NF EN 12464-1 ('Lighting of workplaces – Part 1: indoor workplaces');
  - NF EN 12464-2 ('Lighting of workplaces – Part 2: outdoor workplaces');

    - the series of NF EN 13201 standards (‘Street Lighting’);
    - NF EN 12193 (‘Sports Lighting’).
- adapting the NF EN 62 471 standard (‘Photobiological safety of lamps and lamp systems’) to cover lighting systems using LEDs. It is essential to make it easier for manufacturers to take this standard into account and remove any ambiguity concerning how it should apply to LED systems. ANSES therefore recommends:
    - specifying in the NF EN 62 471 standard the conditions for measuring and evaluating LED systems;
    - publishing a guide to applying this standard, geared exclusively to LED systems;
    - determining the risk group for the worst case of observation (at a distance of 200 mm from the system) that will thus constitute the most unfavourable risk group;
    - adapting the standard to cover children and aphakic or pseudophakic individuals, taking into account the phototoxicity curve of the relevant type of light published by the ICNIRP;
    - considering proposing sub-groups for each risk group that would allow the risk to be assessed more precisely as a function of exposure time;
    - in the case of risk groups greater than 0, evaluating safe distances (at which observation corresponds to Risk Group 0) and indicating these explicitly on products intended for consumers (for devices for the general public) or for professionals responsible for installing lighting systems.
- introducing photobiological safety requirements in all safety standards concerning LEDs. This mainly concerns the following standards:
    - the NF EN 60 598 series of standards ‘Luminaires’;
    - NF EN 62 031: ‘LED modules for general lighting. Safety specifications’;
    - IEC 62 560: ‘Self-ballasted LED lamps for general lighting services by voltage > 50 V – Safety specifications’;
    - draft IEC standard 62 663-1 ‘Non-ballasted single capped LED lamps for general lighting – safety requirements’.

Concerning use, information and traceability

ANSES recommends that consumer information about health risks related to the use of LED lighting systems be made available immediately pending the implementation of an appropriate regulatory framework.

Considering:

- the proven risk resulting from acute exposure to blue light and the uncertainty surrounding the effects of chronic exposure at low doses, together with the uncertainty concerning the effects on the biological clock and diminished pupil contraction;
- that certain populations are sensitive to light in general (children, aphakics, pseudophakics, patients suffering from certain eye and skin diseases, patients taking photosensitising treatments, etc.);

ANSES recommends:

- avoiding the use of light sources emitting cold white light (light with a strong blue component) in places frequented by children (maternity wards, nurseries, schools, leisure centres, etc.) or in the objects they use (toys, electronic display panels, game consoles and joysticks, night lights, etc.);
- informing patients taking photosensitising drugs about the risks related to exposure to light with a strong blue component.

Considering:

- that there are populations of workers likely to be exposed to bright LED lighting systems;

ANSES recommends:

- developing appropriate means of protection (such as safety goggles specifically to protect against exposure to LEDs) for workers highly exposed to LED lighting systems.

Considering:

- the lack of information available to the public concerning the LED lighting systems on the market;

ANSES recommends:

- ensuring that manufacturers and integrators of LEDs carry out quality controls and qualify their products with regard to the different Risk Groups;
- setting up a clear, easy-to-understand labelling system for consumers, particularly concerning the technical characteristics of the lighting and any potential health effects;
- mandatory indication of the photobiological safety Risk Group on the packaging of LED products, after assessing the product at a distance of 200 mm. For light sources falling into Risk Group 1, the labelling should also indicate the safety distance beyond which the risk moves down to Group 0;
- mandatory indication of the photobiological safety Risk Group for all types of lighting.

CONCERNING STUDIES AND RESEARCH THEMES

Considering the lack of data about exposure of the general and working populations to artificial light, ANSES recommends:

- enriching the available documentation on exposure of the population to artificial light in both occupational and general environments;
- defining a suitable index for evaluating the intensity of glare produced by an LED source, as the Unified Glare Rating used for other types of lighting is unsuitable for LEDs, which are sources of low-angle light.

Concerning studies and research on the health effects of LED lighting systems, ANSES recommends:

- developing clinical research to define maximum exposure limits for blue light and, for this purpose:
  - studying the cumulative medium- and long-term effects of exposure to blue light;
  - carrying out prospective and retrospective studies of populations undergoing light therapy with the use of blue LEDs;
- undertaking research to improve characterisation of the effects of artificial light, and in particular light emitted by LED systems, on biological rhythms. ANSES therefore recommends:
  - further studies to improve characterisation of the spectra of action of the mechanisms by which light regulates the human biological clock;
  - quantifying the impact of exposure to cold artificial lights on circadian rhythms and pupil contraction;
  - in general, studying how health is affected by light pollution (linked with possible disruption of the biological clock) and systematic installation of LED lighting systems;
- studying the triggering or aggravation of photodermatoses caused by LED lighting;
- organising measurement campaigns to characterise the electromagnetic fields generated by LED lighting systems.

Concerning studies and research to be carried out on LED technology to prevent potential health risks, ANSES recommends:

- encouraging research for the development of new emissive materials coupled with optimised luminophores, to obtain a high quality white light, with the highest possible luminous efficacy;
- developing research into the design of lighting units adapted to LEDs with a view to reducing luminance, by applying optical solutions;
- studying the mechanisms that cause the degradation of the phosphor layers in white LEDs, potentially leading to an increase in the amount of blue light emitted.

The Director General

Marc Mortureux

EXPERT COLLECTIVE APPRAISAL:
SUMMARY AND CONCLUSIONS

concerning the internally-solicited request entitled
"Health effects of lighting systems using light-emitting diodes (LEDs)"

This document summarises the work of the Expert Committee and the Working Group

Presentation of the question

The European Eco-design Directive (2005/32/EC), known as "EuP" for Energy-using Products, aims to improve the energy efficiency of certain consumer goods. This Directive was transposed into national law by the Member States of the European Union in 2007 and came into force between 2008 and 2010.
On 18 March 2009, in application of the EuP Directive, the European Commission decided in favour of a gradual ban on the sale of the most energy-consuming lamps, to be implemented from 1 September 2009 to 1 September 2016. Compact fluorescent or "low-energy" lamps, or other sources of energy-saving lighting such as light-emitting diodes, are destined to replace them eventually.
Light-emitting diodes are currently undergoing rapid technological and financial development. They have been used for several years in electronics as weak, monochromatic light sources for indicator or warning lights and are now commonly used as normal light sources in lighting systems such as traffic lights, portable lighting, vehicle lights and domestic room-lighting.

The first visible-spectrum LED was created in 1962 and emitted only very low intensity light. The blue diode was invented in 1990, and was followed by the development of the white diode that made it possible for new and important applications to be adopted, mainly for lighting and for television and computer screens. The first white LEDs appeared on the market gradually and have now become increasingly powerful[1] (attaining several Watts). The most widely-used procedure for producing white light couples a blue LED and a yellow phosphor.

The French company OSYRIS[2] expressed concern in a letter addressed to the French Institute for Public Health Surveillance (InVS), dated 27 December 2007, about the possible impact on the retina of light from LEDs. The letter underlined the possible link between exposure of the eye to shortwave radiation, close to ultraviolet light (characteristic of the light spectra of LEDs) and the risk of age-related macular degeneration, an eye disease. The InVS forwarded the OSYRIS letter to the French Agency for Environmental and Occupational Health Safety (AFSSET) in a letter dated 14 January 2008.
Simultaneously, the question of the impact of LEDs on occupational health was raised during informal discussions between AFSSET and the Directorate-General for Labour (DGT), the latter having recently been alerted by the projected use of indoor LED lighting for buildings. The development of this type of lighting solution is likely to accelerate, mainly due to cost considerations.

[1] Source - ADEME: "Low-power LEDs (i.e. lower than 1 Watt) are used as indicator lights on domestic appliances, for example. More energy-consuming LEDs (i.e. higher than 1 Watt) can withstand stronger currents (up to 1500 mA) and supply more light (135 lm/W)".
[2] A French company specialising in lasers and their application in medicine and industry.

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Scientific context and applicable standards

In France, lighting accounts for 10% of total electricity consumption, or 350 kWh per year and per household[3]. LEDs consume far less energy than other types of lighting and last much longer.

The luminous efficacy of incandescent lamps is of the order of 10 to 15 lumens[4] per Watt (lm/W), for halogen lamps it is from 15 to 30 lm/W and for compact fluorescent lamps it is in the range of 50 to 100 lm/W. Some of the latest LEDs achieve an efficacy of up to 100 to 150 lm/W, with predictions in the region of 200 lm/W for 2020[5].

There is as yet no standard definition of the lifetime of an LED. Current LEDs have considerable lifetimes (estimated at up to 50,000 hours[6], or 50 times longer than incandescent lamps and 3 to 5 times longer than compact fluorescent lamps).

The technology behind LEDs, which have certain advantages over other types of lighting, (energy efficiency and lifetime), is constantly changing but the quality of the light (colour temperature[7], colour rendering index[8]) emitted by these lamps is not always as high as for other types of lighting. At present, LEDs have a greater impact on the environment than other types of lighting.

Strong components in the blue part of the light spectrum emitted by LEDs, as well as the intense radiation of what are highly concentrated point sources, raise concern about new potential health risks.

Some scientific studies [Dawson *et al.*, 2001[9], Ueda *et al.*, 2009[10]] based on laboratory experiments with blue LEDs conducted on monkeys, have concluded that the retina is in danger of being damaged by exposure to light-emitting diodes.

Another study by Altkorn [Altkorn *et al.*, 2005] investigated the health impact of LEDs by reviewing the current debate on the position of LEDs with regard to standards: should they be rated, in terms of photobiological risk, according to the same standards as those applied to lasers or according to the standards applied to incoherent light sources? Indeed, until 2008, LEDs were treated in the same way as laser sources. Since January 2008, the NF EN 60825-1 'Lasers' standard has recommended using, for LED devices, the CIE[11] S009:2002 'Photobiological safety of lamps and lamp systems' standard, which became a French standard (NF EN 62471) in December 2008.

Organisation of the expert appraisal

At its meeting on 23 September 2008, the AFSSET Expert Committee (CES) on "Physical agents, new technologies and development areas" discussed the impact of LEDs on human

[3] Source ADEME 2010
[4] The lumen is the unit used to quantify luminous flux
[5] The theoretical limit for the luminous efficacy of light sources is set at 683 lm/W.
[6] Source ADEME 2010
[7] The colour temperature of a white light is used to define its hue, which can be warmer or colder; lights with warm hues tend to yellow-orange and have colour temperatures below 3000 K. Higher colour temperatures correspond to "colder" hues.
[8] The Colour Rendering Index (CRI) runs from 0 to 100 and defines the aptitude of a light source to reproduce the different colours of the objects on which its light falls, compared to a reference source. Sunlight has a CRI of 100, while some low-pressure sodium-vapour lamps (used in road tunnels, for example) have a CRI of 20. In shops, school premises and offices, the CRI should always be greater than 80.
[9] Dawson, et al, *Local fundus response to blue (LED and laser) and infrared (LED and laser) sources*, Exp. Eye Res., 73(1):137-47 2001
[10] Ueda et al, *Eye damage control by reduced blue illumination*, Exp. Eye Res, 89(6):863-8. 2009
[11] CIE: *Commission Internationale de l'Eclairage* (International Commission on Illumination)

health. The CES judged the subject to be a matter of some concern and decided that an internally-solicited request should be made to investigate the issue.

The AFSSET Scientific Council issued an Opinion, on 29 September 2008, in favour of AFSSET itself investigating the health consequences of exposure to lighting systems using light-emitting diodes. AFSSET mandated the CES on "Physical agents, new technologies and development areas" to conduct the expert appraisal. At the suggestion of the CES, the Agency then set up a Working Group to carry out the expert appraisal. After a public call for applications from 12 December 2008 to 12 March 2009, the Working Group was formed with experts in ophthalmology, dermatology, lighting and optical radiation physics.

The Working Group coordinated by AFSSET held 10 plenary sessions between 13 May 2009 and 26 March 2010. It also interviewed leading French and international scientists and also representatives of the French Association of Lighting Professionals (*Association Française de l'Eclairage* – AFE) in order to obtain all relevant information for carrying out the investigation. To conduct its appraisal, the Working Group carried out a broad review of the international scientific literature alongside its interviews with leading scientists. At the group's request, the French Environment and Energy Management Agency (ADEME) submitted a written contribution on the French and European market for lighting systems and the recycling of lamps.

The bibliographical analysis carried out by the 'LED' Working Group was as thorough as possible. The scientific studies taken into account in the report had all been published in international, English-language, peer-reviewed journals.

The Working Group's ongoing appraisal was submitted to the CES at regular intervals, regarding both its methodological and scientific aspects. The report produced by the Working Group takes account of feedback and additional information from the members of the CES.

This expert appraisal was therefore conducted by a group of experts with complementary skills. It was carried out in accordance with the French Standard NF X 50-110 "Quality in Expertise Activities" to ensure compliance with the following points: competence, independence and transparency, while at the same time ensuring traceability.

Result of the collective expert appraisal

The work of the experts was based on five main approaches:

- a review of the current situation regarding lighting;
- a presentation of the technology behind LEDs;
- an analysis of the way light interacts with biological systems (the eyes and skin);
- a summary of the standards currently applicable to LEDs;
- an analysis of the potential health effects of LEDs.

A special feature of this study concerned the calculations and measurements conducted by the members of the Working Group in their respective laboratories (CSTB[12], INRS[13], LNE[14]) to assign some examples of LED-based lighting systems to specific Risk Groups in accordance with the photobiological standard applicable to LEDs (NF EN 62471).

[12] CSTB: *Centre Scientifique et Technique du Bâtiment* (French Scientific and Technical Centre for Construction)
[13] INRS: *Institut National de Recherche et de Sécurité pour la prévention des accidents du travail et des maladies professionnelles* (National Research and Safety Institute).
[14] LNE: *Laboratoire National de Métrologie et d'Essais* (the Metrology Institute and Reference Laboratory for French Industry).

The CES on "Physical agents, new technologies and development areas" adopted the collective expert appraisal, together with the conclusions and recommendations in this summary, at its meeting on 3 June 2010 and informed AFSSET's General Directorate.

Conclusions of the expert appraisal

As a result of its analysis of the existing scientific literature and the information collected during the additional hearings, the Working Group identified potential health issues related to the use of LEDs.

Characteristics of LEDs relevant to risk assessment

The technology behind light-emitting diodes is based on the polarisation of a semiconductor by applying a voltage that causes photons to be emitted in the form of quasi-monochromatic radiation, whose wavelength depends on the semiconductor used. There are no semiconductors capable of emitting white light on their own. There are, however, currently three different ways of producing white light indirectly with an LED. Given the technological constraints and the imperatives concerning electrical efficiency, currently the most widely-used method for producing white light uses a yellow luminophore to transform part of the light from a blue diode.

- ***Spectral imbalance within the blue***

The light spectrum from white LEDs is largely made up of very weak emissions ranging between blue and yellow, but with a high proportion of blue light (a blue spike in the spectrum). These characteristics are highly specific to LEDs, and are not found in other, traditional types of lighting.

- ***High luminance***[15]

LEDs are point sources of light that can be aggregated in lighting units to achieve high luminous flux. Because the emission surfaces of LEDs are highly concentrated point sources, the luminance of each individual source produces very high luminance, at least 1 000 times higher (10^7 cd/m²) than that from a traditional lighting source.

- ***Stroboscopic effect***

Depending on their architecture, the electrical power supplied to LED lighting systems can vary, causing fluctuations in the intensity of the light produced that are barely perceptible to the naked eye. These fluctuations have not yet been characterised in any detail[16]. The frequency of these effects can vary from a few Hertz to several hundred Hertz[17] for those LEDs that have already been studied.

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[15] Luminance (expressed in candela per square meter, or cd/m²) is the unit used to quantify the light emitted by a non-point source, per surface unit. It defines the brilliance of a light source as perceived by the human eye. It can therefore be used to measure glare.

[16] Both the frequency and the modulation rate (the ratio between the amplitude of the fluctuation and the mean value of the light) depend heavily on the type of supply. For a power supply in direct current (rectified and filtered), the frequency of fluctuation is 100 Hz and the modulation rate can attain values from 2% to 20% depending on the quality of filtering. For a Pulse Width Modulation (PWM) power supply, the frequency is of the order of tens of kilo-Hertz and the modulation rate can vary, and may even exceed 50%. Lastly, for the new technology by which LEDs are powered by alternating current, the frequency of fluctuation is 100 Hz and the modulation rate can reach 100 %.

[17] *A Review of the Literature on Light Flicker: Ergonomics, Biological Attributes, Potential Health Effects, and Methods in Which Some LED Lighting May Introduce Flicker*, IEEE Standard P1789 (2010)

Identified health issues

The main health risks associated with LED-based lighting systems result from their high luminance (i.e. the high brightness density per surface unit emitted by these very small sources) associated with the unusual emission spectrum of white LEDs, which have a high proportion of blue (shortwave) light. Other potential effects are raised in the report, such as disturbance to circadian rhythms and stroboscopic effects.

With regard to the many potential health effects identified (photochemical effect, glare, etc.), there is currently little information on human exposure to lighting to enable us to quantify the corresponding health risks adequately, whether for systems using LEDs or other types of light sources.

The Working Group was therefore only able to make quantified risk assessments for exposure to blue light, under the terms of the NF EN 62471 standard for photobiological safety. However, this standard is unsuited to lighting systems using LEDs. In the light of current knowledge, the maximum exposure limits given in this standard do not take account of daily exposure to LEDs.
In the following description of the risks identified by the Working Group, the effects on the eye, both thermal and photochemical, have been dealt with separately from the other effects particularly related to disturbance of circadian rhythms.

<u>Effects on the eye</u>

- **Risk related to the thermal effect of light**

The risk of thermal effects is related to burns to the retina, generally resulting from short-term exposure to a very intense light. This type of danger concerns all wavelengths, from ultraviolet to infrared and the entire visible spectrum. This type of risk, usually associated with lasers, is unlikely in conventional uses of LEDs.

- **Risk related to the photochemical effects of blue light**

The risk of photochemical effects is related to human exposure to blue light and the risk level depends on the accumulated dose to which the person is exposed. It therefore generally involves repeated, low-intensity exposure over long periods.

  - ***Characterisation of the risk***

Evidence from human observation and experimental studies on cell cultures and various animal species has converged to demonstrate the specific toxicity of shortwave (blue) light to the retina.

Blue light can cause photochemical damage. Lesions occur on the outer retina (photoreceptors and cells of the pigment epithelium) and appear after some time has passed. The lesions may not be visible via ophthalmoscopy. Two types of photochemical lesions have been described: those resulting from interaction with visual pigments, which affect the photoreceptors, and those related to interaction with the lipofuscin, which affect the cells of the pigment epithelium.

These interactions lead to the production of high doses of cytotoxic free radicals. The photoreactive pigments (lipofuscin) in the epithelium accumulate with age, increasing the risk of oxidative stress. Cellular death has functional consequences which are particularly significant as they concern the macular region (central vision).

There is no current consensus as to whether accumulated lesions resulting from low doses of oxidative stress could, over long periods, accelerate premature aging of the retina and favour macular degeneration.

At the moment there are no appropriate animal models of age-related macular degeneration (ARMD), as all the models use rodents, whereas only primates and certain birds have maculae. The necessary follow-up times for these species are not compatible with the experimental protocols.
In humans, repeated exposure to very bright sunlight can cause irreversible macular lesions close to those observed in age-related maculopathies, but the epidemiological studies carried out in this field have not all identified exposure to sunlight as a risk factor for ARMD.

Following converging observations on experimental models, there is a strong suspicion that blue light aggravates ARMD. Epidemiological studies in humans have never clearly shown such effects, as a result of difficulties in evaluating the exposure and individual predisposition.

In adults, the crystalline lens (which, as it turns yellow, partly absorbs blue radiation) and the macular pigments partially protect against this toxicity through their capacity to absorb blue light. These protective mechanisms are weaker in children (whose crystalline lenses are transparent), aphakics (with no crystalline lenses) and pseudophakics (with artificial crystalline lenses). There is also less protection available in cases of reduced macular pigment, as observed during certain macular pathologies (e.g. ARMD).

- ***Exposure to LEDs***

There is currently no information about human exposure to lighting, whether for systems using LEDs or other types of light sources.

- ***Photobiological safety standards***

<u>Description of the NF EN 62471 standard and risk groups</u>

The NF EN 62471 standard concerning the photobiological safety of lamps and devices using lamps suggests maximum exposure limits for radiation from light sources commonly used for lighting, and provides a method of classification based on radiance and actual irradiance together with a method for measuring these values. This standard covers all photobiological hazards for the eye (thermal and photochemical hazards), for ultraviolet to infrared wavelengths.

The standard defines four Risk Groups:
- Risk Group 0 (no risk): the product involves no photobiological risk;
- Risk Group 1 (low risk): the product involves no risk in terms of maximum exposure limits under normal conditions of use;
- Risk Group 2 (moderate risk): the product involves no risk in terms of aversion response to very bright light sources or due to thermal discomfort;
- Risk Group 3 (high risk): the product may involve a risk even during momentary or short exposure periods.

Gaps and inadequacies in the standard

- *Maximum exposure limits unsuitable for repeated exposure to blue light*

The maximum exposure limits for the general public designed to avoid acute lesions to the retina have been put forward by the ICNIRP[18,19] and used in the NF EN 62 471 standard and in European Directive 2006/25/CE concerning artificial optical radiation.

These maximum exposure limits were calculated for exposure to a light source in the field of vision for one 8-hour working day. They were calculated from experimental data weighted by a reduction factor of 5 to 10 times the energy necessary to produce observable lesions.

In practice, experiments on animals have established the energy thresholds for inducing lesions to the ocular fundus that can be observed macroscopically by ophtalmoscopy after a single exposure to light. These lesions take the form of a whitening of the neural retina, as a result of an oedema of the superficial retinal layers.

In the light of current knowledge, the maximum exposure limits in force do not allow evaluation of daily chronic exposure limits to blue light. The classification of lamps by these values does not take account of the long-term risk resulting from accumulated exposure. This means that repeated and prolonged exposure could induce an accumulated risk potentially greater than that assessed using the maximum exposure limits.

- *Ambiguity in measurement distances*

For the most common lighting lamps, the NF EN 62 471 standard requires the risk group to be evaluated at the distance at which they produce a brightness of 500 lx. For other types of lamps, the risk group must be determined for the worst observation case, i.e. a distance of 200 mm.
The risk group for any lighting system using LEDs can be determined using either of these measurement protocols, leading to very different classifications (evaluation at 500 lx always gives a lower value than evaluation at 200 mm). There is therefore ambiguity concerning the distance at which these measurements should be taken.

- *Failure to take into account population groups sensitive to blue light*

To assess the risk related to blue light, the NF EN 62 471 standard recommends using the phototoxicity curve for blue light suggested by the ICNIRP. This curve is only suitable for adults. The standard includes no specific recommendations for population groups whose natural mechanisms for filtering blue light are diminished (children, aphakics and pseudophakics), or who are more sensitive to blue light as a result of retinal diseases. In fact, the ICNIRP gives a different phototoxicity curve for blue light for aphakics. The current standard does not take account of the situation of population groups sensitive to blue light.

[18] ICNIRP (International Commission for Non-Ionising Radiation Protection), "*Guidelines on limits of exposure to broad-band incoherent optical radiation (0.38 to 3 µm)"* (1997)
[19] ICNIRP (International Commission for Non-Ionising Radiation Protection), "*ICNIRP statement on light-emitting diodes (LED) and laser diodes : implication for hazard assessment"* (2000)

- ***Measurements taken by the Working Group***

The Working Group made risk assessments defined according to the NF EN 62 471 standard for different lighting systems, in order to compare LEDs with other types of lighting.
It seems that certain LEDs that are very widely used in lighting, signage and guide lights fall into Risk Group 2, whereas all other light sources currently on sale to the public fall into either Risk Group 0 or 1. The maximum exposure times implied by placing these items in Group 2 vary from a few seconds for certain royal blue LEDs to a few tens of seconds for certain cold white LEDs.
LEDs and LED-base lighting systems can be classified in different Risk Groups depending on their radiance and hue (cold white, warm white, etc.), thus increasing the difficulty of preventing this risk.

- ***Sensitive or highly exposed population groups***

Three population groups have been identified as being either especially sensitive to the risk or highly exposed to blue light:

  - children (because of the transparency of their crystalline lens) and both aphakics (with no crystalline lens) and pseudophakics (with artificial crystalline lenses) who consequently either cannot or can only insufficiently filter short wavelengths (especially blue light);
  - population groups which are already light-sensitive: patients suffering from certain eye and skin conditions and patients taking treatments one of whose side-effects is to increase photosensitivity, etc., for whom blue light can be an aggravating factor for their condition;
  - population groups highly exposed to LEDs (certain categories of workers: those installing lighting systems, theatre and film industry professionals, etc.) which are subjected to high-intensity lighting, and are therefore susceptible to exposure to large quantities of blue light.

- ***Conclusions concerning the risk related to blue light***

It is important to emphasise that other widely-used sources of lighting, particularly high-pressure gas discharge lamps (metal-halide lamps for outdoor lighting), also fall into Risk Group 2. However, these lamps are intended for use in clearly-identified applications and can only be installed by professionals who are required to limit the exposure level for the population.

The arrival of LEDs on the lighting market for the general public is an unprecedented development: it is the first time that sources classified in Risk Group 2 have become accessible to the general public, for use in the home and, most importantly, with no indication of the risk.

The same LED considered individually or integrated in a lighting system could be assigned to different Risk Groups depending on the evaluation distance imposed by the NF EN 62 471 standard.
As the technology behind LED lighting evolves over the next few years, lighting performance is likely to improve considerably. The risks associated with exposure to LED-based lighting systems are therefore likely to increase as the radiance increases.

The methodology adopted in this report enabled the experts to evaluate the photobiological risks related to LEDs producing a luminous flux close to the mean of LEDs found in the range of fluxes available on the market at the time of writing this document. At present and for the next few years it seems unlikely that technological progress will yield LEDs that can be classified in Risk Group 3. On the other hand, with the increase in both luminous flux and radiance, there is no doubt that more and more LEDs will fall into Risk Group 2.

- ### Risks related to glare

There are two types of glare: discomfort glare and disability glare.

Discomfort glare produces a disagreeable sensation, without necessarily impairing the vision of objects. It is related to the luminance of the lighting unit and to contrast differences. It is associated with a momentary reduction in visual performance.

Disability glare perturbs the vision of objects (veiling luminance) without necessarily causing a disagreeable sensation. It is related to the quantity of incident light on the eye and the luminance of the lighting unit. It can cause accidents in the home (either slip-and-trip falls or falls from heights), in traffic (collisions) and elsewhere.

In indoor lighting, it is generally agreed that luminance higher than 10,000 cd/m² causes visual discomfort irrespective of the position of the lighting unit in the field of vision. This value is commonly cited for discomfort glare in indoor lighting as being the value above which subjects are bound to suffer the effects of glare.

The French NF X 35 103 standard for visual ergonomics gives a limit value of 2,000 cd/m² for discomfort glare, for the case of a small source located in the central area of the field of vision.

Because the emission surfaces of LEDs are highly concentrated point sources, the luminance of each individual source can be at least 1000 times higher than the luminance from traditional lighting sources. The level of direct radiation from this type of source greatly exceeds the level of visual discomfort.

The Working Group recorded luminances of more than 10,000,000 cd/m² for certain LEDs with an electrical power of 1 W (in devices on public sale for domestic use).

In LED lighting systems available on the market, the LEDs are often directly visible in order to avoid attenuating the level of brightness produced. This leads to non-compliance with the requirements laid down in the standards (visual ergonomics and safety requirements) for lighting intended to avoid excessive luminance in the field of vision.

<u>Other effects</u>

- ***Risk of deregulating the biological clock and pupil contraction***

In humans, the biological clock and pupil contraction are regulated by wavelengths close to 480 nm which suppress the production of melatonin (a hormone participating in the regulation of the biological clock and therefore the circadian cycle).

The spectrum produced by LEDs differs fundamentally from that of natural light, with a very low proportion near 480 nm. This could expose subjects to a risk of deregulation of their biological clocks and, in consequence, of their circadian rhythms. These risks are exacerbated by high-temperature colours (cold white and blue), which are frequently found in LED-based lighting systems.

Deregulation of the biological clock can affect the metabolism, the thymus (depression, mood swings), the waking/sleeping rhythm, etc.
Furthermore, the pupil contraction reflex is induced in strong light by these same wavelengths. It could be reduced under LED lighting, which could lead to stronger light falling on the retina and an increase in the risks associated with blue light.

- **Risk related to flicker in the light emitted by LEDs**

As a consequence of the manner in which they are powered electronically, the light emitted by LEDs may be subject to rapid fluctuation of great amplitude. This fluctuation, combined with the fact that LEDs have very low remanence, is usually imperceptible to human vision. In situations involving movement or in confined spaces with periodic variations in contrast, it can be responsible for stroboscopic effects. Although such stroboscopic effects have never been studied in depth, they can have a direct impact on health (epileptic seizures for subjects at risk), visual performance and safety. A recent publication[20] showed that LEDs can produce fluctuations in light at frequencies known to produce effects on health (from 3 to 60 Hz for visible fluctuations and from 120 à 150 Hz for non-visible fluctuations).

Recommendations

The following recommendations apply to both lighting systems using LEDs already on the market and future LED-based systems.

Concerning health risks related to exposure to LEDs,

Considering:
the health risks related to blue light emitted by LED lighting systems in products available to the public despite belonging to Risk Groups higher than 1 (according to the NF EN 62 471 standard);

the CES recommends:

- banning the sale to the public of lighting systems falling into Risk Groups higher than 1, evaluated at an observation distance of 200 mm;
- reserving LEDs falling into Risk Groups higher than 1 for applications designed to be installed safely by professionals.

Considering:
the health risks created by LED lighting systems, related to very high luminance and substantial glare;

the CES recommends that manufacturers and integrators**:**

-in order to protect the population against excessive luminance from LED systems and strong glare,

- design lighting systems such that the beams emitted by LEDs are not directly visible. In particular, the CES recommends the use of optical devices that reduce the intensity of

[20] *A Review of the Literature on Light Flicker: Ergonomics, Biological Attributes, Potential Health Effects, and Methods in Which Some LED Lighting May Introduce Flicker*, IEEE Standard P1789 (2010)

light perceived directly or by reflection and to make the sources of LED light more diffuse;

- take account of the progressive wear of phosphor layers in white LEDs, which in time could lead to devices moving to a higher photobiological risk group.

- in order to protect the drivers of vehicles, pedestrians, cyclists and motorcyclists from the risk of glare related to excessive luminance emitted by LED headlights,

- only be authorised to install LED-based lighting systems from Risk Groups 0 or 1 for motor vehicle headlights by day or night, given that daytime running lights will be mandatory for all new cars from February 2011 (European Directive on daytime lighting 2008/89/EC);

Considering:

- the proven risks resulting from acute exposure to blue light and the uncertainty surrounding the effects of chronic exposure at low doses, together with the uncertainty concerning the effects on the biological clock and pupil contraction;
- that certain population groups are sensitive to light in general (children, aphakics, pseudophakics, patients suffering from certain eye and skin diseases, or who are taking photosensitising drugs, etc.);
- that there are populations of workers susceptible to exposure to bright LED lighting systems;

the CES makes the following recommendations:

- specifically to protect population groups at risk, such as those sensitive to light and those highly exposed to LEDs. The CES thus recommends:

- for children, avoiding the use of sources emitting a cold white light or blue light in places frequented by children (maternity wards, nurseries, schools, recreation centres, etc.) or in the objects they use (toys, electronic display panels, game consoles and joysticks, night lights, etc.).
- developing appropriate means of protection (such as safety goggles specifically to protect against exposure to LEDs) for workers highly exposed to LED lighting systems;
- informing patients taking medicines one of whose side-effects is to increase photosensitivity about the risks related to exposure to cold light and particularly light emitted by LEDs, even those classified as belonging to Risk Group 0; informing health workers of the existence of this risk;
- employing caution in the use of devices to increase the effective size of LEDs, even if such devices do not increase the luminance (such as optical collimators and multichip assemblies of LEDs). Indeed, the use of these devices leads to shorter maximum exposure times to blue light than in the case of single chip LEDs without additional optics. A higher Risk Group may then be appropriate.

Considering:
that LED-based products for light therapy, comfort and well-being are available on the market, the CES recommends evaluating the safety and compliance of these devices.

Concerning standards relative to the lighting quality and the photobiological safety of LEDs,

Considering:

- that the standards in force for lighting installations are not always applied by professionals (electricians, lighting specialists, designers of lighting systems) in the case of LED systems;
- that the standards related to photobiological safety might prove to be ill-adapted to LED lighting systems;

the CES makes the following recommendations:

- That professionals installing LED-based lighting systems be obliged to apply all standards relative to lighting quality:

- French standard NF X 35-103 (‘*Ergonomie : Principes d´ergonomie visuelle applicables à l´éclairage des lieux de travail*’ – Ergonomics: Ergonomic principles applicable to the lighting of workplaces for visual comfort);
- NF EN 12464-1 (‘Lighting of workplaces – Part 1: indoor workplaces’);
- NF EN 12464-2 (‘Lighting of workplaces – Part 2: outdoor workplaces’);
- the series of NF EN 13201 standards (‘Street Lighting’);
- NF EN 12193 (‘Sports Lighting’).

- Adapting the NF EN 62 471 standard (‘Photobiological safety of lamps and lamp systems’) to cover lighting systems using LEDs. It is essential to make it easier for manufacturers to take this standard into account and remove any doubt as to how it should apply to LED systems. The CES therefore recommends:

- specifying in the NF EN 62 471 standard the conditions for measuring and evaluating LED systems;
- publishing a guide to applying this standard, exclusively for LED systems;
- determining the risk group for the worst case of observation: at a distance of 200 mm from the system, thus giving the most unfavourable Risk Group;
- adapting the standard to cover children and people who are either aphakic or pseudophakic, taking into account the phototoxicity curve of the relevant type of light published by the ICNIRP;
- proposing sub-groups for each risk group that would allow the risk to be assessed more precisely as a function of exposure time;
- in the case of risk groups greater than 0, evaluating safe distances (distance at which observation corresponds to Risk Group 0) and for these to be indicated explicitly on products intended for consumers (the case of devices for the general public) or for professionals responsible for installing lighting systems.

- To reinforce the photobiological safety aspect in the requirements for upgrading existing lighting systems to bring them into compliance with standards:

- introducing photobiological safety requirements into all safety standards covering LED lamps, LED modules and LED lighting units. This mainly concerns the following standards:
    - the NF EN 60 598 series of standards: ‘Luminaires’;
    - NF EN 62 031: ‘LED modules for general lighting. Safety specifications’;
    - IEC 62 560: ‘Self-ballasted LED lamps for general lighting services by voltage > 50 V – Safety specifications’;
    - draft IEC standard 62 663-1 ‘Non ballasted single capped LED lamps for general lighting – safety requirements’.

Concerning information for consumers, traceability and the quality and labelling of LEDs,

Considering*:*

- the lack of information available to the public concerning LED-based products;

the CES makes the following recommendations:

- That consumers be informed of the quality and performance of the lighting systems they choose to buy. That consumers be given easy access to information about the characteristics of the products they buy. The CES recommends:

- ensuring that manufacturers and integrators of LEDs carry out quality and traceability controls on LEDs; apart from the quality in terms of lighting, it is essential that they ensure that their products comply with their assigned Risk Group;
- considering a labelling system that will be comprehensible for consumers and contain all relevant information (power, voltage, colour temperature, luminous flux, etc.);
- making it mandatory to indicate the photobiological safety Risk Group on the packaging of LED products, after assessing the product at a distance of 200 mm. For light sources falling into Risk Group 1, the labelling should also indicate the safety distance beyond which the risk moves down to Group 0;
- making it mandatory to indicate the photobiological safety Risk Group for all types of lighting;
- considering the creation of a quality label (reproducibility, ecolabelling, etc.).

Recommendations for studies and research themes

Considering the lack of data on exposure of the general public and the working population to artificial light, the CES makes the following recommendations:

- Characterising and studying the exposure of the population to artificial light.

- Defining a suitable index for evaluating the intensity of glare produced by an LED-based source, as the Unified Glare Rating (UGR) used for other types of lighting is not appropriate for LEDs, which are sources of low-angle light.

Concerning studies and research on the health effects of LED lighting systems, the CES recommends:

- Developing clinical research to obtain information for defining exposure limit values for blue light. The CES therefore recommends:

- studying the cumulative medium- and long-term effects of exposure to blue light;
- carrying out prospective and retrospective studies of subjects undergoing light therapy with blue LEDs;
- implementing experimental protocols for evaluating the consequences of prolonged and accumulated exposure at levels inferior to the exposure limit values.

- Undertaking research to improve characterisation of the effects of artificial light, and particularly the light emitted by LED systems, on biological rhythms. The CES therefore recommends:

- further studies to improve characterisation of the spectra of action of the mechanisms by which light regulates the human biological clock;
- quantifying the impact of exposure to cold artificial lights on circadian rhythms and diminished pupil contraction;
- in general, studying how health is affected by light pollution (linked with possible disruption of the biological clock) and systematic installation of LED lighting systems.

- Systematically studying the triggering and/or aggravation of photo-dermatoses caused by LED lighting.

Concerning studies and research to be carried out on LED technology to prevent health risks, the CES makes the following recommendations;

- Improving LED technology. The CES therefore recommends:

- encouraging research for the development of new emissive materials coupled with optimised luminophores, to obtain a high quality white light, with the highest possible luminous efficacy;
- developing research into the design of lighting units adapted for LEDs (small size and considerable luminous flux) with a view to reducing luminance, by applying optical solutions;
- studying the mechanisms that cause the degradation of white LEDs, potentially leading to a drift towards the blue end of the visible spectrum in the light emitted.

Maisons-Alfort, 03/06/2010

On behalf of the experts of the CES "Physical agents, new technologies and development areas",

Chairperson of the CES, Jean-François Doré

May 4, 2012

Light from laptops, TVs, electronics, and energy-efficient lightbulbs may harm health

Humans once spent their nights in relative darkness. No longer. When the sun sets, TVs, computers, mobile devices, and artificial lighting burn on. The May issue of the ***Harvard Health Letter*** reports that this aspect of modern life may be great for efficiency, but not for health. At night, light throws the body's biological clock—the circadian rhythm—out of whack. Sleep suffers. The combination of poor sleep and exposure to artificial light exposure may contribute to a number of health problems.

Studies have linked working the night shift and getting exposed to light at night to several types of cancer (including breast and prostate cancer), diabetes, heart disease, and obesity. It's not exactly clear why nighttime light exposure seems to be problematic. It could be because exposure to light at night curbs the secretion of melatonin, a hormone that influences circadian rhythms.

But all light is not created equal, says the *Health Letter*. Blue wavelengths—which are beneficial during daylight hours because they boost attention, reaction times, and mood—seem to be the most disruptive at night. While light of any kind can suppress the secretion of melatonin, blue light does so more powerfully. In an experiment, researchers exposed people to 6.5 hours of light—either blue or green. The blue light suppressed melatonin for about twice as long as the green light and shifted circadian rhythms by twice as much.

While fluorescent lightbulbs and LED lights are much more energy-efficient than incandescent lights, they also tend to produce more blue light. That means the proliferation of electronic devices with screens, as well as energy-efficient lighting, is increasing exposure to blue wavelengths, especially after sundown.

What can you do? The editors of the *Harvard Health Letter* make the following recommendations:

- Use dim red lights for nightlights. Red light has the least power to shift circadian rhythm and suppress melatonin.
- Avoid looking at brightly lit screens beginning two to three hours before bed.
- If you work a night shift or use a lot of electronic devices at night, consider wearing blue-blocking glasses.
- Expose yourself to lots of bright light during the day, which will boost your ability to sleep at night, as well as your mood and alertness during daylight.

Read the full-length article: "Blue li

Harvard Health Letter

Blue light has a dark side

What is blue light? The effect blue light has on your sleep and more.

Updated: July 7, 2020 **Published: May, 2012**

Although it is environmentally friendly, blue light can affect your sleep and potentially cause disease. Until the advent of artificial lighting, the sun was the major source of lighting, and people spent their evenings in (relative) darkness. Now, in much of the world, evenings are illuminated, and we take our easy access to all those lumens pretty much for granted.

But we may be paying a price for basking in all that light. At night, light throws the body's biological clock—the circadian rhythm—out of whack. Sleep suffers. Worse, research shows that it *may* contribute to the causation of cancer, diabetes, heart disease, and obesity.

What is blue light?

Not all colors of light have the same effect. Blue wavelengths—which are beneficial during daylight hours because they boost attention, reaction times, and mood—seem to be the most disruptive at night. And the proliferation of electronics with screens, as well as energy-efficient lighting, is increasing our exposure to blue wavelengths, especially after sundown.

Light and sleep

Everyone has slightly different circadian rhythms, but the average length is 24 and one-quarter hours. The circadian rhythm of people who stay up late is slightly longer, while the rhythms of earlier birds fall short of 24 hours. Dr. Charles Czeisler of Harvard Medical School showed, in 1981, that daylight keeps a person's internal clock aligned with the environment.

Is nighttime light exposure bad?

Some studies suggest a link between exposure to light at night, such as working the night shift, to diabetes, heart disease, and obesity. That's not proof that nighttime light exposure causes these conditions; nor is it clear why it could be bad for us.

A Harvard study shed a little bit of light on the possible connection to diabetes and possibly obesity. The researchers put 10 people on a schedule that gradually shifted the timing of their circadian rhythms. Their blood sugar levels increased, throwing them into a prediabetic state, and levels of leptin, a hormone that leaves people feeling full after a meal, went down.

Exposure to light suppresses the secretion of melatonin, a hormone that influences circadian rhythms. Even dim light can interfere with a person's circadian rhythm and melatonin secretion. A mere eight lux—a level of brightness exceeded by most table lamps and about twice that of a night light—has an effect, notes Stephen Lockley, a Harvard sleep researcher. Light at night is part of the reason so many people don't get enough sleep, says Lockley, and researchers have linked short sleep to increased risk for depression, as well as diabetes and cardiovascular problems.

Effects of blue light and sleep

While light of any kind can suppress the secretion of melatonin, blue light at night does so more powerfully. Harvard researchers and their colleagues conducted an experiment comparing the effects of 6.5 hours of exposure to blue light to exposure to green light of comparable brightness. The blue light suppressed melatonin for about twice as long as the green light and shifted circadian rhythms by twice as much (3 hours vs. 1.5 hours).

In another study of blue light, researchers at the University of Toronto compared the melatonin levels of people exposed to bright indoor light who were wearing blue-light–blocking goggles to people exposed to regular dim light without wearing goggles. The fact that the levels of the hormone were about the same in the two groups strengthens the hypothesis that blue light is a potent suppressor of melatonin. It also suggests that shift workers and night owls could perhaps protect themselves if they wore eyewear that blocks blue light. Inexpensive sunglasses with orange-tinted lenses block blue light, but they also block other colors, so they're not suitable for use indoors at night. Glasses that block out only blue light can cost up to $80.

LED blue light exposure

If blue light does have adverse health effects, then environmental concerns, and the quest for energy-efficient lighting, could be at odds with personal health. Those curlicue compact fluorescent lightbulbs and LED lights are much more energy-efficient than the old-fashioned incandescent lightbulbs we grew up with. But they also tend to produce more blue light.

The physics of fluorescent lights can't be changed, but coatings inside the bulbs can be so they produce a warmer, less blue light. LED lights are more efficient than fluorescent lights, but they also produce a fair amount of light in the blue spectrum. Richard Hansler, a light researcher at John Carroll University in Cleveland, notes that ordinary incandescent lights also produce some blue light, although less than most fluorescent lightbulbs.

Protect yourself from blue light at night

- Use dim red lights for night lights. Red light is less likely to shift circadian rhythm and suppress melatonin.
- Avoid looking at bright screens beginning two to three hours before bed.
- If you work a night shift or use a lot of electronic devices at night, consider wearing blue-blocking glasses or installing an app that filters the blue/green wavelength at night.
- Expose yourself to lots of bright light during the day, which will boost your ability to sleep at night, as well as your mood and alertness during daylight.

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Outdoor Light at Night and Breast Cancer Incidence in the Nurses' Health Study II

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Abstract

Background: Animal and epidemiologic studies suggest that exposure to light at night (LAN) may disrupt circadian patterns and decrease nocturnal secretion of melatonin, which may disturb estrogen regulation, leading to increased breast cancer risk.

Objectives: We examined the association between residential outdoor LAN and breast cancer incidence using data from the nationwide U.S.-based Nurses' Health Study II cohort.

Methods: We followed 109,672 women from 1989 through 2013. Cumulative LAN exposure was estimated using time-varying satellite data for a composite of persistent nighttime illumination at $\sim$ 1 km^2 scale for each residence during follow-up. Incident invasive breast cancer cases were confirmed by medical record review. We used Cox proportional hazard models to calculate hazard ratios (HRs) and 95% confidence intervals (CIs), adjusting for anthropometric, reproductive, lifestyle, and socioeconomic risk factors.

Results: Over 2,187,425 person-years, we identified 3,549 incident breast cancer cases. Based on a fully adjusted model, the estimated HR for incident breast cancer with an interquartile range (IQR) (31.6 $nW/cm^2/sr$) increase in cumulative average outdoor LAN was 1.05 (95% CI: 1.00, 1.11). An association between LAN and breast cancer appeared to be limited to women who were premenopausal at the time of a case [HR = 1.07 (95% CI: 1.01, 1.14) based on 1,973 cases vs. HR = 1.00 (95% CI: 0.91, 1.09) based on 1,172 cases in postmenopausal women; $p-\text{interaction} = 0.08$]. The LAN–breast cancer association was observed only in past and current smokers at the end of follow-up [HR = 1.00 (95% CI: 0.94, 1.07) based on 2,215 cases in never smokers; HR = 1.10 (95% CI: 1.01, 1.19) based on 1,034 cases in past smokers vs. HR = 1.21 (95% CI: 1.07, 1.37) for 300 cases in current smokers; $p-\text{interaction} = 0.08$].

Conclusions: Although further work is required to confirm our results and to clarify potential mechanisms, our findings suggest that exposure to residential outdoor light at night may contribute to invasive breast cancer risk. https://doi.org/10.1289/EHP935

Introduction

International differences in breast cancer incidence rates and increases in rates among populations that

et al. 2004b; Willett 2001). In addition, twin studies show that inherited genetic factors explain only a minor proportion of susceptibility to breast cancer, which further implicates the environment in driving breast cancer risk (Lichtenstein et al. 2000). Recent evidence has demonstrated associations between night-shift work and invasive breast cancer (Schernhammer et al. 2006b), and shift work is currently classified as a 2A "probable human carcinogen" by the International Agency for Research on Cancer (IARC) (Straif et al. 2007). It has been hypothesized that the relationship between night shift work and invasive breast cancer is mediated by exposure to light at night (LAN) (Schernhammer et al. 2006b). Evidence points to the potential role of exposure to LAN in contributing to breast cancer risk (Blask et al. 2011; Stevens et al. 2007; Stevens 2009), and animal and epidemiologic data suggest that exposure to LAN can modulate pineal gland function to decrease melatonin secretion (Haim and Zubidat 2015; Jasser et al. 2006) and disrupt circadian patterns and sleep (Blask et al. 2014; Stevens et al. 2007), which may increase breast cancer risk (Blask 2009). Mechanistically, light falling onto specific retinal ganglion cells at night triggers the pineal gland to stop the release of melatonin and disrupts the circadian system (Blask et al. 2014). Outdoor LAN has been used as a surrogate for greater total evening and nighttime circadian-effective light exposure because people living in communities with higher outdoor LAN likely drive on roads that are lit by street lighting, experience higher levels of light exposure during evening outdoor activities, and have more outdoor light intrusion into their bedrooms in the evening (Stevens 2011), although it is unclear how well outdoor LAN captures personal LAN exposure (Rea et al. 2011).

With the above biological mechanisms as a foundation, recent studies have examined links between outdoor LAN and breast cancer in six ecological analyses (Keshet-Sitton et al. 2016a; Kim et al. 2015; Kloog et al. 2008; Kloog et al. 2010; Portnov et al. 2016; Rybnikova et al. 2015), two case–control studies (Bauer et al. 2013; Keshet-Sitton et al. 2016b), and one prospective cohort in California (Hurley et al. 2014). These studies have all reported associations between outdoor LAN and breast cancer; however, to our knowledge, no prior study has participants living throughout the continental United States; time-varying, residence-level exposure data; and individual-level information on anthropometric, reproductive, lifestyle, and sociodemographic risk factors.

Previous studies have reported that the association between LAN and breast cancer may be modified by body mass index (BMI), menopausal status, and urbanicity (Hurley et al. 2014; Keshet-Sitton et al. 2016c; Portnov et al. 2016). In addition, race and socioeconomic status (SES) (Palmer et al. 2012), as well as air pollution (Parikh and Wei 2016; Wong et al. 2016), and smoking (Cui et al. 2006; Gaudet et al. 2013; Gaudet et al. 2016; Gram et al. 2015; Reynolds et al. 2004a) have been associated with breast cancer risk in past analyses, and these exposures could have possible synergistic effects on breast cancer risk in concert with LAN if these factors increase susceptibility to breast cancer. Analyses within the Nurses' Health Study cohorts have shown some regional differences in breast cancer risk (Laden et al. 1997), and differing underlying susceptibility may lead associations between LAN and breast cancer risk to vary across regions. Night-shift work has been consistently associated with breast cancer within the Nurses' Health Study cohorts, and it has been proposed that this association may be mediated by circadian disruption (Schernhammer et al. 2001; Schernhammer et al. 2006b). Because both LAN exposure and night-shift work are hypothesized to increase breast cancer risk through the same pathway of circadian disruption, it is possible that these two factors may by synergistic. For instance, for women working rotating shifts, their circadian patterns may be disrupted on the days they work night shifts, and LAN exposure may additionally disrupt their circadian patterns on days that they are working day shifts or not working.

Using data from the nationwide U.S.-based Nurses' Health Study II (NHSII) from 1989 through 2013, we aimed to examine the association between outdoor LAN and invasive breast cancer incidence. We hypothesized that there would be a positive association between LAN and invasive breast cancer incidence. *A priori*, we also aimed to examine whether this association differed by menopausal status, tumor estrogen receptor status, race, smoking, night-shift work, census-tract SES, air pollution exposure, region, or urban/nonurban residence status.

Population

NHSII is an ongoing prospective cohort study of 116,430 women who were registered nurses, 25–42 y of age, and living in 14 U.S. states when enrolled in 1989. Participants complete biennial questionnaires on lifestyle factors, health behaviors, medical history, and incident disease. Response rates at each questionnaire cycle have consistently been ~ 90%. All mailing addresses over follow-up were geocoded to the street or ZIP code centroid level to obtain latitude and longitude (Figure 1A). NHSII participants have changed residences since baseline, and currently there are ≥ 24 nurses in each of the 48 U.S. continental states. We excluded women who did not have a geocoded address at the street segment level (n = 17,629 at baseline), who had missing LAN exposure information (n = 1,299 at baseline), who had missing information on menopausal status (n = 2,320 at baseline), or who had a prior history of breast cancer at baseline (n = 685 at baseline).

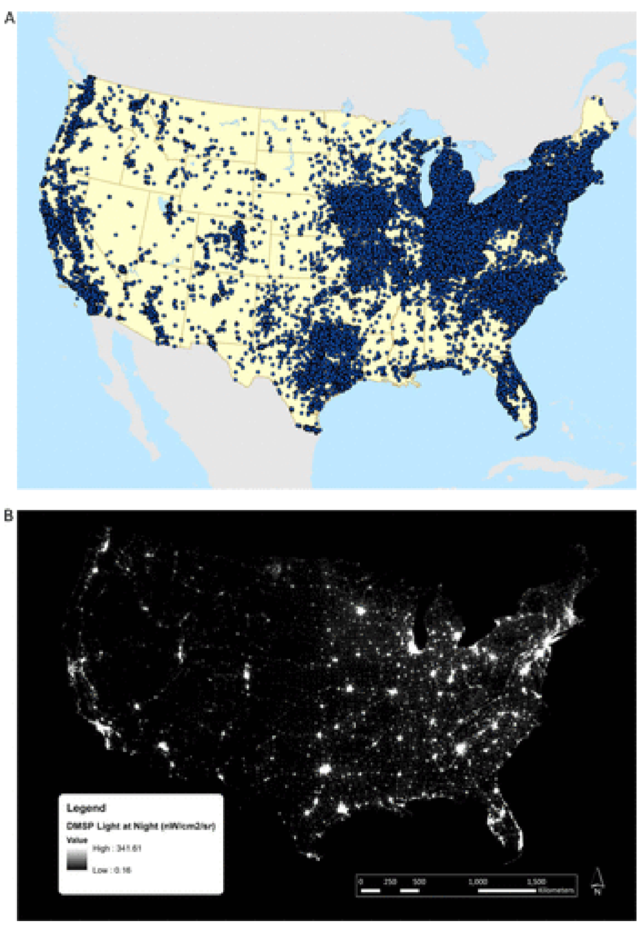

Figure 1. Locations of Nurses' Health Study II (NHSII) addresses from 1989–2011 (*A*) and 2010 U.S. Defense Meteorological Satellite Program's (DMSP's) Operational Linescan System (OLS) light at night data in nanowatts

per centimeter squared per steradian (*B*).

Informed consent was implied by return of the baseline questionnaire. The institutional review boards of Brigham and Women's Hospital and Harvard T.H. Chan School of Public Health approved the original NHSII as well as this analysis.

Outcome

We identified incident invasive breast cancer cases by self-report on biennial questionnaires from 1989 through 2013. A study physician performed medical record review to confirm cases (ICD-8 code 174.0) (**WHO 1965**) and to abstract information on invasiveness. Over 82% of cases were confirmed after medical record review; the remaining cases were confirmed by state cancer registries, death records, contact with participants, or contact with next of kin. Tissue block collection and tissue microarray (TMA) construction were described in detail previously (**Sisti et al. 2016**; **Tamimi et al. 2008**). Immunohistochemical (IHC) analysis was performed according to a standard protocol (**Sisti et al. 2016**; **Tamimi et al. 2008**). Cases were considered estrogen receptor (ER) positive if any tissue core showed any nuclear staining for ER. Cases with complete absence of staining for ER were considered ER negative. For cases missing ER status by IHC (77% of all cases), ER status was based on the pathology report or on the medical record. We could not determine ER status for ~ 25% of cases, primarily in the later years, because study staff are still working to collect data. For the years 2011–2013, we are actively collecting tissue, and the majority of data on tumor ER status for these years are based on pathology reports. We have previously demonstrated a very high concordance between pathology reports and TMA (**Collins et al. 2008**). Additionally, we have shown in previous analyses that cases missing tumor marker information were not significantly different from cases with tumor marker information in terms of characteristics and accepted breast cancer risk factors (**Wang et al. 2015**).

Exposure

Data on annual outdoor LAN were derived from satellite imagery data from the U.S. Defense Meteorological Satellite Program's (DMSP's) Operational Linescan System, maintained by the National Oceanic and Atmospheric Administration's (NOAA's) Earth Observation Group (**NOAA National Geophysical Data Center 2015**). This database contains annual composites made after excluding the outer quarters of the satellite swath, sun and moon luminance, glare, clouds, atmospheric lightning, and ephemeral events such as fires. Although these images capture only a fraction of the light originating from the Earth's surface, they represent the relative levels of nighttime illumination at ground level (**Hsu et al. 2015**). The processed imagery data are georectified to a 30 arc-second grid equivalent to ~ 1 km^2. Previous studies have shown that the low-dynamic range 6-bit DMSP data do not vary within urban areas, where levels of LAN are high (nearly every residence in an urban or suburban area was assigned the maximum value of 63) (**Hurley et al. 2013**). Therefore, we used the DMSP Global Radiance Calibrated Nighttime Lights high-dynamic range data, which can be transformed into units of radiance ($nW/cm^2/sr$) (Figure 1B) (**Hsu et al. 2015**). High-dynamic range data were available for 1996, 1999, 2000, 2002, 2004, 2005, and 2010. To ensure comparability across years and satellites, we used interannual calibration coefficients provided by NOAA to derive exposure estimates (**NOAA 2017**). We assigned a nighttime radiance value for each geocoded address in each questionnaire year from 1989–2011 using ArcGIS (ESRI, Redlands, CA). If a participant changed addresses during follow-up, their estimated exposure was updated at the date of the new questionnaire in which they indicated their new address. For addresses before 1997, exposure was assigned based on the 1996 LAN data. For addresses after 1997, exposure was assigned based on the most recent past LAN measure. We calculated cumulative average outdoor LAN for each participant at each questionnaire response, which accounted for changes in LAN over time as well as for participant changes of address.

Statistical Analysis

Person-years of follow-up were accrued from the return date of the 1989 questionnaire until the participant missed a questionnaire or temporarily moved outside of the contiguous United States, but these participants could contribute person-time to the analysis if they filled out a subsequent questionnaire or moved back to the contiguous United States. We used the date of the last questionnaire completed as the end of follow-up. Deaths were usually reported by families, and deaths among nonrespondents were identified by searching the National Death Index, which has been validated in prior studies in this cohort (**Rich-Edwards et al. 1994**). We fit time-varying Cox proportional hazards regression models to calculate the hazard ratio (HR) for developing breast cancer (overall and by ER status) associated with cumulative average outdoor LAN, using both continuous LAN based on an interquartile range (IQR) increase ($31.6\ \mathrm{nW/cm^2/sr}$) as well as quintiles of LAN with a test for trend based on the median value for each quintile. We used likelihood ratio tests to compare the fit of models that included cubic splines with models having linear terms only to test for statistically significant departures from linearity. To test for violations of the proportional hazards assumption, we included interaction terms of LAN exposure and calendar time and performed likelihood ratio tests.

Analyses were stratified by age at follow-up and by calendar year, and we adjusted for all of the following covariates *a priori* as potential confounders based on questionnaire data because they are potential breast cancer risk factors and may be correlated with LAN. Time-invariant factors included race (white/nonwhite), benign breast disease history at baseline (yes/no), family history of breast cancer at baseline (yes/no), age at menarche (years), height at baseline (inches), BMI at age 18 (kilograms per meter squared), and personal income assessed in 2001 (thousands of U.S. dollars per year; $<15/15–19/20–29/30–39/40–49/50–74/75–99/100–149/\geq 150$). Time-varying factors included parity and age (years) at first birth [nulliparous/1–2 children (before 25/25–29/≥ 30)/3–4 children (before 25/25–29/≥ 30)/5–8 children (before 25/ ≥ 25], BMI (kilograms per meter squared; based on self-reported weight at each questionnaire and height at baseline), menopausal status (yes/no), oral contraceptive use (yes/no), mammography screening (yes/no), smoking status (current/past/never), marital status (married/nonmarried), living alone (yes/no), night-shift work (never/ever performing shift work after 1989), alternative healthy eating index (AHEI) (continuous) (**Chiuve et al. 2012**), and physical activity [total metabolic equivalent of task hours per week (MET hrs/wk)]. Family history of breast cancer was defined as a mother, sister, or grandmother with any type of breast cancer. Menopausal status was assessed every two years based on self-report and was used as time-varying in analyses. Physical activity was evaluated every 2–6 y based on a validated measure of self-reported total physical activity in the past year (**Wolf et al. 1994**). Values were carried forward for years between physical activity questionnaires. The AHEI, an overall diet quality measure based on alcohol consumption, foods, and nutrients predictive of chronic disease risk, was calculated from food frequency questionnaires asking about typical consumption in the past year (**Willett et al. 1985**) that were completed every 4 y. Values were carried forward for years between food frequency questionnaires. We accounted for area-level SES by including census-tract median home value and income, and we also adjusted for census-tract population density and for region of United States based on geocoded address. Census data came from the 2000 U.S. Census (**U.S. Census Bureau 2000**). To reduce potential confounding by air pollution exposures that have been associated with breast cancer in previous studies (**Parikh and Wei 2016**; **Wong et al. 2016**), we adjusted for modeled 24-mo average particulate matter $< 2.5\ \mu\mathrm{m}$ ($PM_{2.5}$) exposure, which was predicted at each geocoded address using a generalized additive mixed model (**Yanosky et al. 2014**). The $PM_{2.5}$ model extended from 1989–2006; values from 2007–2013 were carried forward. We used indicator variables in models to account for missing values in covariates, which has been shown to be a valid approach for dealing with missing data without losing power (**Song 2016**).

To assess whether the association between LAN and breast cancer differed across subpopulations, we examined effect modification by current menopausal status, BMI (BMI < 30 vs. BMI ≥ 30), race (white vs. nonwhite), smoking (current vs. past vs. never), $PM_{2.5}$ (quintiles), census-tract population density (quintiles), census-tract median income (quintiles), census-tract home value (quintiles), census region (northeast, midwest, west, and south), census-tract urbanicity (urban vs. nonurban), and night-shift work (no night-shift work since 1989 vs. any night-shift work since 1989). Urbanicity was determined by the participant's residence

people)] census tract. To evaluate whether the association between continuous LAN and breast cancer risk varied across these factors, we fit separate Cox proportional hazards models within strata of these factors and estimated stratum-specific HRs. For all time-varying factors, analyses were stratified by person-time. To test for significance of statistical interaction between LAN and each factor, we used a likelihood ratio test comparing models with cross-product terms and main-effects-only models. Observations with missing values for each factor were excluded from effect modification analyses. We examined whether there was heterogeneity in the association between LAN and breast cancer risk by tumor ER status (negative vs. positive) using the contrast test method (Wang et al. 2016). We performed sensitivity analyses restricting observations to 1997–2013 and estimating cumulative average LAN exposure starting in 1997, when concurrent LAN satellite data were available. An alpha level of 0.05 was used to define statistical significance, and all analyses were performed in SAS v.9.3 (SAS Institute Inc.).

Results

We observed 3,549 invasive breast cancer cases over 2,187,425 person-years of follow-up among the 109,672 eligible cohort members from 1989–2013. Over the person-time contributing to this analysis, participants were predominantly white and were more likely to be premenopausal and married (Table 1). The majority of person-time came from participants who lived in metropolitan areas, and two-thirds of the person-time came from participants who lived in the northeastern or midwestern United States. As expected in a population of nurses, 42% of the person-years contributed came from women who had performed night-shift work. Higher cumulative average LAN was associated with higher average values over follow-up for census-tract population density and median home value as well as with nulliparity, nonwhite race, and being nonmarried.

Table 1 Age-adjusted participant characteristics overall and by quintile of cumulative average LAN (n = 109,672) over 2,187,425 person-years of follow-up 1989–2013 (mean ± SD or %)[a].

Characteristic	Overall	LAN quintile 1 (0.4–7.2 nW/cm²/sr)	LAN quintile 2 (6.3–15.9 nW/cm²/sr)	LAN quintile 3 (14.4–30.1 nW/cm²/sr)	LAN quintile 4 (26.0–53.3 nW/cm²/sr)	LAN q 5 (41.4–248 /cm²/
Cumulative average light at night (nW/cm²/sr)	29.7 ± 26.0	3.8 ± 1.7	10.9 ± 2.4	21.1 ± 3.7	36.2 ± 5.8	69 ± 2
Age (years)[b]	45.7 ± 8.2	46.7 ± 8.0	46.0 ± 8.1	45.4 ± 8.3	45.4 ± 8.3	45.
Race[c]						
White (%)	95	98	98	97	95	90
Nonwhite (%)	5	2	2	3	5	10
Menopausal status						

Characteristic	Overall	LAN quintile 1 (0.4) /cm²/sr	LAN quintile 2 (6.3) /cm²/sr	LAN quintile 3 (14.4) /cm²/sr	LAN quintile 4 (26.0) /cm²/sr	LAN quintile 5 (41.4 /cm²/
Premenopausal (%)	74	73	74	74	75	75
Postmenopausal (%)	26	27	26	26	25	25
BMI (kg/m²)	26.41 ± 6.2	26.8 ± 6.3	26.4 ± 6.1	26.3 ± 6.2	26.2 ± 6.2	26.[illegible]
Physical activity (MET hrs/wk)	19.9 ± 27.9	18.7 ± 26.5	20.0 ± 27.5	20.1 ± 27.5	20.4 ± 28.7	20[illegible] ± 2[illegible]
Missing physical Activity (%)	7	7	7	7	7	9
Smoking status						
Never smoker (%)	65	67	65	65	65	62
Past smoker (%)	25	23	25	25	25	27
Current smoker (%)	9	9	9	9	9	9
History of benign breast disease[c]						
Yes (%)	44	45	45	45	44	43

of breast

No (%)	89	90	90	89	89	89
Age at menarche[c]						

Characteristic	Overall	LAN quintile 1 (0.4) nW/cm^2/sr	LAN quintile 2 (8.3) nW/cm^2/sr	LAN quintile 3 (14.4) nW/cm^2/sr	LAN quintile 4 (26.0) nW/cm^2/sr	LAN quintile 5 (41.4) nW/cm^2/sr
< 12 years old (%)	24	25	24	24	24	25
12 years old (%)	30	30	31	30	30	29
13 years old (%)	27	28	28	27	28	27
≥ 14 years old (%)	18	17	18	18	18	18
Parity and age at first birth						
Nulliparous (%)	17	12	13	16	19	24
1–2 children, < 25 years old (%)	14	18	16	13	12	10
1–2 children, 25-29 years old (%)	19	21	22	20	19	15
1–2 children, ≥ 30 years old (%)	13	10	12	14	14	15
3–4 children, < 25 years old (%)	10	14	12	10	9	7
3–4 children, 25-29 years old (%)	10	11	10	10	9	8
3–4 children, ≥ 30 years old (%)	2	2	2	3	3	3
5–9 children, < 25 years old (%)	1	1	1	1	1	1
5–9 children, ≥ 25 years old (%)	1	1	1	1	1	1
Missing parity and age at first birth	13	10	12	13	14	17
Height at baseline (cm)[c]						
127–155 (%)	9	8	8	8	9	10

Characteristic	Overall	LAN quintile 1 (0.4) /cm²/sr	LAN quintile 2 (6.3) /cm²/sr	LAN quintile 3 (14.4) /cm²/sr	LAN quintile 4 (26.0) /cm²/sr	LAN quintile 5 (41.4 /cm²/
156–163 (%)	37	38	38	37	37	37
164–170 (%)	38	39	39	38	38	37
> 170 (%)	[illegible]	[illegible]	15	[illegible]	[illegible]	[illegible]
Oral contraceptive use						
Never (%)	12	10	11	11	12	13
Past (%)	73	77	76	74	72	68
Current (%)	7	6	6	7	7	7
Missing oral contraceptive use (%)	9	7	7	8	9	12
Mammography screening						
No mammogram (%)	21	22	21	21	21	21
Screening mammogram (%)	53	53	54	53	53	51
Missing mammography (%)	26	25	25	26	26	28
BMI at Age 18[c]						
< 19 (%)	22	20	21	22	22	22
19–20.4 (%)	26	26	26	26	26	25
20.5–21.9 (%)	23	24	23	23	23	22
22–24.9 (%)	19	19	18	18	18	19
25–29.9 (%)	8	8	7	7	8	8
≥ 30 (%	2	2	2	2	2	3
Missing BMI at	1	1	1	1	1	1

Characteristic	Overall	LAN quintile 1 (0.4 … /cm²/sr)	LAN quintile 2 (6.3 … /cm²/sr)	LAN quintile 3 (14.4 … /cm²/sr)	LAN quintile 4 (26.0 … /cm²/sr)	LAN quintile 5 (41.4 … /cm²/
Missing BMI at age 18 (%)						
Alternative healthy eating index[d]	54.2	52.7	53.7	54.2	54.7	55
Missing alternative healthy eating index[d] (%)						
Living alone (%)						
Yes	7	4	5	7	8	11
No	93	96	95	93	92	89
Personal income (USD)[c]						
< 15,000 (%)	0	0	0	0	0	0
15,000–19,000 (%)	0	0	0	0	0	0
20,000–29,000 (%)	1	1	1	1	1	1
30,000–39,000 (%)	2	3	3	2	2	2
40,000–49,000 (%)	6	7	6	5	5	5
50,000–74,000 (%)	17	19	17	16	16	17
75,000–99,000 (%)	13	14	14	13	13	13
100,000–149,000 (%)	14	12	14	15	15	14
≥ 150,000 (%)	8	4	8	9	9	9
Missing income (%)	38	38	38	38	38	39

Characteristic	Overall	LAN quintile 1	LAN quintile 2	LAN quintile 3	LAN quintile 4	LAN quintile 5
Marital status						
Married (%)	56	62	59	57	55	49
Not married (%)	44	38	41	43	45	51
Night shift work						
Shift work since 1989 (%)	42	43	42	42	41	42
No shift work since 1989 (%)	58	57	58	58	59	58
$PM_{2.5}$ **(10 $\mu g/m^3$)**	1.4 ± 0.3	1.2 ± 0.3	1.3 ± 0.3	1.4 ± 0.3	1.4 ± 0.3	1.5
Census tract population density (per square kilometer)	1,481 ± 4,047	124 ± 235	493 ± 570	927 ± 957	1,406 ± 1,378	4,0 ± 8
Census tract median home value (1000 USD)	168 ± 122	122 ± 68	151 ± 101	170 ± 118	185 ± 126	202
Census tract median income (1000 USD)	65 ± 24	55 ± 16	64 ± 22	68 ± 23	70 ± 25	68
Census region						
Northeast (%)	33	32	39	32	28	33
Midwest (%)	33	40	31	31	34	29
West (%)	16	7	10	17	20	22
South (%)	19	21	20	21	18	16
Census tract urbanicity						
Urban (%)	87	62	79	92	97	99

Characteristic (%)	Overall	LAN quintile 1 (0.4 /cm²/sr	LAN quintile 2 (6.3 /cm²/sr	LAN quintile 3 (14.4 /cm²/sr	LAN quintile 4 (26.0 /cm²/sr	LAN quintile 5 (41.4 /cm²/

Note: BMI, body mass index; LAN, light at night; MET, metabolic equivalent of task; PM, particulate matter with aerodynamic diameter < 2.5 μm; SD, standard deviation.

[a]Means and percentages are based on the person-time over follow-up. All time-varying factors are updated at each questionnaire cycle.

[b]Estimate not age-adjusted.

[c]Not time-varying.

[d]Based on reported consumption of foods and nutrients that have been associated consistently with lower risk of chronic disease (Chiuve et al. 2012).

Estimated associations between cumulative average outdoor LAN and breast cancer are shown in Table 2. There was an estimated 14% increased risk of breast cancer in the top quintile of outdoor LAN compared with the lowest quintile of LAN (95% CI: 1.01, 1.29) in the fully adjusted model. The association was strongest for the highest quintile but was not monotonic with increasing LAN. Cubic spline models did not significantly improve model fit relative to linear models (data not shown). Continuous analyses also showed a positive association between outdoor LAN and breast cancer, with a 5% higher rate of breast cancer (95% CI: 1.00, 1.11) in fully adjusted models for each IQR (31.6 nW/cm ^{2}/sr) increase in cumulative average outdoor LAN in the area around participants' homes. The results were similar when analyses were restricted to 1997–2013, when concurrent outdoor LAN data were available [HR = 1.06 (95% CI: 1.00, 1.13) based on 105,304 women and 2,954 breast cancer cases] (Table 3).

Table 2 Associations between cumulative average outdoor LAN and breast cancer in the Nurses' Health Study II (*n* = 109,672) with 3,549 breast cancer cases over 2,187,425 person-years of follow-up (1989–2013).

Exposure	**Cumulative average light at night**			
	Cases (*n*)	**Person-years**	**Age-adjusted HR (95% CI)**	**Fully adjusted HR (95% CI)[a]**
LAN quintile 1 (Median 4.3 nW/cm ^{2}/sr**)**	571	360,609	Reference	Reference
LAN quintile 2 (Median 12.4 nW/cm ^{2}/sr**)**	715	432,584	1.08 (0.97, 1.21)	1.05 (0.94, 1.18)
LAN quintile 3 (Median 22.9 nW/cm ^{2}/sr**)**	710	459,789	1.05 (0.94, 1.17)	1.01 (0.90, 1.13)
LAN quintile 4 (Median 37.2 nW/cm ^{2}/sr**)**	776	469,624	1.12 (1.01, 1.25)	1.08 (0.97, 1.22)
LAN quintile 5 (Median 64.0 nW/cm ^{2}/sr**)**	777	464,820	1.13 (1.02, 1.26)	1.14 (1.01, 1.29)

Exposure	Cumulative average light at night			
	Cases	Person-	Age-adjusted HR	Fully adjusted HR
***p* for trend**[b]			0.03	0.02
Continuous LAN (per IQR increase[c]**)**			1.03 (0.99, 1.07)	1.05 (1.00, 1.11)

Note: BMI, body mass index; CI, confidence interval; HR, hazard ratio; IQR, interquartile range; LAN, light at night; $PM_{2.5}$, particulate matter with aerodynamic diameter < 2.5 μm.

[a]HRs are adjusted for benign breast disease history, family history of breast cancer, age at menarche, parity and age at first birth, height, white race, BMI, BMI at age 18, oral contraceptive use, mammography screening, menopausal status, smoking status, alternative healthy eating index, physical activity, marital status, living alone, personal income, shift work after 1989, region, $PM_{2.5}$, census-tract median home value, income, and population density.

[b]Test for trend is based on the median value for each quintile.

[c]An IQR increase in cumulative average LAN is 31.6 $nW/cm^2/sr$.

Table 3 Associations of cumulative average outdoor LAN and breast cancer risk in the Nurses' Health Study II (*n* = 105,304) with 2,954 breast cancer cases over 1,497,270 person-years of follow-up 1997–2013.

Exposure	Cumulative average light at night			
	Cases (*n*)	Person-years	Age-adjusted HR (95% CI)	Fully adjusted HR (95% CI)[a]
LAN quintile 1 (Median 4.3 $nW/cm^2/sr$**)**	486	263,512	Reference	Reference
LAN quintile 2 (Median 12.4 $nW/cm^2/sr$**)**	611	298,740	1.09 (0.97, 1.24)	1.07 (0.94, 1.21)
LAN quintile 3 (Median 22.9 $nW/cm^2/sr$**)**	583	309,527	1.07 (0.95, 1.21)	1.04 (0.92, 1.18)
LAN quintile 4 (Median 37.2 $nW/cm^2/sr$**)**	625	314,141	1.19 (1.06, 1.34)	1.17 (1.03, 1.33)
LAN quintile 5 (Median 64.0 $nW/cm^2/sr$**)**	649	311,351	1.09 (0.97, 1.23)	1.12 (0.98, 1.29)
***p* for trend**[b]			0.06	0.07
Continuous LAN (per IQR increase[c]**)**			1.02 (0.98, 1.07)	1.06 (1.00, 1.13)

Note: BMI, body mass index; CI, confidence interval; HR, hazard ratio; IQR, interquartile range; LAN, light at night; $PM_{2.5}$, particulate matter with aerodynamic diameter < 2.5 μm.

[a]Hazard ratios are adjusted for benign breast disease history, family history of breast cancer, age at menarche, parity and age at first birth, height, white race, BMI, BMI at age 18, oral contraceptive use, mammography screening, menopausal status, smoking status, alternative healthy eating index, physical activity, marital status, living alone, personal income, shift work after 1989, region, $PM_{2.5}$, census-tract median home value, income, and population density.

[b]Test for trend is based on the median value for each quintile.

[c]An IQR increase in cumulative average LAN is 31.6 $nW/cm^2/sr$.

Analyses stratified by current menopausal status at the time of breast cancer diagnosis suggested that the positive association between LAN and breast cancer was specific to premenopausal women [HR per IQR increase in LAN for premenopausal women=1.07 (95% CI: 1.01, 1.14) based on 1,973 cases; HR for postmenopausal women=1.00 (95% CI: 0.91, 1.09) based on 1,172 cases; p for interaction=0.08] (Table 4; see also Figure S1). We did not detect statistically significant heterogeneity in the HRs for outdoor LAN when comparing ER-positive versus ER-negative tumors (see Table S1; p for heterogeneity=0.33), although we did observe a positive association for ER-positive tumor types [HR per IQR increase in LAN=1.06 (95% CI: 0.99, 1.13) based on 2,137 cases], which comprised the majority of cases, and no association for ER-negative tumors [HR=0.98 (95% CI: 0.85, 1.13) based on 512 cases]. Associations were stronger in those who had worked night shifts [HR per IQR increase in LAN=1.09 (95% CI: 1.01, 1.18) based on 1,196 cases] compared with those who had never worked night shifts since 1989 [HR=1.03 (95% CI: 0.97, 1.09) based on 2,353 cases] (Table 5; see also Figure S1). The association between LAN and breast cancer was observed only in past and current smokers [HR for current smokers=1.21 (95% CI: 1.07, 1.37) based on 300 cases; HR for past smokers=1.10 (95% CI: 1.01, 1.19) based on 1,034 cases; HR for never smokers=1.00 (95% CI: 0.94, 1.07) based on 2,215 cases; p for interaction=0.008] (Table 6; see also Figure S1). There were no statistically significant differences in the association between LAN and breast cancer by BMI, race, $PM_{2.5}$, census-tract median income, census-tract median home value, census region, census-tract population density, or census-tract urban/nonurban status (see Figure S1).

Table 4 Cumulative average LAN and breast cancer risk stratified by menopausal status at the time of an event in the Nurses' Health Study II (n = 109,155)[a].

Exposure	**Premenopausal**		**Postmenopausal**	
	Cases (n)	**Fully adjusted HR (95% CI)[b]**	**Cases (n)**	**Fully adjusted HR (95% CI)[b]**
LAN quintile 1 (Median 4.3 $nW/cm^2/sr$**)**	282	Reference	223	Reference
LAN quintile 2 (Median 12.4 $nW/cm^2/sr$**)**	367	1.02 (0.87, 1.19)	242	0.96 (0.80, 1.16)
LAN quintile 3 (Median 22.9 $nW/cm^2/sr$**)**	415	1.08 (0.92, 1.26)	229	0.92 (0.77, 1.11)

Exposure	Premenopausal		Postmenopausal	
	Cases	Fully adjusted HR	Cases	Fully adjusted HR
LAN quintile 4 (Median 37.2 nW/cm ^{2}/sr**)**	447	1.12 (0.96, 1.31)	248	0.99 (0.82, 1.19)
LAN quintile 5 (Median 64.0 nW/cm ^{2}/sr**)**	462	1.20 (1.02, 1.41)	230	0.95 (0.78, 1.15)
Continuous LAN (per IQR increase[c])		1.07 (1.01, 1.14)		1.00 (0.91, 1.09)
***p* for interaction**	0.08			

Note: BMI, body mass index; CI, confidence interval; HR, hazard ratio; IQR, interquartile range; LAN, light at night; $PM_{2.5}$, particulate matter with aerodynamic diameter < 2.5 *μ*m.

See Figure S1 for a graphical representation of this table.

[a]There were 404 cases who were missing menopausal status at the time of an event. These observations are excluded from this analysis.

[b]Hazard ratios are adjusted for benign breast disease history, family history of breast cancer, age at menarche, parity and age at first birth, height, white race, BMI, BMI at age 18, oral contraceptive use, mammography screening, smoking status, alternative healthy eating index, physical activity, marital status, living alone, personal income, shift work after 1989, region, $PM_{2.5}$, census-tract median home value, income, and population density.

[c]An IQR increase in cumulative average LAN is 31.6 nW/cm ^{2}/sr.

Table 5 Cumulative average LAN and breast cancer risk stratified by night shift work since 1989 in the Nurses' Health Study II (*n* = 109,672).

Exposure	No shift work since 1989		Any shift work since 1989	
	Cases (*n*)	Fully adjusted HR (95% CI)[a]	Cases (*n*)	Fully adjusted HR (95% CI)[a]
LAN quintile 1 (Median 4.3 nW/cm ^{2}/sr**)**	386	Reference	185	Reference
LAN quintile 2 (Median 12.4 nW/cm ^{2}/sr**)**	469	0.98 (0.86, 1.13)	246	1.18 (0.98, 1.43)
LAN quintile 3 (Median 22.9 nW/cm ^{2}/sr**)**	472	0.96 (0.84, 1.10)	238	1.09 (0.90, 1.32)
LAN quintile 4 (Median 37.2 nW/cm ^{2}/sr**)**	515	1.01 (0.88, 1.16)	261	1.19 (0.98, 1.44)

Exposure	No shift work since 1989		Any shift work since 1989	
	Cases	Fully adjusted HR	Cases	Fully adjusted HR
LAN quintile 5 (Median 64.0 nW/cm ^{2}/sr**)**	511	1.04 (0.90, 1.20)	266	1.29 (1.06, 1.56)
Continuous LAN (per IQR increase[b])		1.03 (0.97, 1.09)		1.09 (1.01, 1.18)
***p* for interaction**	0.10			

Note: BMI, body mass index; CI, confidence interval; HR, hazard ratio; IQR, interquartile range; LAN, light at night; $PM_{2.5}$, particulate matter with aerodynamic diameter < 2.5 μm.

See Figure S1 for a graphical representation of this table.

[a]Hazard ratios are adjusted for benign breast disease history, family history of breast cancer, age at menarche, parity and age at first birth, height, white race, BMI, BMI at age 18, oral contraceptive use, mammography screening, menopausal status, smoking status, alternative healthy eating index, physical activity, marital status, living alone, personal income, region, $PM_{2.5}$, census-tract median home value, income, and population density.

[b]An IQR increase in cumulative average LAN is 31.6 nW/cm ^{2}/sr.

Table 6 Cumulative average LAN and breast cancer risk stratified by smoking status in the Nurses' Health Study II (*n* = 109,672).

Exposure	Never		Past		Current	
	Cases (*n*)	Fully adjusted HR (95% CI)[a]	Cases (*n*)	Fully adjusted HR (95% CI)[a]	Cases (*n*)	Fully adjusted HR (95% CI)[a]
LAN quintile 1 (Median 4.3 nW/cm ^{2}/sr**)**	382	Reference	146	Reference	43	Reference
LAN quintile 2 (Median 12.4 nW/cm ^{2}/sr**)**	460	1.04 (0.91, 1.20)	189	1.01 (0.81, 1.25)	66	1.27 (0.87, 1.87)
LAN quintile 3 (Median 22.9 nW/cm ^{2}/sr**)**	465	1.02 (0.89, 1.18)	192	0.97 (0.78, 1.21)	53	0.97 (0.65, 1.46)
LAN quintile 4 (Median 37.2 nW/cm ^{2}/sr**)**	473	1.02 (0.88, 1.17)	250	1.23 (1.00, 1.51)	53	0.98 (0.65, 1.46)

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Exposure	Never		Past		Current	
	Cases	Fully (95% CI)[a]	Cases	Fully (95% CI)[a]	Cases	Fully HR (95% CI)[a]
LAN quintile 5 (Median 64.0 nW/cm ^{2}/sr)	435	1.02 (0.88, 1.18)	257	1.23 (0.99, 1.52)	85	1.54 (1.06, 2.23)
Continuous LAN (per IQR increase[b])		1.00 (0.94, 1.07)		1.10 (1.01, 1.19)		1.21 (1.07, 1.37)
p for interaction	0.008					

Note: BMI, body mass index; CI, confidence interval; HR, hazard ratio; IQR, interquartile range; LAN, light at night; $PM_{2.5}$, particulate matter with aerodynamic diameter < 2.5 μm.

See Figure S1 for a graphical representation of this table.

[a]Hazard ratios are adjusted for benign breast disease history, family history of breast cancer, age at menarche, parity and age at first birth, height, white race, BMI, BMI at age 18, oral contraceptive use, mammography screening, menopausal status, alternative healthy eating index, physical activity, marital status, living alone, personal income, shift work after 1989, region, $PM_{2.5}$, census-tract median home value, income, and population density.

[b]An IQR increase in cumulative average LAN is 31.6 nW/cm ^{2}/sr.

Discussion

In this nationwide prospective analysis of female nurses, we observed a positive association between cumulative average exposure to residential outdoor LAN and breast cancer risk, which was robust to adjustment for many important breast cancer risk factors. This association was generally consistent across categories of BMI, race, $PM_{2.5}$, and census-tract level median income, median home value, population density, and urban/nonurban status. The association between LAN and breast cancer was observed only among current and past smokers and premenopausal women. The association between LAN and breast cancer risk was more pronounced among women who had worked night shifts and was linked most strongly to ER-positive tumor types, although differences were not statistically significant across these factors.

Studies have observed an association between exposure to LAN and cancer risk in animal models (Blask et al. 2014; Stevens et al. 2007); however, few epidemiologic studies have examined the association between outdoor LAN and breast cancer. Several ecological studies reported that satellite-based LAN was associated with breast cancer incidence at the country or community level (Keshet-Sitton et al. 2016a; Kim et al. 2015; Kloog et al. 2008, 2010; Portnov et al. 2016; Rybnikova et al. 2015). For example, one study reported a 73% higher incidence of breast cancer in communities with the highest LAN than in those with the lowest LAN across 147 communities in Israel (Kloog et al. 2008). Although these studies were consistent with our findings, they were limited by their inability to link individual exposure and outcome as well as by the lack of information on individual-level confounding. A case–control study using breast cancer cases and lung cancer controls in the U.S. state of Georgia suggested a link between higher levels of outdoor LAN exposure, assessed at the geocoded address, and breast cancer risk. The authors found that high LAN exposure (> 41 nW/cm ^{2}/sr) was associated with increased odds of breast cancer compared with low LAN exposure (≤ 20 nW/cm^2/sr) [OR = 1.12 (95% CI: 1.04, 1.20)] (Bauer et al. 2013). In a small case–control study in Israel, participants who reported living near "strong artificial light at night sources" had higher odds of being a breast cancer case

one prior prospective cohort study examining outdoor LAN and breast cancer risk. Hurley et al. (2014) examined California Teacher's Study (CTS) data on 106,731 participants and found that women living in areas with the highest quintile of LAN (range: 53.4–175.2 nW/cm^2/sr) compared with the lowest quintile (range: 0–14.2 nW/cm^2/sr) had the highest risk of invasive breast cancer [HR=1.12 (95% CI: 1.00, 1.26)]. The authors assessed LAN exposure for baseline addresses (1995–96) using high-dynamic range LAN data for 2006. Consistent with our findings, the association appeared to be specific to premenopausal women [HR for the highest vs. lowest LAN quintile=1.34 (95% CI: 1.07, 1.69) vs. 1.04 (95% CI: 0.90, 1.20), respectively, for postmenopausal women], although the difference was not significant (p for interaction = 0.34). Because only one year of high-dynamic range data was available at the time of analysis, the CTS study did not include time-varying information on exposure. The present analysis extends that research by including time-varying exposure information at a broader range of outdoor LAN levels (ranging from 0.39–248.1 nW/cm^2/sr) and by expanding the geographic scope to the entire contiguous United States. Our results corroborate the findings of the CTS and provide further evidence that outdoor LAN may be associated with increased breast cancer risk.

Our analysis of effect modification of the LAN–breast cancer relationship by smoking status revealed that associations were only evident in current and past smokers. Smoking has been associated with breast cancer in some studies (Cui et al. 2006; Gaudet et al. 2013; Gaudet et al. 2016; Gram et al. 2015; Luo et al. 2011; Reynolds et al. 2004a), although other studies have not reported associations (Egan et al. 2002; Palmer and Rosenberg 1993). A prior study of 459 NHSII participants reported that creatinine-corrected melatonin concentrations in spot urine samples were significantly lower in women with ≥ 15 pack-years of smoking than in never smokers (Schernhammer et al. 2006a), and lower melatonin has been associated with increased breast cancer risk (Schernhammer and Hankinson 2009). Our finding of increased relative risks among smokers exposed to higher LAN suggests that LAN and smoking may share similar melatonin-mediated pathways to breast cancer risk.

This study is one of the first analyses of LAN and breast cancer that incorporates information on night-shift work. In stratified analyses, the association between LAN and breast cancer was stronger among participants who worked night shifts at any time since 1989 than among those who did not, although the difference was not statistically significant (interaction $p-\text{value} = 0.10$). This finding suggests that both exposure to LAN and night-shift work contribute jointly to increase breast cancer risk, possibly through mechanisms involving circadian disruption.

Although our results should be interpreted with caution given the small numbers of ER-negative cases, this analysis suggests that the association with LAN was limited to ER-positive tumors. This finding is consistent with the hypothesis that LAN acts through estrogen receptor signaling–mediated pathways to increase breast cancer risk. Hurley et al. (2014) also examined associations with LAN according to ER (and progesterone receptor) status, but they noted that numbers of cases within subgroups were small, and they did not report quantitative estimates from this analysis.

Our study has a few limitations. First, exposure misclassification could occur because of missing satellite data and data processing errors. In addition, satellite-based measures of outdoor LAN are a proxy for total personal exposure to LAN, and a study has demonstrated that outdoor LAN measures may not capture true individual exposure to LAN, including indoor sources, that is thought to drive breast cancer risk (Rea et al. 2011). Although total personal exposure to LAN may be important to discern the etiologic association between LAN and breast cancer, the association between outdoor LAN and breast cancer risk may be relevant in a policy context because city- or county-scale policies that limit outdoor nighttime lighting may affect ambient

LAN levels. Alternatively, outdoor LAN could be a proxy for an unmeasured breast cancer risk factor, where policies to limit outdoor LAN would have little effect. In addition, in this analysis, LAN data were available starting in 1996, so there was a temporal mismatch between LAN measures and our breast cancer data for

successfully geocoded 85% of addresses to the street level, residences that could not be geocoded may differ in urban/nonurban characteristics, and thus, they may differ in LAN exposure. Given the relatively low proportion of missing exposure data, any selection bias is expected to be minimal. In addition, participants were 25–42 y old at baseline in 1989, so this analysis is missing data on exposure before this period, which might be an etiologically important time window. With any study of neighborhood factors and health, there is a possibility that participants may self-select into certain neighborhoods they deem "healthier" than others. However, adjustment for established breast cancer risk factors reduces the likelihood that neighborhood self-selection explains the associations that we observed. Because > 95% of participants classified themselves as white, we were underpowered to detect differences in the association between outdoor LAN and breast cancer by race/ethnicity, and our findings may not be generalizable to women who are not white. Because all participants were nurses at enrollment, the generalizability of our findings to lower SES, nonworking groups is also potentially limited. Finally, although we adjusted for air pollution and population density, we cannot rule out the possibility that other factors that are correlated with outdoor LAN [e.g., economic activity (**Rybnikova and Portnov 2015**)] might explain the observed association between LAN and breast cancer risk.

This analysis has a number of strengths. First, this study was conducted over more than two decades with time-varying information about outdoor LAN recorded at the residence level. Second, this study applied high-dynamic range, objective satellite data to capture potentially important intraurban differences in outdoor LAN and included information on higher levels of LAN exposure. Third, we have time-varying information on a number of factors, including menopausal status, family history of breast cancer, parity, oral contraceptive use, smoking status, diet, physical activity, air pollution, and area-level SES. To our knowledge, no prior LAN analyses have examined effect modification by smoking status, and our findings suggest that the association between LAN and breast cancer risk existed only in current or past smokers. This is also the first LAN study of which the authors are aware to incorporate information about night-shift work into the analysis, with > 42% of the study population having worked night shifts since 1989. Thus, we were able to adjust for potential confounding by many established and suspected breast cancer risk factors. Finally, this nationwide study covers a broad geographic range of outdoor LAN levels, including participants in both urban and nonurban areas.

Conclusions

This prospective study, conducted over 22 y of follow-up with time-varying and objective measures of ambient LAN across the contiguous United States, provides evidence that women living in areas with high levels of outdoor LAN may be at higher risk of breast cancer even after accounting for individual and area-level risk factors for breast cancer. Athough further work is required to confirm our results and to clarify potential mechanisms, our findings suggest that exposure to outdoor light at night may contribute to breast cancer risk.

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Exhb 2r Footnote 22 Light at Night Co-distributes with Incident Breast but not Lung Cancer (234-239)

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Original

Light at Night Co-distributes with Incident Breast but not Lung Cancer in the Female Population of Israel

Itai Kloog, Abraham Haim, Richard G. Stevens, Micha Barchana &
Prof. Boris A. Portnov

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Abstract

Recent studies of shift-working women have reported that excessive exposure to light at night (LAN) may be a risk factor for breast cancer. However, no studies have yet attempted to examine the co-distribution of LAN and breast cancer incidence on a population level with the goal to assess the coherence of these earlier findings with population trends. Coherence is one of Hill's “criteria” (actually, viewpoints) for an inference of causality. Nighttime satellite images were used to estimate LAN levels in

147 communities in Israel. Multiple regression analysis was performed to investigate the association between LAN and breast cancer incidence rates and, as a test of the

population density, and local income level, a strong positive association between LAN intensity and breast cancer rate was revealed ($p<0.05$), and this association strengthened ($p<0.01$) when only statistically significant factors were filtered out by stepwise regression analysis. Concurrently, no association was found between LAN intensity and lung cancer rate. These results provide coherence of the previously reported case-control and cohort studies with the co-distribution of LAN and breast cancer on a population basis. The analysis yielded an estimated 73% higher breast cancer incidence in the highest LAN exposed communities compared to the lowest LAN exposed communities.

Keywords: Breast cancer, Light at night, Melatonin Lung cancer

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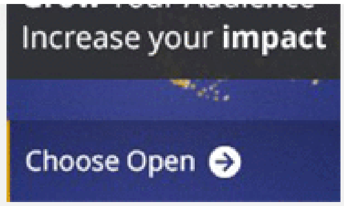
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REVIEW

Melatonin, environmental light, and breast cancer

V. Srinivasan · D. W. Spence · S. R. Pandi-Perumal · I. Trakht · A. I. Esquifino · D. P. Cardinali · G. J. Maestroni

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Abstract Although many factors have been suggested as causes for breast cancer, the increased incidence of the disease seen in women working in night shifts led to the hypothesis that the suppression of melatonin by light or melatonin deficiency plays a major role in cancer development. Studies on the 7,12-dimethylbenz[a]anthracene and *N*-methyl-*N*-nitrosourea experimental models of human breast cancer indicate that melatonin is effective in reducing cancer development. In vitro studies in MCF-7 human breast cancer cell line have shown that melatonin exerts its anticarcinogenic actions through a variety of mechanisms, and that it is most effective in estrogen receptor (ER) α-positive breast cancer cells. Melatonin suppresses ER gene, modulates several estrogen dependent regulatory proteins and pro-oncogenes, inhibits cell proliferation, and impairs the metastatic capacity of MCF-7 human breast cancer cells. The anticarcinogenic action on MCF-7 cells has been demonstrated at the physiological concentrations of melatonin attained at night, suggesting thereby that melatonin acts like an endogenous antiestrogen. Melatonin also decreases the formation of estrogens from androgens via aromatase inhibition. Circulating melatonin levels are abnormally low in ER-positive breast cancer patients thereby supporting the melatonin hypothesis for breast cancer in shift working women. It has been postulated that enhanced endogenous melatonin secretion is responsible for the beneficial effects of meditation as a form of psychosocial intervention that helps breast cancer patients.

Keywords Melatonin · Breast cancer · Estrogen receptor · Light at night · Shift-work · Melatonin receptors · Meditation

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Introduction

Breast cancer is the most frequent form of cancer in women (22%), with an estimated incidence of over 1 million new cases every year worldwide. In the year 2000 breast cancer accounted for the death of more than 375,000 people worldwide [1]. The American Cancer Society has estimated that approximately 212,920 new cases of invasive breast cancer, 61,980 in situ cases, and 40,970 deaths were expected to occur among US women in 2006 [2].

Many factors such as genetics, hormonal environment, age, dietary and alcohol consumption or cigarette smoking, have all been hypothesized as contributors to the development of breast cancer [3]. For example, estrogens significantly contribute to the development of cancer depending upon timing of exposure [4, 5]. Whether the stimulatory actions of estrogens on epithelial cell proliferation, their mutagenic actions or their metabolites contribute to the genesis and growth of mammary tumors is still a matter of debate [6].

More recently, epidemiological studies have cited associational evidence that night shift work and exposure to light at night are risk factors for breast cancer [7–9]. Exposure to light at night was proposed as a major occupational hazard for breast cancer and a ''melatonin hypothesis'' of breast cancer, was put forth by Stevens in 1987 [10–12].

Reduced melatonin levels and elevated estrogen secretion have been documented in nurses who developed breast cancer and who had long employment stories of rotating night shifts [13]. However, interpretation of retrospective epidemiological studies is hampered by the possibility that the disease itself affects melatonin levels. It must be noted that the first study of prediagnosis melatonin level failed to find a difference between women who later developed breast cancer and those who did not [14]. Further evidence of the need for caution in interpreting associational studies has been provided by the finding of an inverse correlation between stages of breast cancer and nocturnal melatonin levels have been reported in breast cancer patients [15].

Despite the difficulties involved in inferring causality from epidemiological studies, other lines of evidence have suggested that disrupted melatonin rhythms due to phototransduction effects may nevertheless be important factors in breast cancer development [8]. The scope of this review is focused upon the suggested role of light in the etiology of breast cancer and how melatonin acts as an effective oncostatic agent for prevention and control of breast cancer. Indeed, it has been suggested that the pineal gland may function as an ''oncostatic gland'' since its main secretory product melatonin is antitumorigenic against a broad spectrum of neoplasms both in vivo and in vitro [16].

Pineal gland and melatonin: biosynthesis

Melatonin is synthesized primarily in the pineal gland of all vertebrates including humans. The pineal gland is mainly concerned with translation of photoperiodic information into the melatonin signal that serves as a ''chemical code for darkness'' to all tissues in the body [17]. In humans, the pineal gland is a part of epithalamus and is attached to the roof of the third ventricle. Its average weight is 100–180 mg, with adult dimensions 5–9 mm in length, 1–5 mm in width and 3–5 mm in thickness [18, 19]. The pinealocytes are the principal cell type of the pineal gland and are not capable of responding directly to light [20], even though they contain photoreceptor specific proteins like rhodopsin and the S-antigen [21].

Although melatonin is synthesized primarily in the pineal gland, synthesis also occurs in other organs and tissues such as the eye [22–24], skin [25], gastrointestinal tract [26, 27], lymphocytes [28], platelets [29] and bone marrow [30].

Tryptophan is converted into 5-hydroxytryptophan, and then to serotonin by 5-HT *N*-acetyl transferase. Serotonin is subsequently acetylated to form *N*-acetylserotonin, by the enzyme arylalkylamine-*N*-acetyltransferase. *N*-acetylserotonin is then converted into melatonin, by 5-hydroxyindole-O-methyl transferase, which is now considered as the rate limiting enzyme for melatonin biosynthesis [31]. Once formed, melatonin is released into the capillaries and in higher concentrations into the cerebrospinal fluid [32] and then is rapidly distributed to most body tissues [33]. Melatonin synthesis in the pineal gland exhibits a circadian rhythm with low levels being produced during daytime hours and higher levels during the scotophase [34]. The extent of melatonin increase at night shows marked individual variations and both groups of individuals with low and high melatonin secretion have been identified [35, 36]. These individual variations are presumably genetic [37]. The pineal gland remains the major source of melatonin in body fluids inasmuch as melatonin levels in plasma, CSF and urine are suppressed after pinealectomy [34].

Intravenously administered melatonin exhibits a biexponential decay with a first distribution half-life of 2 min and a second metabolic half life of 20 min [34]. Melatonin is metabolized mainly in the liver where it is first hydroxylated by Cytochrome P450 monooxygenases and then conjugated with sulfate to form 6-sulfatoxymelatonin [38]. In the brain, melatonin is metabolized by oxidative pyrrole-ring cleavage into kynurenine derivatives [39]. The primary cleavage product is N^1-acetyl-N^2-formyl-5-methoxykynuramine (AFMK), which is deformylated, either by arylamine formamidase or hemoperoxidases to N^1-acetyl-5-methoxykynuramine [40, 41]. Evidence from some studies have supported estimates that pyrrole ring cleavage contributes to about one third of the total catabolism, but the percentage may be even higher in certain tissues [41].

Regulation of melatonin synthesis and secretion

The circadian rhythm of melatonin secretion is regulated by the suprachiasmatic nucleus (SCN) of the hypothalamus, through a multicircuitry pathway involving descending projections to the intermediolateral column of the spinal cord, preganglionic sympathetic fibers to the superior cervical ganglion and postganglionic sympathetic fibers ending in the pineal gland [42]. The endogenous rhythm of melatonin secretion is synchronized to the environmental light-dark (L/D) cycle via the retino-hypothalamic tract, which originates in special photoreceptive, melanopsin-containing, retinal ganglion cells (RGCs) [43, 44]. These melanopsin containing RGCs are maximally sensitive to short wavelengths at 484 nm. Although the melanopsin pathway has been identified as the main pathway by which light influences suppression of melatonin by light in humans [45], studies undertaken in transgenic rodents suggest that rod and cone photoreceptors also have the capability for transducing light signals into photoperiodic responses [46].

The SCN electrical activity is inhibited during the dark phase of daily photoperiod [47] at the time of activation of pineal sympathetic nerves [48] and promotion of melatonin synthesis [49]. Norepinephrine released from postganglionic sympathetic nerve fibers innervating the pineal gland activates the adenylyl cyclase and through 3′,5′-cyclic adenosine monophosphate (cAMP) mechanism which in turn enhances the activity of melatonin synthesizing enzymes that promotes melatonin formation [49]. In addition to β adrenergic receptors activation in the pinealocytes, α_1 receptors have also been detected [50]. The α_1 receptors are activated through increases in Ca^{2+} concentration and protein kinase (PKC) activity. The α_1 activation in turn promotes melatonin biosynthesis through synergistic activation of both cAMP and PKC mechanisms [51]

Melatonin functions in the body

Melatonin has a wide range of functions in the body. It is termed a 'chronobiotic' because it synchronizes bodily rhythms [52] and it is used as a biochemical marker for circadian phase [53]. The chronobiotic action of melatonin is attributed to its direct inhibitory influence on electrical and metabolic activity of the SCN [54]. The close relationship between the nocturnal increase of endogenous melatonin and timing of sleep in humans suggests that melatonin is involved in the physiological regulation of sleep [55–57]. Melatonin and some of its metabolites (e.g., AFMK) are effective antioxidants [40, 41] and scavengers of hydroxyl radicals [58]. Melatonin also acts as an antioxidant by up-regulating several anti-oxidative enzymes [59–62] Melatonin's antioxidant action can be beneficial not only in retarding aging but also in arresting age-induced degenerative diseases such as Alzheimer's disease and Parkinsonism [63, 64] and neoplastic growth [65, 66].

Melatonin has also a well established immunomodulatory role as demonstrated in number of experimental conditions (for reviews see [67–69]). It might be postulated that the ability of melatonin to boost NK cell differentiation and activity is of relevance in the initial stage of the neoplastic disease. As a consequence, melatonin may have an oncostatic effect against a variety of tumor cells [70].

In addition to immunomodulatory, anti-proliferative and antioxidant effects of melatonin, a melatonin's possible influence on angiogenesis (a major mechanism responsible for tumor growth and dissemination) has been also addressed. In one of the initial studies in this line of research Lissoni and co-workers found that in patients with advanced cancer vascular endothelial growth factor (VEGF) was the most highly active factor in promoting angiogenesis [71]. In 20 patients abnormally high circulating levels of the growth factor were found to occur and were associated with a poor prognosis. The patient sample included those who had progressed on previous conventional antitumor therapies and for whom no other effective treatment was available. The patients were given oral doses of melatonin at 20 mg/day in the evening for at least 2 months. By evaluating changes in VEGF levels in relation to the clinical response, non-progressing patients showed a significant decline in VEGF mean concentrations, whereas no effect was achieved in progressing patients. The authors concluded that melatonin may control tumor growth at least in part by acting as a natural anti-angiogenic molecule [71].

By using Western blot analyses for p53, Bax and Bcl-2 expression in human umbilical vein endothelial cells Cui et al. reported significant anti-proliferative and apoptosis-inducing effects of melatonin [72]. All these effects were associated with cell cycle arrest, upregulation of p53 and Bax and downregulation of Bcl-2. The authors concluded that these results offered support to the anti-angiogenic activity of melatonin [72].

Insulin-like growth factor-I (IGF-I) is involved in promoting both normal and neoplastic cell growth, angiogenesis, and neoplasma progression. In 24 patients with stage II breast cancer a trend to statistically significant relations between mean plasma melatonin and IGF-I was found [73]. In the breast cancer group the correlation coefficient between IGF-I concentration in plasma and melatonin was $r = -0.392$ ($P = 0.058$). The authors concluded that, after confirmation in a larger population, the presence of such a negative correlation between plasma melatonin and IGF-I concentrations in patients with neoplastic disease implied the existence of an additional defense mechanism for the oncostatic influence of melatonin, presumably involving inhibition of angiogenesis [73].

In a study designed to assess whether melatonin affects healing of incisions, melatonin was given to either normal or pinealectomized rats [74]. While collagen deposition and epithelization increased concurrently in incision wounds after pinealectomy, exogenous melatonin decreased collagen synthesis and epithelium proliferation and had negative effects on wound healing in both normal and pinealectomized rats. It must be noted, however, that under certain circumstances melatonin may be pro-angiogenic. In a study on angiogenesis in wound healing in rats, angiogenesis evaluated in healing tissues by light and electron microscopy and by hydroxyproline level measurements, was significantly increased by melatonin treatment [75].

Melatonin receptors

The melatonin receptors cloned so far belong to the super family of G-protein-coupled receptors (GPCRs) containing the typical 7 transmembrane domains. Both MT_1 (Mel 1a) and MT_2 (Mel 1b) melatonin receptors have a 60% homology in amino acid sequence; presumably, they are not splice variants of each other but represent two related receptors which are expressed in different tissues [76]. A melatonin binding site initially called ''MT_3 receptor'' was later identified as the enzyme quinone reductase 2 [77].

Melatonin also binds to orphan nuclear receptors of the retinoic acid receptor family ROR α_1, ROR α_2 and RZRβ [78]. Although some believe that melatonin exerts its actions through nuclear receptors [79] the subject remains unsettled. By acting through MT_1, melatonin modulates the transcriptional activity of the ROR α receptors in breast cancer [80].

Activation of MT_1 receptors inhibits adenylyl cyclase through a pertusis toxin sensitive mechanism [81]. It has been conclusively demonstrated that the majority of anti-proliferative effects of melatonin on MCF-7 human breast tumor cells are mediated through activation of MT_1 membrane associated GPCRs [76].

Light, night shift and breast cancer: The melatonin hypothesis

A number of studies now point to a linkage between shift work and breast cancer development, and, further, that changes in melatonin synthesis or secretion may mediate this association. It has been found for instance that exposure to light (500 lux) at night reduces melatonin secretion [82] and that breast cancer occurrence in healthy women who have been chronically exposed to light during night shift-work [10, 83, 84]. In a study on premenopausal women who have been working on rotating nightshifts, a 56% reduction of urinary 6-sulfatoxymelatonin concentration was reported which inversely correlates with high levels of estradiol, thus suggesting an association between suppression of melatonin secretion at night and the occurrence of breast cancer [13]. As noted above, the interpretations of findings from retrospective epidemiological studies are confounded by the possibility that low melatonin levels were the consequence and not the cause of the disease. The single study available on prediagnosis melatonin production did not support such a relationship [14].

Epidemiological studies of women (age group 30–54) engaged in night-shift work (over 7,000 cases *vs.* 7,000 controls) yielded an overall estimate of Odds Ratio (OR) equal to 1.5 (95% confidence interval, CI = 1.3–1.7) [85]. In a study by Schernhammer et al. [13] those nurses who reported working in rotating shifts for more than 30 years had a greater risk (OD = 1.36, 95% CI = 1.04–1.78) than nurses who had no history of rotating night shift-work. The elevated breast cancer risk in women engaged in night-shift work was also a consistent finding in epidemiological studies conducted in Denmark [86].

Conversely a reduced risk of breast cancer was reported in blind women. In a case control study, women with bilateral blindness had almost half the risk of breast cancer as compared to the control group [87]. Swedish women who were blind had reduced risk of breast cancer than women with intact vision [88]. Low risk of breast cancer was observed among Norwegian women in a cohort study of 15,412 visually impaired women [89]. The risk among totally blind women was 0.64 (95% CI = 0.21–1.49). It was suggested that totally blind women were well protected against breast cancer because they did not suffer from light induced suppression of melatonin secretion [87].

In a recent cohort study of 17,557 of persons with visual impairment (11,147 women, 6,410 men) there were 184 cases of breast cancer (Standard incidence ratio = 0.94, 95% CI 0.81–1.07), which represented a 40% decrease in the risk of breast cancer [90]. Collectively, these epidemiological data support the possibility of a relationship between visible light at night and breast cancer risk.

Concerning the influence of the intensity of light on melatonin suppression and the occurrence of breast cancer, an experimental study reported that low intensity light suppresses melatonin secretion as effectively as constant bright light exposure [91]. Tumor growth and linoleic acid (LA) metabolism in rats exposed to a low intensity fluorescent light (0.2 lux at eye level) during the dark phase for one week prior to the implantation of rat hepatomas, resulted in complete suppression of melatonin levels and enhancement of tumor growth rate, The uptake of LA and its metabolism to 13-hydroxyoctadecadienoic acid (13 HODE in low intensity light was equivalent to the uptake in constant bright light, thus showing thereby that low intensity light was as effective as constant light for inducing melatonin suppression, enhanced tumor growth and LA metabolism [92]. Alternatively, exposure to light for one week during the dark phase could had effected the immune functions of the animals which in its turn would effect the survival of hepatomas. Similarly, human breast cancer xenografts that were perfused with blood obtained from women exposed to 2,800 lux bright light (resulting in 40% reduction of melatonin levels) took up more LA and showed an increased cancer growth [93]. It must be noted that melatonin levels are largely unaffected by brief exposures (less than 30 min) to low ambient levels of white (incandescent) light (of less than 30 lux), as are typically found in residential homes [94]. Indeed threshold values for light effect are highly variable among individuals [95, 96]. Thus, the casual link among light at night, melatonin levels and increased incidence of breast cancer remains to be fully established until knowing the spectrum, quantity, distribution, duration and timing of light exposure [97].

In addition to light at night, exposure to ionizing radiations of cosmic origin to people working in certain occupations such as like female flight attendants is also a major risk factor for breast cancer [98]. During the time of high solar activity emissions there is an increased in cosmic radiation affecting airline crew members [99]. A review of the accumulating evidence from a number of epidemiological studies [100] has also supported the inference that female flight attendants, pilots, and cabin crew members have an increased risk of developing breast cancer. Further, a recent meta-analysis of breast cancer risk in flight attendants and shift working women has estimated that the overall relative risk is about 1.5 [101].

Melatonin effects in experimental models of breast cancer

The oncostatic effect of melatonin in experimental models of human breast cancer has been demonstrated. In several studies the 7,12 DMBA (7,12, dimethylbenz[a]anthracene)-induced rat mammary adenocarcinoma model (a hormone responsive model) was employed. By using procedures such as blinding or removal of the olfactory bulbs that provided a maximum stimulation of melatonin secretion, the volume of DMBA-induced mammary tumors decreased significantly [102, 103]. It is important to note that these procedures also reduce the circulating levels of estradiol and prolactin [103] which may also contribute to the decrease of tumor volume. Chronic late afternoon injections of melatonin (250 μg/mg/day) suppressed the development and growth of *N*-methyl-*N*-nitrosourea (NMU)-induced and transplanted R3230 AC rat mammary tumors [104]. In the case of spontaneous mammary cancers found in C3H/Jax mice (due to ingestion of Bittner virus through mother's milk), procedures such as surgical or physiological pinealectomy accelerated mammary tumor growth while melatonin injection suppressed tumor growth [105]. Using the DMBA and NMU experimental models of mammary cancer, it was found that procedures which enhance pineal function resulted either in significantly lower incidence or reduction in the size and number of tumors when compared to pinealectomized animals [106].

TG NK transgenic mice which overexpress *c-neu* (the human breast cancer oncogene homologue of *erbB2*) spontaneously develop mammary adenocarcinoma [107]. In this model melatonin administration (50–200 mg/kg) significantly delayed the appearance and growth of tumors in a dose-related manner and there was a negative trend for the incidence of tumors [107]. It is important to note that this human breast cancer oncogene codes for the human epidermal growth factor receptor (HER2) which is amplified in 25–30 % of breast cancers. In these cases the encoded protein is present in abnormally high levels in the malignant cells [108]. Women with breast cancers that overexpress HER2 have an aggressive form of the disease with significantly shortened disease-free rate of surviva and overall survival. Several murine monoclonal antibodies against the extracellular domain of the HER2 protein were found to inhibit the proliferation of human cancer cells that overexpressed HER2, both in vitro and in vivo [108]. One of these antibodies (called trastuzumab), was found to inhibit tumor growth when used alone and has synergistic and additive effects when used in combination with Taxol and doxorubicin (Doxil) chemotherapy. [109]. The findings thus support the conclusion that melatonin can be a useful adjuvant therapy in cases of breast cancer where the tumor overexpresses HER2.

In female F344 Fischer rats, chronic administration of melatonin in drinking water was found to inhibit the growth of carcinosarcoma tumors (passage 2 tumors) by 30%, whereas sarcoma tumors (passage 12 tumors) were not affected [110]. The mechanisms by which melatonin inhibited the growth of passage 2 cells depended upon the presence of estrogen receptor (ER) positive cells [111].

Effects of melatonin on human breast cancer cells

The human breast cancer cell lines used in experimental studies can be divided in two types—ERα-positive and ERα-negative. The presence or absence of specific ER proteins is critical in differentiating human breast tumors as hormone responsive or non responsive [112]. Nearly 60–70% of all primary breast adenocarcinomas are ER positive.

There are several mechanisms by which estrogens promote the growth of breast cancer cells. They include the induction of changes in expression of specific mRNAs and growth factors such as transforming growth factor (TGF)-α and TGF-β, insulin-like growth factor (IGF), cathepsin, etc. [113] or the expression of oncogenes such as *c-myc* [114] and *c-fos* [115].

A number of studies have demonstrated the inhibitory effect of melatonin on the growth of estrogen responsive human breast cancer cells [16]. The inhibitory effects of melatonin on MCF-7 breast cancer cells was shown to be exerted through the suppression of both translation ER protein and transcription of ER mRNA [116].

Melatonin receptors in the human breast cancer cells

Melatonin binding sites and receptors have been demonstrated in human breast cancer cell lines [117]. It has now been conclusively demonstrated that the MT_1 GPCR mediates melatonin's growth inhibitory and gene modulatory effects on human breast cancer cells.

Melatonin inhibits the proliferation of ERα-positive MCF-7 breast cancer cells but not ERα-negative MDA-MB-231 breast cancer cells [118]. Even in the absence of exogenous melatonin, overexpression of MT_1 receptors may inhibit the basal proliferative rate in MCF-7 human breast cancer lines thus demonstrating the importance of these receptors for the growth inhibitory effect of melatonin [118].

Since the MCF-7 human breast cancer cells express both MT_1 and RORα nuclear orphan receptors, the possibility that melatonińs growth inhibitory effects were exerted through both types of receptors was evaluated [76]. Melatonin, the synthetic compound CGP-52608 (a specific agonist for ROR α receptors), *N*-acetyl-4-aminomethyl-6-methoxy-9-methyl-1,2,3,4-tetrahydrocarbazol (AMMTC, a MT_1/MT_2 receptor agonist) and CBPT (a MT_1 antagonist) were used for evaluation. Both melatonin and AMMTC, but not CGP-52608, inhibited cell proliferation by about 40% and the effect was blocked by CBPT thus showing the involvement of MT_1, receptors (but not of ROR α receptors) in melatonin's growth inhibitory effect on MCF-7 breast cancer cells [76].

Melatonin effects on human breast cancer cells—role of ERα receptors

ERα belongs to the steroid/thyroid receptor superfamily and it is phosphorylated even in the absence of ligands but at a very low rate [119]. In the presence of estrogens the phosphorylation of ERα receptors was found to increase 3–4 fold, an event essential for estrogen-controlled gene transcription. The phosphorylation of ERα is also achieved through a 17β estradiol-independent, mitogen activated protein kinase (MAPK) pathway [120]. As ERα overexpression has been shown to be one of the important factors for breast cancer [121], tackling the ERα receptors in a suitable way can be one of the ways by which breast cancer can become curtailed.

Melatonin pretreatment decreased the ERα mRNA and protein and the basal phosphorylation state of ER α [117, 122]. The decreased transcription of the ER gene by melatonin has been proposed as a cause for the down regulation of ER mRNA levels. A study demonstrated that melatonin at 10^{-8} M or 10^{-6} M when administered along with forskolin, reduced forskolin induction of intracellular cAMP by 57 and 55% respectively [123]. Inasmuch as intracellular cyclic AMP is known to activate ERα, the inhibitory effect on adenylyl cyclase by melatonin is one plausible signal transduction mechanism through which melatonin decreases ERα transcriptional activity [123].

Melatonin effects on estrogen induced breast cancer—possible mediation through calmodulin

Melatonin binds with calmodulin (CaM) in a Ca^{2+} dependent fashion and inhibits its activity [124, 125]. This effect has been proposed as one of the mechanisms by which melatonin exerts its antiestrogenic actions [126]. ERα, but not ERβ, interacts with calmodulin [127] and mutations in ERα binding sites abolishes this interaction. Melatonin, like CaM antagonists, was found to inhibit the estrogen—ERα-induced transcription pathway but did not affect ERβ-induced activity [128]. Specifically, melatonin inhibited the estrogen—ERα-mediated transcription in AP 1 driven promoters This ERα-CaM/AP1 pathway is more important since it establishes melatonin's blocking action on the mitogenic activity of ER α in both antiestrogen responsive and antiestrogen resistant breast cancer cells [128]. The effect of melatonin was specific since other related indoles neither interacted with CaM nor inhibit ERα-mediated transactivation. Interestingly, melatonin does not affect the binding of coactivators to ERα, indicating that melatonin action is different from that of current therapeutic anti-estrogens used in breast cancer therapy. The authors suggested that melatonin and current anti-estrogen drugs might have synergistic effects [128].

Melatonin rhythm in patients with breast cancer

The circadian rhythm of melatonin production can be a unique regulatory signal for the carcinogenic process and may explain the importance of circadian rhythm disruption as one of the major factors for increasing the risk of breast cancer [8, 11]. It has been suggested that the nighttime physiological surge of melatonin is important since it acts as a natural restraint against tumor initiation, promotion, and progression [129].

The measurement of melatonin levels as a ''biomarker'' in the body fluids of patients with breast cancer has yielded mixed results. In an initial study conducted in 10 post-menopausal women suffering from advanced stages of breast cancer and 9 women who served as controls, Bartsch et al. reported that the 24 h urinary melatonin excretion in the breast cancer patients was 31% lower than that of controls [130]. A correlation of serum melatonin levels with ER in breast tumor specimens was reported in another study [131]. In patients with stage I or II of breast cancer and ER positive tumors the nocturnal increase in plasma melatonin was much lower than in controls. From this study it was concluded that low nocturnal melatonin concentrations could be a marker for the presence of ER positive breast cancer [131].

Bartsch et al. [132] examined the circadian rhythms of serum melatonin and its metabolite 6-sulfatoxymelatonin in 17 patients with breast cancer and reported that they were significantly reduced in patients with primary breast cancer [132]. The circadian amplitudes of both melatonin and 6-sulfatoxy melatonin were depressed by 81 and 63%, respectively. Since patients with secondary breast cancers had melatonin and 6-sulfatoxymelatonin levels similar to that of controls it was concluded that depression of circulating melatonin in patients with primary breast cancer reflected a reduced pineal function and melatonin secretion rather than an enhanced liver metabolism [132]. A correlation between serum melatonin levels and tumor size has also been reported. In a study on 23 patients with primary breast tumor, the peak nocturnal concentration of serum melatonin declined with increasing tumor size: 27% at stage T1, 53% at T2 and 73% at T3 [133]. Besides the serum, melatonin concentration has been found to correlate with ER status within the breast malignant tissue. Maestroni et al. [134] reported that human breast cancer tissue contains very high levels of melatonin and that the concentration correlated positively with ER and negatively with tumor grade. The concentration of melatonin found in breast tissue was three order of magnitude higher than that normally found in the serum. This concentration of melatonin was, however, not characteristic of malignancy because it was also found in normal breast tissue.

Other studies have not found a relation between the melatonin levels and breast cancer. For example, significantly lower concentrations of urinary 6-sulfatoxymelatonin correlated with decrease in the amplitude of the rhythm in patients with breast cancer when compared to women with benign tumors. However, when the women with malignant tumors were compared with a larger group of normal women of the same age their urinary 6-sulfatoxymelatonin levels were not outside the normal range suggesting that age matched correlation was an important factor [135]. In a recently published study women with breast cancer had higher levels of disturbances on psychological indices, but their nocturnal melatonin levels did not differ significantly from controls [136].

Therefore, while some studies suggest an inverse interaction between melatonin and breast cancer conclusive evidence in this respect is far for being established. This is of focal importance in formulating concept of an inhibitory role for the pineal gland on malignancies [15].

Psychosocial interventions, sleep and breast cancer

Evidence is accumulating that a cognitive-behavioral regimen integrating cognitive techniques such as meditation-based anti-stress procedures can be useful for improving the quality of life in cancer patients. Improvements in mood, sleep quality and reductions in stress, as well as a dose-response effect, have been reported after practicing Mindfulness-Based Stress Reduction (MBSR) in breast cancer patients [137, 138]. It is interesting to note that MBSR is also an effective treatment for increasing the quality and duration of sleep in solid-organ transplant recipients [139].

Among the molecular mediators of this effect melatonin plays an important role. Indeed, the pineal gland is not only photosensitive but also responds to psychosocial intervention procedures such as meditation [139]. In a study of 30 healthy male volunteers to evaluate the effect of 3 months of Hatha yoga and Omkar yogic meditation [140] the investigators found that the treatments increased the maximum nighttime levels of melatonin while concurrently improving the participants' cardiorespiratory performance and psychologic profile. The authors concluded that meditation practice can be used as psychophysiologic stimuli to increase endogenous secretion of melatonin [141].

Carlson et al. [141] investigated the effect of MBSR on a number of measures of quality of life in early stage breast cancer (59 patients) and prostate cancer (10 patients). Significant improvements were seen in patient reports of their overall quality of life, symptoms of stress, and sleep quality, but not in mood fluctuations. Improvements in quality of life were associated with the decrease in afternoon cortisol levels. Although no overall changes in DHEAS or melatonin were found, it must be noted that the melatonin sample was obtained at 1400 h, when circulating melatonin levels are very low. Therefore, it remains to be determined whether melatonin levels at night change in patients under a MBSR program. In a similar experimental setting the MBSR program resulted in increased levels of IL4 and decreased levels of IFN-γ and IL-10 [142].

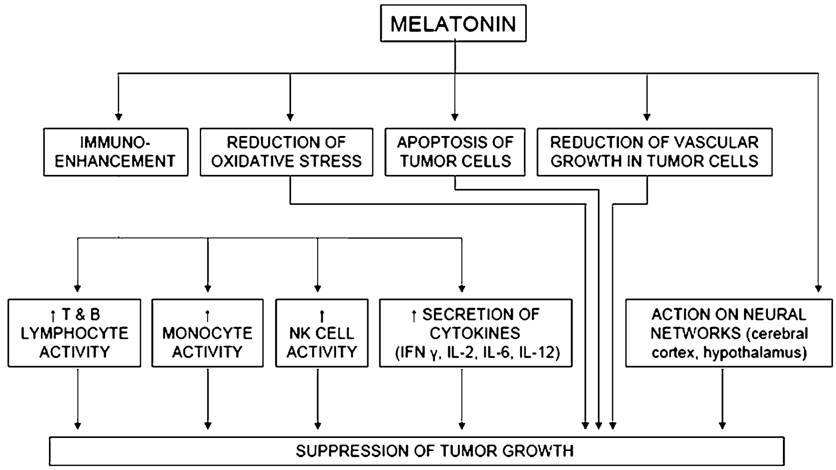

Fig. 1 Possible mechanism involved in melatonińs oncostatic activity

An inverse relationship between sleep duration and breast cancer risk occurs and was attributed to a greater overall melatonin production rate in longer sleepers [143]. The inhibitory action of endogenous melatonin on cancer is presumably attributed to its effect on the immune function. Melatonin increases IL-2 production and synergizes with IL-2 anti cancer action [67], a finding of importance in a view that IL-2, can increase NK cell activity, and has been used as adjuvant therapy in high risk breast cancer patients [144].

Conclusion

Epidemiological studies have shown a strong association between incidence of breast cancer and work on rotating or permanent night shifts. Melatonin suppression by light at night has been hypothesized as the major determining factor for the reported high incidence of breast cancer in women engaged in night-shift work. This is supported by epidemiological studies on blind women who have relatively lower incidence of breast cancer. On this basis, it would be interesting to perform long-term studies in women who are at high risk of developing breast cancer. Chronic , oral melatonin treatment in these women might reduce the incidence of the disease.

Melatonin is effective in inhibiting growth of mammary tumors in a variety of animal models of human breast cancer. The mechanism by which melatonin exerts its oncostatic action is not fully understood. The immunostimulating and antioxidant actions of melatonin are possibly paramount. However, the relative role of these effects in breast cancer inhibition needs further investigation. The possible immunostimulating action of melatonin in humans has not yet been addressed by systematic and well controlled studies. A better knowledge of the immunologic effect of melatonin might be fundamental for its targeted therapeutic use in breast cancer as well as in other diseases. In particular, the melatonin/IL-2 connection recently described in human lymphocytes (reviewed in 69) should be addressed for its possible impact on the function of the immunosuppressive T regulatory cells subset. The immunostimulating and antioxidant action of melatonin should also be considered in clinical studies for its potential synergism with common chemotherapeutic regimens. In addition, direct antiproliferative action on neoplastic cell growth via regulation of apoptosis or angiogenesis and the indirect action through the endocrine system must be considered (Fig. 1).

Studies using MCF-7 human breast cancer cell lines have shown that melatonin is effective against ER positive breast cancer cells and it acts at physiological concentrations through variety of mechanisms on MCF-7 human breast cancer cells via MT_1 melatonin receptors. Direct tumor growth inhibition, gene modulation, cell cycle regulation, and inhibition of aromatase enzyme effects in breast tissue have all been proposed as some of the important anti carcinogenic actions of melatonin on human breast cancer tissue. The melatonin-ER connection should also be better defined and then possibly exploited in clinical studies. The reported association of ER positive status of human breast cancer with high levels of tissue melatonin (134) deserves to be further investigated.

Psychosocial intervention procedures such as Yoga and mediation have been found to be of benefit for enhancing the quality of life in breast cancer patients [145]. These practices have also been shown to increase melatonin secretion. Taken together the findings reviewed here demonstrate that melatonin is a neurohormone with a broad range of direct or mediated effects on breast cancer.

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References

1. Parkin DM, Bray FI, Devesa SS (2001) Cancer burden in the year 2000. The global picture. Eur J Cancer 37(Suppl 8):S4–S66
2. Smigal C, Jemal A, Ward E et al (2006) Trends in breast cancer by race and ethnicity: update 2006. CA Cancer J Clin 56:168–183
3. Key TJ, Verkasalo PK, Banks E (2001) Epidemiology of breast cancer. Lancet Oncol 2:133–140
4. Hankinson SE, Colditz GA, Willett WC (2004) Towards an integrated model for breast cancer etiology: the lifelong interplay of genes, lifestyle, and hormones. Breast Cancer Res 6:213–218
5. Russo J, Hasan LM, Balogh G, Guo S, Russo IH (2003) Estrogen and its metabolites are carcinogenic agents in human breast epithelial cells. J Steroid Biochem Mol Biol 87:1–25
6. Yue W, Santen RJ, Wang JP et al (2003) Genotoxic metabolites of estradiol in breast: potential mechanism of estradiol induced carcinogenesis. J Steroid Biochem Mol Biol 86:477–486
7. Anisimov VN (2003) The role of pineal gland in breast cancer development. Crit Rev Oncol Hematol 46:221–234
8. Jasser SA, Blask DE, Brainard GC (2006) Light during darkness and cancer: relationships in circadian photoreception and tumor biology. Cancer Causes Control 17:515–523
9. Rajaratnam SM, Arendt J (2001) Health in a 24-h society. Lancet 358:999–1005
10. Stevens RG (1987) Electric power use and breast cancer: a hypothesis. Am J Epidemiol 125:556–561
11. Stevens RG (2005) Circadian disruption and breast cancer: from melatonin to clock genes. Epidemiology 16:254–258
12. Stevens RG (2006) Artificial lighting in the industrialized world: circadian disruption and breast cancer. Cancer Causes Control 17:501–507
13. Schernhammer ES, Rosner B, Willett WC, Laden F, Colditz GA, Hankinson SE (2004) Epidemiology of urinary melatonin in women and its relation to other hormones and night work. Cancer Epidemiol Biomarkers Prev 13:936–943
14. Travis RC, Allen DS, Fentiman IS, Key TJ (2004) Melatonin and breast cancer: a prospective study. J Natl Cancer Inst 96:475–482
15. Bartsch C, Bartsch H (2006) The anti-tumor activity of pineal melatonin and cancer enhancing life styles in industrialized societies. Cancer Causes Control 17:559–571
16. Hill SM, Ram PT, Molis TM, Spriggs LL (1998) Melatonin at the neoplastic cellular level. In: Shaffi M, Shaffi SL (eds) Melatonin in psychiatric and neoplastic disorders. American Psychiatric Press Inc., Washington DC, pp. 191–241
17. Reiter RJ (1991) Melatonin: the chemical expression of darkness. Mol Cell Endocrinol 79:C153–C158
18. Vollrath L (1979) Comparative morphology of the vertebrate pineal complex. Prog Brain Res 52:25–38
19. Macchi MM, Bruce JN (2004) Human pineal physiology and functional significance of melatonin. Front Neuroendocrinol 25:177–195
20. Cardinali DP, Nagle CA, Denari JH, Bedes GDP, Rosner JM (1973) Lack of effects of light on the rat pineal in organ culture. Gen Comp Endocrinol 21:573–577
21. Huang SK, Klein DC, Korf HW (1992) Immunocytochemical demonstration of rod-opsin, S-antigen, and neuron-specific proteins in the human pineal gland. Cell Tissue Res 267:493–498
22. Cardinali DP, Rosner JM (1971) Retinal localization of hydroxyindole-O-methyl transferase (HIOMT) in the rat. Endocrinology 89:301–303
23. Tosini G, Menaker M (1998) The clock in the mouse retina: melatonin synthesis and photoreceptor degeneration. Brain Res 789:221–228
24. Lundmark PO, Pandi-Perumal SR, Srinivasan V, Cardinali DP (2006) Role of melatonin in the eye and ocular dysfunctions. Vis Neurosci 23(6):853–862
25. Slominski A, Fischer TW, Zmijewski MA et al (2005) On the role of melatonin in skin physiology and pathology. Endocrine 27:137–148
26. Raikhlin NT, Kvetnoy IM (1976) Melatonin and enterochromaffine cells. Acta Histochem 55:19–24
27. Bubenik GA (2002) Gastrointestinal melatonin: localization, function, and clinical relevance. Dig Dis Sci 47:2336–2348
28. Carrillo-Vico A, Calvo JR, Abreu P et al (2004) Evidence of melatonin synthesis by human lymphocytes and its physiological significance: possible role as intracrine, autocrine, and/or paracrine substance. FASEB J 18:537–539
29. Champier J, Claustrat B, Besancon R et al (1997) Evidence for tryptophan hydroxylase and hydroxy-indol-O-methyl-transferase mRNAs in human blood platelets. Life Sci 60:2191–2197
30. Conti A, Conconi S, Hertens E, Skwarlo-Sonta K, Markowska M, Maestroni JM (2000) Evidence for melatonin synthesis in mouse and human bone marrow cells. J Pineal Res 28:193–202
31. Liu T, Borjigin J (2005) N-acetyltransferase is not the rate-limiting enzyme of melatonin synthesis at night. J Pineal Res 39:91–96
32. Tricoire H, Moller M, Chemineau P, Malpaux B (2003) Origin of cerebrospinal fluid melatonin and possible function in the integration of photoperiod. Reprod Suppl 61:311–321
33. Cardinali DP, Pevet P (1998) Basic aspects of melatonin action. Sleep Med Rev 2:175–190
34. Claustrat B, Brun J, Chazot G (2005) The basic physiology and pathophysiology of melatonin. Sleep Med Rev 9:11–24
35. Arendt J, Wirz-Justice A, Bradtke J, Kornemark M (1979) Long-term studies on immunoreactive human melatonin. Ann Clin Biochem 16:307–312
36. Bergiannaki JD, Soldatos CR, Paparrigopoulos TJ, Syrengelas M, Stefanis CN (1995) Low and high melatonin excretors among healthy individuals. J Pineal Res 18:159–164
37. Griefahn B, Brode P, Remer T, Blaszkewicz M (2003) Excretion of 6-hydroxymelatonin sulfate (6-OHMS) in siblings during childhood and adolescence. Neuroendocrinology 78:241–243
38. Skene DJ, Papagiannidou E, Hashemi E et al (2001) Contribution of CYP1A2 in the hepatic metabolism of melatonin: studies with isolated microsomal preparations and liver slices. J Pineal Res 31:333–342
39. Hirata F, Hayaishi O, Tokuyama T, Seno S (1974) In vitro and in vivo formation of two new metabolites of melatonin. J Biol Chem 249:1311–1313
40. Hardeland R, Reiter RJ, Poeggeler B, Tan DX (1993) The significance of the metabolism of the neurohormone melatonin: antioxidative protection and formation of bioactive substances. Neurosci Biobehav Rev 17:347–357
41. Tan DX, Manchester LC, Terron MP, Flores LJ, Reiter RJ (2007) One molecule, many derivatives: a never-ending interaction of melatonin with reactive oxygen and nitrogen species? J Pineal Res 42:28–42
42. Moore RY (1996) Neural control of the pineal gland. Behav Brain Res 73:125–130
43. Brainard GC, Hanifin JP, Greeson JM et al (2001) Action spectrum for melatonin regulation in humans: evidence for a novel circadian photoreceptor. J Neurosci 21:6405–6412
44. Berson DM, Dunn FA, Takao M (2002) Phototransduction by retinal ganglion cells that set the circadian clock. Science 295:1070–1073

45. Brainard GC, Hanifin JP, Rollag MD et al (2001) Human melatonin regulation is not mediated by the three cone photopic visual system. J Clin Endocrinol Metab 86:433–436
46. Panda S, Sato TK, Castrucci AM et al (2002) Melanopsin (Opn4) requirement for normal light-induced circadian phase shifting. Science 298:2213–2216
47. Burgoon PW, Lindberg PT, Gillette MU (2004) Different patterns of circadian oscillation in the suprachiasmatic nucleus of hamster, mouse, and rat. J Comp Physiol A Neuroethol Sens Neural Behav Physiol 190:167–171
48. Gonzalez Burgos G, Rosenstein RE, Cardinali DP (1994) Daily changes in presynaptic cholinergic activity of rat superior cervical ganglion. Brain Res 636:181–186
49. Klein DC, Coon SL, Roseboom PH et al (1997) The melatonin rhythm-generating enzyme: molecular regulation of serotonin N-acetyltransferase in the pineal gland. Recent Prog Horm Res 52:307–357
50. Vacas MI, Lowenstein P, Cardinali DP (1980) Dihydroergocryptine binding sites in bovine and rat pineal glands. J Auton Nerv Syst 2:305–313
51. Ho AK, Chik CL, Klein DC (1987) Protein kinase C is involved in adrenergic stimulation of pineal cGMP accumulation. J Biol Chem 262:10059–10064
52. Armstrong SM, Redman JR (1991) Melatonin: a chronobiotic with anti-aging properties? Med Hypotheses 34:300–309
53. Dawson D, Armstrong SM (1996) Chronobiotics–drugs that shift rhythms. Pharmacol Ther 69:15–36
54. Pevet P, Bothorel B, Slotten H, Saboureau M (2002) The chronobiotic properties of melatonin. Cell Tissue Res 309:183–191
55. Dijk DJ, Cajochen C (1997) Melatonin and the circadian regulation of sleep initiation, consolidation, structure, and the sleep EEG. J Biol Rhythms 12:627–635
56. Zhdanova IV, Tucci V (2003) Melatonin, circadian rhythms, and sleep. Curr Treat Options Neurol 5:225–229
57. Pandi-Perumal SR, Zisapel N, Srinivasan V, Cardinali DP (2005) Melatonin and sleep in aging population. Exp Gerontol 40:911–925
58. Poeggeler B, Saarela S, Reiter RJ et al (1994) Melatonin–a highly potent endogenous radical scavenger and electron donor: new aspects of the oxidation chemistry of this indole accessed in vitro. Ann N Y Acad Sci 738:419–420
59. Barlow-Walden LR, Reiter RJ, Abe M et al (1995) Melatonin stimulates brain glutathione peroxidase activity. Neurochem Int 26:497–502
60. Urata Y, Honma S, Goto S et al (1999) Melatonin induces gamma-glutamylcysteine synthetase mediated by activator protein-1 in human vascular endothelial cells. Free Radic Biol Med 27:838–847
61. Mayo JC, Sainz RM, Antoli I, Herrera F, Martin V, Rodriguez C (2002) Melatonin regulation of antioxidant enzyme gene expression. Cell Mol Life Sci 59:1706–1713
62. Rodriguez C, Mayo JC, Sainz RM et al (2004) Regulation of antioxidant enzymes: a significant role for melatonin. J Pineal Res 36:1–9
63. Srinivasan V (2002) Melatonin oxidative stress and neurodegenerative diseases. Indian J Exp Biol 40:668–679
64. Srinivasan V, Pandi-Perumal SR, Poeggeler B, Hardeland R (2006) Melatonin in Alzheimer's disease and other neurodegenerative disorders. Behav Brain Funct 2:15
65. Karbownik M, Tan DX, Reiter RJ (2000) Melatonin reduces the oxidation of nuclear DNA and membrane lipids induced by the carcinogen delta-aminolevulinic acid. Int J Cancer 88:7–11
66. Vijayalaxmi, Reiter RJ, Tan DX, Herman TS, Thomas CR Jr. (2004) Melatonin as a radioprotective agent: a review. Int J Radiat Oncol Biol Phys 59:639–653
67. Maestroni GJ (2001) The immunotherapeutic potential of melatonin. Expert Opin Investig Drugs 10:467–476
68. Srinivasan V, Maestroni GJM, Cardinali DP, Esquifino AI, Pandi-Perumal SR, Miller SC (2005) Melatonin, immune function and aging. Immun Ageing 2:17
69. Miller SC, Pandi-Perumal SR, Esquifino AI, Cardinali DP, Maestroni GJM (2006) The role of melatonin in immunoenhancement: potential application in cancer. Int J Exp Pathol 87:81–87
70. Vijayalaxmi, Thomas CR Jr., Reiter RJ, Herman TS (2002) Melatonin: from basic research to cancer treatment clinics. J Clin Oncol 20:2575–2601
71. Lissoni P, Rovelli F, Malugani F, Bucovec R, Conti A, Maestroni GJ (2001) Anti-angiogenic activity of melatonin in advanced cancer patients. Neuro Endocrinol Lett 22:45–47
72. Cui P, Luo Z, Zhang H et al (2006) Effect and mechanism of melatonin's action on the proliferation of human umbilical vein endothelial cells. J Pineal Res 41:358–362
73. Kajdaniuk D, Marek B, Kos-Kudla B et al (2002) Does the negative correlation found in breast cancer patients between plasma melatonin and insulin-like growth factor-I concentrations imply the existence of an additional mechanism of oncostatic melatonin influence involved in defense? Med Sci Monit 8:CR457–CR461
74. Bulbuller N, Dogru O, Yekeler H, Cetinkaya Z, Ilhan N, Kirkil C (2005) Effect of melatonin on wound healing in normal and pinealectomized rats. J Surg Res 123:3–7
75. Soybir G, Topuzlu C, Odabas O, Dolay K, Bilir A, Koksoy F (2003) The effects of melatonin on angiogenesis and wound healing. Surg Today 33:896–901
76. Ram PT, Dai J, Yuan L et al (2002) Involvement of the mt1 melatonin receptor in human breast cancer. Cancer Lett 179:141–150
77. Nosjean O, Ferro M, Coge F et al (2000) Identification of the melatonin-binding site MT3 as the quinone reductase 2. J Biol Chem 275:31311–31317
78. Wiesenberg I, Missbach M, Kahlen JP, Schrader M, Carlberg C (1995) Transcriptional activation of the nuclear receptor RZR alpha by the pineal gland hormone melatonin and identification of CGP 52608 as a synthetic ligand. Nucleic Acids Res 23:327–333
79. Schaeren-Wiemers N, Andre E, Kapfhammer JP, Becker-Andre M (1997) The expression pattern of the orphan nuclear receptor RORbeta in the developing and adult rat nervous system suggests a role in the processing of sensory information and in circadian rhythm. Eur J Neurosci 9:2687–2701
80. Dai J, Ram PT, Yuan L, Spriggs LL, Hill SM (2001) Transcriptional repression of RORalpha activity in human breast cancer cells by melatonin. Mol Cell Endocrinol 176:111–120
81. Reppert SM, Weaver DR, Ebisawa T (1994) Cloning and characterization of a mammalian melatonin receptor that mediates reproductive and circadian responses. Neuron 13:1177–1185
82. Lewy AJ, Wehr TA, Goodwin FK, Newsome DA, Markey SP (1980) Light suppresses melatonin secretion in humans. Science 210:1267–1269
83. Davis S, Mirick DK, Stevens RG (2001) Night shift work, light at night, and risk of breast cancer. J Natl Cancer Inst 93:1557–1562
84. Schernhammer ES, Laden F, Speizer FE et al (2001) Rotating night shifts and risk of breast cancer in women participating in the nurses' health study. J Natl Cancer Inst 93:1563–1568
85. Hansen J (2001) Light at night, shiftwork, and breast cancer risk. J Natl Cancer Inst 93:1513–1515

86. Hansen J (2006) Risk of breast cancer after night- and shift work: current evidence and ongoing studies in Denmark. Cancer Causes Control 17:531–537
87. Hahn RA (1991) Profound bilateral blindness and the incidence of breast cancer. Epidemiology 2:208–210
88. Feychting M, Osterlund B, Ahlbom A (1998) Reduced cancer incidence among the blind. Epidemiology 9:490–494
89. Kliukiene J, Tynes T, Andersen A (2001) Risk of breast cancer among Norwegian women with visual impairment. Br J Cancer 84:397–399
90. Pukkala E, Ojamo M, Rudanko SL, Stevens RG, Verkasalo PK (2006) Does incidence of breast cancer and prostate cancer decrease with increasing degree of visual impairment. Cancer Causes Control 17:573–576
91. Dauchy RT, Sauer LA, Blask DE, Vaughan GM (1997) Light contamination during the dark phase in ‘‘photoperiodically controlled’’ animal rooms: effect on tumor growth and metabolism in rats. Lab Anim Sci 47:511–518
92. Dauchy RT, Blask DE, Sauer LA, Brainard GC, Krause JA (1999) Dim light during darkness stimulates tumor progression by enhancing tumor fatty acid uptake and metabolism. Cancer Lett 144:131–136
93. Blask DE, Brainard GC, Dauchy RT et al (2005) Melatonin-depleted blood from premenopausal women exposed to light at night stimulates growth of human breast cancer xenografts in nude rats. Cancer Res 65:11174–11184
94. Figueiro MG, Rea MS, Bullough JD (2006) Circadian effectiveness of two polychromatic lights in suppressing human nocturnal melatonin. Neurosci Lett 406:293–297
95. Hebert M, Martin SK, Lee C, Eastman CI (2002) The effects of prior light history on the suppression of melatonin by light in humans. J Pineal Res 33:198–203
96. Smith KA, Schoen MW, Czeisler CA (2004) Adaptation of human pineal melatonin suppression by recent photic history. J Clin Endocrinol Metab 89:3610–3614
97. Figueiro MG, Rea MS, Bullough JD (2006) Does architectural lighting contribute to breast cancer? J Carcinog 5:20
98. Butler GC, Nicholas J, Lackland DT, Friedberg W (2000) Perspectives of those impacted: airline pilot’s perspective. Health Phys 79:602–607
99. Lim MK (2002) Cosmic rays: are air crew at risk? Occup Environ Med 59:428–432
100. Sigurdson AJ, Ron E (2004) Cosmic radiation exposure and cancer risk among flight crew. Cancer Invest 22:743–761
101. Megdal SP, Kroenke CH, Laden F, Pukkala E, Schernhammer ES (2005) Night work and breast cancer risk: a systematic review and meta-analysis. Eur J Cancer 41:2023–2032
102. Tamarkin L, Cohen M, Roselle D, Reichert C, Lippman M, Chabner B (1981) Melatonin inhibition and pinealectomy enhancement of 7,12-dimethylbenz(a)anthracene-induced mammary tumors in the rat. Cancer Res 41:4432–4436
103. Chang N, Spaulding TS, Tseng MT (1985) Inhibitory effects of superior cervical ganglionectomy on dimethylbenz(a)anthracene-induced mammary tumors in the rat. J Pineal Res 2:331–340
104. Blask DE, Pelletier DB, Hill SM et al (1991) Pineal melatonin inhibition of tumor promotion in the N-nitroso-N-methylurea model of mammary carcinogenesis: potential involvement of antiestrogenic mechanisms in vivo. J Cancer Res Clin Oncol 117:526–532
105. Subramanian A, Kothari L (1991) Melatonin, a suppressor of spontaneous murine mammary tumors. J Pineal Res 10:136–140
106. Cos S, Sanchez-Barcelo EJ (2000) Melatonin, experimental basis for a possible application in breast cancer prevention and treatment. Histol Histopathol 15:637–647
107. Rao GN, Ney E, Herbert RA (2000) Effect of melatonin and linolenic acid on mammary cancer in transgenic mice with c-neu breast cancer oncogene. Breast Cancer Res Treat 64:287–296
108. Gonzalez-Angulo AM, Hortobagyi GN, Esteva FJ (2006) Adjuvant therapy with trastuzumab for HER-2/neu-positive breast cancer. Oncologist 11:857–867
109. Smith I, Procter M, Gelber RD et al (2007) 2-year follow-up of trastuzumab after adjuvant chemotherapy in HER2-positive breast cancer: a randomised controlled trial. Lancet 369:29–36
110. Karasek M, Marek K, Zielinska A, Swietoslawski J, Bartsch H, Bartsch C (1994) Serial transplants of 7,12-dimethylbenz[a]anthracene-induced mammary tumors in Fischer rats as model system for human breast cancer. 3. Quantitative ultrastructural studies of the pinealocytes and plasma melatonin concentrations in rats bearing an advanced passage of the tumor. Biol Signals 3:302–306
111. Blask DE (2001) An overview of the neuroendocrine regulation of experimental tumor growth by melatonin and its analogues and the therapeutic use of melatonin in oncology. In: Bartsch C, Bartsch H, Blask DE, Cardinali DP, Hrushesky WJM, Mecke D (eds) The pineal gland and cancer: neuroimmunoendocrine mechanisms in malignancy. Springer, Berlin, pp. 309–342
112. Edwards DP, Chamness GC, McGuire WL (1979) Estrogen and progesterone receptor proteins in breast cancer. Biochim Biophys Acta 560:457–486
113. Dickson RB, Lippman ME (1987) Estrogenic regulation of growth and polypeptide growth factor secretion in human breast carcinoma. Endocr Rev 8:29–43
114. Dubik D, Shiu RP (1988) Transcriptional regulation of c-myc oncogene expression by estrogen in hormone-responsive human breast cancer cells. J Biol Chem 263:12705–12708
115. Weisz A, Bresciani F (1988) Estrogen induces expression of c-fos and c-myc protooncogenes in rat uterus. Mol Endocrinol 2:816–824
116. Molis TM, Spriggs LL, Jupiter Y, Hill SM (1995) Melatonin modulation of estrogen-regulated proteins, growth factors, and proto-oncogenes in human breast cancer. J Pineal Res 18:93–103
117. Ram PT, Kiefer T, Silverman M, Song Y, Brown GM, Hill SM (1998) Estrogen receptor transactivation in MCF-7 breast cancer cells by melatonin and growth factors. Mol Cell Endocrinol 141:53–64
118. Yuan L, Collins AR, Dai J, Dubocovich ML, Hill SM (2002) MT(1) melatonin receptor overexpression enhances the growth suppressive effect of melatonin in human breast cancer cells. Mol Cell Endocrinol 192:147–156
119. Le Goff P, Montano MM, Schodin DJ, Katzenellenbogen BS (1994) Phosphorylation of the human estrogen receptor. Identification of hormone-regulated sites and examination of their influence on transcriptional activity. J Biol Chem 269:4458–4466
120. Kato S, Endoh H, Masuhiro Y et al (1995) Activation of the estrogen receptor through phosphorylation by mitogen-activated protein kinase. Science 270:1491–1494
121. Pujol P, Rey JM, Nirde P et al (1998) Differential expression of estrogen receptor-alpha and -beta messenger RNAs as a potential marker of ovarian carcinogenesis. Cancer Res 58:5367–5373
122. Molis TM, Spriggs LL, Hill SM (1994) Modulation of estrogen receptor mRNA expression by melatonin in MCF-7 human breast cancer cells. Mol Endocrinol 8:1681–1690
123. Kiefer T, Ram PT, Yuan L, Hill SM (2002) Melatonin inhibits estrogen receptor transactivation and cAMP levels in breast cancer cells. Breast Cancer Res Treat 71:37–45
124. Benitez-King G, Huerto-Delgadillo L, Anton-Tay F (1991) Melatonin modifies calmodulin cell levels in MDCK and N1E-

115 cell lines and inhibits phosphodiesterase activity in vitro. Brain Res 557:289–292
125. Romero MP, Garcia-Perganeda A, Guerrero JM, Osuna C (1998) Membrane-bound calmodulin in Xenopus laevis oocytes as a novel binding site for melatonin. FASEB J 12:1401–1408
126. Rato AG, Pedrero JG, Martinez MA, del Rio B, Lazo PS, Ramos S (1999) Melatonin blocks the activation of estrogen receptor for DNA binding. FASEB J 13:857–868
127. Garcia Pedrero JM, Del Rio B, Martinez-Campa C, Muramatsu M, Lazo PS, Ramos S (2002) Calmodulin is a selective modulator of estrogen receptors. Mol Endocrinol 16:947–960
128. del Rio B, Garcia Pedrero JM, Martinez-Campa C, Zuazua P, Lazo PS, Ramos S (2004) Melatonin, an endogenous-specific inhibitor of estrogen receptor alpha via calmodulin. J Biol Chem 279:38294–38302
129. Blask DE (1998) The melatonin rhythm in cancer patients. In: Shaffi M, Shaffi SL (eds) Melatonin in psychiatric and neoplastic disorders. American Psychiatric Press Inc., Washington DC, pp. 243–260
130. Bartsch C, Bartsch H, Jain AK, Laumas KR, Wetterberg L (1981) Urinary melatonin levels in human breast cancer patients. J Neural Transm 52:281–294
131. Tamarkin L, Danforth D, Lichter A et al (1982) Decreased nocturnal plasma melatonin peak in patients with estrogen receptor positive breast cancer. Science 216:1003–1005
132. Bartsch C, Bartsch H, Bellmann O, Lippert TH (1991) Depression of serum melatonin in patients with primary breast cancer is not due to an increased peripheral metabolism. Cancer 67:1681–1684
133. Bartsch C, Bartsch H, Fuchs U, Lippert TH, Bellmann O, Gupta D (1989) Stage-dependent depression of melatonin in patients with primary breast cancer. Correlation with prolactin, thyroid stimulating hormone, and steroid receptors. Cancer 64:426–433
134. Maestroni GJM, Conti A (1996). Melatonin in human breast cancer tissue: Association with nuclear grade and estrogen receptor status. Lab Inv 75:557–561
135. Skene DJ, Bojkowski CJ, Currie JE, Wright J, Boulter PS, Arendt J (1990) 6-sulphatoxymelatonin production in breast cancer patients. J Pineal Res 8:269–276
136. Carlson LE, Campbell TS, Garland SN, Grossman P (2007) Associations among Salivary cortisol, melatonin, catecholamines, sleep quality and stress in women with breast cancer and healthy controls. J Behav Med 30:45–58
137. Smith JE, Richardson J, Hoffman C, Pilkington K (2005) Mindfulness-Based Stress Reduction as supportive therapy in cancer care: systematic review. J Adv Nurs 52:315–327
138. Shapiro SL, Bootzin RR, Figueredo AJ, Lopez AM, Schwartz GE (2003) The efficacy of mindfulness-based stress reduction in the treatment of sleep disturbance in women with breast cancer: an exploratory study. J Psychosom Res 54:85–91
139. Kreitzer MJ, Gross CR, Ye X, Russas V, Treesak C (2005) Longitudinal impact of mindfulness meditation on illness burden in solid-organ transplant recipients. Prog Transplant 15:166–172
140. Massion AO, Teas J, Hebert JR, Wertheimer MD, Kabat-Zinn J (1995) Meditation, melatonin and breast/prostate cancer: hypothesis and preliminary data. Med Hypotheses 44:39–46
141. Harinath K, Malhotra AS, Pal K et al (2004) Effects of Hatha yoga and Omkar meditation on cardiorespiratory performance, psychologic profile, and melatonin secretion. J Altern Complement Med 10:261–268
142. Carlson LE, Speca M, Patel KD, Goodey E (2003) Mindfulness-based stress reduction in relation to quality of life, mood, symptoms of stress, and immune parameters in breast and prostate cancer outpatients. Psychosom Med 65:571–581
143. Verkasalo PK, Lillberg K, Stevens RG et al (2005) Sleep duration and breast cancer: a prospective cohort study. Cancer Res 65:9595–9600
144. Tonini G, Nunziata C, Prete SP et al (1998) Adjuvant treatment of breast cancer: a pilot immunochemotherapy study with CMF, interleukin-2 and interferon alpha. Cancer Immunol Immunother 47:157–166
145. Carlson LE, Speca M, Patel KD, Goodey E (2004) Mindfulness-based stress reduction in relation to quality of life, mood, symptoms of stress and levels of cortisol, dehydroepiandrosterone sulfate (DHEAS) and melatonin in breast and prostate cancer outpatients. Psychoneuroendocrinology 29:448–474

Removal of the blue component of light significantly decreases retinal damage after high intensity exposure

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Abstract

Light causes damage to the retina (phototoxicity) and decreases photoreceptor responses to light. The most harmful component of visible light is the blue wavelength (400–500 nm). Different filters have been tested, but so far all of them allow passing a lot of this wavelength (70%). The aim of this work has been to prove that a filter that removes 94% of the blue component may protect the function and morphology of the retina significantly. Three experimental groups were designed. The first group was unexposed to light, the second one was exposed and the third one was exposed and protected by a blue-blocking filter. Light damage was induced in young albino mice (p30) by exposing them to white light of high intensity (5,000 lux) continuously for 7 days. Short wavelength light filters were used for light protection. The blue component was removed (94%) from the light source by our filter. Electroretinographical recordings were performed before and after light damage. Changes in retinal structure were studied using immunohistochemistry, and TUNEL labeling. Also, cells in the outer nuclear layer were counted and compared among the three different groups. Functional visual responses were significantly more conserved in protected animals (with the blue-blocking filter) than in unprotected animals. Also, retinal structure was better kept and photoreceptor survival was greater in protected animals, these differences were significant in central areas of the retina. Still, functional and morphological responses were significantly lower in protected than in unexposed groups. In conclusion, this blue-blocking filter decreases significantly photoreceptor damage after exposure to high intensity light. Actually, our eyes are exposed for a very long time to high levels of blue light (screens, artificial light LED, neons…). The potential damage caused by blue light can be palliated.

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Abbreviations: A2E, di-retinoid-pyridinium-ethanolamine; ABCA4, ABC binding cassette transporter 4; ARVO, Association for Research in Vision and Ophthalmology; atRal, all-trans retinal; BSA, bovine serum albumin; DAPI, 4' 6-diamidino-2-phenylindole dihydrochloride; dUTP, deoxyuridine triphosphate; ERG, electroretinographical; IOL, intraocular lens; ipRGCs, intrinsically-photosentitive retinal ganglion cells; ISCEV, International Society for Clinical Electrophysiology of Vision; L/M, Long/Medium; LED, light emission diode; LW, Long Wave; MW, Medium Wave; NMRI, Naval Medical Research Institute; N-ret-PE, N-retinylidene-phosphatidylethanolamine; ONL, outer nuclear layer; OP, oscillatory potentials; PBS, phosphate buffered saline; PE, phosphatidylethanolamine; RPE, retinal pigmented epithelium; S, Short; SW, Short Wave; TdT, deoxynucleotidyl transferase; TUNEL, Terminal-deoxynucleotidyl transferase dUTP nick end labeling; Tx, triton X-100; UV, Ultraviolet.

Introduction

Light is converted into useful visual information in the retina. Photoreceptor cells express light-sensitive pigments that absorb photons, initiating a chemical cascade of events known as phototransduction that culminates in the generation of electrical signals. There are three classes of retinal cells that contain visual pigments and are thus responsive to light: the classic photoreceptors, rods and cones, and the intrinsically-photosentitive retinal ganglion cells (ipRGCs). Rods and cones contain rhodopsin and cone opsins respectively, allowing visual perception and color distinction, whereas ipRGCs contain melanopsin and are involved in the entrainment of the circadian rhythms [1,2].

In the mouse retina, rods (502 nm) are more abundant, while cones constitute 2.7–3% of the photoreceptors [3,4]. In contrast to primates, the murine retina has only two spectral cone types: short (S) cones are sensitive to short wavelengths in the ultraviolet (UV) spectrum (359 nm, short wave (SW)), while long/medium (L/M) cones are sensitive to middle-to-long wavelengths (508 nm, medium wave (MW) and long wave (LW)) [5]. In the mouse retina, topographic separation of different classes of cones has been reported [6]. Variations in retinal topography of S and L/M cones have been observed among different strains (albino and pigmented mice) [7]. In addition, five morphological types of ipRGCs have been identified in mice and rats. These cells have diverse functional roles in non-imaging forming vision and in pattern vision [8,9]. Distinct absorbance spectrum in the different photoreceptor cells is due to apoproteins [10]. These opsins provide specific environment for the absorption of light at particular wavelengths [11]. A protonated Schiff base links opsin and chromophore (retinal), producing a spectral shift from ultraviolet (cromophore: maximal absorption 380 nm) to visible light [12]. However, the S cone cromophore is unprotonated and, consequently, is not capable of such spectral shift (<450 nm) [13].

It has been shown that excessive exposure to visible light can cause toxicity in the vertebrate retina [14]. The degree of damage depends on the level of retinal irradiance, wavelength and exposure duration [15,16]. In this regard, the same visible radiation that activates phototransduction is the responsible for causing damage in photosensitive cells [14].

Phototoxicity related retinal damage has been classified into two groups depending on variables such as the incident wavelength, the exposure time and the cell type affected. Class I takes place after long periods of exposure (days to weeks) to low irradiances and the cells affected are the photoreceptors whose wavelengths are activated [14]. Class II occurs after a short exposure (minutes to hours) to high irradiances of white light and the damage is at level of the retinal pigmented epithelium (RPE) [17]. This effect is also known as "blue-light" damage and has been reported for living animals, either anesthetized [18] or free-running [19].

It has been documented that light causes apoptotic death of photoreceptors and RPE cells [20]. Since light bleaches rhodopsin in the course of this process, it is believed that the main factor of susceptibility to damage is the amount of rhodopsin that can be regenerated after bleaching [18]. During photoactivation of rhodopsin, 11cis retinal becomes all-trans retinal (atRal), which may be condensed with phosphatidylethanolamine (PE) to generate N-retinylidene-phosphatidylethanolamine (N-ret-PE). Both, free atRal and N-ret-PE, are released to the cytosol of outer segments with the help of a member of the ATP binding cassette transporter family (ABC transporters, specifically ABCA4) [21]. In the cytosol, condensation of free atRal with N-ret-PE initiates a process that generates toxic products like A2E (di-retinoid-pyridinium-ethanolamine) [22]. In situations of high illumination, rhodopsin is completely photobleached and free atRal increases above baseline levels. In this scenario, removal of atRal is limited by the ordinary rates of these processes [22].

Current lifestyle relies on artificial illumination that may extend to 16/18 hours per day. Little is known about the levels of light exposure that are safe for the retina [23]. Among the structures that protect the eye from light induced damage are the cornea and the lens, which prevent short wavelengths from reaching the retina. The cornea absorbs wavelengths below 295 nm, while the lens absorbs UV radiation (in the range of 300–400 nm). In addition, these structures (cornea, lens, and even retina) contain chromophores that absorb certain wavelengths, dissipating energy [24].

Blue light (short wavelength) has been shown to be the most harmful to the retina [23,25]. For this reason, many experimental studies have sought to mitigate the effect of blue light radiation on the retinal tissue [26]. It has been reported that in older eyes, due to the yellowish coloration of the crystalline lens, the amount of blue light that reaches the retina decreases [27], giving an extra protection against harmful short wavelengths [28,29]. Cataract extraction and intraocular lens (IOL) implantation could thus increase the amount of blue light that reaches retina. To prevent the deleterious effects of blue light on the retina, the addition of a blue filter to the IOL has been proposed, but advantages of this procedure have not yet been proved clinically [30].

Previous works have shown that the use of blue-blocking filters provides protection to the retina [31,32]. However, the filters used so far absorb blue radiation only partially (30–50%) [33,34]. Furthermore, these filters do not only block blue light but usually block spectra of other wavelengths too [34]. In this work, we have analyzed the structural and functional changes of the retina after exposure to damaging light and the protective effect of a filter that selectively blocks 94% of blue radiation, affecting minimally to other wavelengths (less than 10%). Therefore, we may consider that the effects obtained are genuinely due to blue radiation.

Materials and methods

Animals

A total of 18 albino Hds/Win:NMRI mice were used. One-month-old mice were obtained from local providers (JANVIER-Europe, France, www.janvier-europe.com). Before light damage mice were kept in a 12/12 hour light (*ca*. 60 lux) /dark cycle. All animal procedures were carried out in accordance with the ARVO Statement for the Use of Animals in Ophthalmic and Vision Research, the European Community Council (86/609/EEC) guidelines and current Spanish legislation (RD 53/2013). The research and animal experimentation ethics committee of the University of Alcalá approved the protocols applied (permit number OH UAH2016/016)

Experimental groups and light exposure

Mice were randomly distributed into three study groups (6 animals per group): Group 1: unexposed to damaging light; Group 2: exposed to damaging light without any filter; and Group 3: exposed but protected by a blue blocking filter (ROSCO Company, Roscolux #312, Spain).

In light-exposure experiments, individual animals were placed in a non-acrylic grid cage. Light source was a cold light fluorescent emission lamp (400–820 nm; City Bright International Ltd., Wanchai, China) fixed on the lateral wall of the cage (height 10 cm), at 30 cm of distance from the animal. Mice were exposed to continuous bright light (5,000 lux) for 7 days. The pupils were dilated pharmacologically with a drop of atropin (Colicursí Atropin 1%, Alcan Cusí SA; Spain) applied daily.

Light composition and light filter parameters

The spectral irradiance of the fluorescent light source inside the cages, with and without blue-blocking filters, was measured using a spectrometer (USB650 Red Tide Spectrometer; Ocean Optics, USA). The blue-blocking filter absorbed 93.93% of the blue spectrum emitted by our tube lamps (<500 nm), while greater wavelengths were transmitted integrally (Fig 1A). Also, the amount of light of all wavelengths that reached the cage was measured with a spectrophotometer (Zeiss Humphrey LA360 laser, Vision Systems Inc, USA) and expressed as transmittance normalized units (Fig 1B).

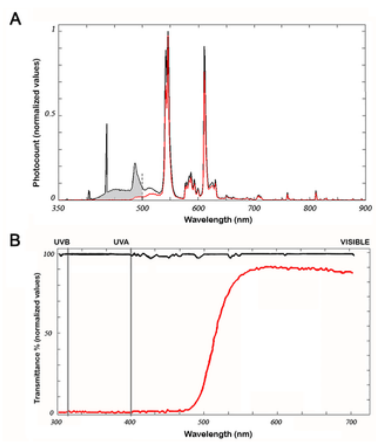

Fig 1. Characterization of the blue-blocking filter.
(A) Irradiance of the light source used in phototoxicity experiments in the presence (red trace) or absence (black trace) of the blue-blocking filter. Note that black and red traces are identical for wavelengths longer than 520 nm. The shaded area corresponds to the radiation absorbed by the filter (93.934% of the whole blue radiation). (B) Percent transmittance of the blue-blocking filter: wavelength emissions measured by the Zeiss Humphrey lens analyzer (LA360) without filter (100% value of transmittance; black line) and with the blue-blocking filter (red line).
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Electroretinography

The electroretinogram (ERG) experiments were carried out with a self-made Ganzfeld Dome illuminated by light emission diodes (RS310-6707; RS-Amidata, Spain). Flash light pulses of 5 ms duration were used for all ERG recordings. PowerLab/4ST (ADInstrumts, United Kingdom) equipment was used for the control of pulse stimulation. ERG recordings were performed in all animals one day before light exposure and eight days after the first ERG. Four animals per group were used for histological experiments (see below), and two animals per group were maintained alive and used for ERG re-test one month after inducing the injury, just to confirm the maintenance of functional photodamage. Full-field electroretinogram was performed following the ISCEV standard protocol (www.iscev.org/standards). Prior to ERG recording, mice were maintained in darkness overnight. Then, mice were anaesthetized under dim red light with an intraperitoneal injection of ketamine (95 mg/kg) and xylazine (5 mg/kg) and kept on a heating pad at 37°C. The pupils were dilated by applying a topical drop of 1% Tropicamide (Colicursí Tropicamida, Alcan Cusí SA, Barcelona, Spain). A topical drop of 2% Methocel (Ciba Vision AG, 8442 Hetlingen, Switzerland) was instilled in each eye immediately before placing the corneal electrode. Anesthetized animals were placed on a Faraday cage and experiments were performed sequentially in scotopic and photopic conditions. Flash-induced ERG responses were recorded from the right eye in response to light stimuli. Retinal responses mediated by rod photoreceptors (Rod-driven Response) were recorded under dark adaptation to light flashes of -2 log $cd \cdot s \cdot m^{-2}$. Rod and cone mediated responses (Mixed rod-cone Responses) were recorded under dark adaptation in response to light flashes of 0.48 log $cd \cdot s \cdot m^{-2}$. Oscillatory potentials (OP) were isolated from the mixed response by band pass filtering between 100–10,000 Hz. Under scotopic conditions, five to ten light responses were averaged for each ERG trace; flash intervals were set at 30 seconds. Then, the animals were light-adapted for 10 minutes under white rod-suppressing background light (100 $cd \cdot m^{-2}$) and photopic responses were recorded. Responses mediated by cone photoreceptors (Cone-driven Response) were recorded under photopic conditions in response to light flashes of 2 log $cd \cdot s \cdot m^{-2}$. Under photopic conditions thirty to sixty responses were averaged and flash intervals were set at 1 second. ERG signals were amplified and band filtered between 1 and 1,000 Hz with a Grass amplifier (CP511 AC amplifier, Grass instruments, Quinay, MA, USA). Electrical signals were digitalized at 20 KHz with Power Lab data acquisition board (Power Lab 4ST). Electrical potential changes were recorded with a fixed corneal lens electrode (Burian-Allen electrode, Hansen Ophtalmic Development Lab Coralville, IA, USA), a reference electrode located inside the mouth and a ground electrode located on the tail. Calibration of the light stimuli was performed with a digital photometer (GO 4068 Gossen Mavo-monitor USB, Gossen Corporation, Milwaukee, USA).

ERG wave amplitudes were measured for every recording and averaged from the six animals of each experimental group. The amplitude of the positive deflection of the Rod-driven Response (namely b_{rod}) was measured from the baseline to the peak of the positive deflection. The amplitude of the negative deflection of the Mixed rod-cone Response (namely a_{mixed}) was measured from the baseline to the trough of the negative deflection. The amplitude of the positive deflection of the Mixed rod-cone Response (namely b_{mixed}) was measured from the trough of the negative deflection to the peak of the positive deflection (excluding the oscillatory potentials). The amplitude of the OP was measured from peak to peak. The amplitude of the positive deflection of the Cone-driven Response (namely b_{cone}) was measured from the baseline to the peak of the positive deflection. Arrows in Fig 2 show the measurement criteria for the amplitudes of the ERG responses. The retinal origin of the different ERG components was elucidated in previous works [35] and we used the nomenclature recommended by ISCEV [36,37].

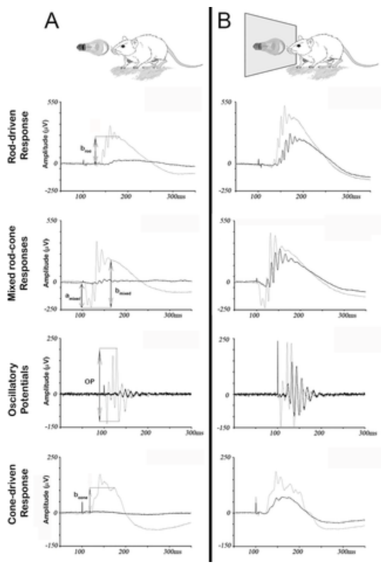

Fig 2. Protective effect of the blue-blocking filter on retinal response to damaging light.

Representative ERG traces from unprotected (A) and protected (B) groups of mice, obtained before (grey traces) and after (black traces) exposure to white light (5,000 lux) for seven days. Arrows indicate the amplitudes measured for each different ERG wave. In the unprotected group (A), amplitudes of scotopic (rod-driven, mixed rod-cone and Oscillatory Potentials) and photopic (cone-driven) parameters are strongly reduced upon light-induced damage, while in the protected group (B), this reduction is attenuated.

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Retinal histology

A total of 12 animals (4 per group) were sacrificed after the second ERG recording by cervical dislocation and both eyes were enucleated and immersed in 4% (w/v) paraformaldehyde for 2 hours at room temperature. After removing the cornea and lens, the eyes were immersed in the same fixative solution for one more hour. Then the eyes were sequentially cryoprotected in 20% (1 hour), 30% (1 hour) and 40% (overnight) sucrose at 4°C. Eyecups were then embedded in tissue tek, oriented and frozen in liquid nitrogen. An average of 15 dorsal-ventral retinal sections, 12-μm-thick, were obtained with a cryostat (Leica CM3000 Cryostat, Leica Biosystems, Nussloch, Germany) from each eye.

After washing with 0.1M PBS (phosphate-buffered saline, pH 7,4, SIGMA-ALDRICH, St Louis, USA), retinal sections were preincubated for 1 hour and 30 minutes with 0.1M PBS containing 2% (w/v) bovine serum albumin (BSA) and 0.02% (v/v) Triton X-100 (PBS-Tx). A total of six retinal sections per animal were immunostained by incubation in PBS-Tx containing goat polyclonal anti-Red/Green opsin (1:200 dilution; #AB5405; Merck MILLIPORE, Billerica, MA, USA) for 14–15 hours at room temperature. After washing, sections were incubated with Cy3-conjugated secondary antibodies (1:200 dilution; Jackson, West Grove, PA, USA) for 1 hour. Negative controls omitting the primary or secondary antibody were included. In addition, nuclei were stained with 4', 6-diamidino-2-phenylindole dihydrochloride (DAPI) at 5 mg/ml (#10 236 276 001; Sigma Aldrich). Sections were mounted with a mixture (0.42% glycine, 0.021% NaOH, 0.51% NaCl, 0.03% sodium azide, 5% N-propylgalate, 70% glycerine and distilled water) for fading protection purposes.

Detection of apoptotic nuclei was accomplished by the Terminal-deoxynucleotidyl transferase dUTP nick end labeling (TUNEL technique). A total of six retinal sections per animal were fixed in ethanol and acetic acid (2:1) at -32°C for 5 minutes. Then, sections were rinsed with 0.1M PBS and immersed in 0.1M PBS with 0.2% (v/v) Triton X-100 and 0.1% (w/v) sodium citrate for 15 minutes. After washing, sections were immersed in TUNEL buffer (30mM Tris, 140 mM sodium cacodylate, 1mM cobalt chloride, 0,3% Tritón X-100 and distilled water) for 30 minutes and then they were incubated 1 hour and 30 minutes with the same buffer containing terminal deoxynucleotidyl transferase (#11767305001; TdT; Roche; Switzerland) (800 U/ml) and dUTP (#11093070910; Roche) (1 μM) at 37°C. The reaction was terminated by addition of sodium chloride and sodium citrate buffer followed by rinsing with 0.1 M PBS. After staining with DAPI, all sections were washed with PBS three times and cover-slipped with mounting medium. Microscope fluorescent images were obtained with a LEICA TCS-SP5 laser confocal microscope (Leica Instruments, Wetzlar, Germany).

Photoreceptor count

Cell count was performed on DAPI stained sagittal retinal sections. A total of six sections per animal were averaged for cell counts. In each section, four regions of interest (200 μm in length each) [38], located along the dorsal-ventral axis at four different eccentricities: 30° dorsal (Z2) and ventral (Z3), and 60° dorsal (Z1) and ventral (Z4) from the optic nerve head, were selected. Photoreceptor nuclei in each region of interest were counted manually on the six retinal sections from the four animals of the three experimental groups (Table 1).

	Unexposed	Protected	Unprotected
Location			
Z1	541 ± 135	336 ± 64	209 ± 97
Z2	544 ± 136	314 ± 73	104 ± 67
Z3	524 ± 131	367 ± 71	208 ± 73
Z4	605 ± 151	403 ± 86	320 ± 28
Total	2214 ± 552	1421 ± 263	841 ± 214

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Table 1. Photoreceptor cell counts in the different experimental groups (mean ± SD).
https://doi.org/10.1371/journal.pone.0194218.t001

Statistical analysis

The amplitudes of the different ERG waves were compared in protected and unprotected animal groups using unpaired Student´s *t*-test with Welch correction. Changes in global number of surviving cells were studied between different groups by two-way ANOVA (*two-tailed*). Differences between retinal areas within the same experimental group were studied by two-way ANOVA (*two-tailed*) followed by Tukey's posthoc test. Statistical analyses were performed with GraphPad Prism version 5.00 for Windows (Graph Pad Software, San Diego, CA, USA, www.graphpad.com).

Results

In a series of preliminary experiments, albino mice were exposed to white light (5,000 lux) for 2, 3 or 5 days (data not shown). All these animals suffered a decrease in the amplitude of their ERG waves. However, a functional recovery was observed in those animals in which light exposure lasted 5 days or less. Then, we decided to expose animals to light for 7 days. No functional recovery was observed for such exposure time.

Electroretinogram recordings

To evaluate the potential protective effect of a blue-blocking filter on visual responses, two groups of mice were exposed to 5,000 lux of fluorescent light for 7 days. In one of the groups, a filter that absorbed 94% of the blue spectrum (<500 nm) covered permanently the light source. Following retinal damage, scotopic and photopic visual responses were evaluated by full-field ERG and compared to equivalent recordings performed before light exposure. Amplitudes for five different ERG waves (b_{rod}, a_{mixed}, b_{mixed}, oscillatory potentials (OP) and b_{cone}) were measured and averaged from both groups, unprotected and protected (Fig 2 and S1 Fig). In unprotected mice, ERG wave amplitudes were reduced approximately 90% (Figs 2A and 3). However, under the effect of the blue-blocking filter, the decrease was only about 40% (Figs 2B and 3). As shown in Fig 3, the differences between unprotected and protected animals were statistically significant for all ERG wave amplitudes studied. Therefore, despite protection of retinal function was not complete, the blue-blocking filter partially prevented light-induced damage to the retina.

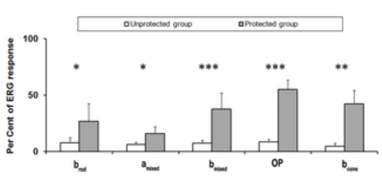

Fig 3. Effect of the blue-blocking filter on ERG wave amplitudes.
Percentages of ERG wave amplitudes in unprotected and protected groups after exposure to white light (5,000 lux for seven days; 100% response corresponds to averaged ERG wave amplitudes before the exposure). Statistically significant differences were observed in all measured ERG parameters Data in each group were averaged from a total of 6 animals (mean ± SD). Asterisks indicate significant differences using unpaired *Student´s t-test* (*p<0.05, **p<0.01, ***p<0.001).
https://doi.org/10.1371/journal.pone.0194218.g003

Photoreceptor cell count and morphology after light exposure

Following assessment of visual function, we wanted to correlate our findings with the number of surviving photoreceptors in the ONL. Retinal sections obtained in the dorsal-ventral axis were stained with the fluorescent dye DAPI to label nuclei. In each retinal section four regions of interest, at different eccentricities, were selected (Fig 4A) and the total number of photoreceptor nuclei was counted in a 200-μm-long sampling region (Fig 4B). For every retinal location, the number of photoreceptors in the unexposed group of mice was significantly higher than in the unprotected or the protected groups (p<0.01, *two way ANOVA*) (Fig 4B and 4C).

In addition, statistically significant differences were found between the protected and the unprotected groups for retinal locations Z2 (p<0.01) and Z3 (p<0.05) (Fig 4C, Table 1 and S2 Fig), which correlated with the protective effect of the blue-blocking filter, already seen by ERG.

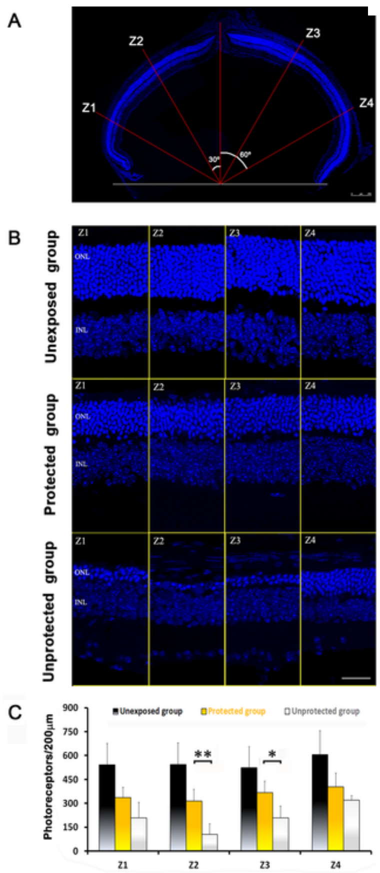

Fig 4. Number of surviving photoreceptors under different experimental lighting conditions.

(A) Photoreceptor survival was analyzed in cryosections at four retinal eccentricities: Z1, 60° dorsal from the optic nerve head (ONH); Z2, 30° dorsal from the ONH; Z3, 30° ventral from the ONH; and Z4, 60° ventral from the ONH. Scale bar 250 μm. (B) Representative images of retinal sections stained with DAPI from the three experimental groups. ONL: outer nuclear layer, INL: inner nuclear layer. Scale bar: 80 μm. (C) Averaged number of photoreceptors (mean ± SD; n = 4) at the different eccentricities. Statistically significant differences were observed between the unexposed group and the other two for all retinal eccentricities (p<0.01, *two way ANOVA*) and between the unprotected and the protected groups for Z2 and Z3 eccentricities (*p<0.05, **p<0.01, respectively; *two way ANOVA*).

https://doi.org/10.1371/journal.pone.0194218.g004

In unexposed and protected groups, the number of photoreceptor nuclei was similar between different sampling locations within the same retinal section, i.e. statistically significant differences were not found using *one way ANOVA*. On the contrary, the number of photoreceptor nuclei between different sampling locations was variable in the unprotected group of mice. Specifically, significant differences were found in retinal locations Z2 and Z4 (p<0.01, *one way ANOVA;* Tukey's multiple comparison post-test) (Table 1).

Cell death was studied by TUNEL labeling of retinal sections. While in unexposed animals no labeling was observed, in mice exposed to damaging light TUNEL+ cells could be detected in the ONL. However, the amount of apoptotic nuclei in unprotected retinas was larger than in the protected group (Fig 5A).

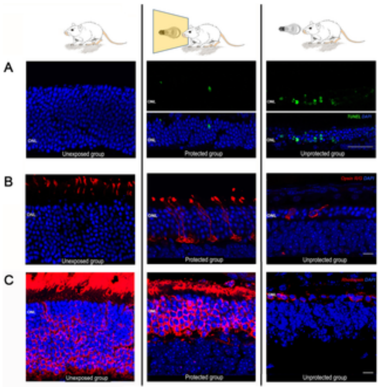

Fig 5. Photoreceptor cell death and protective effect of the blue-blocking filter on cone photoreceptors.
Representative photomicrographs of retinal sections (eccentricity Z2, 30° dorsal from the ONH) obtained from the three experimental groups: unexposed (left panel), protected (middle panel) and unprotected (right panel). (A) Photoreceptor cell death was revealed by the TUNEL technique (green fluorescence). Unprotected animals showed an intense labeling at the ONL, while little or no labeling was observed in protected and unexposed animals, respectively. Nuclei were counterstained with DAPI (blue fluorescence). Scale bar: 50 µm. (B) Immunostaining of cone photoreceptors with red/green opsin antibodies (red fluorescence). Scale bar: 10µm. (C) Immunostaining of rod photoreceptors with rhodopsin antibodies (red fluorescence) Gain settings were maintained at the same level for all experimental groups. Scale bar: 7 µm.
https://doi.org/10.1371/journal.pone.0194218.g005

Appropriate morphology of photoreceptors and normal compartmentalization of visual pigments are signs of retinal wellbeing. Thus, the shielding effect of the blue-blocking filter, evidenced by ERG recordings, should correlate with an improved morphology of rods and cones in the protected group of mice. To evaluate photoreceptor morphological changes following light-induced damage, as well as the degree of protection conferred by the blue filter, retinal sections were immunostained with antibodies against red/green opsin, to label single cones, and rhodopsin, to visualize rod outer segments and somas (Fig 5B and 5C). In unexposed retinas immunostained with red/green opsin, only cone outer segments were labeled, as expected (Fig 5B, left panel). In the protected group, however, the labeling extended to the somas, axons and axon terminals, suggesting that cone opsin was being redistributed along cell compartments (Fig 5B, middle panel). Also, cone outer segments were shorter than in the unexposed group. In the unprotected group cones showed an abnormal morphology, lacking outer segments, axons and axon terminals (Fig 5B, right panel). Rhodopsin expression was analyzed in every group as well (Fig 5C). The unexposed group showed strong labeling of rod outer segments and somas (Fig 5C, left panel). A similar pattern was observed in the protected group, but the size of the outer segments and the number of nuclei rows in the ONL was diminished (Fig 5C, middle panel). The unprotected group showed a huge decrease in the number of rod somas and a lack of outer segments, mainly at Z2 location (Fig 5C, right panel). Therefore, light-induced decrease in visual function correlated with photoreceptor morphological changes and apoptosis, which were attenuated in the presence of a blue-blocking filter.

Discussion

The aim of this work was to test the protective capacity of a specific blue filter against the effects of damaging light. To meet this purpose, retinas were exposed to a constant and intense light and, consequently, suffered a significant decrease in the number of photoreceptors and the amplitude of their functional recordings. However, when the same exposure to light took place through a blue-blocking filter, the decrement in the number of photoreceptors was significantly lower in central areas of the retina and the loss of functional response was attenuated.

Before analyzing the protective effect of the blue-blocking filter, it was necessary to know the exact amount of light that was being removed from the spectrum. In order to ascertain this, spectrometric measurements of the same light source used afterward to induce retinal damage, were carried out in the presence or absence of the filter. We found that the filter used in this study absorbed up to 93% of light below 500 nm and, at the same time, did not alter other components of the spectrum above 530 nm. Therefore, we were able to characterize, in a rather accurate way, structural and functional retinal damage caused by blue light. Similar studies recently published, like the one performed by Narimatsu and colleagues [34], were less precise in terms of the characterization of the protective effects of blue-blocking filters, given that their transmittance data showed that a large percentage of the emitted light below 500 nm passed through the blocking filter (blue-light blockade was 24% or 40%, depending on the filter used). In addition, the transmittance decrease of non-blue wavelengths, due to the use of filters, was disregarded. Therefore, in the present study we provide additional reliable data regarding the efficacy of blue-blocking filters that agree with and round up what has been published before.

Following exposure to damaging light, a decrease in functional responses has been reported. Complete disappearance of the a-wave means that photoreceptors suffer a very aggressive damage, while a decreased b-wave suggests that rod and cone pathways are altered. However, when mice are housed in the same light conditions but with a blue-blocking filter, retinal responses are partially maintained [39]. Some studies have looked for differences between light exposure with and without filters, but not changes within the same groups after light exposure. Our results show pre and post-stress differences for each light condition. This is especially necessary, and not always done, if we take into account the great variability that may exist between mice of the same strains.

Some phototoxicity protocols require a long exposure to low intensities of light [40], while others require a shorter exposure to higher intensities [39,41]. Additionally, some studies have reported to induce photochemical damage through exposure to moderate light for a short time although this damage was temporary when the exposure did not exceed 12 hours [42]. However, some other studies report transient damage as well for exposures longer than 12 hours [40]. In contrast, functionality could not be recovered after a long exposure in our hands. A possible explanation could lie in the use of a higher light intensity. Differences between all these studies could be also attributed to the use of different species or strains and to the housing conditions (plastic cages could cause an increase in temperature).

Functional impairment has a direct correlation with structural alterations in the retina. The low expression of cone opsin in unprotected animals may justify the lack of cone response observed in the ERG. Differences in the number of photoreceptors between protected and unprotected groups were significant in central areas of the outer nuclear layer, mainly in Z2 (dorsal retina). This was in agreement with other works that tested the protective effect of different antioxidants and growth factors in the light-induced retinal damage model and reported the strongest protective effect in the dorsal-temporal retina [41,43,44]. Of note, the smallest density of blue cones can be found in this particular area [7,45]. Therefore, it is reasonable to think that photoreceptors lacking chromophores for short wavelengths show increased sensitivity to light-induced damage when the blue light is involved. Interestingly, when retina is exposed for a long time to non-blue wavelenghts, all areas are affected similarly.

Although the blue-blocking filter promoted photoreceptor survival, this protection was incomplete. Remaining damage might be attributed to the residual blue radiation (in the range of 400 to 500 nm) passing through the filter. Given that the filter used in our experiments did not avoid radiation between 500 and 580 nm, another possible explanation for the residual damage to the retina would imply green light, which is potentially harmful [46]. However, it has been reported that green light does not seem to induce photoreceptor apoptosis after short periods of exposure [18].

The residual damage in the protected group was evidenced by the presence of TUNEL positive cells, more previously described [47,48], although this group showed a lower number of TUNEL+ profiles than the non-protected one. In high light exposure protocols, death mechanisms occur despite the protection system used [41].

It has been reported that a deprivation of light for 9 months, after suffering a 50% reduction in functional responses caused by photostress, allowed a full recovery [40]. For this reason, it is reasonable to think that although our filter does not avoid damage completely, injury could be mitigated enough for getting a full recovery later.

After photostress, cones and rods suffer severe modifications before dying by apoptosis. Such morphological changes occur throughout different phases, involving a series of metabolic processes whose ultimate stage is the demise of the cell [49] Thus, destruction of photoreceptors explains the irreversible loss of retinal function. The use of filters allows the survival of a large number of photoreceptors, but does not completely prevent the development of morphological and functional alterations in the retina. One of these modifications is the change in the distribution of opsins, which may vary depending on cell types [50]. The cause may be in the wavelengths at which chromophores are excited. While for rods and SW cones is 500 nm or less, for L/M cones is 508 nm. Thereby, the filter would prevent the passage of the lowest wavelengths and allow excitation of most L/M cones.

Different opsins are composed of an apoprotein and a specific chromophore. Since the synthesis of new apoprotein is dependent on the excitation of the chromophore [51], an elevated excitation of the chromophore will produce a greater synthesis of apoprotein. This would explain why L/M cones are able to synthesize more apoproteins than rods.

The increment of rhodopsin bleaching products (atRal) produces retinal photodamage, as previously reported [52]. Furthermore, if light exposure is high enough, photobleaching (high levels of atRal) can cause a permanent damage [41]. Physiologically, atRal within Metharhodopsin II (a metastable state of rhodopsin) is cleared by natural mechanisms (ABCA4 transporter and enzymatic reduction by retinal DH) in a slow process [22,53]. However, when rhodopsin regeneration is faster than atRal reduction, free atRal may increase [51]. It is known that free atRal (a toxic aldehyde) is a powerful photosensitizer when exposed to UVA or blue light of high intensity and long duration [21,54,55], comparable to our experimental conditions. It has been shown atRal is greatly released through three different mechanisms [21,54,55]. The first one is due to the bleaching of all rhodopsin at MII. The second implies the presence of all wavelengths (including blue visible light), which allows rhodopsin photoregeneration [53] and inactivation of ABCA4 transport [54], both leading to further increase in atRal accumulation. The third, photoreversal, implies the re-isomerization of the retinal chromophore after absortion of additional photons by other ways. Free atRal causes photoxidative damage to the retina through singlet oxygen [56] and as a precursor of A2E.

After light exposure there is a retinal damage. However, rhodopsin stimulation does not disappear completely, as evidenced by functional responses (Fig 6A and 6B). Illumination through a blue-blocking filter would possibly cause a decrease in atRal photoexcitation due to the lack of blue light [22,55]. In addition, inhibition of ABCA would not occur, enabling the recycling of atRal [21], and the activation pathways triggered by toxic aldehydes would be attenuated as a consequence of blue light removal. However, even in these conditions, remaining excitation could be due to green light that has the ability to bleach rhodopsin without causing photoreversal [53] (Fig 6C).

Fig 6. Excitation and metabolic cycle of rhodopsin depending on the use of the blue-blocking filter.

(A) In the presence of light of all wavelengths, rhodopsin absorption spectrum falls below the black curve. (B) When a blue-blocking filter is used, the spectrum is only possible in the space below the black curve limited by the red line. (C) All-trans Retinal (atRal) is generated after rhodopsin excitation. This may follow two different pathways depending on the excitation wavelength: after a blue-green-yellow flash (400 to 600 nm) or after a green-yellow flash (500 to 600 nm). Both pathways are represented to the right and left of the rhodopsin molecule, respectively. In high and continuous light exposure, total bleaching of rhodopsin takes place and much toxic atRal is accumulated. Then, atRal is slowly recycled to MII in a process that involves blue light (photoreversal). Blue light is also implied in MIII storage increase. The huge atRal accumulation and its

photoactivation by blue light have important implications for photoreceptors, like the genesis of photoreactive metabolites (A2E and lipofuscin). Also, in the presence of molecular oxygen, photo-oxidative reactions are initiated, as well as blocking of its conveyor ABCA4 and subsequent action of retinal dehydrogenase (in rods, RDH8) (red arrow). Conversely, in the absence of blue light all these processes disappear or are strongly attenuated (right side of the drawing). Gray arrows indicate a decreased effect or a blockade.
https://doi.org/10.1371/journal.pone.0194218.g006

Wavelengths that can activate rhodopsin range from 400 nm to almost 600 nm [5]. We can distinguish two parts in the spectrum. One consists on the "non-blue" (above 500 nm) wavelengths that excite rhodopsin and generate toxic waste, but do not cause retinal degeneration. The other part of the spectrum, below 500 nm, causes retinal degeneration in addition to toxic waste. This degeneration seems to affect primarily retinal cells capable of absorbing photons of these wavelengths. Rhodopsin and its sub-products of excitation seem to have a major role in retinal damage.

The relationship among blue light, generated toxic products (atRal, A2E, lipofuscin) and degenerative diseases such as age-related macular degeneration, Stargardt's disease and others [54,57,58], makes it necessary to control the amount of radiation that the human retina receives. These reasons are especially important given our current lifestyles, both from a technological point of view (the use of blue LED on mobile terminals, screens, etc.), as well as from an occupational perspective (night shifts with high exposure to blue lights).

Conclusions

In summary, retinal photodamage caused by a conventional light source (cold) can become chronic if exposure is high and long enough. In contrast, the use of blue-blocking filters can significantly alleviate the functional loss of retinal photosensitive cells. Therefore, these filters might be an effective mechanism to protect us from ocular pathologies.

Supporting information

S1 Fig. Values of ERG wave amplitudes.
Data of unprotected and protected groups after exposure to white light. Fig 3 and the subsequent statistical analysis were done with these data.
https://doi.org/10.1371/journal.pone.0194218.s001
(DOCX)

S2 Fig. Number of surviving photoreceptors following exposure to white light.
Photoreceptor survival in unexposed, protected and exposed retinas, after light-induced damage. Cell counting was performed at four different retinal eccentricities. Fig 4C and the subsequent statistical analysis were done with these data.
https://doi.org/10.1371/journal.pone.0194218.s002
(DOCX)

References

1. Lucas RJ, Freedman MS, Munoz M, Garcia-Fernandez JM, Foster RG (1999) Regulation of the mammalian pineal by non-rod, non-cone, ocular photoreceptors. Science 284: 505–507. pmid:10205062
View Article • PubMed/NCBI • Google Scholar

2. Panda S, Provencio I, Tu DC, Pires SS, Rollag MD, et al. (2003) Melanopsin is required for non-image-forming photic responses in blind mice. Science 301: 525–527. pmid:12829787
View Article • PubMed/NCBI • Google Scholar

3. Carter-Dawson LD, LaVail MM (1979) Rods and cones in the mouse retina. I. Structural analysis using light and electron microscopy. J Comp Neurol 188: 245–262. pmid:500858
View Article • PubMed/NCBI • Google Scholar

4. Jeon CJ, Strettoi E, Masland RH (1998) The major cell populations of the mouse retina. J Neurosci 18: 8936–8946. pmid:9786999
View Article • PubMed/NCBI • Google Scholar

5. Kojima D, Mori S, Torii M, Wada A, Morishita R, et al. (2011) UV-sensitive photoreceptor protein OPN5 in humans and mice. PLoS One 6: e26388. pmid:22043319
View Article • PubMed/NCBI • Google Scholar

6. Szel A, Rohlich P, Caffe AR, Juliusson B, Aguirre G, et al. (1992) Unique topographic separation of two spectral classes of cones in the mouse retina. J Comp Neurol 325: 327–342. pmid:1447405
View Article • PubMed/NCBI • Google Scholar

7. Ortin-Martinez A, Nadal-Nicolas FM, Jimenez-Lopez M, Alburquerque-Bejar JJ, Nieto-Lopez L, et al. (2014) Number and distribution of mouse retinal cone photoreceptors: differences between an albino (Swiss) and a pigmented (C57/BL6) strain. PLoS One 9: e102392. pmid:25029531
View Article • PubMed/NCBI • Google Scholar

8. Hu C, Hill DD, Wong KY (2013) Intrinsic physiological properties of the five types of mouse ganglion-cell photoreceptors. J Neurophysiol 109: 1876–1889. pmid:23343892
View Article • PubMed/NCBI • Google Scholar

9. Reifler AN, Chervenak AP, Dolikian ME, Benenati BA, Meyers BS, et al. (2015) The rat retina has five types of ganglion-cell photoreceptors. Exp Eye Res 130: 17–28. pmid:25450063
View Article • PubMed/NCBI • Google Scholar

10. Terakita A (2005) The opsins. Genome Biol 6: 213. pmid:15774036
View Article • PubMed/NCBI • Google Scholar

11. Shichida Y, Matsuyama T (2009) Evolution of opsins and phototransduction. Philos Trans R Soc Lond B Biol Sci 364: 2881–2895. pmid:19720651
View Article • PubMed/NCBI • Google Scholar

12. Okada T, Ernst OP, Palczewski K, Hofmann KP (2001) Activation of rhodopsin: new insights from structural and biochemical studies. Trends Biochem Sci 26: 318–324. pmid:11343925
View Article • PubMed/NCBI • Google Scholar

13. Vought BW, Dukkipatti A, Max M, Knox BE, Birge RR (1999) Photochemistry of the primary event in short-wavelength visual opsins at low temperature. Biochemistry 38: 11287–11297. pmid:10471278
View Article • PubMed/NCBI • Google Scholar

14. Noell WK, Walker VS, Kang BS, Berman S (1966) Retinal damage by light in rats. Invest Ophthalmol 5: 450–473. pmid:5929286
View Article • PubMed/NCBI • Google Scholar

15. Wu J, Seregard S, Algvere PV (2006) Photochemical damage of the retina. Surv Ophthalmol 51: 461–481. pmid:16950247
View Article • PubMed/NCBI • Google Scholar

16. Youssef PN, Sheibani N, Albert DM (2011) Retinal light toxicity. Eye (Lond) 25: 1–14.
View Article • Google Scholar

17. Ham WT Jr., Mueller HA, Ruffolo JJ Jr., Clarke AM (1979) Sensitivity of the retina to radiation damage as a function of wavelength. Photochem Photobiol 29: 735–743. pmid:109869
View Article • PubMed/NCBI • Google Scholar

18. Grimm C, Wenzel A, Williams T, Rol P, Hafezi F, et al. (2001) Rhodopsin-mediated blue-light damage to the rat retina: effect of photoreversal of bleaching. Invest Ophthalmol Vis Sci 42: 497–505. pmid:11157889
View Article • PubMed/NCBI • Google Scholar

19. Wasowicz M, Morice C, Ferrari P, Callebert J, Versaux-Botteri C (2002) Long-term effects of light damage on the retina of albino and pigmented rats. Invest Ophthalmol Vis Sci 43: 813–820. pmid:11867603
View Article • PubMed/NCBI • Google Scholar

20. Wenzel A, Grimm C, Marti A, Kueng-Hitz N, Hafezi F, et al. (2000) c-fos controls the "private pathway" of light-induced apoptosis of retinal photoreceptors. J Neurosci 20: 81–88. pmid:10627584
View Article • PubMed/NCBI • Google Scholar

21. Maeda T, Golczak M, Maeda A (2012) Retinal photodamage mediated by all-trans-retinal. Photochem Photobiol 88: 1309–1319. pmid:22428905
View Article • PubMed/NCBI • Google Scholar

22. Rozanowska M, Sarna T (2005) Light-induced damage to the retina: role of rhodopsin chromophore revisited. Photochem Photobiol 81: 1305–1330. pmid:16120006
View Article • PubMed/NCBI • Google Scholar

23. Boulton M, Rozanowska M, Rozanowski B (2001) Retinal photodamage. J Photochem Photobiol B 64: 144–161. pmid:11744401
View Article • PubMed/NCBI • Google Scholar

24. Roberts JE (2001) Ocular phototoxicity. J Photochem Photobiol B 64: 136–143. pmid:11744400
View Article • PubMed/NCBI • Google Scholar

25. Organisciak DT, Vaughan DK (2010) Retinal light damage: mechanisms and protection. Prog Retin Eye Res 29: 113–134. pmid:19951742
View Article • PubMed/NCBI • Google Scholar

26. Sparrow JR, Miller AS, Zhou J (2004) Blue light-absorbing intraocular lens and retinal pigment epithelium protection in vitro. J Cataract Refract Surg 30: 873–878. pmid:15093654
View Article • PubMed/NCBI • Google Scholar

27. Knels L, Valtink M, Roehlecke C, Lupp A, de la Vega J, et al. (2011) Blue light stress in retinal neuronal (R28) cells is dependent on wavelength range and irradiance. Eur J Neurosci 34: 548–558. pmid:21781192
View Article • PubMed/NCBI • Google Scholar

28. Yanagi Y, Inoue Y, Iriyama A, Jang WD (2006) Effects of yellow intraocular lenses on light-induced upregulation of vascular endothelial growth factor. J Cataract Refract Surg 32: 1540–1544. pmid:16931269
View Article • PubMed/NCBI • Google Scholar

29. Meyers SM, Ostrovsky MA, Bonner RF (2004) A model of spectral filtering to reduce photochemical damage in age-related macular degeneration. Trans Am Ophthalmol Soc 102: 83–93; discussion 93–85. pmid:15747748
View Article • PubMed/NCBI • Google Scholar

30. Yang H, Afshari NA (2014) The yellow intraocular lens and the natural ageing lens. Curr Opin Ophthalmol 25: 40–43. pmid:24270599
View Article • PubMed/NCBI • Google Scholar

31. Wu J, Seregard S, Spangberg B, Oskarsson M, Chen E (1999) Blue light induced apoptosis in rat retina. Eye (Lond) 13 Pt 4): 577–583.
View Article • Google Scholar

32. Seiler MJ, Liu OL, Cooper NG, Callahan TL, Petry HM, et al. (2000) Selective photoreceptor damage in albino rats using continuous blue light. A protocol useful for retinal degeneration and transplantation research. Graefes Arch Clin Exp Ophthalmol 238: 599–607. pmid:10955662
View Article • PubMed/NCBI • Google Scholar

33. Tanito M, Kaidzu S, Anderson RE (2006) Protective effects of soft acrylic yellow filter against blue light-induced retinal damage in rats. Exp Eye Res 83: 1493–1504. pmid:16997296
View Article • PubMed/NCBI • Google Scholar

34. Narimatsu T, Ozawa Y, Miyake S, Kubota S, Yuki K, et al. (2014) Biological effects of blocking blue and other visible light on the mouse retina. Clin Experiment Ophthalmol 42: 555–563. pmid:24304494
View Article • PubMed/NCBI • Google Scholar

35. Wachtmeister L (1998) Oscillatory potentials in the retina: what do they reveal. Prog Retin Eye Res 17: 485–521. pmid:9777648
View Article • PubMed/NCBI • Google Scholar

36. Marmor MF, Fulton AB, Holder GE, Miyake Y, Brigell M, et al. (2009) ISCEV Standard for full-field clinical electroretinography (2008 update). Doc Ophthalmol 118: 69–77. pmid:19030905
View Article • PubMed/NCBI • Google Scholar

37. McCulloch DL, Marmor MF, Brigell MG, Hamilton R, Holder GE, et al. (2015) ISCEV Standard for full-field clinical electroretinography (2015 update). Doc Ophthalmol 130: 1–12.
View Article • Google Scholar

38. Marchena M, Lara J, Aijon J, Germain F, de la Villa P, et al. (2011) The retina of the PCD/PCD mouse as a model of photoreceptor degeneration. A structural and functional study. Exp Eye Res 93: 607–617. pmid:21824473
View Article • PubMed/NCBI • Google Scholar

39. Kurihara T, Omoto M, Noda K, Ebinuma M, Kubota S, et al. (2009) Retinal phototoxicity in a novel murine model of intraocular lens implantation. Mol Vis 15: 2751–2761. pmid:20019883
View Article • PubMed/NCBI • Google Scholar

40. Richards A, Emondi AA, Rohrer B (2006) Long-term ERG analysis in the partially light-damaged mouse retina reveals regressive and compensatory changes. Vis Neurosci 23: 91–97. pmid:16597353
View Article • PubMed/NCBI • Google Scholar

41. Tanito M, Kaidzu S, Anderson RE (2007) Delayed loss of cone and remaining rod photoreceptor cells due to impairment of choroidal circulation after acute light exposure in rats. Invest Ophthalmol Vis Sci 48: 1864–1872. pmid:17389522
View Article • PubMed/NCBI • Google Scholar

42. Moriya M, Baker BN, Williams TP (1986) Progression and reversibility of early light-induced alterations in rat retinal rods. Cell Tissue Res 246: 607–621. pmid:3791385
View Article • PubMed/NCBI • Google Scholar

43. Ueki Y, Wang J, Chollangi S, Ash JD (2008) STAT3 activation in photoreceptors by leukemia inhibitory factor is associated with protection from light damage. J Neurochem 105: 784–796. pmid:18088375
View Article • PubMed/NCBI • Google Scholar

44. Mandal MN, Moiseyev GP, Elliott MH, Kasus-Jacobi A, Li X, et al. (2011) Alpha-phenyl-N-tert-butylnitrone (PBN) prevents light-induced degeneration of the retina by inhibiting RPE65 protein isomerohydrolase activity. J Biol Chem 286: 32491–32501. pmid:21785167
View Article • PubMed/NCBI • Google Scholar

45. Applebury ML, Antoch MP, Baxter LC, Chun LL, Falk JD, et al. (2000) The murine cone photoreceptor: a single cone type expresses both S and M opsins with retinal spatial patterning. Neuron 27: 513–523. pmid:11055434
View Article • PubMed/NCBI • Google Scholar

46. Gorgels TG, van Norren D (1995) Ultraviolet and green light cause different types of damage in rat retina. Invest Ophthalmol Vis Sci 36: 851–863. pmid:7706033
View Article • PubMed/NCBI • Google Scholar

47. Montalban-Soler L, Alarcon-Martinez L, Jimenez-Lopez M, Salinas-Navarro M, Galindo-Romero C, et al. (2012) Retinal compensatory changes after light damage in albino mice. Mol Vis 18: 675–693. pmid:22509098
View Article • PubMed/NCBI • Google Scholar

48. Li F, Cao W, Anderson RE (2003) Alleviation of constant-light-induced photoreceptor degeneration by adaptation of adult albino rat to bright cyclic light. Invest Ophthalmol Vis Sci 44: 4968–4975. pmid:14578424
View Article • PubMed/NCBI • Google Scholar

49. Wenzel A, Grimm C, Samardzija M, Reme CE (2005) Molecular mechanisms of light-induced photoreceptor apoptosis and neuroprotection for retinal degeneration. Prog Retin Eye Res 24: 275–306. pmid:15610977
View Article • PubMed/NCBI • Google Scholar

50. Edward DP, Lim K, Sawaguchi S, Tso MO (1993) An immunohistochemical study of opsin in photoreceptor cells following light-induced retinal degeneration in the rat. Graefes Arch Clin Exp Ophthalmol 231: 289–294. pmid:8319919
View Article • PubMed/NCBI • Google Scholar

51. Schadel SA, Heck M, Maretzki D, Filipek S, Teller DC, et al. (2003) Ligand channeling within a G-protein-coupled receptor. The entry and exit of retinals in native opsin. J Biol Chem 278: 24896–24903. pmid:12707280
View Article • PubMed/NCBI • Google Scholar

52. Maeda A, Maeda T, Golczak M, Chou S, Desai A, et al. (2009) Involvement of all-trans-retinal in acute light-induced retinopathy of mice. J Biol Chem 284: 15173–15183. pmid:19304658
View Article • PubMed/NCBI • Google Scholar

53. Grimm C, Reme CE, Rol PO, Williams TP (2000) Blue light's effects on rhodopsin: photoreversal of bleaching in living rat eyes. Invest Ophthalmol Vis Sci 41: 3984–3990. pmid:11053303
View Article • PubMed/NCBI • Google Scholar

54. Sun H, Nathans J (2001) ABCR, the ATP-binding cassette transporter responsible for Stargardt macular dystrophy, is an efficient target of all-trans-retinal-mediated photooxidative damage in vitro. Implications for retinal disease. J Biol Chem 276: 11766–11774. pmid:11278627
View Article • PubMed/NCBI • Google Scholar

55. Sparrow JR, Wu Y, Kim CY, Zhou J (2010) Phospholipid meets all-trans-retinal: the making of RPE bisretinoids. J Lipid Res 51: 247–261. pmid:19666736
View Article • PubMed/NCBI • Google Scholar

56. Delmelle M (1977) Retinal damage by light: possible implication of singlet oxygen. Biophys Struct Mech 3: 195–198. pmid:890057
View Article • PubMed/NCBI • Google Scholar

57. Marc RE, Jones BW, Watt CB, Vazquez-Chona F, Vaughan DK, et al. (2008) Extreme retinal remodeling triggered by light damage: implications for age related macular degeneration. Mol Vis 14: 782–806. pmid:18483561
View Article • PubMed/NCBI • Google Scholar

58. Adler Lt, Boyer NP, Chen C, Ablonczy Z, Crouch RK, et al. (2015) The 11-cis Retinal Origins of Lipofuscin in the Retina. Prog Mol Biol Transl Sci 134: e1–12. pmid:26310175
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Blue light excited retinal intercepts cellular signaling

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Blue light excited retinal intercepts cellular signaling

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Abstract

Photoreceptor chromophore, 11-cis retinal (11CR) and the photoproduct, all-trans retinal (ATR), are present in the retina at higher concentrations and interact with the visual cells. Non-visual cells in the body are also exposed to retinal that enters the circulation. Although the cornea and the lens of the eye are transparent to the blue light region where retinal can absorb and undergo excitation, the reported phototoxicity in the eye has been assigned to lipophilic non-degradable materials known as lipofuscins, which also includes retinal condensation products. The possibility of blue light excited retinal interacting with cells; intercepting signaling in the presence or absence of light has not been explored. Using live cell imaging and optogenetic signaling control, we uncovered that blue light-excited ATR and 11CR irreversibly change/distort plasma membrane (PM) bound phospholipid; phosphatidylinositol 4,5 bisphosphate (PIP2) and disrupt its function. This distortion in PIP2 was independent of visual or non-visual G-protein coupled receptor activation. The change in PIP2 was followed by an increase in the cytosolic calcium, excessive cell shape change, and cell death. Blue light alone or retinal alone did not perturb PIP2 or elicit cytosolic calcium increase. Our data also suggest

that photoexcited retinal-induced PIP2 distortion and subsequent oxidative damage incur in the core of the PM. These findings suggest that retinal exerts light sensitivity to both photoreceptor and non-photoreceptor cells, and intercepts crucial signaling events, altering the cellular fate.

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Introduction

Light activatable G-protein coupled receptors (GPCRs), also known as opsins, harvest light through their covalently bound chromophore 11-*cis* retinal (11CR), an aldehyde derivative of vitamin A[1,2]. Once an opsin is activated, all *trans* retinal (ATR) is released, and converted back to 11CR within the retinal pigment epithelium (RPE) by a multi-component ATR clearance mechanism composed of retinaldehyde dehydrogenase, RPE65, lecithin retinol acyltransferase and ATP-binding cassette transporter A4[3]. Dysfunctions in 11CR regeneration process result in ATR accumulation in the retina[3,4,5]. ATR mediated cytotoxicity and associated pathological conditions have been reported[5,6,7,8]. Studies in mice have demonstrated that, ATR accumulation and photodegradation leads to diseases such as age related macular degeneration (AMD), Stargardt disease, acute light-induced retinopathy, retinitis pigmentosa and night blindness[5]. Although retinal undergoes degradation upon exposure to light, neither photodegradation pathways leading to specific photoproducts formation nor plausible non-visual signaling of these photoproducts are sufficiently understood[6]. Several mechanisms of retinal induced toxicity in photoreceptor cells have been proposed[5,9,10]. In the retina, higher ATR concentrations have been linked to cytotoxicity due to their ability to form oxidized condensation products known as lipofuscins[10,11,12,13,14]. Lipofuscins include ATR dimers/adducts, N-retinylidene-N-retinylethanolamine (A2E), N-retinylidene and N-retinylethanolamine. While lipofuscins can produce reactive oxygen species (ROS) with a low quantum yield[15], photooxidation of ATR in photoreceptor cells is linked to NADPH oxidase activation, ROS generation and calcium mobilization, inducing cytotoxicity and apoptosis[3,5,8,9,16]. Additionally, photodegraded ATR is linked to cytotoxicity observed in ARPE-19 retinal pigment epithelium cells[6]. Since cytosolic calcium is increased by GPCR activation[17,18,19,20], it has been suggested that ATR induces phototoxicity by interacting with a ligand binding Gq-coupled GPCR, activating phosphatidylinositol pathway through an unknown mechanism[5]. Collectively, if visible light photosensitizes free retinal in cells, what subcellular location chemically supports retinal photochemistry, and what subsequent signaling perturbations photoexcited retinal elicits in living cells are not known.

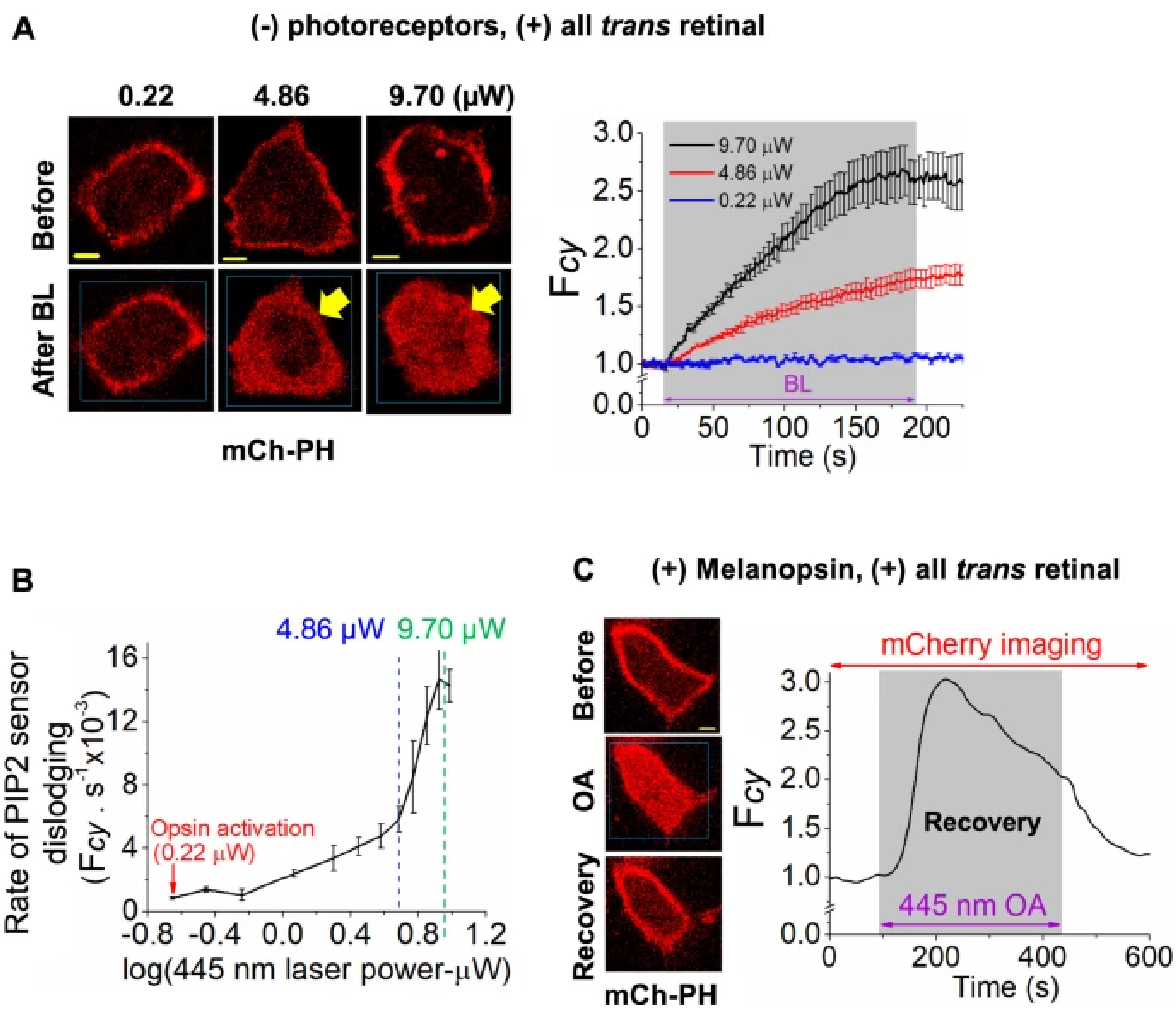
The present study examines mechanisms of photoexcited retinal intercepting signaling networks in living cells, especially perturbing phospholipid, phosphatidylinositol 4,5 bisphosphate (PIP2) signaling. Results show that photoexcited retinal mediated PIP2 signaling perturbation is independent of GPCR activation. Since PIP2 has been identified as a crucial regulator of cellular functions including cytoskeleton remodeling, cell migration, endocytosis, cell motility and cell shape[21,22], perturbation of PIP2 signaling by photoexcited retinal could significantly affect cellular physiology. Overall, our data elaborate molecular underpinnings of retinal associated cytotoxicity and its physiological consequences.

Results

Retinal absorbs blue light and induces translocation of PIP2 sensor to the cytosol

The objective was to examine whether retinal or blue light excited retinal, independent of photoreceptors, elicits PIP2 hydrolysis and inositol (1,4,5) triphosphate (IP3) generation in cells, because calcium and its regulatory pathways are suggested as key players of cytotoxicity in the retina[5,23]. We employed HeLa cells as the major cell line here to eliminate potential response contamination due to retinal and blue light activating endogenous photoreceptors in cells derived from retina. Upon retinal addition to HeLa cells expressing PIP2 sensor (mCherry-PH), cells did not show any change in sensor distribution (Fig. 1A, left). These cells were exposed to blue light at every one-second interval for 10 minutes. Starting blue light intensity was set to 0.22 µW, since this power is sufficient to activate retinal bound to photoreceptors. Cells were imaged for mCherry while gradually increasing blue light intensity. Intensities at 1 µW and above, cells exhibited mCherry-PH translocation to cytosol (Fig. 1A,B, Movie-S1). However, at these intensities, photobleaching of fluorescence proteins was not observed. Interestingly, the translocated mCherry-PH did not recover, even after termination of blue light exposure, suggesting the likelihood of irreversible photochemical perturbation of PIP2 by blue light excited retinal.

Figure 1



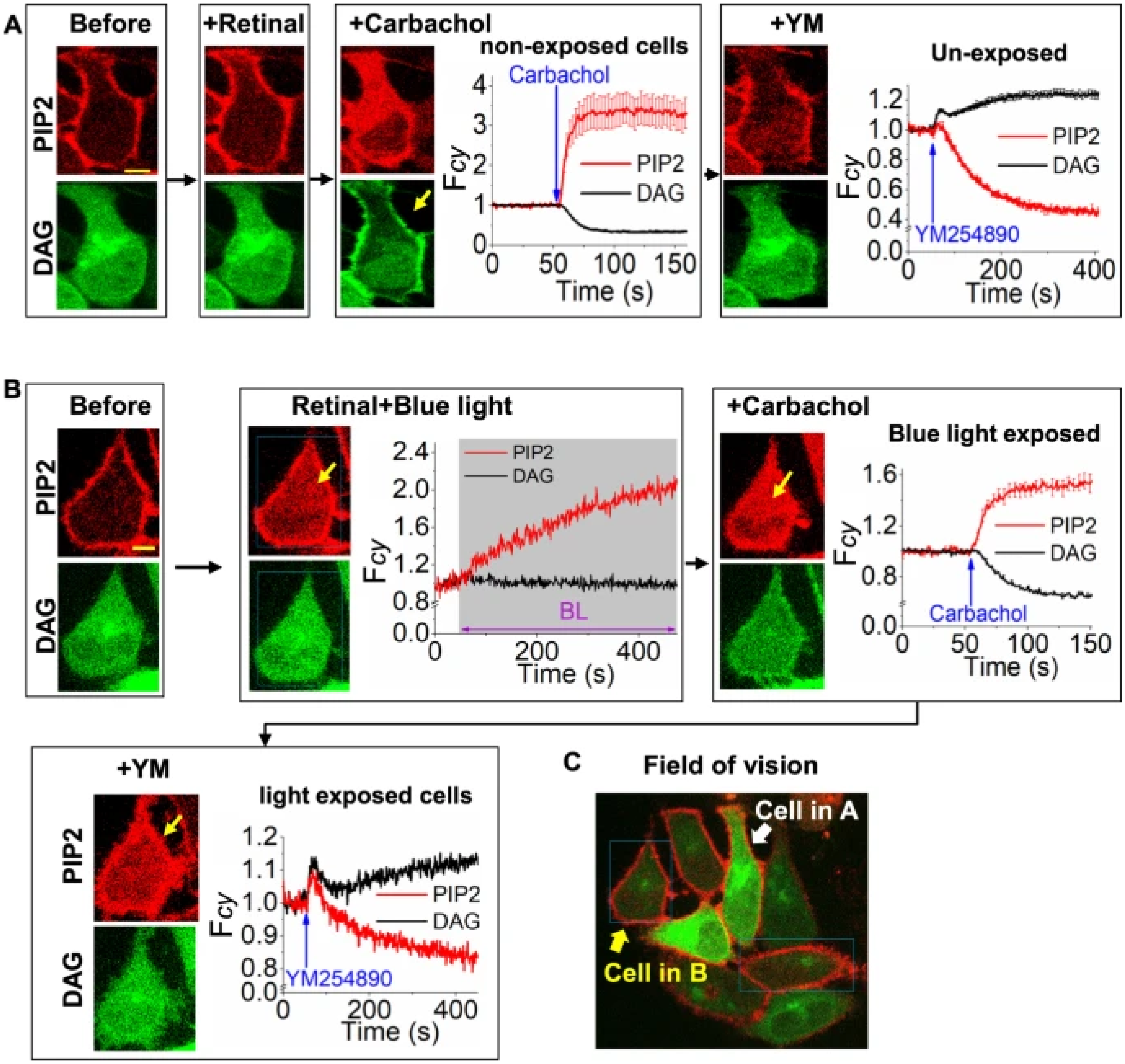
Comparison of photoreceptor dependent PIP2 hydrolysis vs photoreceptor independent PIP2 sensor translocation by photoexcited retinal. (**A**) Images of HeLa cells incubated with 50 μM ATR (retinal) expressing PIP2 sensor (mCherry-PH). Both images and the plot of F_{cy} vs time show that cells exposed to 0.22 μW 445 nm blue light did not respond, while cells exposed to 4.86 μW and 9.70 μW blue light exhibited mCherry-PH translocation to cytosol (mean ± S.E.M.). (**B**) The plot of initial PIP2 sensor dislodging rate vs laser power of 445 nm blue light. (mean ± S.E.M., n = 6 cells in each experiments). (**C**) Images of HeLa cells expressing Gq-coupled Melanopsin and mCherry-PH. Cells were incubated with ATR (50 μM) for 5 minutes. A significant PIP2 hydrolysis was observed upon optical activation (OA = blue box) of melanopsin using short pulses of blue light (0.22 μW of 445 nm). Recovery of PIP2 sensor to the PM was observed even the blue light exposure is continued. The plot shows the dynamics of PIP2 sensor translocation in cytosol. Mean and S.E.M. are from 3 < independent experiments. (blue light (BL) = blue box). Scale = 5 μm.

Response signatures of mCherry-PH translocation induced by blue light (4.86 μW) excited retinal (BLE-retinal) were compared with PIP2 hydrolysis elicited by melanopsin-Retinal Schiff Base (RSB), to examine if both processes trigger similar chemical changes to PIP2. HeLa cells expressing melanopsin and mCherry-PH were incubated with ATR (50 μM) for 5 minutes in dark to allow RSB formation. Cells exhibited PIP2 hydrolysis upon exposure to low intensity blue light (0.22 μW), as indicated by the translocation of mCherry-PH from PM to cytosol (Fig. 1C, Movie-S2). The observed PIP2 hydrolysis was transient and recovered within 2–3 minutes. Gq-coupled GPCR activation induced-PIP2 hydrolysis recovers over time due to signaling adaptation[24,25]. Similar to melanopsin activation, addition of carbachol to HeLa cells expressing M3R and PIP2 sensor exhibited PIP2 hydrolysis. A similar recovery of PIP2 was also observed (Fig. S1, Movie-S3).

During PIP2 hydrolysis, IP3 moiety of PIP2 dissociates from PM anchored diacylglycerol (DAG) domain. The PH domain of PLCδ1 in the PH sensor moves to cytosol with IP3 upon

PIP2 hydrolysis[26]. The irreversible translocation of mCherry-PH by BLE-retinal was further characterized to determine if this is due to PIP2 hydrolysis or a photochemical perturbation to PIP2, either by breaking the molecule or preventing PIP2 sensor binding. To examine whether BLE-retinal induces mCherry-PH translocation due to PIP2 hydrolysis, leaving DAG on the PM, DAG generation was imaged using cytosolic DAG sensor, YFP-DBD, that translocates to PM. Cells incubated with ATR failed to exhibit a detectable mCherry-PH translocation (Fig. 2A). When a selected cell in the field of vision (Fig. 2C, yellow arrow) was exposed BLE-retinal for 400 seconds, a robust mCherry-PH translocation only in blue light exposed cell was observed (Fig. 2B). However, the DAG sensor did not translocate to PM (Fig. 2B), indicating that, exposure to BLE-retinal does not leave DAG at PM. We also comparatively examined Gq-coupled M3-muscarinic receptor (M3R) activation in the same HeLa cells transiently expressing M3R. When cells were exposed to 10 μM carbachol, both PIP2 hydrolysis and DAG formation were observed (Fig. 2A). When this cell was exposed to YM254890 (1 μM), which inhibits Gαq heterotrimer activation, both PIP2 and DAG sensors reversed to their basal pre-activation status, suggesting PIP2 recovery (Fig. 2A). Interestingly, the cell exposed to BLE-retinal did not show such a recovery upon addition of YM254890 (Fig. 2B). This further confirms that BLE-retinal induced PIP2 distortion in cells is irreversible.

Figure 2

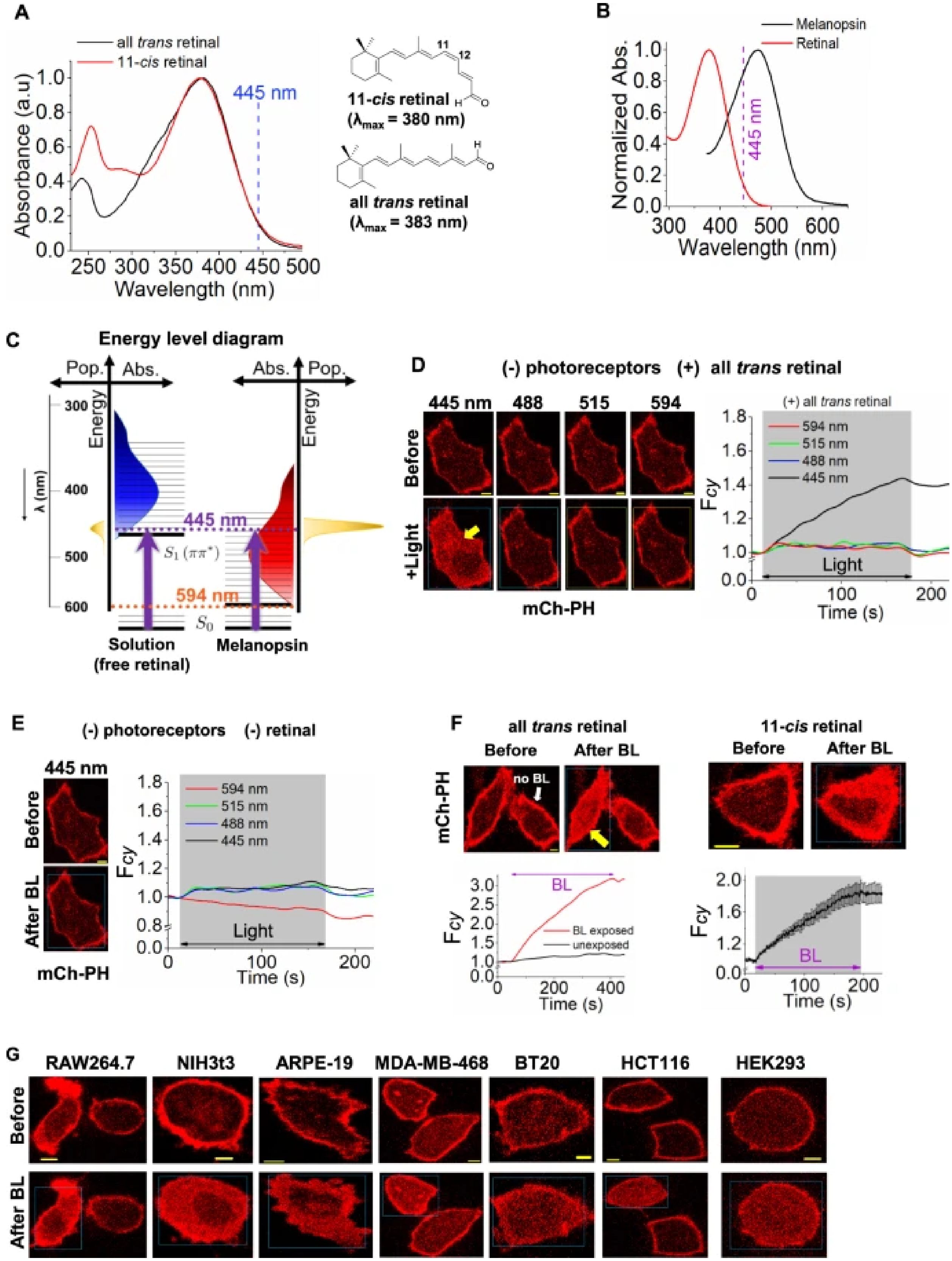


Comparison of M3-muscarnic receptor mediated PIP2 hydrolysis vs blue light excited retinal (BLE-retinal) induced PIP2 sensor translocation. Images of HeLa cells expressing M3-muscarinic receptor, mCherry-PH (PIP2 sensor), DBD-YFP (DAG sensor). (**A**) Without blue light exposure, retinal addition does not change PIP2 or DAG sensor distribution (left), while the addition of carbachol resulted in PIP2 hydrolysis and DAG formation (middle). The addition of Gq inhibitor, YM254890 (1 µM) to cells resulted in reverse translocation of PIP2 and DAG sensors. (mean ± S.E.M., n = 6 cells) (**B**) When cells were exposed to blue light (4.86 µW of 445 nm) in the presence of retinal, they only showed PIP2 sensor translocation while no change in DAG sensor was observed (left). The addition of carbachol to these cells exhibited an additional PIP2 sensor translocation to the cytosol with a mild DAG sensor translocation to the PM (left) (mean ± S.E.M., n = 4 cells). Interestingly, addition of YM254890 only reversed both PIP2 and DBD responses elicited by carbachol. (**C**) The field of vision of cells shown in A and B. Mean and S.E.M. are from 3 < independent experiments. (blue light (BL) = blue box). Scale = 5 μm.

Characteristics of retinal photoexcitation in cellular environment

Compared to the light power required for opsin activation (~0.2 μW), a higher power of blue light (>1 μW) was required for free retinal to induce PIP2 distortion. This can be partly due to the bathochromic shift in the absorption spectrum of melanopsin-retinal Schiff base (m-RSB) with a λ_{max} = 478 nm, compared to the λ_{max} = 383 nm of free retinal (Fig. 3A,B). This allows m-RSB to have a greater spectral overlap with blue light (445 nm) that drives a larger population of molecules to the excited $S_1(\pi^* \leftarrow \pi)$ state, compared to free retinal (Fig. 3C). Since quantum yield of m-RSB isomerization is estimated to be at near unity[27,28,29], all absorbed photons result in GPCR activation. Additionally, the lower power requirement for melanopsin activation induced PIP2 hydrolysis is due to the enhanced photosensitivity of m-RSB and PIP2 hydrolysis being an enzymatic process while BLE-excited retinal induced PIP2 distortion is likely to be a non-enzymatic and stoichiometric reaction.

Figure 3

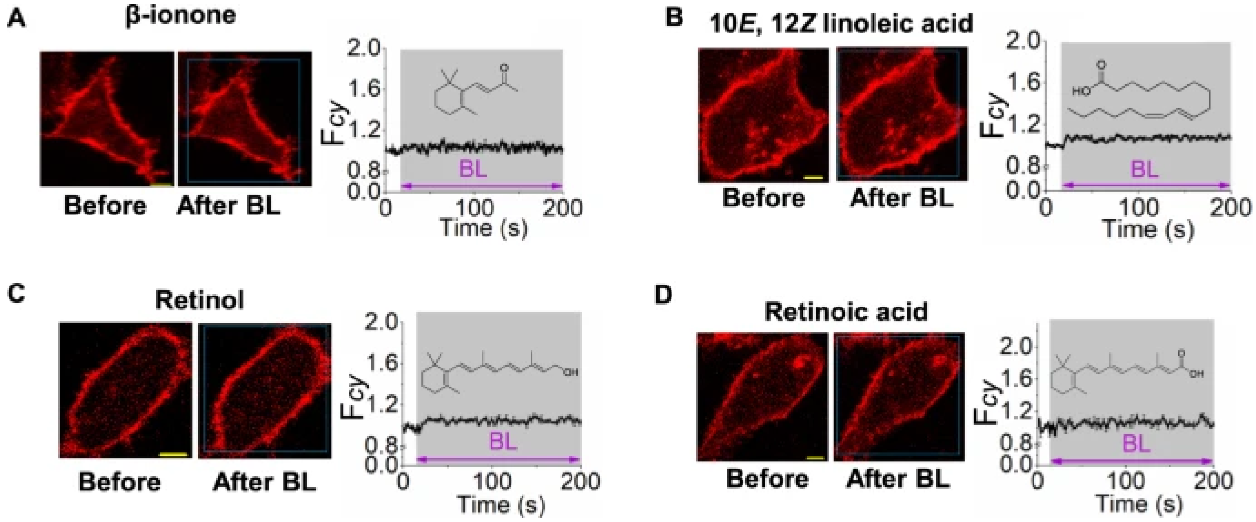

A
all trans retinal
11-cis retinal
Absorbance (a.u)
445 nm
Wavelength (nm)
11-cis retinal
(λmax = 380 nm)
all trans retinal
(λmax = 383 nm)
B
Melanopsin
Retinal
Normalized Abs.
445 nm
Wavelength (nm)
C
Energy level diagram
Pop.
Abs.
Energy
λ (nm)
445 nm
594 nm
Solution
(free retinal)
Melanopsin
D
(-) photoreceptors (+) all trans retinal
445 nm
488
515
594
Before
+Light
mCh-PH
(+) all trans retinal
594 nm
515 nm
488 nm
445 nm
Fcy
Light
Time (s)
E
(-) photoreceptors (-) retinal
445 nm
Before
After BL
mCh-PH
594 nm
515 nm
488 nm
445 nm
Fcy
Light
Time (s)
F
all trans retinal
Before
After BL
no BL
mCh-PH
11-cis retinal
Before
After BL
BL
BL exposed
unexposed
Fcy
Time (s)
BL
G
RAW264.7
NIH3t3
ARPE-19
MDA-MB-468
BT20
HCT116
HEK293
Before
After BL

Energy and wavelength requirement for PIP2 solubilization by photoexcited retinal. (**A**) UV-VIS absorption spectra for both 11-cis retinal (11CR) and all *trans* retinal (ATR). Note that 445 nm blue light spectrally overlaps with both absorption spectra. (**B**) The absorption spectra of melanopsin and retinal (left), (ε_{ATR} = 44180.0 $M^{-1}cm^{-1}$). (**C**) The energy level diagram and the population (pop.) of energy levels of free retinal (blue) and melanopsin (red) according to their respective absorption maxima (right). Note that blue light (445 nm) can highly populate melanopsin compared to that of free retinal. (**D**–**F**) Images of HeLa cells expressing PIP2 sensor (mCherry-PH). (**D**) Cells were incubated with ATR (50 μM) for 5 minutes. A substantial PIP2 sensor translocation was observed upon exposing cells to short pulses of blue light (4.86 μW of 445 nm). The plot shows the dynamics of PIP2 sensor translocation to cytosol. (**E**) In the absence of retinal, cells did not show a detectable PIP2 sensor translocation when exposed to blue light or other wavelengths. (**F**) Both blue light excited ATR (50 μM) and 11CR (50 μM) exhibited a permanent accumulation of PIP2 sensor cytosol. Compared to exposed cell (yellow arrow), control cell without blue light (BL) exposure (white arrow) did not show any detectable PIP2 response. The plots show the dynamics of PIP2 sensor translocation in cells shown in F (mean ± S.E.M., n = 6 cells). (**G**) All *trans* retinal and blue light induce PIP2 sensor translocation in cells with distinct origins. Images of RAW264.7, NIH3t3, ARPE-19, MDA-MB-468, BT-20, HCT116 and HEK293 cells expressing mCherry-PH (PIP2 sensor). ATR (50 μM) was incubated in cells for 5 minutes followed by continuous exposure of blue light for 5 minutes. Blue light exposure induced PIP2 sensor translocation from PM in all the cell types tested while cells that were not exposed to blue light did not respond. Mean and S.E.M. are from 3 < independent experiments. (blue light (BL) = blue box). Scale = 5 μm.

To examine the wavelength dependency of BLE-retinal induced PIP2 distortion, HeLa cells expressing mCherry-PH were exposed to 445 nm, 488 nm, 515 nm and 594 nm wavelengths of light at 4.86 μW respectively, in the presence or absence of retinal. Cells exposed to 488, 515 and 594 nm light, in the presence of retinal did not show a detectable signal (Fig. 3D). Control cells also did not exhibit PIP2 distortion with blue light in the absence of retinal (Figs 3E and S3). Retinal addition alone (without blue light) also showed no PIP2 distortion (Fig. 3F). Only the selected cell in the field of vision exposed to blue light exhibited PIP2 distortion (Fig. 3F, yellow arrow, Movie-S4). Similar to ATR, 11CR also induces PIP2 distortion when exposed to blue light (Fig. 3F). Unless specified, all the experiments henceforward employed blue light with the power of 4.86 µW to excite retinal. At this light power, photobleaching of fluorescent biosensors was not observed. All the cell types examined including RAW264.7 (mouse macrophage), ARPE-19, MDA-MB-468 (triple negative breast cancer), BT20 (triple negative breast cancer), HCT116 (colon cancer), NIH3t3 (mouse embryonic fibroblast), and HEK293 (human embryonic kidney) exhibited mCherry-PH translocation upon exposure to BLE-Retinal (Fig. 3G) which indicates a universal mechanism operated by BLE-retinal.

To decipher molecular features of retinal for its blue light-induced cellular effects, compounds with analogous functional groups such as retinol, retinoic acid, β-ionone (β-ionone ring of retinal) and conjugated linoleic acid (CLA- mimicking the extended π conjugated system) were examined as follows. HeLa cells expressing mCherry-PH were incubated for 10 minutes with the retinal-like molecules at 50 µM concentrations (Fig. 4). Interestingly, none of these compounds were able to induce PIP2 distortion upon exposure to blue light (Fig. 4A–D). Examination of absorption spectra of these screened molecules show that they do not have sufficient spectral overlaps with the blue light (Fig. S3). However, both retinol and retinoic acid exhibited mCherry-PH translocation when exposed to 365 nm ultra violet light (Fig. S4).

Figure 4

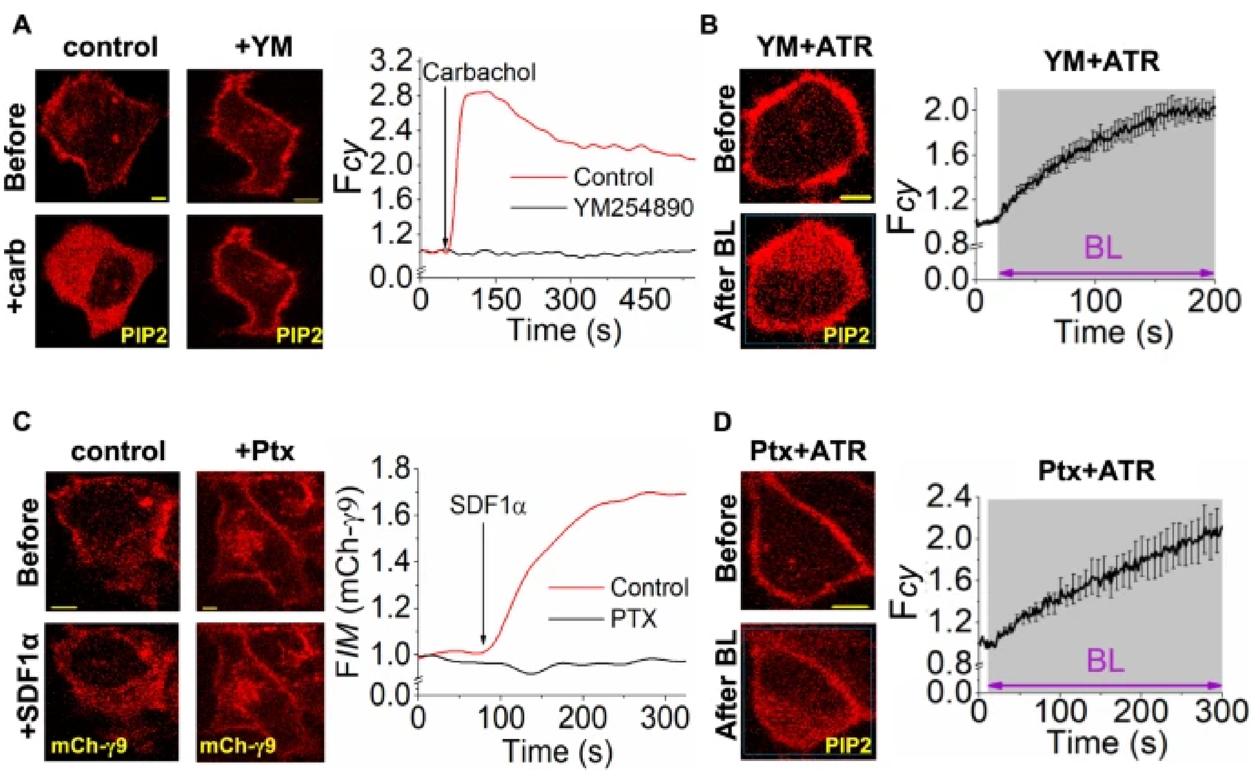


Retinal-like molecules exhibited no effect on PIP2 upon blue light exposure. Images of HeLa cells expressing PIP2 sensor (mCherry-PH) on PM. In all of the experiments conducted, cells were exposed to blue light (4.86 μW of 445 nm) which is indicated by the white box. Cells were incubated with (**A**) β-ionone (50 μM), (**B**) 10*E*, 12*Z* linoleic acid (50 μM), (**C**) Retinol (50 μM) and (**D**) Retinoic acid (50 μM), for 10 minutes followed by continuous exposure of short pulses of blue light for 200 s. In all experiments, cells did not show a detectable PIP2 sensor translocation. Plots show the dynamics of PIP2 sensor translocation in cells shown in **A–E**. (mean ± S.E.M., n = 5–10 cells). Mean and S.E.M. are from 3 < independent experiments. (blue light (BL) = blue box). Scale = 5 μm.

BLE-retinal induced PIP2 distortion is independent of GPCR-G protein activation

Retinal and blue light mediated activation of Gq-coupled GPCRs are suggested to trigger signaling and cytotoxicity in ARPE-19 photoreceptor cells[5]. This study measured degeneration of cells in the mouse retina, however the underlying mechanism was unclear. Upon GPCR activation, both Gαq-GTP and Gβγ can induce PIP2 hydrolysis since they activate PLCβ[30]. To examine whether BLE-retinal activates GPCR-G proteins pathways, PIP2 distribution was studied in the presence of Gαq inhibitor-YM254890 (1 μM) and Gi-pathway inhibitor-pertussis toxin (PTX) (50 ng/mL) respectively (Fig. 5A–D). Previously, we showed that pertussis toxin inhibits Gβγ mediated PIP2 hydrolysis since inhibition of Gi-pathway activation prevents generation of free Gβγ[31]. After inhibitor treatment, cells incubated with retinal were exposed to blue light for 2–3 minutes while imaging the PIP2 sensor response. Both inhibitors failed to inhibit BLE-retinal induced PIP2 distortion (Fig. 5B,D). Additionally, HeLa cells were treated with both Gαq and Gβγ inhibitors simultaneously to rule out the possibility of activation of PLCβ by BLE-retinal. Regardless of the collective inhibition of Gβγ and Gαq, BLE-retinal induced PIP2 disruption in cells (Fig. S5). This indicates that BLE-retinal induced responses are not due to the GPCR-G protein pathway activation. Control experiments show YM254890 and PTX inhibit Gq-pathway induced PIP2 hydrolysis and Gi-pathway induced Gγ9 translocation, respectively (Fig. 5A,C)[32]. In addition, retina-derived ARPE-19 cells exhibited PIP2 disruption upon BLE-retinal in the presence of Gαq, Gβγ and Gi pathway inhibitors (Fig. S6). Contrary to the previous reports[7], these experiments and data confirm that free retinal with or without light does not activate GPCR pathways.

Figure 5

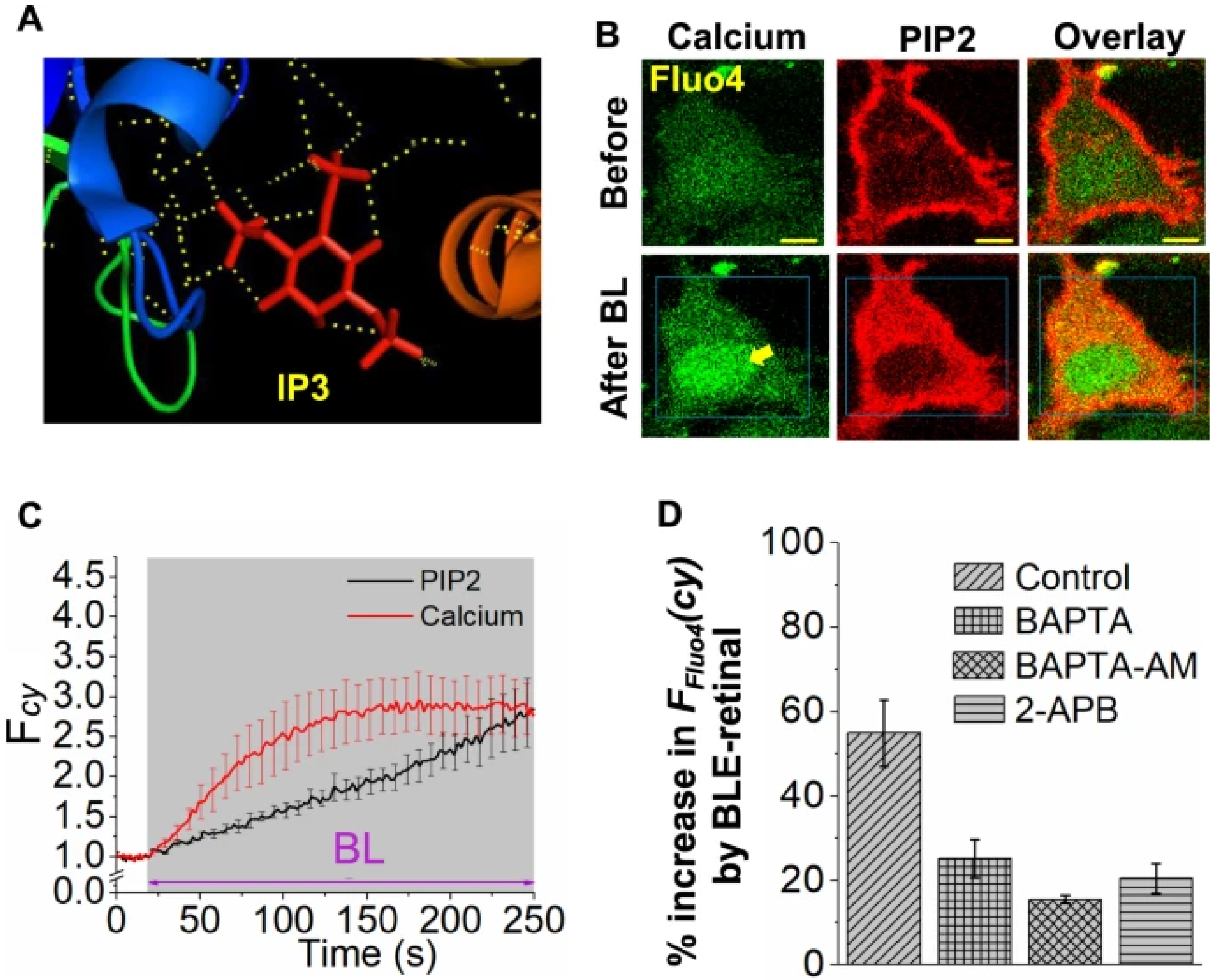


Photoexcited retinal induced PIP2 translocation is not due to GPCR pathway activation. (**A**) HeLa cells expressing M3 receptor and mCherry-PH, carbachol (10 μM) was added to activate M3R in the presence (left) and absence (middle) of Gq inhibitor (YM254890, 1 μM, 5 min). Only control cells (no YM254890), showed PIP2 hydrolysis (left). (**B**) Even in the presence of Gq inhibitor, blue light excited retinal induced PIP2 sensor translocation (middle). The plots show the dynamics of PIP2 sensor translocation in the cells shown in A and B. (**C**) To HeLa cells expressing CXCR4-GFP, mCh-γ9, SDF1α (100 ng/mL) was added to activate CXCR4 in the presence (left) and absence (middle) of Gαi inhibitor (pertussis toxin = Ptx, 50 ng/mL, overnight incubation). Only control cells with no added Ptx exhibited mCh-γ9 translocation from PM to IMs (left). (**D**) Exposure to photoexcited retinal induced PIP2 sensor translocation in cells treated with Ptx. The plots show the dynamics of mCh-γ9 and PIP2 sensor translocation. In all the experiments conducted, cells were exposed to 4.86 μW of 445 nm blue light. (mean ± S.E.M., n = 5–10 cells). Mean and S.E.M. are from 3 < independent experiments. (blue light (BL) = blue box). Scale = 5 μm.

PIP2 distortion by BLE-retinal is associated with an increase in intracellular calcium, $[Ca^{2+}]_i$

According to the crystal structure of IP3 receptor[33], IP3 molecule forms H-bonds with the putative interacting domain (Fig. 6A, PDB code:1N4K). To examine whether distorted PIP2, that may be entering cytosol could also increase cytosolic calcium, HeLa cells expressing mCherry-PH were incubated with cell permeable calcium sensor fluo4-AM and exposed to BLE-retinal. Cells exhibited a robust upsurge of calcium and a synchronized mCherry-PH translocation response was observed (Fig. 6B,C, Movie-S5). Unlike Gq-coupled GPCR induced calcium response, which recovers over time (Fig. S7A), BLE-retinal induced response did not exhibit signaling adaptation (Fig. 6C). To examine the source of calcium mobilized by BLE-retinal, cellular calcium modulators were deployed as follows and percent change in fluo-4 fluorescence in the cell upon exposure to BLE-retinal was calculated with respect to fluo-4 fluorescence observed prior to blue light exposure. Upon BLE-retinal exposure, cells without a calcium modulator was considered as the control and exhibited a 55 ± 8% increase in fluo4 fluorescence compared to basal fluorescence. Cells incubated in extracellular calcium free medium (using BAPTA) and with intracellular calcium chelator, BAPTA-AM, induced only 25 ± 5% and ~16 ± 1% increases respectively, (Fig. 6D). Treating cells with IP3 receptor inhibitor, 2-aminoethoxydiphenyl borate (2-APB) resulted in ~21 ± 4% increase (Fig. 6D). These data indicate possible interactions of the IP3 domain of distorted PIP2 with IP3 receptors[33]. Calcium modulators above were validated as follows (Fig. S7). Cells incubated with BAPTA-AM showed only PIP2 hydrolysis but no calcium response upon M3-muscarinic receptor activation (Fig. S7B), while 2-APB treated cells showed a transient PIP2 hydrolysis with no calcium response (Fig. S7C). Compared to BLE-retinal induced calcium responses, M3R activation induced responses were rapid and transient. These results also show the ability of BLE-retinal to induce downstream signaling, independent of GPCR activation. Collectively, these data suggest that BLE-retinal induced distortion of PIP2 not only induces mobilization of stored calcium, but also stimulate influx of extracellular calcium.

Figure 6

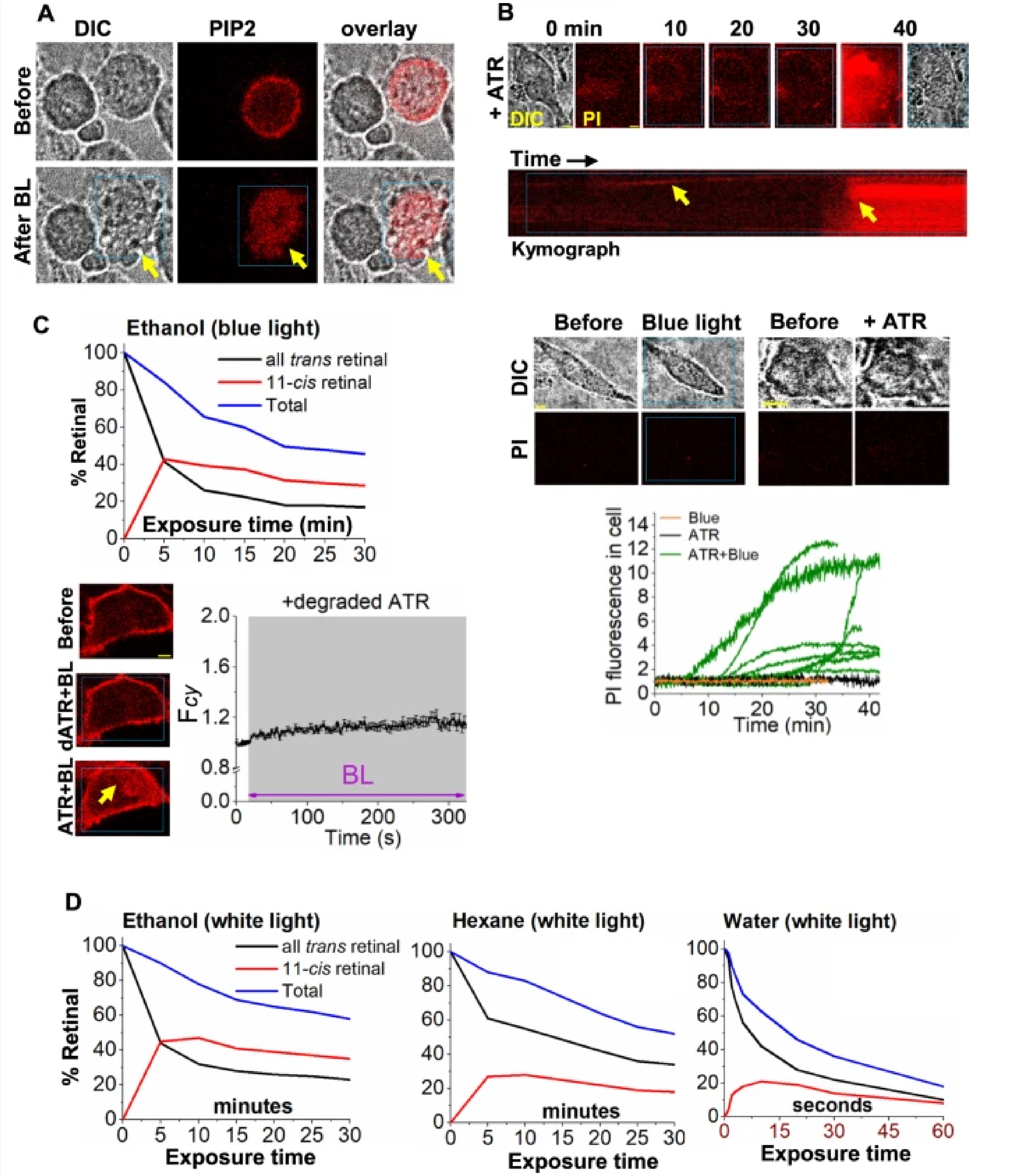


All trans retinal and blue light induced signaling in cells. (**A)** Crystal structure of the IP3 receptor bound with IP3 with H-bonding interactions (PDB code:1N4K), suggesting the PIP2 can have the majority of interactions exhibited by IP3. (**B)** HeLa cells expressing PIP2 sensor (mCherry-PH) and incubated with calcium sensor Fluo4. Fluo4 stained cells were incubated with ATR (50 µM) for 5 minutes, followed by exposure of blue light (4.86 µW of 445 nm) for 3 minutes. Here the whole cell was exposed to blue light. A substantial increase in cytosolic calcium is observed. (**C**) Dynamics of calcium responses and PIP2 translocation in the cells shown in B (mean ± S.E.M., n = 5 cells). (**D**) Calcium responses in control and calcium modulator-incubated (using BAPTA-AM and 2-APB) HeLa cells in regular and extracellular calcium free (using BAPTA) buffers. Here, cells were pre-incubated Fluo4 were incubated with 2-APB (5 µM for 15 min), BAPTA-AM (10 µM for 30 min), or BAPTA (5 µM for 5 min) in calcium free HBSS buffer. The cells were then incubated with ATR (50 µM) for 5 minutes, followed by continuous exposure of blue light for 5 minutes. The bar chart shows the changes in calcium sensor fluorescence in the cytosol before and after blue light exposure on cells for all the above mentioned experiments (mean ± S.E.M., n = 5–15 cells). Mean and S.E.M. are from 3 < independent experiments. (blue light (BL) = blue box). Scale = 5 µm.

Blue light-excited retinal induces cytotoxicity

The possibility of PIP2 distortion and calcium mobilization elicited by BLE-retinal to induce cytotoxicity was examined. Morphology of HeLa cells incubated in retinal containing medium was observed using time-lapse microscopy while only selected cells were exposed to blue light. PIP2 distortion and substantial morphological changes, including extensive bleb formation, were observed only in blue light exposed cells (Fig. 7A, Movie-S6). Unexposed control cells in the same field remained morphologically intact. To identify whether exposure of BLE-retinal induces cell death, HeLa cells were incubated with cell-death marker, propidium iodide (PI) and examined its inclusion, since apoptotic cells fail to exclude PI[34,35]. Cells were supplemented with 100 µL of PI (50 µg/mL) and 50 µM ATR, while selected cells were exposed to blue light. Control cells were either exposed to blue light without retinal or incubated with retinal without blue light exposure. Cells exposed to blue light in the presence of retinal showed gradual incorporation of PI, indicated by the increase in red fluorescence (Fig. 7B). Observed time curves of PI incorporation into cells were heterogenous (Fig. 7B, plot). Cells in both the control experiments did not incorporate PI (Fig. 7B). These results indicate that prolonged exposure of cells to BLE-retinal leads to cell death.

Figure 7



Photoexcited retinal induced cytotoxicity. (**A**) Fluorescence and DIC images of HeLa cells treated with ATR (50 μM) followed by blue light exposure (4.86 μW of 445 nm). Only the middle cell (yellow arrow) expresses PIP2 sensor. Blue light exposed (blue box) cell showed substantial change in cell shape and morphology. The PIP2 sensor also accumulates in cytosol upon blue light exposure. (**B**) HeLa cells were incubated with propidium iodide (PI) with ATR (50 μM) and exposed to blue light (4.86 μW) for 45 minutes. Incorporation of PI in to cells were observed upon light exposure. The control experiments performed with cells exposed to only to blue light or only to ATR, did not show PI incorporation into cells over time. Plot shows the different rates of PI incorporation into cells compared to control experiments. (**C**,**D)** Solvent dependent degradation and isomerization of ATR. (**C**) ATR (20 μL of 50 mM in ethanol) was exposed to blue LED light for 30 minutes. The blue light exposed ATR (injection sample: 1 μL of exposed ATR was diluted in 1 mL of ethanol) was analyzed by HPLC where degradation of ATR is observed by reduction of corresponding ATR peak in chromatogram. *right:* The degraded ATR (dATR) (1 μL) was added to HeLa cells (final volume of imaging buffer = 1 mL) expressing PIP2 sensor and continuously exposed to 445 nm light (4.86 μW). Cells did not show detectable PIP2 translocation upon blue light. Exposure of cells to fresh ATR (50 μM) and blue light (BL) induced PIP2 distortion (mean ± S.E.M., n = 12). (**D**) HPLC analysis of retinal in different solvents after exposing to white light for varying durations. Note that retinal in water degrades in *seconds* while in ethanol and hexane show over 100 times enhanced stability. Improved isomerizations were seen as well. Mean and S.E.M. are from 3 < independent experiments. (blue light (BL) = blue box). Scale = 5 μm.

mCherry-PH sensor translocation by BLE-retinal indicates distortion of the PIP2 molecule

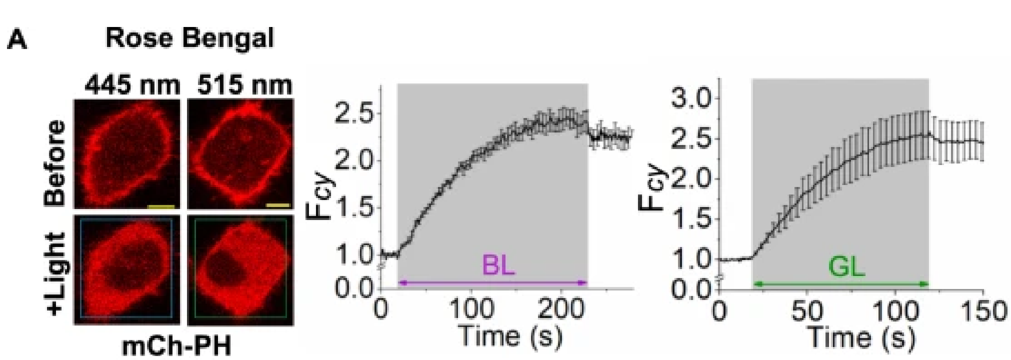
To determine whether translocation of mCherry-PH is a common response exhibited by fluorescence proteins on exposure to BLE-retinal, a membrane anchor with a transmembrane domain (from mouse ICAM5) and a C-terminal mCherry, DenMark-mCherry was used[36]. In addition to DenMark-mCherry, HeLa cells were also expressed with YFP-PH. Upon exposure to BLE-retinal, PM localization of DenMark did not change, while YFP-PH translocated to cytosol (Fig. S8A,C). A saturated lipid anchor bearing glycoprotein, glycosylphosphatidylinositol (GPI) which anchors extracellularly to cells also did not respond to BLE-retinal (Fig. S8B,C). HeLa cells expressing GPI-GFP and NIH3t3 cells expressing GPI-mCherry were used for the experiment. BLE-retinal did not remove GPI anchored proteins from PM. This suggests that specifically PIP2, that contains an unsaturated arachidonoyl chain is susceptible to photochemical reactions elicited by BLE-retinal. Since PIP2 also contains one stearyl anchor, a saturated lipid, it is not clear how oxidation of only arachidonoyl anchor induces PIP2 solubilization. One possibility is that only a small fraction of distorted PIP2 undergoes additional cleavage from the stearyl anchor. This could result in a fraction of PIP2 molecules solubilizing to cytosol and induce calcium mobilization.

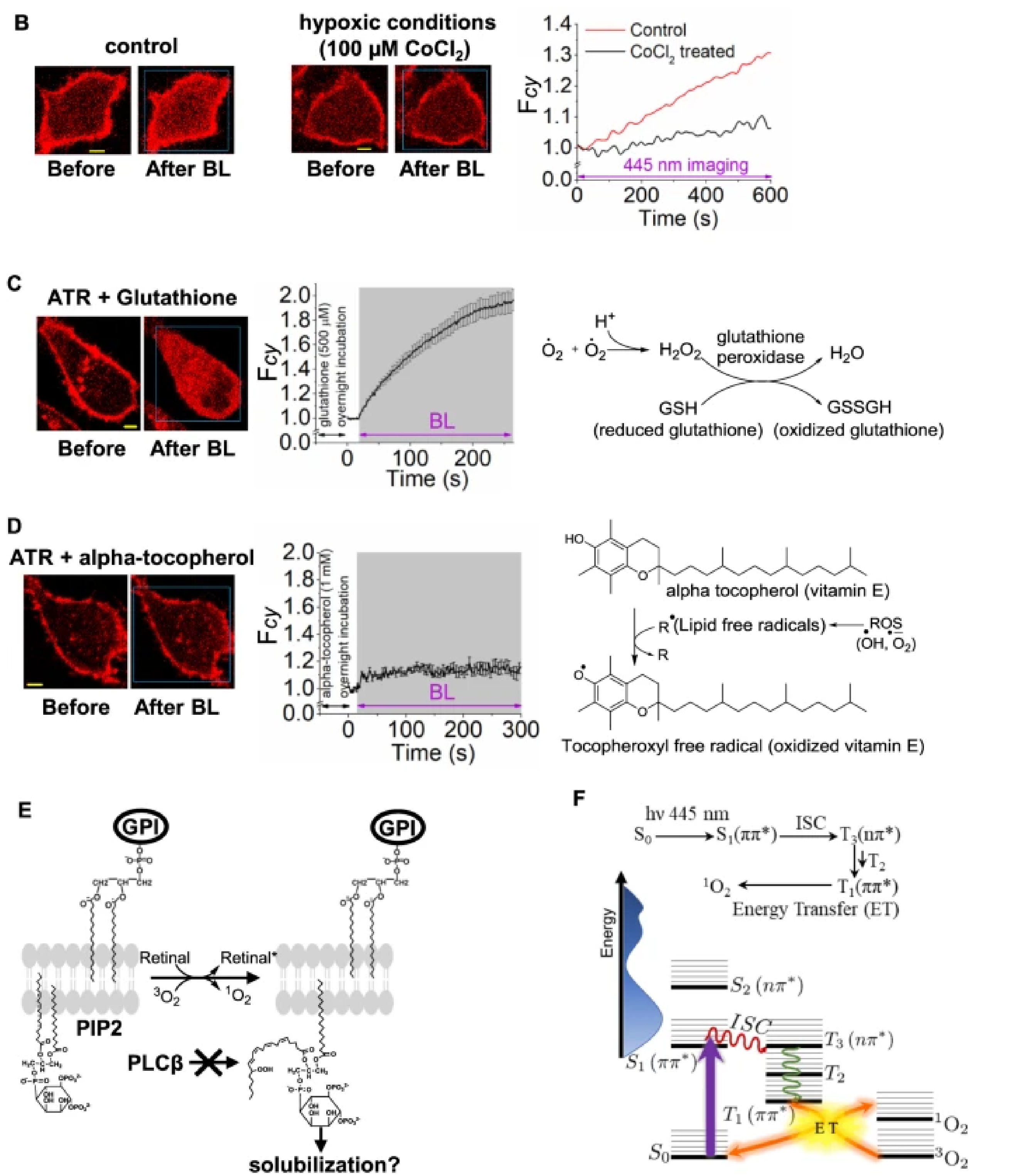
Cell membranes are likely to facilitate retinal photoexcitation and cellular damage

As the location of retinal in the cellular environment could be crucial, the next objective was to examine the subcellular environment that can support the photochemical reactions of retinal. When a 20 µL solution of ATR in ethanol (50 mM) was exposed to blue LED light (5 W, 460–470 nm) for 30 minutes, a significant retinal degradation was observed (Fig. 7C). The retinal content in the solution was analyzed using high performance liquid chromatography (HPLC), before and after blue light exposure. HeLa cells expressing mCherry-PH sensor were incubated with 1 µL of this pre-blue light exposed retinal for 10 minutes. However, the addition of pre-blue light exposed retinal did not exhibit PIP2 distortion in cells. Exposure of these cells to blue light at 4.86 µW intensity also failed to exhibit a detectable mCherry-PH translocation, suggesting that (i) the mixture does not have sufficient retinal left and (ii) extracellularly generated retinal photoproducts are not able to disrupt cellular PIP2. Nevertheless, addition of fresh retinal (50 µM) followed by blue light exposure resulted in mCherry-PH translocation (Fig. 7C). Next, we examined if household white fluorescent light also induces retinal degradation, since both fluorescent and LED light contain a peak ~450 nm. Retinal degradation observed under white light was lower in ethanol (Fig. 7D). When retinal in hexane was exposed to white light, it showed even lower degradation. Interestingly, retinal in water exhibited over a 100 times faster degradation (within seconds) than in ethanol or hexane (within minutes) (Fig. 7D). These experiments collectively suggest that in cellular context, retinal must retain in a relatively non-aqueous and hydrophobic environment, not in the cytosol. These data also show that retinal undergoes efficient isomerization, in non-aqueous media upon photon absorption. PM lipid bilayer of cells is likely to provide an ideal environment for retinal to undergo continuous photoisomerization over degradation.

Ability of retinal to harvest light and induce PIP2 distortion was examined to understand whether this process is governed by photosensitization of retinal. A known photosensitizer rose bengal (RB) absorbs green light (Fig. S9) and exhibits singlet oxygen generation[37] and cell death[38]. HeLa cells expressing PIP2 sensor were incubated with RB (50 μM) and exposed to blue and green light respectively. Cells were imaged to observe whether RB too induces a similar PIP2 distortion. Both blue and green light exposure induced a significant PIP2 sensor translocation (Fig. 8A). To assess whether observed PIP2 distortion requires dissolved oxygen in cell culture media to produce singlet oxygen, HeLa cells were treated with $CoCl_2$ for 12 hours to expose cells to hypoxia[39]. Upon exposure to BLE-retinal, compared to control normoxic cells, hypoxic cells exhibited an attenuated PIP2 sensor translocation (Fig. 8B). To validate that BLE-retinal induced PIP2 distortion was governed through free radical/ROS mechanisms, prior to blue light exposure, cells were incubated with antioxidants, glutathione ethyl ester and alpha-tocopherol respectively (Fig. 8C,D). Alpha-tocopherol is lipid soluble while glutathione is water soluble and cytosolic. Only cells incubated with alpha-tocopherol exhibited an attenuated PIP2 sensor translocation (Fig. 8C,D). This indicates that reactions of oxidative damage induced by BLE-retinal are likely taking place in lipid membranes (Fig. 8E).

Figure 8





Comparison of PIP2 sensor dissociation from PM by retinal vs a known photosensitizer, rose bengal. (**A**) Images of HeLa cells expressing PIP2 sensor (mCherry-PH). (**A**) PIP2 sensor translocation was induced by rose bengal (50 μM), incubated with cells for 5 minutes, in the presence of blue (4.86 μW of 445 nm) and green (light (0.22 μW of 515 nm) respectively. Plot shows the cytosolic fluorescence of PIP2 sensor in HeLa cells upon exposing to light. (mean ± S.E.M., n = 6). (**B**) HeLa cells were incubated with $CoCl_2$ (100 μM) for 24 h to expose cells to hypoxia. The control cells were kept in same conditions without $CoCl_2$ treatment. Cells were incubated with ATR (50 μM) and 445 nm imaging for 10 minutes was performed. Cell in hypoxic condition did not exhibit detectable PIP2 sensor accumulation in cytosol while control cells showed a gradual PIP2 sensor accumulation from PM to cytosol. (**C**,**D**) Antioxidants were tested to examine if they prevent PIP2 sensor translocation induced by retinal and blue light. HeLa cells expressing PIP2 sensor were incubated with antioxidants, alpha-tocopherol (1 mM) and reduced-glutathione ethyl ester (500 μM) overnight. Prior to imaging experiments ATR (50 μM) was added and incubated for 5 minutes followed by exposure of blue light (4.86 μW of 445 nm) for 5 minutes. (**C**) Cells treated with reduced-glutathione ethyl ester exhibited PIP2 sensor translocation from PM to cytosol upon blue light exposure. Plot shows the dynamics of PIP2 sensor (mean ± S.E.M., n = 14 cells). Overview of the antioxidant mechanism exert by reduced glutathione *in vivo (right)*. (**D**) Cells treated with alpha-tocopherol showed a reduced rate and extent of PIP2 sensor translocation from PM to cytosol upon blue light exposure. Plot shows the dynamics of PIP2 sensor translocation (mean ± S.E.M., n = 6 cells). Note the reduction of PIP2 sensor accumulation in IMs of cells. *Right:* Overview of the antioxidant mechanism exert by alpha-tocopherol *in vivo*. (**E**) Proposed mechanism for blue light excited retinal induced PIP2 distortion process. (**F**) TD-DFT calculations (CAM-B3LYP/6–31++G**) of retinal's energy states and the Jablonsky diagram shows strong absorption band due to the $\pi \rightarrow \pi^*$ transition where triplet excited states are energetically and symmetrically matched to allow for efficient intersystem crossing and energy transfer to O_2 which allows for singlet oxygen and ROS generation. Mean and S.E.M. are from 3 < independent experiments. (blue light (BL) = blue box and green light (GL) = green box). Scale = 5 μm.

To validate the ability of retinal to generate ROS via direct photoexcitation, spectroscopic calculations were performed with TD-DFT on the retinoids. The low-lying excited states of both 11CR and ATR are a series of strong singlet $\pi \rightarrow \pi^*$ transitions and a dark singlet $n \rightarrow \pi^*$ transition (Fig. 8F). The predicted absorption spectra for 11CR and ATR are in a reasonable agreement with the experimental spectra (Fig. S10A,B). For ATR, the strong absorption at 380 nm (S_1) is the allowed HOMO to LUMO transition ($\pi \rightarrow \pi^*$), followed by a spectroscopically dark $n \rightarrow \pi^*$ transition (S_2). 11CR also has a similar spectral assignment. For both 11CR and ATR, S_1 is nearly degenerate with a triplet state ($^3n\pi^*$) and, by El Sayed's rules, efficient intersystem crossing (ISC) should be observed where S_1 ($^1\pi\pi^*$) ISC to T_3 ($^3n\pi^*$). Interestingly, when examining the rotation around the 11-*cis* bond (Fig. S10C–E), S_1 ($^1\pi\pi^*$) and T_3 ($^3n\pi^*$) states cross with only a slight torsional twist about the 11-*cis* bond indicating that the two states are energetically degenerate to allow ISC. Once in the triplet manifold, the system should non-radiatively decay to the lowest triplet state (T_1, $^3\pi\pi^*$) with sufficient energy (1.20 eV and 1.25 eV, relaxed T_1 structure of 11CR and ATR) to transfer and promote oxygen to a cytotoxic singlet state ($^3O_2(^3\Sigma_g^-) \rightarrow {}^1O_2(^1\Delta_g^-)$ is 0.97 eV from experiment). The other retinoids studied are not expected to generate ROS because their absorptions occur in the UV (Fig. S3).

Discussion

When absorption spectrum and λ_{max} of retinal (380 nm) are considered, blue light induced PIP2 distortion should be due to the ability of retinal to undergo photoexcitation because just addition of retinal alone or exposure to wavelengths longer than blue failed to respond. Multiple experiments conducted using inhibitors of G-proteins pathway suggest that, BLE-retinal mediated cellular responses are not due to retinal's ability to interact with ligand binding GPCRs, further supporting the notion that BLE-retinal is directly responsible for its cellular effects. Lack of DAG formation observed in BLE-retinal mediated process further eliminates the possibility of PIP2 hydrolysis. Lack of sufficient spectral overlap in absorption spectra of retinol and retinoic acid with blue region is in agreement with their inability to induce cellular responses. In mouse mammary tumor cells, 10E, 12Z-CLA induced PIP2 hydrolysis and subsequent cell death was reported, and the activation of Gq-coupled GPCR(s) that results in PIP2 hydrolysis by activation of PLCβ has been proposed as the mechanism[40]. Nevertheless, in our experiments 10E, 12Z-CLA did not exhibit any effect on PIP2.

Acyl chains in PIP2 are crucial for its interactions with the PM. The difference in the acyl chain length in PIP2 have been shown to affect the localization of PIP2 on the PM[41]. If BLE-retinal modifies/changes properties of acyl chains, by oxidizing them, PIP2 is likely to lose the ability to stay bound to the PM. This can result in translocation of the modified PIP2, together with the bound mCherry-PH sensor to the cytosol. Alternatively, if the chemical modifications on PIP2 disrupt its interactions with mCherry-PH sensor as well as with PLCβ, irreversible translocation of PIP2 sensor to cytosol should be observed. However, using this argument, calcium responses induced by BLE-retinal cannot be explained. Therefore, it is likely that upon exposure to BLE-retinal, PIP2 becomes solubilized, at least to a certain extent, due to reduction of its PM affinity.

Increase in cytosolic calcium induced by BLE-retinal can be attributed to either (i) calcium influx from activated ion channels on PM or (ii) activation of IP3 receptors (IP3R) allowing ER to mobilize stored calcium or both. IP3R activation is likely to be induced by the IP3 moiety of solubilized PIP2 since it can still have the majority of interactions that IP3 possesses[33,42]. If solubilized PIP2 induces even a slight increase in cytosolic calcium, calcium activated ion channels on PM can further increase cytosolic calcium[43,44,45]. Lack of extracellular calcium resulted in reduction of calcium response compared to control cells, suggesting a partial involvement of the possibility (i) above. Inhibition of IP3 receptors by 2-APB which showed a reduction in calcium response compared to control cells by BLE-retinal suggests the possibility (ii). Collectively, these results suggest that calcium signaling induced by ATR and blue light is likely to be controlled by more than one mechanism.

PIP2 has been proposed to promote the interactions between PM and cytoskeleton, and cellular PIP2 levels are linked to bleb formation[46,47]. Therefore, observed extensive bleb formation in cells exposed to BLE-retinal can be a result of PIP2 activity reduction at

PM. Additionally, BLE-excited retinal induced inclusion of propidium iodide into cells suggests activation of apoptosis-promoting pathways since excessive intracellular calcium results in cell death through apoptosis and necrosis[18]. Recent studies link ROS generation to non-inflammatory cell death termed as oxeiptosis through cellular ROS sensor and antioxidant factor KEAP1[48]. Although photodegradation products suggested to cause cytotoxicity in photoreceptor cells[6], cells did not exhibit either PIP2 distortion or cell death on exposure to photoproducts of retinal. Our data show that household fluorescent white light (3 mW) induces extensive photo degradation of retinal in solution. However, at this intensity white light did not exhibit either PIP2 distortion or cell death, highlighting the blue light requirement for the process (Fig. 7A,B). Upon blue light exposure, accumulated lipophilic non-degradable lipofuscins have been shown to induce cytotoxicity in the retina[10,11,12,13,14]. Compared to the quantum yield of singlet oxygen $^1O_2$ generation (Φ) by lipofuscin A2E, *all-trans* retinal exhibited a two times higher quantum yield (Φ = 0.2–0.3) in benzene[49]. While the quantum yield of $^1O_2$ generation is vastly dependent on the solvent used, retinal usually exhibited higher quantum yield[50,51,52,53,54,55] (Table S1). Our data show that retinal has enhanced lifetimes in relatively non-polar media and undergoes isomerization over degradation. Could retinal converted to A2E lipofuscins be responsible for its blue light induced cellular effects? Optimized conditions, such as two days in the dark in acidic medium were required for *in vitro* A2E synthesis using retinal and ethanolamine[56]. Therefore, it is unlikely that observed cellular effects within minutes are due to formation of A2E. Reactive singlet oxygen ($^1O_2$) forms due to excitation of molecular oxygen from its ground state to triplet state[57]. Singlet oxygen induces production of ROS such as superoxide, peroxide, and hydroxyl radicals[58,59]. The direct generation of $^1O_2$ by absorption of a photon at 1270 nm (0.97 eV) is a weak transition due to the forbidden spin flip[60]. Thus, the proposed mechanism for generation of $^1O_2$ involves a sensitizing chromophore which has a significant population of an excited triplet state with sufficient energy to excite $^3O_2 \rightarrow {}^1O_2$ by electronic energy transfer[61]. Most chromophores are in a ground state singlet and gain triplet state population by ISC after initial photon absorption in the singlet manifold. ISC is usually spin forbidden. However, if there is a significant spin-orbit coupling via heavy atom effect or electronic transitions according to El Sayed rules, where $^1\pi\pi^*$ state → $^3n\pi^*$ state, ISC is observed[62]. Thus, we suggest that upon photoexcitation of ATR and 11CR to S_1, retinal relaxes to triplet manifold by allowed ISC. Then the energy may be transferred to $^3O_2$ generating $^1O_2$. Collectively, both retinal-based experimental and computational data suggest that retinal dissolved in lipid bilayer is a major contributor for its blue light induced cellular effects.

Retinal is fat-soluble, and therefore transported through cytosol by carrier protein, Retinol/Retinal Binding Protein (RBP), while being protected against water[63]. When ethanolic solutions of retinal were dissolved in water, retinal was stable for a prolonged time in the dark (~1 week). However, exposure to light results in a rapid degradation. In contrast, retinal in relatively non-polar and non-aqueous media showed an enhanced photostability, suggesting that retinal prefers photoisomerization over degradation. Therefore, even if free retinal was present in cytosol, it is likely to degrade quickly. On the contrary, PM is an appropriate hydrophobic environment for retinal to be accumulated. Recently, transport of retinol in the hydrophobic core of serum amyloid A has been demonstrated[64], further suggesting that PM core of cells can act as a reservoir of retinal. If photoexcited retinal can generate $^1O_2$ in PM bilayer, it is more likely to interact with molecules in the PM. The ability of lipid soluble α-tocopherol to attenuate BLE-retinal induced PIP2 response also suggests that the resultant oxidative photodamage occurs within PM bilayer. Since PM and endoplasmic reticulum (ER), as well as mitochondria maintain direct contacts[65,66], retinal has the potential to diffuse through the lumen of PM to ER, and to mitochondria. Although the presented data is limited to BLE-retinal induced signaling perturbation of PIP2, retinal's photosensitizing ability in the cellular environment has the potential to elicit cell-wide oxidative damage to crucial signaling molecules and change the cellular fate.

Materials and Methods

Reagents

All *trans* retinal, retinol, retinoic acid, BAPTA, BAPTA-AM, conjugated (10*E*, 12*Z*) linoleic acid, propidium iodide (Cayman chemicals, Ann Arbor, USA), Beta-ionone (Acros Organics), 11-*cis* retinal (National eye institute, USA), YM254890 (Focus biomolecules), Gallein (TCI-America), Carbachol (Fisher Scientific), 2-APB, Pertussis toxin, SDF1α, alpha-tocopherol, glutathione ethyl ester (Sigma-Aldrich), Fluo4-AM (Molecular probes, Thermofisher), Rose bengal (Chem Impex) and Cobalt chloride (Alfa aesar) were purchased. All reagents were dissolved as per manufacturers' recommendations unless otherwise noted. Stock solution of SDF1α was prepared in HBSS with 0.1% bovine serum albumin (Sigma-Aldrich). Propidium iodide was dissolved in water to make a working solution of 50 μg/mL. Rose bengal and Cobalt chloride were dissolved in water. Stock solutions of retinals (50 mM of 11CR or ATR) were prepared in Ethanol and dilutions were done appropriately using Ethanol and HBSS buffer. Concentrations of retinals were measured by UV-VIS spectrometer (UV-1800 spectrophotometer, Shimadzu corporation, Kyoto, Japan) or HPLC (CBM-20A, Shimadzu, USA) prior to live cell imaging experiments by plotting calibration curves with 11CR and ATR standards. In HPLC analysis of free retinal, a normal phase column (Waters Nova-Pak® Silica-60 Å, 4 μm, 3.9 × 150 mm) with an isocratic flow of 96:4 Hexane: Ethyl acetate at 0.5 mL/min flow rate was used. Deuterium lamp UV detector was used at 370 nm to identify retinals.

Cell culture

HeLa cells (ATCC, Manassas, VA) were cultured in minimum essential medium (MEM) (CellGro) supplemented with 10% dialyzed fetal bovine serum (DFBS) (Atlanta Biologicals), in the presence of 1% penicillin–streptomycin (PS) in 35 mm/60 mm/100 mm tissue culture dishes at 37 °C in a 5% CO_2 humidified incubator. At 70–80% confluency, adherent cells were detached using versene-EDTA (Lonza), centrifuged at 1000 × g for 3 minutes, and versene-EDTA was aspirated carefully without disturbing the cell pellet followed by addition of regular cell culture media at a cell density of 1×10^6 cells/mL. For live cell imaging experiments, HeLa cells were cultured on 35 mm glass bottom dishes (*In Vitro* Scientific) with 1×10^5/mL cell density. Types of cells and their respective cell culture media used in this study are as follows. RAW264.7 (RPMI/10%

DFBS/1% PS), NIH3T3 (DMEM/10% BCS/ 1% PS), HEK293 (DMEM/10% DFBS/1% PS), MDA-MB-468, HCT116 and BT20 (DMEM/10% FBS/1% PS) and ARPE-19 (DMEM-F12 (50:50)/10% FBS/1% PS) (ATCC, Manassas, VA). Above mentioned cells were cultured using similar procedure as in HeLa cells.

Cell culture under hypoxic conditions

A procedure was followed as described previously[39]. Briefly, a solution of $CoCl_2$ (25 mM) was prepared in water. HeLa cells were incubated with $CoCl_2$ (100 μM) in the presence of regular cell culture media for 24 h at 37 °C in a 5% CO_2 humidified incubator.

In vitro transfection

HeLa, RAW264.7, NIH3t3, MDA-MB-468, HCT116, BT20, HEK293 and ARPE-19 cells were transfected using *in vitro* transfection reagent-PolyJet® (Signagen) or lipofectamine2000® reagent (invitrogen) according to manufacturer's protocol with following recombinant DNA plasmids; mCherry-PH, YFP-PH, DBD-YFP, M3-muscarinic receptor-untagged, mCherry-γ9, bicistronic Melanopsin-GFP, CXCR-GFP, DenMark-mCherry, GPI-mCherry, GPI-GFP. Engineering of plasmids has been described previously[26,36,67,68,69,70,71]. Transfection was performed on cells seeded on glass bottom dishes. After 5 hours of incubation with the transfection reagent, the medium was replaced with 1 mL of fresh cell culture medium. Live cell imaging experiments were performed 12–24 hours after transfection.

Live cell imaging, image analysis and data processing

Live cell imaging experiments were performed using a spinning-disk (Yokogawa CSU-X1, 5000 rpm) XD confocal TIRF imaging system composed of a Nikon Ti-R/B inverted microscope with a 60X, 1.4 NA oil objective and iXon ULTRA 897BVback-illuminated deep-cooled EMCCD camera. Photoactivation and spatio-temporal light exposure on cells in regions of interests (ROI) were performed using laser combiner with 40–100 mW 445, 488, 515, and 594 nm solid-state lasers equipped with Andor® FRAP-PA (fluorescence recovery after photobleaching and photoactivation) unit in real time, controlled by Andor iQ 3.1 software (Andor Technologies, Belfast, United Kingdom). Fluorescent sensors such as mCherry-PH, GPI-mCherry, mCherry-γ9, DenMark were imaged using 594 nm excitation–624 nm emission settings, YFP-PH and DBD-YFP were imaged using 515 nm excitation and 542 nm emission and GPI-GFP, Melanopsin-GFP, CXCR-GFP, Fluo4-AM were imaged using 488 nm excitation and 525 nm emission. Using a modulator, powers of solid state lasers were adjusted to 5 mW in above wavelengths for photoactivation studies where additional adjustments for laser power with 0.1–10% transmittance (0.22 µW–9.70 µW) were further achieved using Acousto-optic tunable filters (AOTF) to avoid photobleaching of fluorescent sensors. Continuous optical activation (OA) of cells expressing opsins was performed at every one second (1 Hz) using the 0.22 µW of 445 nm laser across the selected region and blue light exposure on cells without opsins was done with 4.86 µW of 445 nm laser. The laser power of light exposure was measured using a light meter (Ophir PD300-UV). Time-lapse images were analyzed using Andor iQ 3.1 software by acquiring the changes in mean pixel fluorescence intensity of the entire cell or in selected area/regions of interest (ROIs) of the cell. Briefly, background intensity of images was subtracted from the intensities of the ROIs assigned to the desired areas of cells (PM, IMs and cytosol), prior to intensity data collection from the time-lapse images. The intensity data from multiple cells were opened in Excel (Microsoft office®) and normalized to the base-line by dividing the whole data set with the average value of initial stable base-line. Data was processed further using Origin-pro data analysis software (OriginLab®).

Light exposure induced PIP2 sensor translocation

Cells cultured on 35 mm glass bottom dishes were checked for PIP2 sensor (mCherry-PH) expression. After identification of cells expressing PIP2 sensor, the focal plane was locked to prevent the drifts in the imaging cross section using perfect focusing system (PFS). Next, cells were supplemented with 50 µM retinal (ATR or 11CR) for 5 minutes before light exposure on the cells. After retinal addition, cells were exposed only to 595 nm light to image mCherry fluorescence and all live cell imaging experiments were conducted in the dark. After capturing time-lapse images for mCherry at 1 Hz for 20–60 seconds, using the FRAP-PA module control of the assigned optical stimuli, whole cells or subcellular regions were exposed to light (445–594 nm laser light depending on the experiment) and time-lapse imaging was continued for additional 5–10 minutes. Additionally, 445 nm imaging was conducted to induce PIP2 solubilization in cells with hypoxic conditions ($CoCl_2$ treated) and compared that with normoxic cells with same imaging parameters (445 nm excitation) without FRAP-PA.

Cytosolic calcium measurements

Calcium imaging was performed with a cell permeable fluorescent calcium indicator, Fluo4-AM. Cells seeded on glass bottom dishes were washed twice with 1 mL of 1X HBSS (supplemented with calcium, pH 7.2) and incubated with Fluo4-AM (2.28 µM in 1X HBSS) for 30 minutes at room temperature. The glass bottom dish was washed with 1 mL of 1X HBSS three times before imaging experiments. The fluorescence intensity of Fluo4-AM was continuously imaged at 1 second intervals using 488 nm excitation –515 nm emission wavelength settings using confocal microscopy. Additional experiments were done in cells that were pre-incubated with Fluo4-AM (2.28 µM) followed by incubation of either 2-APB (5 µM for 15 minutes), BAPTA-AM (10 µM for 30 minutes), or BAPTA (5 µM for 5 minutes) in 1X calcium free HBSS buffer. The cells were then incubated with ATR (50 µM) for 5 minutes followed by continuous exposure of blue light for 5 minutes. The fluorescence intensity of Fluo4 was acquired. Fluorescence intensity obtained from regions of interest were normalized to initial values and data were further processed to obtain statistical data.

Cell cytotoxicity imaging

Live cell imaging of HeLa cells was conducted with propidium iodide (PI) staining to assess cytotoxicity of cells upon exposing cells to either blue light only, ATR only, or exposing blue light in the presence of ATR. Incorporation of PI was monitored over time using time-lapse fluorescence imaging of cells. Briefly, cells were washed with 1X PBS and replaced with the cell culture medium. Then, 100 µL of PI (50 µg/mL) was added to the glass bottom dish with cells. The live cell imaging was started after selecting cells using differential interference contrast (DIC) microscopy. Blue light used here was 4.86 μW of 445 nm wavelength laser. DIC images and PI fluorescence were acquired over time. For PI imaging, 488 nm-excitation and 624 nm-emission filter settings were used. Final concentration of ATR was 50 μM used for experiments.

HPLC analysis of retinal degradation

ATR (50 μM) solutions in different solvents (ethanol, hexane and water) were prepared using an ethanolic ATR stock solution (50 mM). ATR in ethanol was exposed to blue LED (5 W, 460–470 nm) up to 30 minutes. Similarly, ATR in ethanol and hexane were exposed to white fluorescent light (22 W) continuously up to 30 minutes. For retinal degradation studies in water, separate solutions were prepared and exposed to white light for time intervals from 1 s to 60 s in individual experiments. HPLC (CBM-20A, Shimadzu, USA) analysis of retinal degradation in each time interval was performed using a normal phase column (Waters Nova-Pak® Silica-60 Å, 4 μm, 3.9 × 150 mm) with an isocratic flow of 96:4 Hexane: Ethyl acetate at 0.5 mL/min flow rate was used. Deuterium lamp UV detector was used at 370 nm to identify percent retinal remaining in the solution. Percent retinal content in each sample was determined by calculating the percent area under each peak corresponding to type of retinals using Origin-pro data analysis software (OriginLab®).

Light power measurements

Light power measurements were determined using a light meter, Ophir® PD-300UV (Ophir photonics, Israel) with the filter-in mode. StarLab® (Ophir photonics) software was used to acquire power measurements of lasers and white fluorescent light.

Computational methods

Quantum chemical calculations were performed using time dependent density functional theory (TD-DFT) with the coulomb attenuating method (CAM-B3LYP) and a 6–31++G** basis set[72,73,74]. CAM-B3LYP and other long range corrected functionals have been shown to accurately determine spectroscopic properties and minimize the appearance of low lying spurious states[75]. All computations were performed using Gaussian09®[76] in parallel with shared memory. Retinoids' ground state and excited state energies in gas phase and in solution phase with polarized continuum model (PCM)[77] were computed with heptane and water as the solvents.

References

1. Zhong, M., Kawaguchi, R., Kassai, M. & Sun, H. Retina, retinol, retinal and the natural history of vitamin A as a light sensor. *Nutrients* **4**, 2069–2096, https://doi.org/10.3390/nu4122069 (2012).

2. Buczylko, J., Saari, J. C., Crouch, R. K. & Palczewski, K. Mechanisms of opsin activation. *J. Biol. Chem.* **271**, 20621–20630 (1996).

3. Maeda, A. *et al*. Involvement of all-trans-retinal in acute light-induced retinopathy of mice. *J. Biol. Chem.* **284**, 15173–15183, https://doi.org/10.1074/jbc.M900322200 (2009).

4. Maeda, T., Golczak, M. & Maeda, A. Retinal photodamage mediated by all-trans-retinal. *Photochem. Photobiol.* **88**, 1309–1319, https://doi.org/10.1111/j.1751-1097.2012.01143.x (2012).

5. Chen, Y. *et al*. Mechanism of All-trans-retinal Toxicity with Implications for Stargardt Disease and Age-related Macular Degeneration. *J. Biol. Chem.* **287**, 5059–5069, https://doi.org/10.1074/jbc.M111.315432 (2012).

6. Rozanowska, M., Handzel, K., Boulton, M. E. & Rozanowski, B. Cytotoxicity of all-trans-retinal increases upon photodegradation. *Photochem. Photobiol.* **88**, 1362–1372, https://doi.org/10.1111/j.1751-1097.2012.01161.x (2012).

7. **7.** Chen, Y. *et al*. Systems pharmacology identifies drug targets for Stargardt disease-associated retinal degeneration. *J. Clin. Invest.* **123**, 5119–5134, https://doi.org/10.1172/jci69076 (2013).

8. Masutomi, K., Chen, C., Nakatani, K. & Koutalos, Y. All-trans retinal mediates light-induced oxidation in single living rod photoreceptors. *Photochem. Photobiol.* **88**, 1356–1361, https://doi.org/10.1111/j.1751-1097.2012.01129.x (2012).

9. Organisciak, D. T. & Vaughan, D. K. Retinal light damage: mechanisms and protection. *Prog. Retin. Eye Res.* **29**, 113–134, https://doi.org/10.1016/j.preteyeres.2009.11.004 (2010).

10. Sparrow, J. R. *et al*. The bisretinoids of retinal pigment epithelium. *Prog. Retin. Eye Res.* **31**, 121–135, https://doi.org/10.1016/j.preteyeres.2011.12.001 (2012).

11. King, A., Gottlieb, E., Brooks, D. G., Murphy, M. P. & Dunaief, J. L. Mitochondria-derived reactive oxygen species mediate blue light-induced death of retinal pigment epithelial cells. *Photochem. Photobiol.* **79**, 470–475 (2004).

12. Rozanowska, M. *et al*. Blue light-induced reactivity of retinal age pigment. *In vitro* generation of oxygen-reactive species. *J. Biol. Chem.* **270**, 18825–18830 (1995).

13. Hunter, J. J. *et al*. The susceptibility of the retina to photochemical damage from visible light. *Prog. Retin. Eye Res.* **31**, 28–42, https://doi.org/10.1016/j.preteyeres.2011.11.001 (2012).

14. Sparrow, J. R. *et al*. A2E, a byproduct of the visual cycle. *Vision Res.* **43**, 2983–2990, https://doi.org/10.1016/S0042-6989(03)00475-9 (2003).

15. Rozanowska, M. & Sarna, T. Light-induced damage to the retina: role of rhodopsin chromophore revisited. *Photochem. Photobiol.* **81**, 1305–1330, https://doi.org/10.1562/2004-11-13-IR-371 (2005).

16. Movitz, C., Sjolin, C. & Dahlgren, C. A rise in ionized calcium activates the neutrophil NADPH-oxidase but is not sufficient to directly translocate cytosolic p47phox or p67phox to b cytochrome containing membranes. *Inflammation* **21**, 531–540 (1997).

17. Clapham, D. E. Calcium signaling. *Cell* **80**, 259–268 (1995).

18. Kass, G. E. & Orrenius, S. Calcium signaling and cytotoxicity. *Environ. Health Perspect.* **107**(Suppl 1), 25–35 (1999).

19. Berridge, M. J., Bootman, M. D. & Roderick, H. L. Calcium signalling: dynamics, homeostasis and remodelling. *Nat. Rev. Mol. Cell Biol.* **4**, 517–529, https://doi.org/10.1038/nrm1155 (2003).

20. Clapham, D. E. Calcium signaling. *Cell* **131**, 1047–1058, https://doi.org/10.1016/j.cell.2007.11.028 (2007).

21. Janmey, P. A. Phosphoinositides and calcium as regulators of cellular actin assembly and disassembly. *Annu. Rev. Physiol.* **56**, 169–191, https://doi.org/10.1146/annurev.ph.56.030194.001125 (1994).

22. Raucher, D. *et al*. Phosphatidylinositol 4, 5-bisphosphate functions as a second messenger that regulates cytoskeleton–plasma membrane adhesion. *Cell* **100**, 221–228 (2000).

23. Sawada, O. *et al*. All-trans-retinal induces Bax activation via DNA damage to mediate retinal cell apoptosis. *Exp. Eye. Res.* **123**, 27–36, https://doi.org/10.1016/j.exer.2014.04.003 (2014).

24. Ferguson, S. S. & Caron, M. G. G protein-coupled receptor adaptation mechanisms. *Semin. Cell Dev. Biol.* **9**, 119–127, https://doi.org/10.1006/scdb.1997.0216 (1998).

25. Gainetdinov, R. R., Premont, R. T., Bohn, L. M., Lefkowitz, R. J. & Caron, M. G. Desensitization of G protein-coupled receptors and neuronal functions. *Annu. Rev. Neurosci.* **27**, 107–144, https://doi.org/10.1146/annurev.neuro.27.070203.144206 (2004).

26. Stauffer, T. P., Ahn, S. & Meyer, T. Receptor-induced transient reduction in plasma membrane PtdIns(4,5)P2 concentration monitored in living cells. *Curr. Biol.* **8**, 343–346 (1998).

27. Roberts, J. E. & Dennison, J. The Photobiology of Lutein and Zeaxanthin in theEye. *J. Ophthalmol.* **2015**, 687173, https://doi.org/10.1155/2015/687173 (2015).

28. Dartnall, H. J. A. The photosensitivities of visual pigments in the presence of hydroxylamine. *Vision Res.* **8**, 339–358, https://doi.org/10.1016/0042-6989(68)90104-1 (1968).

29. Kim, J. E., Tauber, M. J. & Mathies, R. A. Wavelength Dependent Cis-Trans Isomerization in Vision. *Biochemistry* **40**, 13774–13778, https://doi.org/10.1021/bi0116137 (2001).

30. Wu, D., Katz, A. & Simon, M. I. Activation of phospholipase C beta 2 by the alpha and beta gamma subunits of trimeric GTP-binding protein. *Proc. Natl. Acad. Sci. USA* **90**, 5297–5301 (1993).

31. Siripurapu, P., Kankanamge, D., Ratnayake, K., Senarath, K. & Karunarathne, A. Two independent but synchronized Gbetagamma subunit-controlled pathways are essential for trailing-edge retraction during macrophage migration. *J. Biol. Chem.* **292**, 17482–17495, https://doi.org/10.1074/jbc.M117.787838 (2017).

32. Senarath, K., Ratnayake, K., Siripurapu, P., Payton, J. L. & Karunarathne, A. Reversible G Protein betagamma9 Distribution-Based Assay Reveals Molecular Underpinnings in Subcellular, Single-Cell, and Multicellular GPCR and G Protein

Activity. *Anal. Chem.* **88**, 11450–11459, https://doi.org/10.1021/acs.analchem.6b02512 (2016).

33. Bosanac, I. *et al*. Structure of the inositol 1,4,5-trisphosphate receptor binding core in complex with its ligand. *Nature* **420**, 696–700, https://doi.org/10.1038/nature01268 (2002).

34. Suzuki, T., Fujikura, K., Higashiyama, T. & Takata, K. DNA staining for fluorescence and laser confocal microscopy. *J. Histochem. Cytochem.* **45**, 49–53, https://doi.org/10.1177/002215549704500107 (1997).

35. Riccardi, C. & Nicoletti, I. Analysis of apoptosis by propidium iodide staining and flow cytometry. *Nat. Protoc.* **1**, 1458–1461, https://doi.org/10.1038/nprot.2006.238 (2006).

36. Nicolai, L. J. *et al*. Genetically encoded dendritic marker sheds light on neuronal connectivity in Drosophila. *Proc. Natl. Acad. Sci. USA* **107**, 20553–20558, https://doi.org/10.1073/pnas.1010198107 (2010).

37. Kim, S. *et al*. Luciferase-Rose Bengal conjugates for singlet oxygen generation by bioluminescence resonance energy transfer. *Chem. Commun. (Camb)* **53**, 4569–4572, https://doi.org/10.1039/c7cc00041c (2017).

38. Panzarini, E., Inguscio, V., Fimia, G. M. & Dini, L. Rose Bengal acetate photodynamic therapy (RBAc-PDT) induces exposure and release of Damage-Associated Molecular Patterns (DAMPs) in human HeLa cells. *PloS one* **9**, e105778, https://doi.org/10.1371/journal.pone.0105778 (2014).

39. Wu, D. & Yotnda, P. Induction and Testing of Hypoxia in CellCulture. *J. Vis. Exp.*, 2899, https://doi.org/10.3791/2899 (2011).

40.

40. Hsu, Y. C. & Ip, M. M. Conjugated linoleic acid-induced apoptosis in mouse mammary tumor cells is mediated by both G protein coupled receptor-dependent activation of the AMP-activated protein kinase pathway and by oxidative stress. *Cell Signal.* **23**, 2013–2020, https://doi.org/10.1016/j.cellsig.2011.07.015 (2011).

41. Cho, H., Kim, Y. A. & Ho, W. K. Phosphate number and acyl chain length determine the subcellular location and lateral mobility of phosphoinositides. *Mol. Cells* **22**, 97–103 (2006).

42. Wang, H. & Shears, S. B. Structural features of human inositol phosphate multikinase rationalize its inositol phosphate kinase and phosphoinositide 3-kinase activities. *J. Biol. Chem.* **292**, 18192–18202, https://doi.org/10.1074/jbc.M117.801845 (2017).

43. Fill, M. & Copello, J. A. Ryanodine receptor calcium release channels. *Physiol. Rev.* **82**, 893–922, https://doi.org/10.1152/physrev.00013.2002 (2002).

44. Hoth, M. & Penner, R. Calcium release-activated calcium current in rat mast cells. *J. Physiol.* **465**, 359–386 (1993).

45. Roderick, H. L., Berridge, M. J. & Bootman, M. D. Calcium-induced calcium release. *Curr. Biol.* **13**, R425–R425 (2003).

46. Zatulovskiy, E., Tyson, R., Bretschneider, T. & Kay, R. R. Bleb-driven chemotaxis of Dictyostelium cells. *J. Cell Biol.* **204**, 1027–1044, https://doi.org/10.1083/jcb.201306147 (2014).

47. Czech, M. P. PIP2 and PIP3: complex roles at the cell surface. *Cell* **100**, 603–606, https://doi.org/10.1016/S0092-8674(00)80696-0 (2000).

48. Holze, C. *et al.* Oxeiptosis, a ROS-induced caspase-independent apoptosis-like cell-death pathway. *Nat. Immunol.* **19**, 130–140, https://doi.org/10.1038/s41590-017-

0013-y (2018).

49. Różanowska, M. *et al*. Blue Light-Induced Singlet Oxygen Generation by Retinal Lipofuscin in Non-Polar Media. *Free Radic. Biol. Med.* **24**, 1107–1112, https://doi.org/10.1016/s0891-5849(97)00395-x (1998).

50. Krasnovsky, A. A. Jr. & Kagan, V. E. Photosensitization and quenching of singlet oxygen by pigments and lipids of photoreceptor cells of the retina. *FEBS Lett.* **108**, 152–154 (1979).

51. Chattopadhyay, S. K., Kumar, C. V. & Das, P. K. Laser flash photolytic determination of triplet yields via singlet oxygen generation. *J. Photochem.* **24**, 1–9, https://doi.org/10.1016/0047-2670(84)80001-5 (1984).

52. Lamb, L. E. *et al*. Primary Photophysical Properties of A2E in Solution. *J. Phys. Chem. B* **105**, 11507–11512, https://doi.org/10.1021/jp0123177 (2001).

53. Kanofsky, J. R., Sima, P. D. & Richter, C. Singlet-oxygen generation from A2E. *Photochem. Photobiol.* **77**, 235–242 (2003).

54. Wielgus, A. R., Chignell, C. F., Ceger, P. & Roberts, J. E. Comparison of A2E Cyto- and Phototoxicity with all-trans-Retinal in Human Retinal Pigment Epithelial Cells. *Photochem. Photobiol.* **86**, 781–791, https://doi.org/10.1111/j.1751-1097.2010.00750.x (2010).

55. Edge, R. & Truscott, T. Singlet Oxygen and Free Radical Reactions of Retinoids and Carotenoids—A Review. *Antioxidants* **7**, 5 (2018).

56. Parish, C. A., Hashimoto, M., Nakanishi, K., Dillon, J. & Sparrow, J. Isolation and one-step preparation of A2E and iso-A2E, fluorophores from human retinal pigment epithelium. *Proc. Natl. Acad. Sci. USA* **95**, 14609–14613 (1998).

57. **57.** Foote, C. S. Photosensitized oxygenations and the role of singlet oxygen. *Acc. Chem. Res.* **1**, 104–110 (1968).

58. Davies, M. J. Reactive species formed on proteins exposed to singlet oxygen. *Photochem. Photobiol. Sci.* **3**, 17–25, https://doi.org/10.1039/b307576c (2004).

59. Yu, B. P. Cellular defenses against damage from reactive oxygen species. *Physiol. Rev.* **74**, 139–163, https://doi.org/10.1152/physrev.1994.74.1.139 (1994).

60. Schweitzer, C. & Schmidt, R. Physical Mechanisms of Generation and Deactivation of Singlet Oxygen. *Chem. Rev.* **103**, 1685–1758, https://doi.org/10.1021/cr010371d (2003).

61. Schmidt, R. Deactivation of O2(1Δg) Singlet Oxygen by Carotenoids: Internal Conversion of Excited Encounter Complexes. *J. Phys. Chem.* A **108**, 5509–5513, https://doi.org/10.1021/jp048958u (2004).

62. El-Sayed, M. A. Triplet state. Its radiative and nonradiative properties. *Acc. Chem. Res.* **1**, 8–16, https://doi.org/10.1021/ar50001a002 (2002).

63. Silvaroli, J. A. *et al*. Ligand Binding Induces Conformational Changes in Human Cellular Retinol-binding Protein 1 (CRBP1) Revealed by Atomic Resolution Crystal Structures. *J. Biol. Chem.* **291**, 8528–8540, https://doi.org/10.1074/jbc.M116.714535 (2016).

64. Derebe, M. G. *et al*. Serum amyloid A is a retinol binding protein that transports retinol during bacterial infection. *eLife* **3**, e03206, https://doi.org/10.7554/eLife.03206 (2014).

65. Wu, Y. *et al*. Contacts between the endoplasmic reticulum and other membranes in neurons. *Proc. Natl. Acad. Sci. USA* **114**, E4859–E4867, https://doi.org/10.1073/pnas.1701078114 (2017).

66. Saheki, Y. & De Camilli, P. Endoplasmic Reticulum-Plasma Membrane Contact Sites. *Annu. Rev. Biochem.* **86**, 659–684, https://doi.org/10.1146/annurev-biochem-061516-044932 (2017).

67. Akgoz, M., Kalyanaraman, V. & Gautam, N. Receptor-mediated reversible translocation of the G protein betagamma complex from the plasma membrane to the Golgi complex. *J. Biol. Chem.* **279**, 51541–51544, https://doi.org/10.1074/jbc.M410639200 (2004).

68. Saini, D. K., Kalyanaraman, V., Chisari, M. & Gautam, N. A family of G protein betagamma subunits translocate reversibly from the plasma membrane to endomembranes on receptor activation. *J. Biol. Chem.* **282**, 24099–24108, https://doi.org/10.1074/jbc.M701191200 (2007).

69. Gallegos, L. L., Kunkel, M. T. & Newton, A. C. Targeting protein kinase C activity reporter to discrete intracellular regions reveals spatiotemporal differences in agonist-dependent signaling. *J. Biol. Chem.* **281**, 30947–30956, https://doi.org/10.1074/jbc.M603741200 (2006).

70. Yeung, T. *et al.* Receptor activation alters inner surface potential during phagocytosis. *Science (New York, N.Y.)* **313**, 347–351, https://doi.org/10.1126/science.1129551 (2006).

71. Karunarathne, W. K. A., Giri, L., Kalyanaraman, V. & Gautam, N. Optically triggering spatiotemporally confined GPCR activity in a cell and programming neurite initiation and extension. *Proc. Natl. Acad. Sci. USA* **110**, E1565–E1574, https://doi.org/10.1073/pnas.1220697110 (2013).

72. Laurent, A. D., Adamo, C. & Jacquemin, D. Dye chemistry with time-dependent density functional theory. *Phys. Chem. Chem. Phys.* **16**, 14334–14356, https://doi.org/10.1039/c3cp55336a (2014).

73. **73.** Yanai, T., Tew, D. P. & Handy, N. C. A new hybrid exchange–correlation functional using the Coulomb-attenuating method (CAM-B3LYP). *Chem. Phys. Lett.* **393**, 51–57, https://doi.org/10.1016/j.cplett.2004.06.011 (2004).

74. Francl, M. M. *et al*. Self-consistent molecular orbital methods. XXIII. A polarization-type basis set for second-row elements. *J. Chem. Phys.* **77**, 3654–3665, https://doi.org/10.1063/1.444267 (1982).

75. Jensen, L. & Govind, N. Excited states of DNA base pairs using long-range corrected time-dependent density functional theory. *J. Phys. Chem.* A **113**, 9761–9765, https://doi.org/10.1021/jp905893v (2009).

76. Frisch, M. J. *et al*. (Wallingford CT, 2009).

77. Cossi, M., Rega, N., Scalmani, G. & Barone, V. Energies, structures, and electronic properties of molecules in solution with the C-PCM solvation model. *J. Comput. Chem.* **24**, 669–681, https://doi.org/10.1002/jcc.10189 (2003).

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Contributions

K.R. conducted most of the experiments and analyzed the data. J.P. conducted the TD-DFT simulations to calculate energy requirement for opsin-bound with retinal vs free retinal and absorption spectra of retinoids. H.L. conducted HPLC analysis for retinal degradation in different solvents. A.K. and K.R. conceived the idea for the project and designed the experiments. K.R., J.P. and A.K. wrote the manuscript.

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Ethics declarations

Competing Interests

The authors declare no competing interests.

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Exhb 2v Footnote 27 Effects of blue light on the circadian system and eye physiology (310-333)

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Effects of blue light on the circadian system and eye physiology

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Abstract

Light-emitting diodes (LEDs) have been used to provide illumination in industrial and commercial environments. LEDs are also used in TVs, computers, smart phones, and tablets. Although the light emitted by most LEDs appears white, LEDs have peak emission in the blue light range (400–490 nm). The accumulating experimental evidence has indicated that exposure to blue light can affect many physiologic functions, and it can be used to treat circadian and sleep dysfunctions. However, blue light can also induce photoreceptor damage. Thus, it is important to consider the spectral output of LED-based light sources to minimize the danger that may be associated with blue light exposure. In this review, we summarize the current knowledge of the effects of blue light on the regulation of physiologic functions and the possible effects of blue light exposure on ocular health.

Introduction

Lighting sources and technology have experienced a revolution in the last 15–20 years. Lighting sources and technology, especially in non-commercial or industrial illumination applications, have traditionally been slow to change [1]. In most homes, the incandescent bulb and Edison socket have been omnipresent. In the past 10 years, we have seen significant use of other technologies, such as compact fluorescent lamps (CFLs), replacing incandescent sources. However, this transition has often been driven by legislation, which has focused on energy-efficient sources instead of consumer desire for different light sources. The general user quickly noted the difference in the quality of CFL source but not necessarily in the specifics of its power spectrum. Simultaneously, the development and performance of high brightness light-emitting diodes (LEDs) have experienced tremendous advances [2]. The coupling of a blue-light LED with a phosphor has also been used to produce a white light source, the white-light LED. This solid-state fluorescent analog has become known as solid-state lighting (SSL). This approach is now considered the next generation of illumination due to the many inherent and potential advantages over current technologies.

In addition to use for general illumination, LEDs quickly became the choice for mobile devices, such as smart phones [3]. The small size of LEDs and the limited screen size make them ideal for these applications. The potential for the use of LEDs for backlighted liquid crystal displays (LCDs) in laptop computers was also quickly realized. This transition was driven by the fragility of the microfluorescent lamps used for illumination and consumer desire for thinner screens. LEDs have now become the dominant technology for backlighted tablet displays, such as iPads and e-readers, and large LCD television sets. This now means that blue light prevails in red, green, and blue (RGB) and SSL illumination systems that did not exist a decade ago. The ways in which people read have also changed. Light is now being used directly for illumination in smart phones, tablets, and readers instead of for reflection, which is typical for reading from paper.

The white-light LED (i.e., the most common type of LED) is essentially a bichromatic source that couples the emission from a blue LED (peak of emission around 450–470 nm with a full width at half max of 30–40 nm) [4] with a yellow phosphor (peak of emission around 580 nm with a full width at half max of 160 nm) that appears white to the eye when viewed directly [5]. The specific pump wavelength of the phosphor in the range 450–470 nm depends critically on the absorption properties of the phosphor. Although the white-light LED can be considered the SSL analog of the fluorescent source, the power spectrum of the white-light LED is considerably different from traditional, fluorescent, or incandescent white light sources [6] (Figure 1).

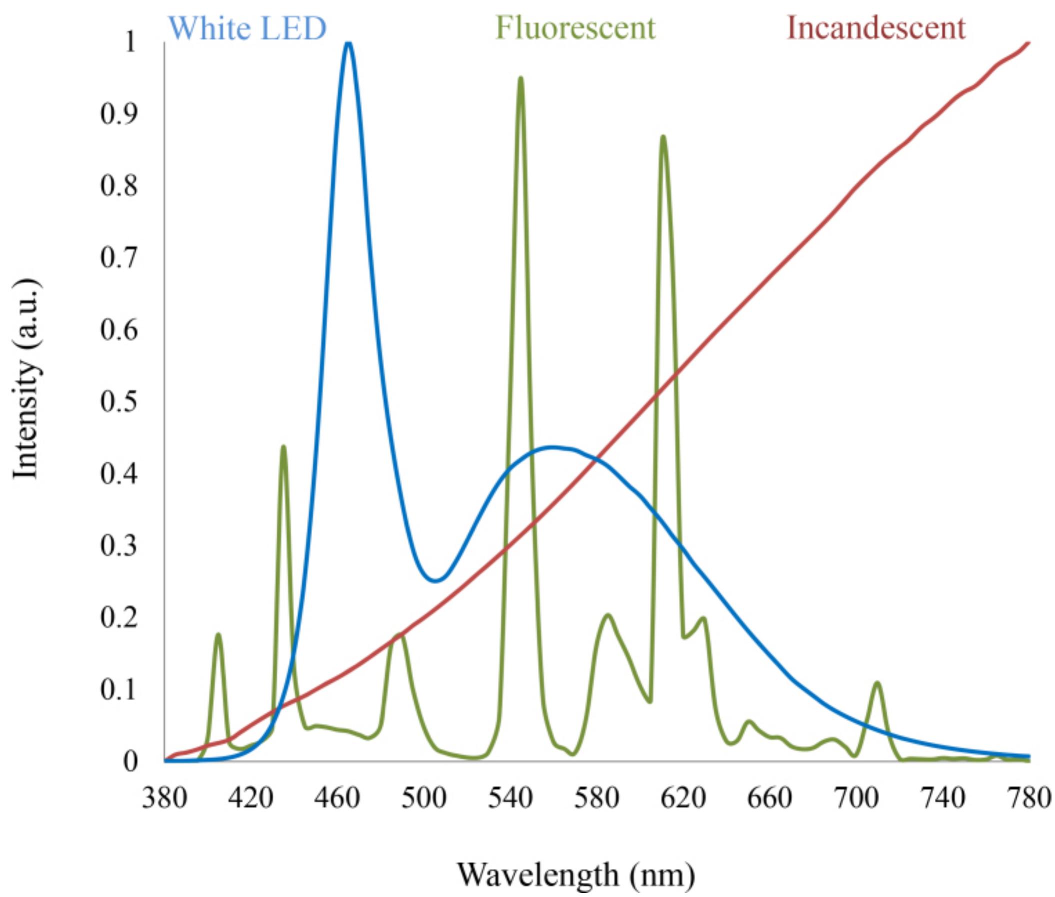

Figure 1

A comparison of the power spectrum of a standard white-light LED, a tricolor fluorescent lamp, and an incandescent source. The radically different power spectrums can look similar when viewed directly by the eye, irrespective of how much blue emission is present.

Early commercial devices lacked sophistication, adopting the currently available LED technology that was small, 350×350 mm^2, and operated at low drive currents, typically 20 mA, producing 1–16 mW of power. The last decade has seen the scaling of LEDs to larger areas, 1×1 μm^2, and higher drive currents of >350 mA with significantly increased power output >1,000 mW [2]. During this period, LED devices were also optimized for use in illumination applications, and reflected from a surface instead of emitted directly.

In addition, white-light LEDs degrade over time primarily through bleaching of phosphors so that they no longer efficiently absorb blue light [7]. This shifts the color temperature of the device over time, with a corresponding change in the color-rendering index but, more importantly, an increasing blue emission from the device with time.

In this review, we summarize the current knowledge of the effects of blue light on the regulation of physiologic function and the effects of blue light exposure on ocular health. Finally, we discuss the available data to determine whether long-term exposure to blue light is safe or whether additional studies are needed to fully understand the effects of blue light exposure on ocular health.

Non-image-forming photoreception

In mammals, photoreception occurs only in the retina [8] by three types of photoreceptor: cones, rods, and the intrinsically photosensitive retinal ganglion cells (ipRGCs). The classical photoreceptors (e.g., rods and cones) are mostly responsible for the image-forming vision, whereas the ipRGCs play a major role in non-image-forming photoreception, that is, the photoreceptive system that regulates circadian photic entrainment, pupillary light response, and other important biologic functions (Figure 2).

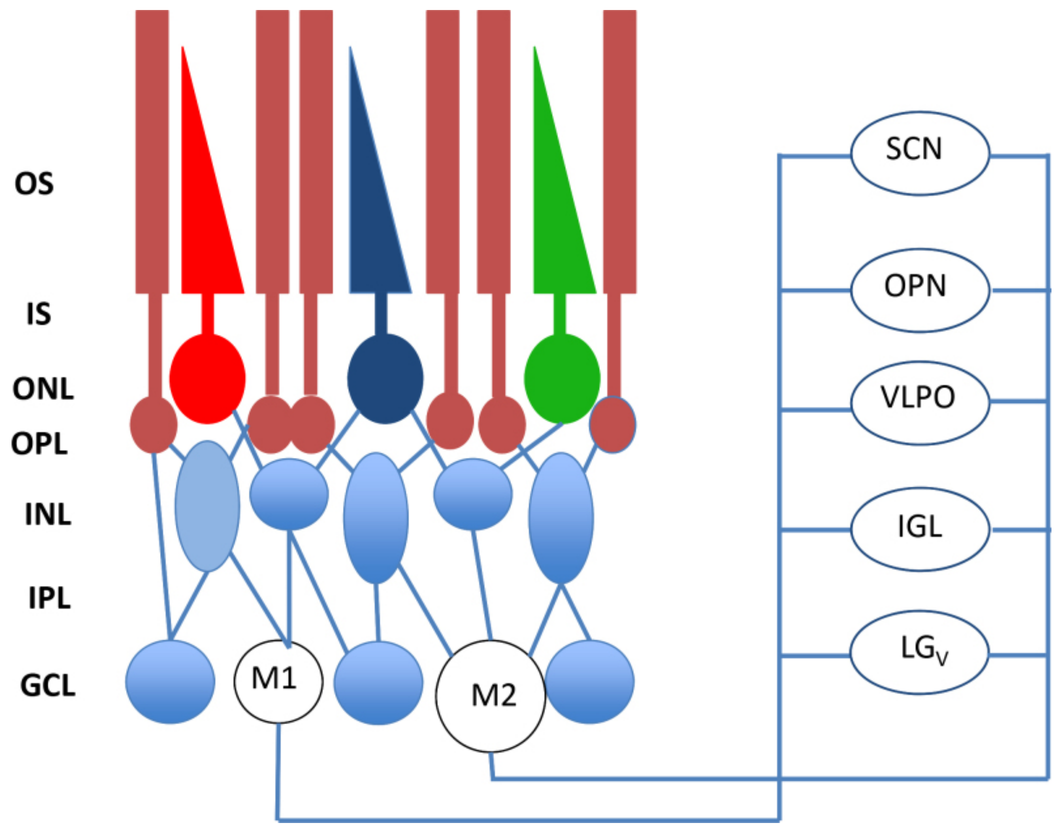

Figure 2

In addition to the classical photoreceptors (rods and cones), ipRGCs are present in the retina. Recent studies have shown that at least two types of intrinsically photosensitive retinal ganglion cells (ipRGCs) have been identified: M1 and M2. Most of the M1 cells project to the suprachiasmatic nucleus (SCN) of the hypothalamus whereas the number of M1 and M2 projecting to the olivary pretectal nucleus (OPN) is similar (55% from M1 cells versus 45% from M2 cells). The M1 cells are considerably smaller but respond with significantly larger depolarizations and light-induced currents than do the M2 cells. Other neural targets of ipRGCs not shown in the figure include the preoptic area, sub-paraventricular zone, anterior hypothalamic nucleus, lateral hypothalamus, medial amygdaloid nucleus, lateral habenula, lateral geniculate nucleus (dorsal division), bed nucleus of the stria terminalis, periaqueductal gray, and superior colliculus. OS=outer segments; IS=inner segments; ONL=outer nuclear layer; OPL=outer plexiform layer; INL=inner nuclear layer; IPL=inner plexiform layer; GCL=ganglion cell layer; from [31] with permission.

The idea that the mammalian retina is capable of non-image-forming photoreception emerged during the 1990s when a series of studies indicated that mice lacking rod photoreceptors (*rd/rd)* have a normal phase response curve (PRC) to light [9], with an action spectrum that peaks around 480 nm [10]. This result suggested that a photo pigment different from rhodopsin (λ_{max} 498 nm), short wavelength sensitive opsin (λ_{max} 460 nm), and middle wavelength sensitive opsin (λ_{max} 508 nm) [11] was responsible for the entrainment of circadian rhythms. Additional studies reported that mice lacking rods and cones were still capable of synchronizing their circadian rhythms to light-dark cycles [12], thus demonstrating that an undiscovered photo pigment/photoreceptor in the mammalian retina was responsible for the photoentrainment of circadian rhythms.

The most likely candidate to emerge as the circadian retinal photo pigment is a mammalian homolog of *Xenopus* melanopsin (*aka Opn4)* [13-15]. In mammals, melanopsin mRNA (and protein) is expressed only in a small population (about 3–5%) of the RGCs [14,16] that are directly photosensitive and have an absorption peak around 470–480 nm [17-19]. These RGCs express pituitary adenylate cyclase-activating polypeptide (PACAP) [20] and form the retinohypothalamic tract (RHT) [16,21]. The RHT is responsible for conveying the light information from RGCs to the part of the brain that controls circadian rhythms within the whole body [22,23]. The RGCs that express melanopsin were named intrinsically photosensitive RGCs (ipRGCs), and these cells were no longer intrinsically photosensitive in melanopsin knockout (KO) mice, although the cell number, morphology, and projections remained unchanged [24].

Additional studies have also shown that melanopsin KO mice entrained to light-dark photoperiods, albeit the response to light was attenuated in the KO animals as the magnitude of the phase-shift is about half (40%) of that of wild-type mice at each of the three non-saturating irradiance levels [25]. A saturating white light pulse also produced a diminished phase shift in the KO animals [26]. The length of the free-running period that follows the exposure to constant light is reduced (to about 55–65% of that of controls) in melanopsin KO animals [25,26].

Melanopsin has also been implicated in regulation of the pupillary light reflex (PLR). Transgenic mice lacking rod and cone photoreceptors (*rdcl*) retain a PLR, and this response is driven by a photo pigment with peak sensitivity of around 479 nm [27]. Melanopsin KO animals showed a PLR indistinguishable from that of the wild-type mice at low irradiances, but at high irradiances, the reflex was incomplete. This result suggests that the melanopsin-associated system and the classical rod/cone system are complementary functions [28,29]. Thus, the current view is that no single photoreceptor type is necessary for the synchronization of circadian rhythms with external light-dark cycles [30,31].

Finally, mice with the melanopsin gene ablated only in ipRGCs have normal outer retinal function but lack non-image-forming visual responses, such as circadian photoentrainment, light modulation of activity, and PLR [32]. Thus, the ipRGCs represent the site of integration of non-image-forming photo responses in mammals.

Further studies have also shown that melanopsin-based photoreception is involved in the modulation of sleep [33-36] and mood and learning [37], and recent data have also indicated that melanopsin-based photoreception may be involved in the regulation of metabolism [38]. Finally, it has been reported that loss of the melanopsin gene abolishes circadian control in some parameters of cone electroretinogram, causing significant attenuation of the diurnal variation in cone vision [39]. Melanopsin signaling may influence intraretinal signaling by acting on dopaminergic neurons [40]. Therefore, these data suggest melanopsin-dependent regulation of visual processing within the retina.

Melanopsin also plays an important role in mediating human circadian rhythms. Several studies have reported that in humans, the action spectra for melatonin suppression has a lambda max (λ_{max}) of around 460 nm, suggesting that melanopsin is a key player in the photic regulation of melatonin levels

[41-43]. Additional studies have also shown that blue light in the range of 460–480 nm is more effective compared to monochromatic light of 555 nm in phase-shifting the human circadian clock [44,45]. Finally, a recent study expanded these previous results by showing that light in the 555 nm range may significantly affect the synchronization of the circadian system to light exposure of short duration or to low irradiance, whereas light in the 460 nm range is more effective in phase-shifting the circadian system than exposure to light of longer duration and higher irradiance [46]. Additional studies have also shown that exposure to blue light can increase alertness [47-50] and stimulate cognitive functions [51-53]. A recent study reported that exposure to light-emitting e-readers at bedtime may negatively affect sleep and the circadian system [54]. Finally, blue light may also be used to treat seasonal affective disorders [55], and mutations in the melanopsin gene may increase the susceptibility to developing seasonal affective disorders [56,57]. However, another study reported that exposure to blue-enriched light was less effective compared to full-spectrum light in the treatment of seasonal affective disorder [58].

With age, the lens becomes more yellowish, and thus, the spectrum of blue light transmission dramatically decreases through the years. It is suspected that one reason older individuals experience sleep problems is the lack of blue light during the daytime. Ayaki et al. [59] reported that after cataract extraction, sleep quality improved dramatically because more blue light could pass through the intraocular lens. In addition, there has been a discussion on whether a clear or yellow lens is preferable [60]. Of course, the yellow lens may protect the retina, but the clear lens provides more blue light during the day, providing better quality of sleep [61]. Consistent with this result, Sletten et al. [62] reported that in older people, acute exposure to blue light, but not to green light, significantly decreased their alertness and suppressed their sleep and melatonin production compared to young people. However, another study reported that in older patients with decreased lens transmittance, melatonin was not significantly suppressed following blue light exposure [43]. Thus, whether the yellowing of the lens associated with aging really affects the non-image-forming photoreception is still a matter of debate.

Light-induced damage to the retina

Several investigations have shown that exposure to light of specific wavelengths or intensity may induce severe damage to the retina [63,64]. This type of damage is called light-induced damage. Light can induce damage via three mechanisms: photomechanical, photothermal, and photochemical. Photomechanical damage is due to a rapid increase in the amount of energy captured by the RPE, which may cause irreversible damage to the RPE and lead to photoreceptor damage. This type of retinal damage depends on the amount of energy absorbed and not on the spectral composition of the light. Photothermal damage occurs when the retina and the RPE are exposed to brief (100 ms to 10 s) but intense light that induce a significant increase in the temperature of these tissues [63,64].

A more common type of retinal/RPE damage is photochemical damage, which occurs when the eyes are exposed to light of high intensity in the visible range (390–600 nm). The current view suggests that there are two distinct types of photochemical damage. The first type is associated with short but intense exposure to light affecting the RPE, and the second type is associated with longer but less intense light exposure, affecting the outer segment of the photoreceptors. Short (up to 12 h) exposure to blue light may induce damage in the RPE of the rhesus monkey [65], and a clear relationship has been found between the extent of the damage and the oxygen concentration [66,67]. The fact that many different antioxidants can reduce the damage suggests that this type of damage is associated with oxidative processes [68,69]. Experimental data suggest that lipofuscin is the chromophore involved in the mediation of light-induced retinal damage following the exposure to blue light [70-73].

The second type of light-induced photochemical damage occurs with longer (12–48 h) but less intense light exposure. This type of damage was initially observed in albino rats [74] but has also been observed in other species. The cones seem to be more vulnerable compared to the rods [75]. Several lines of evidence suggest that the visual photo pigments (e.g., rhodopsin and cone opsins) are involved in this type of damage. Early studies [76-78] also provided evidence that the action spectrum for light-induced photoreceptor damage is similar to the absorption spectrum of rhodopsin, but later studies indicated that blue light (400–440 nm) might be more damaging [79-81]. Grimm et al. [82] provided an explanation for this phenomenon, demonstrating that in vivo bleached rhodopsin may be regenerated not only via a metabolic pathway (e.g., via the visual cycle) but also via a photochemical reaction called photoreversal of bleaching [83] that is most effective with blue light. Photoreversal of bleaching augments the capability of rhodopsin molecules to absorb photons by several orders of magnitude, thus allowing the molecules to reach the critical number of photons required to induce damage in the retinal cells [84].

This process can further increase the potential production of reactive oxygen species (ROS); thus, the oxidative damage can lead to the accumulation and build-up of lipofuscin in the RPE. The build-up of lipofuscin in the RPE can affect the ability of the RPE to provide nutrients to the photoreceptors, affecting photoreceptor viability [85]. Moreover, when lipofuscin absorbs blue light, the material becomes phototoxic, which can lead to further damage in the RPE and in the photoreceptors [70]. The data from our laboratory indicate that in albino rats, exposure to blue light (λ_{max} 474 nm, $1{\times}10^{-1}$ $\mu W/cm^2$) acutely suppressed melatonin levels [6] while exposure to blue light for 4 h/day for 30 days did not produce significant effects on photoreceptor viability (Figure 3). However, this treatment produced a small (10–20%) but significant reduction in the levels of melanopsin and short wavelength opsin mRNAs in rats exposed to white or green (λ_{max}513 nm) light (Figure 4).

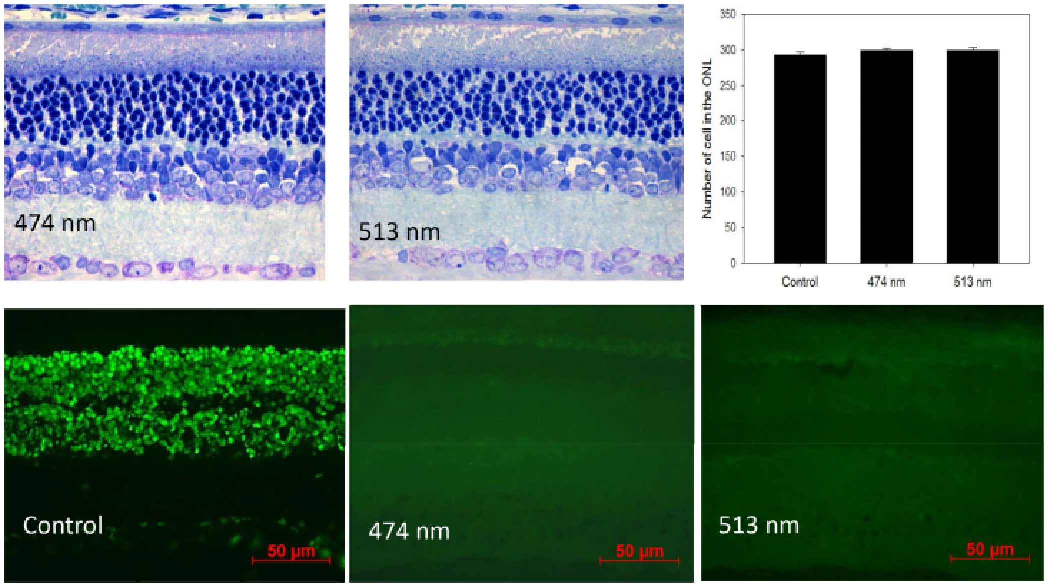

Figure 3

Top panels. The exposure to blue light (λ_{max} 474), green light (λ_{max} 513), or fluorescent light at the intensity of 1×10^{-1} $\mu W/cm^2$ for 4 h/day for 30 days did not produce a significant change in the number of cells in the photoreceptor layers of the Sprague-Dawley rats (n=6; see [121] for details about the methods used to quantify cells in the photoreceptor layer). Lower panels. The exposure to blue or green light-emitting diodes (LEDs) for 4 h in the middle of the day did not induce apoptosis. Terminal deoxynucleotidyl transferase-mediated uridine 5′-triphosphate-biotin nick end labeling (TUNEL) assay: 4- to 6-week-old Sprague-Dawley rats (n=6) were anesthetized (75 mg/kg ketamine and 23 mg/kg xylazine), kept on heating pads (37 °C), and exposed to blue or green light for 4 h. The pupils were dilated with 1% atropine and 2.5% phenylephrine eye drops 45 min before the light exposure. Rats were then killed 16 h after the exposure to blue light or green light. The eyes were explanted and fixed using freshly prepared 4% polyformaldehyde in PBS, pH 7.4 for 20 min at room temperature. They were washed 3X with PBS, permeabilized with freshly prepared 0.1% Triton X-100 in 0.1% sodium citrate for 2 min on ice (2–8 °C), and then the TUNEL reaction was performed according to the instructions included in the manual (In Situ cell Death Detection kit). The slides were incubated in a humidified container for 60 min at 37 °C in the dark. Slides were rinsed 3X with PBS, and samples were analyzed under a fluorescence microscope (Zeiss Axioskop).

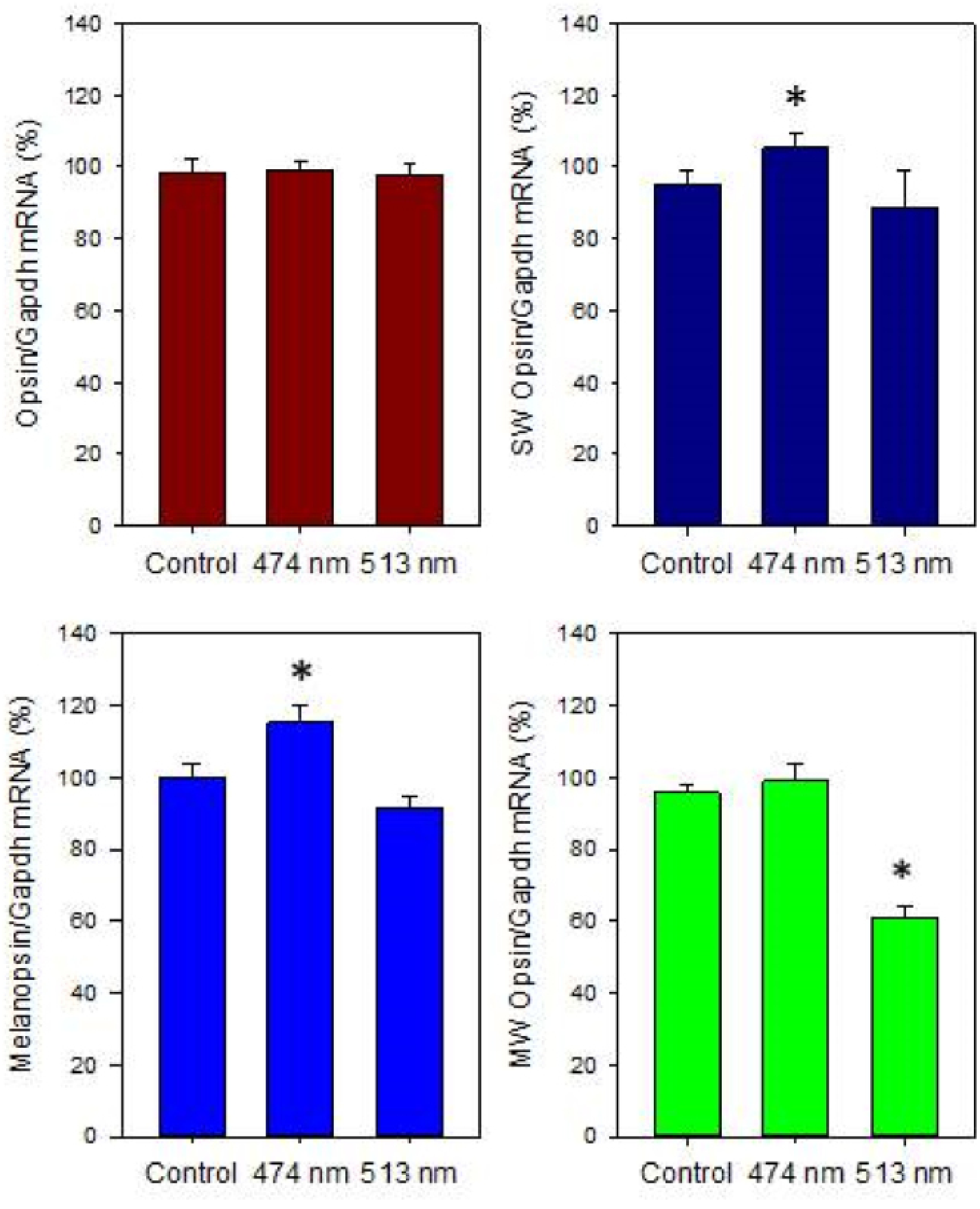

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Figure 4

Different light treatments did not affect rhodopsin mRNA levels (one-way ANOVA, $p>0.1$). Exposure to blue light (λ_{max} 474) at the intensity of 1×10^{-1} $\mu W/cm^2$ for 4 h/day for 30 days produced significant changes in the mRNA levels of short wavelength sensitive (SW) opsin, melanopsin, and medium wavelength sensitive opsin (* one-way ANOVA followed by Holm-Sidak tests, $p<0.05$). Rats were exposed to blue, green, or white light-emitting diodes (LEDs) every day (4 h) for 30 days in the middle of the day (11:00 to 15:00) and then returned to a 12 h:12 h light-dark cycle. The intensity of the light during the light phase of the 12 h:12 h light-dark cycle was about 400–450 lux. Every day, the pupils were dilated with 1% atropine and 2.5% phenylephrine eye drops 45 min before exposure to blue, green, or white light-emitting diodes (LEDs). After 30 days, the rats were killed, and the retinas were explanted, immediately frozen, and stored at −80 °C. mRNA was then extracted, and mRNA levels were measured using real-time quantitative PCR (qPCR; see [122] for details about primers and qPCR conditions).

In this context, two recent studies on the effect of blue light exposure on the RPE and cone-like cells (661W, murine photoreceptor-derived cells [86]) should be mentioned. In the first study, Arnault et al. [87] reported that in the primary porcine RPE, exposure to light with irradiance similar to that of natural sunlight, that is, light in the range of 415–455 nm, was the most effective in reducing cell viability.

In the second study, Kuse et al. [88] reported that 661W cells are more sensitive to light-induced damage when exposed to light emitted by blue (464 nm) LEDs than when exposed to green (522 nm) or white LEDs (wavelength peak at 456 and 553 nm) of the same intensity (0.38 mW/cm^2). The exposure to blue light, unlike the exposure to white and green LEDs, also produced a significant increase in ROS and induced cell damage. Similar results were also observed in primary retinal cells [88]. These data support the idea that exposure to blue light in the range of 400–470 nm (even at low levels) may damage photoreceptors and retinal pigment epithelium cells.

Although most studies have focused on the acute effect of light exposure, several have also investigated the cumulative effect of light. For example, Noell [89] reported that a single 5 min exposure to light did not induce significant damage in photoreceptor cells, whereas a series of 5 min exposures led to significant photoreceptor damage. Furthermore, the time between exposures affects the cumulative effect of light [90-92]. In some cases, intermittent light exposure may produce even more pronounced damage than an equivalent amount of light in a single exposure [93]. In addition, the type of illumination to which the animals had been exposed before the experimental treatment influenced the extent of the retinal damage following light exposure. For example, rats raised in complete darkness showed greater susceptibility to light-induced retinal damage [89], and rats raised in an 800 lux light-dark cycle were more resistant to light-induced retinal damage compared to animals raised in a 5 lux light-dark cycle [94]. Finally, light-induced damage to photoreceptors increases with age. The exposure to light that might affect adult animals might not induce retinal damage in young animals [95]. In this context, with age, superoxide dismutase 1 (SOD1) and protective enzymes do not function as well due to zinc deficiency. SOD1 does not function well because the enzyme activity is controlled by zinc. Imamura et al. have shown that even with normal light that contains some blue light, fluorescent light damaged the retina tremendously in the SOD1 knockout mouse, which is similar to an aging mouse [96]. However, nothing happened in the normal mouse. The protective mechanism of the retina is important. From that point of view, the protective function of lutein, or blue-blocking pigment, on the retina is also considered. Ozawa et al. published research showing that when lutein was given, retina photodamage was alleviated [97].

Finally, the severity of light-induced retinal damage changes with the time of the day [98-102]. For example, rats are three to four times more susceptible to light damage at night (01:00) than during the day (09:00 and 17:00). The circadian dependency of light-induced photoreceptor damage appears to involve mechanisms that control cAMP and c-fos levels (see [63] for a review), both of which are under the control of the retinal circadian clock [103,104]. Exposure to blue light during the night might have more negative effects compared to the same exposure during the daytime. However, in this case, this assumption is based on the experimental data obtained from nocturnal rodents. Thus, it is difficult to determine whether light-induced retinal damage has a daily rhythm in humans, and further studies on diurnal animal models (e.g., non-human primates) are required to address this important point.

Experimental evidence indicates that wavelengths in the blue part of the spectrum (400–490 nm) can induce damage in the retina, and although the initial damage following exposure to blue light may be confined to the RPE, a damaged RPE eventually leads to photoreceptor death. Although most studies on the effects of blue light have focused on the mechanisms responsible for the damage to the photoreceptors following an acute exposure to high intensity light, some studies have reported that sub-threshold exposure to blue light can also induce damage in photoreceptors [105-107]. In addition, several authors have proposed that the amount of blue light received during an individual's entire lifespan can be an important factor in the development of age-related macular degeneration (AMD). The use of lenses (intra- and extraocular) that block blue light ("blue-blockers") may provide some protection against the development of AMD [60,108].

The mechanism through which long-term exposure to blue light may induce photoreceptor damage is mostly unknown. Several studies have indicated lipofuscin (absorption peak around 450 nm) is a possible mediator of the risk associated with long-term exposure to blue light–induced retinal damage [109,110]. Lipofuscin accumulates in the RPE in the form of granules located in the lysosomes of the RPE. The formation of lipofuscin begins in photoreceptors' outer segments as a byproduct of the degradation of rod photoreceptor discs [105]. When lipofuscin absorbs blue light, ROS are produced, and these free radicals are responsible for the oxidative damage that occurs in the retina. The number of reactive oxygen species produced by lipofuscin is directly related to the spectral composition of the light, and it steadily decreases from 400 to 490 nm [73]. The accumulation of lipofuscin in the RPE, particularly in the macula, has been linked to photoreceptor death and to AMD [109]. Furthermore, the amount of lipofuscin present in the RPE increases with age (i.e., the amount of lipofuscin is low in young and high in old animals); thus, the potential for blue light to damage the retina may increase with age [111]. Finally, it has been reported that chronic exposure to blue light may accelerate photoreceptor degeneration in an animal model in the study of retinal degeneration [112].

Thus, experimental evidence obtained from different experimental models indicates that exposure to blue light in the 470–490 nm range may be less damaging to the eye compared to blue light in the 400–460 nm range. We believe that the development of LEDs with a peak emission of around 470–490 nm may represent an important advancement in the safety of LEDs for ocular health [6] (Figure 3).

Light exposure and age-related macular degeneration in humans

A series of studies in many animal models have shown that exposure to blue light may represent a risk for the development of AMD or other retinal pathologies [113,114]. However, the real risk from artificial light (white or blue) exposure in humans is difficult to assess, since light therapy has been in use for only a few years and in a small number of individuals. In addition, individual susceptibility to blue light damage varies significantly among individuals, making the assessment of the risk associated with repeated exposure to blue light in the etiology of AMD difficult.

Previous epidemiological studies have indicated that chronic exposure to visible and blue light may be a cofactor in the development of AMD [115-117]. However, Darzin et al. [118] found no significant relationships between blue light and the development of AMD. Okuno et al. [119] evaluated the blue-light hazards from many different light sources and reported that the exposure (even for less than a minute) to blue light from the sun, arc-welding lamps, and the arc of discharge lamps is hazardous to the retina, whereas the exposure to blue light from fluorescent lamps or LEDs does not pose a significant hazard.

Thus, it is clear that many different factors are involved in the pathogenesis of AMD. This observation, together with the limited data in terms of number of subjects or length of treatment, makes it difficult to predict the association between blue light exposure and the development of AMD.

Finally, ultraviolet (UV) light is a risk factor for age-related macular degeneration. UV is mostly blocked by the cornea or lens; therefore, only visible light can penetrate the eye and reach the retina. A recent study by Narimatsu et al. [120] conducted with an animal model reported that blocking UV light and blue light with yellow-tinted intraocular lenses materials (400–450 nm) could protect the retina [120]. Thus, reducing the amount of blue light reaching the retina in the range 400–450 nm may also be important for the protection of the retina.

Conclusions

The use of blue light is becoming increasingly prominent in our society, and a large segment of the world population is now subjected to daily exposure (from a few minutes to several hours) of artificial light at an unusual time of the day (night). Because light has a cumulative effect and many different characteristics (e.g., wavelength, intensity, duration of the exposure, time of day), it is important to consider the spectral output of the light source to minimize the danger that may be associated with blue light exposure. Thus, LEDs with an emission peak of around 470–480 nm should be preferred to LEDs that have an emission peak below 450 nm. Although we are convinced that exposure to blue light from LEDs in the range 470–480 nm for a short to medium period (days to a few weeks) should not significantly increase the risk of development of ocular pathologies, this conclusion cannot be generalized to a long-term exposure (months to years). Finally, we believe that additional studies on the safety of long-term exposure to low levels of blue light are needed to determine the effects of blue light on the eye.

Acknowledgments

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References

1. Ferguson I, Melton A, Xu T, Jamil M, Fenwick W. What would Edison do with solid state lighting? Proc. SPIE 7784, Tenth International Conference on Solid State Lighting 2010; 77840A. [Google Scholar]

2. Pimputkar S, Speck J, DenBaars S, Nakamura S. Prospects for LED lighting. Nat Photonics. 2009;3:180–2. [Google Scholar]

3. Schubert F. Light-Emitting Diodes. Cambridge University Press; 2006; pp. 434. [Google Scholar]

4. Nakamura S, Chichibu S. Introduction to Nitride Semiconductor Blue Lasers and Light Emitting Diodes. 2000; CRC Press; 1st 386 pages. [Google Scholar]

5. Nakamura S. Present performance of InGaN-based blue/green/yellow LEDs. Light-Emitting Diodes: Research, Manufacturing, and Applications. Proc SPIE. 1997;xxx:26. [Google Scholar]

6. Ferguson I, Melton A, Li N, Nicol D. Park, Tosini G. Imitating Broadband Diurnal Light Variations Using Solid State Light Sources. Journal of Light & Visual Environment. 2008;32:63–8. [Google Scholar]

7. Brinkley S, Pfaff N, Denault K, Zhang Z, Hintzen H, Seshadri R, Nakamura S, DenBaars S. Robust thermal performance of $Sr_2SiN_8:Eu^{2+}$: An efficient red emitting phosphor for light emitting diode based white lighting. Appl Phys Lett. 2011;99:241106. [Google Scholar]

8. Yamazaki S, Goto M, Menaker M. No evidence for extraocular photoreceptors in the circadian system of the Syrian hamster. J Biol Rhythms. 1999;14:197–201. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=10452331&dopt=Abstract [PubMed] [Google Scholar]

9. Foster RG, Provencio I, Hudson D, Fiske S, De Grip W, Menaker M. Circadian photoreception in the retinally degenerate mouse (rd/rd. J Comp Physiol A Neuroethol Sens Neural Behav Physiol. 1991;169:39–50. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=1941717&dopt=Abstract [PubMed] [Google Scholar]

10. Yoshimura T, Ebihara S. Spectral sensitivity of photoreceptors mediating phase-shifts of circadian rhythms in retinally degenerate CBA/J (rd/rd). and normal CBA/N (+/+). mice. J Comp Physiol. 1996;178:797–802. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=8667293&dopt=Abstract [PubMed] [Google Scholar]

11. Nikonov SS, Kholodenko R, Lem J, Pugh EN., Jr Physiological features of the S- and M-cone photoreceptors of wild-type mice from single-cell recordings. J Gen Physiol. 2006;127:359–74. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=16567464&dopt=Abstract [PMC free article] [PubMed] [Google Scholar]

12. Freedman MS, Lucas RJ, Soni B, von Schantz M, Muñoz M, David-Gray Z, Foster R. Regulation of mammalian circadian behavior by non-rod, non-cone, ocular photoreceptors. Science. 1999;284:502–4. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=10205061&dopt=Abstract [PubMed] [Google Scholar]

13. Provencio I, Jiang G, DeGrip WJ, Hayes WP, Rollag MD. Melanopsin: An opsin in melanophores, brain, and eye. Proc Natl Acad Sci USA. 1998;95:340–5. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=9419377&dopt=Abstract [PMC free article] [PubMed] [Google Scholar]

14. Provencio I, Rodriguez IR, Jiang G, Hayes WP, Moreira EF, Rollag MD. A novel human opsin in the inner retina. J Neurosci. 2000;20:600–5. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=10632589&dopt=Abstract [PMC free article] [PubMed] [Google Scholar]

15. Bellingham J, Chaurasia SS, Melyan Z, Liu C, Cameron MA, Tarttelin EE, Iuvone PM, Hankins MW, Tosini G, Lucas RJ. Evolution of melanopsin photoreceptors: Discovery and characterization of a new melanopsin gene in non-mammalian vertebrates. PLoS Biol. 2006;4:e254. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=16856781&dopt=Abstract [PMC free article] [PubMed] [Google Scholar]

16. Hattar S, Liao HW, Takao M, Berson DM, Yau KW. Melanopsin-containing retinal ganglion cells: architecture, projections, and intrinsic photosensitivity. Science. 2002;295:1065–70. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=11834834&dopt=Abstract [PMC free article] [PubMed] [Google Scholar]

17. Berson DM, Dunn FA, Takao M. Phototransduction by ganglion cells innervating the circadian pacemaker. Science. 2002;295:1070–3. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=11834835&dopt=Abstract [PubMed] [Google Scholar]

18. Qiu X, Kumbalasiri T, Carlson SM, Wong KY, Krishna V, Provencio I, Berson DM. Induction of photosensitivity by heterologous expression of melanopsin. Nature. 2005;433:745–9. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=15674243&dopt=Abstract [PubMed] [Google Scholar]

19. Bailes HJ, Lucas RJ. (2013. Human melanopsin forms a pigment maximally sensitive to blue light (λmax ≈ 479 nm. supporting activation of G(q/11. and G(i/o. signalling cascades. Proc Biol Sci. 2013;280:20122987. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=23554393&dopt=Abstract [PMC free article] [PubMed] [Google Scholar]

20. Hannibal J, Hindersson P, Knudsen SM, Georg B, Fahrenkrug J. The photopigment melanopsin is exclusively present in pituitary adenylate cyclase-activating polypeptide-containing retinal ganglion cells of the retinohypothalamic tract. J Neurosci. 2002;22:RC191. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=11756521&dopt=Abstract [PMC free article] [PubMed] [Google Scholar]

21. Gooley JJ, Lu J, Chou TC, Scammell TE, Saper CB. Melanopsin in cells of origin of the retinohypothalamic tract. Nat Neurosci. 2001;4:1165. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=11713469&dopt=Abstract [PubMed] [Google Scholar]

22. Moore RY, Lenn NJ. A retinohypothalamic projection in the rat. J Comp Neurol. 1972;146:1–14. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=4116104&dopt=Abstract [PubMed] [Google Scholar]

23. Johnson RF, Moore RY, Morin LP. Loss of entrainment and anatomical plasticity after lesions of the hamster retinohypothalamic tract. Brain Res. 1988;460:297–313. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=2465060&dopt=Abstract [PubMed] [Google Scholar]

24. Hattar S, Lucas RJ, Mrosovsky N, Thompson S, Douglas RH, Hankins MW, Lem J, Biel M, Hofmann F, Foster RG, Yau KW. Melanopsin and rod-cone photoreceptive systems account for all major accessory visual functions in mice. Nature. 2003;424:76–81. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=12808468&dopt=Abstract [PMC free article] [PubMed] [Google Scholar]

25. Panda S, Sato TK, Castrucci AM, Rollag MD, DeGrip WJ, Hogenesch JB, Provencio I, Kay SA. Melanopsin (Opn4. requirement for normal light-induced circadian phase shifting. Science. 2002;298:2213–6. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=12481141&dopt=Abstract [PubMed] [Google Scholar]

26. Ruby NF, Brennan TJ, Xie X, Cao V, Franken P, Heller HC, O'Hara BF. Role of melanopsin in circadian responses to light. Science. 2002;298:2211–3. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=12481140&dopt=Abstract [PubMed] [Google Scholar]

27. Lucas RJ, Douglas RH, Foster RG. Characterization of an ocular photopigment capable of driving pupillary constriction in mice. Nat Neurosci. 2001;4:621–6. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=11369943&dopt=Abstract [PubMed] [Google Scholar]

28. Lucas RJ, Hattar S, Takao M, Berson DM, Foster RG, Yau KW. Diminished pupillary light reflex at high irradiances in melanopsin-knockout mice. Science. 2003;299:245–7. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=12522249&dopt=Abstract [PubMed] [Google Scholar]

29. Panda S, Provencio I, Tu DC, Pires SS, Rollag MD, Castrucci AM, Pletcher MT, Sato TK, Wiltshire T, Andahazy M, Kay SA, Van Gelder RN, Hogenesch JB. Melanopsin is required for non-image-forming photic responses in blind mice. Science. 2003;301:525–7. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=12829787&dopt=Abstract [PubMed] [Google Scholar]

30. Lucas RJ, Peirson SN, Berson DM, Brown TM, Cooper HM, Czeisler CA, Figueiro MG, Gamlin PD, Lockley SW, O'Hagan JB, Price LL, Provencio I, Skene DJ, Brainard GC. (2014. Measuring and using light in the melanopsin age. Trends Neurosci. 2014;37:1–9. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=24287308&dopt=Abstract [PMC free article] [PubMed] [Google Scholar]

31. Paul KN, Saafir TN, Tosini G. The role of retinal photoreceptors in the regulation of circadian rhythms. Rev Endocr Metab Disord. 2009;10:271–8. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=19777353&dopt=Abstract [PMC free article] [PubMed] [Google Scholar]

32. Hatori M, Le H, Vollmers C, Keding SR, Tanaka N, Buch T, Waisman A, Schmedt C, Jegla T, Panda S. Inducible ablation of melanopsin-expressing retinal ganglion cells reveals their central role in non-image forming visual responses. PLoS One. 2008;3:e2451. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=18545654&dopt=Abstract [PMC free article] [PubMed] [Google Scholar]

33. Lupi D, Oster H, Thompson S, Foster RG. The acute light-induction of sleep is mediated by OPN4-based photoreception. Nat Neurosci. 2008;11:1068–73. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=19160505&dopt=Abstract [PubMed] [Google Scholar]

34. Altimus CM, Güler AD, Villa KL, McNeill DS, Legates TA, Hattar S. Rods-cones and melanopsin detect light and dark to modulate sleep independent of image formation. Proc Natl Acad Sci USA. 2008;105:19998–20003. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=19060203&dopt=Abstract [PMC free article] [PubMed] [Google Scholar]

35. Tsai JW, Hannibal J, Hagiwara G, Colas D, Ruppert E, Ruby NF, Heller HC, Franken P, Bourgin P. Melanopsin as a sleep modulator: circadian gating of the direct effects of light on sleep and altered sleep homeostasis in Opn4 (−/−. mice. PLoS Biol. 2009;7:e1000125. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=19513122&dopt=Abstract [PMC free article] [PubMed] [Google Scholar]

36. Muindi F, Zeitzer JM, Colas D, Heller HC. The acute effects of light on murine sleep during the dark phase: importance of melanopsin for maintenance of light-induced sleep. Eur J Neurosci. 2013;37:1727–36. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=23510299&dopt=Abstract [PMC free article] [PubMed] [Google Scholar]

37. LeGates TA, Altimus CM, Wang H, Lee HK, Yang S, Zhao H, Kirkwood A, Weber ET, Hattar S. Aberrant light directly impairs mood and learning through melanopsin-expressing neurons. Nature. 2012;491:594–8. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=23151476&dopt=Abstract [PMC free article] [PubMed] [Google Scholar]

38. Aytürk DG, Castrucci AM, Carr DE, Keller SR, Provencio I. Lack of Melanopsin Is Associated with Extreme Weight Loss in Mice upon Dietary Challenge. PLoS One. 2015;10:e0127031. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=26011287&dopt=Abstract [PMC free article] [PubMed] [Google Scholar]

39. Barnard AR, Hattar S, Hankins MW, Lucas RJ. Melanopsin regulates visual processing in the mouse retina. Curr Biol. 2006;16:389–95. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=16488873&dopt=Abstract [PubMed] [Google Scholar]

40. Zhang DQ, Wong KY, Sollars PJ, Berson DM, Pickard GE, McMahon DG. Intraretinal signaling by ganglion cell photoreceptors to dopaminergic amacrine neurons. Proc Natl Acad Sci USA. 2008;105:14181–6. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=18779590&dopt=Abstract [PMC free article] [PubMed] [Google Scholar]

41. Brainard GC, Hanifin JP, Greeson JM, Byrne B, Glickman G, Gerner E, Rollag MD. Action spectrum for melatonin regulation in humans: evidence for a novel circadian photoreceptor. J Neurosci. 2001;21:6405–12. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=11487664&dopt=Abstract [PMC free article] [PubMed] [Google Scholar]

42. Thapan K, Arendt J, Skene DJ. An action spectrum for melatonin suppression: evidence for a novel non-rod, non-cone photoreceptor system in humans. J Physiol. 2001;535:261–7. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=11507175&dopt=Abstract [PMC free article] [PubMed] [Google Scholar]

43. Najjar RP, Chiquet C, Teikari P, Cornut PL, Claustrat B, Denis P, Cooper HM, Gronfier C. Aging of non-visual spectral sensitivity to light in humans: compensatory mechanisms? PLoS One. 2014;9:e85837. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=24465738&dopt=Abstract [PMC free article] [PubMed] [Google Scholar]

44. Lockley SW, Brainard GC, Czeisler CA. High sensitivity of the human circadian melatonin rhythm to resetting by short wavelength light. J Clin Endocrinol Metab. 2003;88:4502–5. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=12970330&dopt=Abstract [PubMed] [Google Scholar]

45. Rüger M, St Hilaire MA, Brainard GC, Khalsa SB, Kronauer RE, Czeisler CA, Lockley SW. Human phase response curve to a single 6.5 h pulse of short-wavelength light. J Physiol. 2013;591:353–63. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=23090946&dopt=Abstract [PMC free article] [PubMed] [Google Scholar]

46. Gooley JJ, Rajaratnam SM, Brainard GC, Kronauer RE, Czeisler CA, Lockley SW. Spectral responses of the human circadian system depend on the irradiance and duration of exposure to light. Sci Transl Med. 2010;2:31ra33. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?

cmd=Retrieve&db=PubMed&list_uids=20463367&dopt=Abstract [PMC free article] [PubMed] [Google Scholar]

47. Lockley SW, Gooley JJ. Circadian photoreception: spotlight on the brain. Curr Biol. 2006;16:R795–7. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=16979545&dopt=Abstract [PubMed] [Google Scholar]

48. Viola AU, James LM, Schlangen LJ, Dijk DJ. Blue-enriched white light in the workplace improves self-reported alertness, performance and sleep quality. Scand J Work Environ Health. 2008;34:297–306. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=18815716&dopt=Abstract [PubMed] [Google Scholar]

49. Rahman SA, Flynn-Evans EE, Aeschbach D, Brainard GC, Czeisler CA, Lockley SW. Diurnal spectral sensitivity of the acute alerting effects of light. Sleep. 2014;37:271–81. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=24501435&dopt=Abstract [PMC free article] [PubMed] [Google Scholar]

50. Najjar RP, Wolf L, Taillard J, Schlangen LJ, Salam A, Cajochen C, Gronfier C. Chronic artificial blue-enriched white light is an effective countermeasure to delayed circadian phase and neurobehavioral decrements. PLoS One. 2014;9:e102827. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=25072880&dopt=Abstract [PMC free article] [PubMed] [Google Scholar]

51. Vandewalle G, Gais S, Schabus M, Balteau E, Carrier J, Darsaud A, Sterpenich V, Albouy G, Dijk DJ, Maquet P. Wavelength-dependent modulation of brain responses to a working memory task by daytime light exposure. Cereb Cortex. 2007;17:2788–95. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=17404390&dopt=Abstract [PubMed] [Google Scholar]

52. Vandewalle G, Schmidt C, Albouy G, Sterpenich V, Darsaud A, Rauchs G, Berken PY, Balteau E, Degueldre C, Luxen A, Maquet P, Dijk DJ. Brain responses to violet, blue, and green monochromatic light exposures in humans: prominent role of blue light and the brainstem. PLoS One. 2007;2:e1247. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=18043754&dopt=Abstract [PMC free article] [PubMed] [Google Scholar]

53. Daneault V, Hébert M, Albouy G, Doyon J, Dumont M, Carrier J, Vandewalle G. Aging reduces the stimulating effect of blue light on cognitive brain functions. Sleep. 2014;37:85–96. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=24381372&dopt=Abstract [PMC free article] [PubMed] [Google Scholar]

54. Chang AM, Aeschbach D, Duffy JF, Czeisler CA. Evening use of light-emitting eReaders negatively affects sleep, circadian timing, and next-morning alertness. Proc Natl Acad Sci USA. 2015;112:1232–7. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=25535358&dopt=Abstract [PMC free article] [PubMed] [Google Scholar]

55. Glickman G, Byrne B, Pineda C, Hauck WW, Brainard GC. Light therapy for Seasonal Affective Disorder with blue narrow-band light-emitting diodes (LED. Biol Psychiatry. 2006;59:502–7. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=16165105&dopt=Abstract [PubMed] [Google Scholar]

56. Roecklein KA, Rohan KJ, Duncan WC, Rollag MD, Rosenthal NE, Lipsky RH, Provencio I. A missense variant (P10L. of the melanopsin (OPN4. gene in seasonal affective disorder. J Affect Disord. 2009;114:279–85. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=18804284&dopt=Abstract [PMC free article] [PubMed] [Google Scholar]

57. Roecklein KA, Wong PM, Miller MA, Donofry SD, Kamarck ML, Brainard GC. Melanopsin, photosensitive ganglion cells, and seasonal affective disorder. Neurosci Biobehav Rev. 2013;37:229–39. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=23286902&dopt=Abstract [PMC free article] [PubMed] [Google Scholar]

58. Gordijn MC, 't Mannetje D, Meesters Y. The effects of blue-enriched light treatment compared to standard light treatment in Seasonal Affective Disorder. J Affect Disord. 2012;136:72–80. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=21911257&dopt=Abstract [PubMed] [Google Scholar]

59. Ayaki M, Muramatsu M, Negishi K, Tsubota K. Improvements in sleep quality and gait speed after cataract surgery. Rejuvenation Res. 2013;16:35–42. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=23145881&dopt=Abstract [PMC free article] [PubMed] [Google Scholar]

60. Mainster MA. Violet and blue light blocking intraocular lenses: photoreception versus photoreception. Br J Ophthalmol. 2006;90:784–92. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=16714268&dopt=Abstract [PMC free article] [PubMed] [Google Scholar]

61. Ayaki M, Negishi K, Suzukamo Y, Tsubota K. Color of intra-ocular lens and cataract type are prognostic determinants of health indices after visual and photoreceptive restoration by surgery. Rejuvenation Res. 2015;18:145–52. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=25526429&dopt=Abstract [PMC free article] [PubMed] [Google Scholar]

62. Sletten TL, Revell VL, Middleton B, Lederle KA, Skene DJ. Age-related changes in acute and phase-advancing responses to monochromatic light. J Biol Rhythms. 2009;24:73–84. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=19227580&dopt=Abstract [PubMed] [Google Scholar]

63. Wenzel A, Grimm C, Samardzija M, Reme CE. Molecular mechanisms of light-induced photoreceptor apoptosis and neuroprotection for retinal degeneration. Prog Retin Eye Res. 2005;24:275–306. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=15610977&dopt=Abstract [PubMed] [Google Scholar]

64. Organisciak DT, Vaughan DK. Retinal light damage: mechanisms and protection. Prog Retin Eye Res. 2010;29:113–34. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=19951742&dopt=Abstract [PMC free article] [PubMed] [Google Scholar]

65. Ham WT, Ruffolo JJ, Mueller HA, Clarke AM, Moon ME. Histologic analysis of photochemical lesions produced in rhesus retina by short-wave-length light. Invest Ophthalmol Vis Sci. 1978;17:1029–35. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=100464&dopt=Abstract [PubMed] [Google Scholar]

66. Ruffolo JJ, Ham WT, Mueller HA, Millen JE. Photochemical lesions in the primate retina under conditions of elevated blood-oxygen. Invest Ophthalmol Vis Sci. 1984;25:893–8. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=6746232&dopt=Abstract [PubMed] [Google Scholar]

67. Jaffe GJ, Irvine AR, Wood IS, Wood IS, Severinghaus JW, Pino GR, Haugen C. Retinal phototoxicity from the operating microscope: the role of inspired oxygen. Ophthalmology. 1988;95:1130–41. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=3068607&dopt=Abstract [PubMed] [Google Scholar]

68. Dillon J. The photophysics and photobiology of the eye. J Photochem Photobiol B. 1991;10:23–40. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=1955945&dopt=Abstract [PubMed] [Google Scholar]

69. Organisciak DT, Winkler BS. Retinal light damage: practical and theoretical considerations. Prog Retin Eye Res. 1994;13:1–29. [Google Scholar]

70. Sparrow JR, Nakanishi K, Parish CA. The lipofuscin fluorophore A2E mediates blue light-induced damage to retinal pigmented epithelial cells. Invest Ophthalmol Vis Sci. 2000;41:1981–9. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=10845625&dopt=Abstract [PubMed] [Google Scholar]

71. Rózanowska M, Jarvis-Evans J, Korytowski W, Boulton ME, Burke JM, Sarna T. Blue light-induced reactivity of retinal age pigment. In vitro generation of oxygen-reactive species. J Biol Chem. 1995;270:18825–30. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=7642534&dopt=Abstract [PubMed] [Google Scholar]

72. Rózanowska M, Wessels J, Boulton M, Burke JM, Rodgers MA, Truscott TG, Sarna T. Blue light-induced singlet oxygen generation by retinal lipofuscin in non-polar media. Free Radic Biol Med. 1998;24:1107–12. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=9626564&dopt=Abstract [PubMed] [Google Scholar]

73. Pawlak A, Rozanowska M, Zareba M, Lamb LE, Simon JD, Sarna T. Action spectra for the photoconsumption of oxygen by ocular lipofuscin and lipofuscin extracts. Arch Biochem Biophys. 2002;403:59–62. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=12061802&dopt=Abstract [PubMed] [Google Scholar]

74. Noell WK, Walker VS, Kang BS, Berman S. Retinal damage by light in rats. Invest Ophthalmol Vis Sci. 1966;5:450–73. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=5929286&dopt=Abstract [PubMed] [Google Scholar]

75. Sykes SM, Robison WG, Waxler M. Kuwabara T. Damage to the monkey retina by broad-spectrum fluorescent light. Invest Ophthalmol Vis Sci. 1981;20:425–34. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=7216664&dopt=Abstract [PubMed] [Google Scholar]

76. Noell WK, Albrecht R. Irreversible effects on visible light on the retina: role of vitamin A. Science. 1971;172:76–9. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=5546288&dopt=Abstract [PubMed] [Google Scholar]

77. Organisciak DT, Noell WK. The rod outer segment phospholipid/opsin ratio of rats maintained in darkness or cyclic light. Invest Ophthalmol Vis Sci. 1997;16:188–90. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=832982&dopt=Abstract [PubMed] [Google Scholar]

78. Williams TP, Howell WL. Action spectrum of retinal light-damage in albino rats. Invest Ophthalmol Vis Sci. 1983;24:285–7. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=6832904&dopt=Abstract [PubMed] [Google Scholar]

79. Ham WT, Mueller HA, Ruffolo JJ, Clarke AM. Sensitivity of the retina to radiation damage as a function of wavelength. Photochem Photobiol. 1979;29:735–43. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=109869&dopt=Abstract [PubMed] [Google Scholar]

80. Van Norren D, Schellekens P. Blue light hazard in rat. Vision Res. 1990;30:1517–20. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=2247961&dopt=Abstract [PubMed] [Google Scholar]

81. Rapp LM, Smith SC. Evidence against melanin as the mediator of retinal phototoxicity by short-wavelength light. Exp Eye Res. 1992;54:55–62. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=1541341&dopt=Abstract [PubMed] [Google Scholar]

82. Grimm C, Wenzel A, Williams TP, Rol P, Hafezi F, Remé C. Rhopopsin-mediated blue-light damage to the rat retina: Effect of photoreversal of bleaching. Invest Ophthalmol Vis Sci. 2001;42:497–505. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=11157889&dopt=Abstract [PubMed] [Google Scholar]

83. Williams TP. Photoreversal of rhopospin bleaching. J Gen Physiol. 1964;47:679–89. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=14127606&dopt=Abstract [PMC free article] [PubMed] [Google Scholar]

84. Keller C, Grimm C, Wenzel A, Hafezi F, Remé C. Protective effect of halothane anesthesia on retinal light damage: inhibition of metabolic rhodopsin regeneration. Invest Ophthalmol Vis Sci. 2001;42:476–80. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=11157886&dopt=Abstract [PubMed] [Google Scholar]

85. Steinberg RH. Survival factors in retinal degenerations. Curr Opin Neurobiol. 1994;4:515–24. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=7812140&dopt=Abstract [PubMed] [Google Scholar]

86. Tan E, Ding XQ, Saadi A, Agarwal N, Naash MI, Al-Ubaidi MR. Expression of cone-photoreceptor-specific antigens in a cell line derived from retinal tumors in transgenic mice. Invest Ophthalmol Vis Sci. 2004;45:764–8. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=14985288&dopt=Abstract [PMC free article] [PubMed] [Google Scholar]

87. Arnault E, Barrau C, Nanteau C, Gondouin P, Bigot K, Viénot F, Gutman E, Fontaine V, Villette T, Cohen-Tannoudji D, Sahel JA, Picaud S. Phototoxic action spectrum on a retinal pigment epithelium model of age-related macular degeneration exposed to sunlight normalized conditions. PLoS One. 2013;8:e71398. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=24058402&dopt=Abstract [PMC free article] [PubMed] [Google Scholar]

88. Kuse Y, Ogawa K, Tsuruma K, Shimazawa M, Hara H. Damage of photoreceptor-derived cells in culture induced by light emitting diode-derived blue light. Sci Rep. 2014;4:5223. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=24909301&dopt=Abstract [PMC free article] [PubMed] [Google Scholar]

89. Noell WK. Effects of environmental lighting and dietary vitamin A on the vulnerability of the retina to light damage. Photochem Photobiol. 1979;29:717–23. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=451011&dopt=Abstract [PubMed] [Google Scholar]

90. Lawwill T. Effects of prolonged exposure of rabbit retina to low-intensity light. Invest Ophthalmol. 1973;12:45–51. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=4691946&dopt=Abstract [PubMed] [Google Scholar]

91. Lawwill T, Crockett S, Currier G. Retinal damage secondary to chronic light exposure, thresholds and mechanisms. Doc Ophthalmol. 1977;44:379–402. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=413705&dopt=Abstract [PubMed] [Google Scholar]

92. Griess GA, Blankenstein MF. Additivity and repair of actinic retinal lesions. Invest Ophthalmol Vis Sci. 1981;20:803–7. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=7195384&dopt=Abstract [PubMed] [Google Scholar]

93. Organisciak DT, Jiang YL, Wang HM, Pickford M, Blanks JC. Retinal light damage in rats exposed to intermittent light. Comparison with continuous light exposure. Invest Ophthalmol Vis Sci. 1989;30:795–805. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=2722438&dopt=Abstract [PubMed] [Google Scholar]

94. Penn JS, Naash ML, Anderson RE. Effect of light history on retinal antioxidants and light damage susceptibility in the rat. Exp Eye Res. 1987;44:779–88. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=3653273&dopt=Abstract [PubMed] [Google Scholar]

95. O'Steen WK, Anderson KV, Shear CR. Photoreceptor degeneration in albino rats: dependency on age. Invest Ophthalmol Vis Sci. 1974;13:334–9. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=4823176&dopt=Abstract [PubMed] [Google Scholar]

96. Imamura Y, Noda S, Hashizume K, Shinoda K, Yamaguchi M, Uchiyama S, Shimizu T, Mizushima Y, Shirasawa T, Tsubota K. Drusen, choroidal neovascularization, and retinal pigment epithelium dysfunction in SOD1-deficient mice: a model of age-related macular degeneration. Proc Natl Acad Sci USA. 2006;103:11282–7. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=16844785&dopt=Abstract [PMC free article] [PubMed] [Google Scholar]

97. Ozawa Y, Sasaki M, Takahashi N, Kamoshita M, Miyake S, Tsubota K. Neuroprotective effects of lutein in the retina. Curr Pharm Des. 2012;18:51–6. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=22211688&dopt=Abstract [PMC free article] [PubMed] [Google Scholar]

98. Duncan TE, O'Steen WK. The diurnal susceptibility of rat retinal photoreceptors to light induced damage. Exp Eye Res. 1985;41:497–507. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=4085578&dopt=Abstract [PubMed] [Google Scholar]

99. White MP, Fisher LJ. Degree of light damage to the retina varies with time of day of bright light exposure. Physiol Behav. 1987;39:607–13. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=3588706&dopt=Abstract [PubMed] [Google Scholar]

100. Organisciak DT, Darrow RM, Barsalou L, Kutty RK, Wiggert B. Circadian-dependent retinal light damage in rats. Invest Ophthalmol Vis Sci. 2000;41:3694–701. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=11053264&dopt=Abstract [PubMed] [Google Scholar]

101. Vaughan DK, Nemke JL, Fliesler SJ, Darrow RM, Organisciak DT. Evidence for a circadian rhythm of susceptibility to retinal light damage. Photochem Photobiol. 2002;75:547–53. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=12017483&dopt=Abstract [PubMed] [Google Scholar]

102. Wong P, Organisciak DT, Ziesel AC, Chrenek MA, Patterson ML. (Circadian effects on retinal light damage. In: The Retina and Circadian Rhythms 2014; (Eds G. Tosini, P.M. Iuvone, D.G. McMahon and S.P Collin. pp131–170. Springer. [Google Scholar]

103. Fukuhara C, Liu C, Ivanova TN, Chan GC, Storm DR, Iuvone PM, Tosini G. Gating of the cAMP signaling cascade and melatonin synthesis by the circadian clock in mammalian retina. J Neurosci. 2004;24:1803–11. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=14985420&dopt=Abstract [PMC free article] [PubMed] [Google Scholar]

104. Humphries A, Carter DA. Circadian dependency of nocturnal immediate-early protein induction in rat retina. Biochem Biophys Res Commun. 2004;320:551–6. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=15219864&dopt=Abstract [PubMed] [Google Scholar]

105. Andley UP, Chylack LT. Recent Studies on photodamage to the eye with special reference to clinical and therapeutic procedures. Photodermatol Photoimmunol Photomed. 1990;7:98–105. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=2081122&dopt=Abstract [PubMed] [Google Scholar]

106. Boulton M, Rozanowska M, Rozanowski B. Retinal Photodamage. J Photochem Photobiol B. 2001;64:144–61. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=11744401&dopt=Abstract [PubMed] [Google Scholar]

107. Chu R. Blue light irradiation inhibits the production of HGF by human retinal pigment epithelium cells in vitro. Photochem Photobiol. 2006;82:1247–50. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=16740060&dopt=Abstract [PubMed] [Google Scholar]

108. Margrain TH, Boulton M, Marshall J, Sliney DH. Do blue light filters confer protection against age-related macular degeneration? Prog Retin Eye Res. 2004;23:523–31. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=15302349&dopt=Abstract [PubMed] [Google Scholar]

109. Wolf G. Lipofuscin and macular degeneration. Nutr Rev. 2003;61:342–6. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=14604266&dopt=Abstract [PubMed] [Google Scholar]

110. Sparrow JR, Boulton M. RPE lipofuscin and its role in retinal photobiology. Exp Eye Res. 2005;80:595–606. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=15862166&dopt=Abstract [PubMed] [Google Scholar]

111. Delori FC, Goger DC, Dorey CK. Age-related accumulation and spatial distribution of lipofuscin in RPE of normal subjects. Invest Ophthalmol Vis Sci. 2001;42:1855–66. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=11431454&dopt=Abstract [PubMed] [Google Scholar]

112. Thomas BB, Seiler MJ, Aramant RB, Samant D, Qiu G, Vyas N, Arai S, Chen Z, Sadda SR. Visual functional effects of constant blue light in a retinal degenerate rat model. Photochem Photobiol. 2007;83:759–65. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=17115798&dopt=Abstract [PubMed] [Google Scholar]

113. Cruickshanks KJ, Klein R, Klein BEK. Sunlight and age-related macular degeneration—the Beaver Dam Eye Study. Arch Ophthalmol. 1993;111:514–8. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=8470986&dopt=Abstract [PubMed] [Google Scholar]

114. Klein R, Klein BEK, Jensen SC, Cruickshanks KJ. The relationship of ocular factors to the incidence and progression of age-related maculopathy. Arch Ophthalmol. 1998;116:506–13. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=9565051&dopt=Abstract [PubMed] [Google Scholar]

115. Algvere PV, Marshall J, Seregard S. Age-related maculopathy and the impact of blue light hazard. Acta Ophthalmol Scand. 2006;84:4–15. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=16445433&dopt=Abstract [PubMed] [Google Scholar]

116. Taylor HR, Muñoz B, West S, Bressler NM, Bressler SB, Rosenthal FS. Visible light and risk of age-related macular degeneration. Trans Am Ophthalmol Soc. 1990;88:163–73. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=2095019&dopt=Abstract [PMC free article] [PubMed] [Google Scholar]

117. Taylor HR, West S, Munoz B, Rosenthal FS, Bressler SB, Bressler NM. The long-term effects of visible-light on the eye. Arch Ophthalmol. 1992;110:99–104. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=1731731&dopt=Abstract [PubMed] [Google Scholar]

118. Darzins P, Mitchell P, Heller RF. Sun exposure and age-related macular degeneration—an Australian case-control study. Ophthalmology. 1997;104:770–6. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=9160021&dopt=Abstract [PubMed] [Google Scholar]

119. Okuno T, Saito H, Ojima J. Evaluation of blue-light hazards from various light sources. Dev Ophthalmol. 2002;35:104–12. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=12061267&dopt=Abstract [PubMed] [Google Scholar]

120. Narimatsu T, Ozawa Y, Miyake S, Kubota S, Yuki K, Nagai N, Tsubota K. Biological effects of blocking blue and other visible light on the mouse retina. Clin Experiment Ophthalmol. 2014;42:555–63. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=24304494&dopt=Abstract [PubMed] [Google Scholar]

121. Baba K, Pozdeyev N, Mazzoni F, Contreras-Alcantara S, Liu C, Kasamatsu M, Martinez-Merlos T, Strettoi E, Iuvone PM, Tosini G. Melatonin modulates visual function and cell viability in the mouse retina via the MT1 melatonin receptor. Proc Natl Acad Sci USA. 2009;106:15043–8. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=19706469&dopt=Abstract [PMC free article] [PubMed] [Google Scholar]

122. Sakamoto K, Liu C, Kasamatsu M, Iuvone PM, Tosini G. Intraocular injection of kainic acid does not abolish the circadian rhythm of arylalkylamine N-acetyltransferase mRNA in rat photoreceptors. Mol Vis. 2006;12:117–24. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&list_uids=16518309&dopt=Abstract [PubMed] [Google Scholar]

Are LED Streetlights Disrupting Your Sleep?

Many municipalities have switched to LED streetlights to save energy and money. But the change still comes at a cost.

BY ELIZABETH DAIGNEAU / JULY 6, 2016

New LED-based streetlights are whiter than traditional ones and contain more blue light, which can disrupt people's circadian rhythms. FLICKR/MELTEDPLASTIC

When asked about his favorite energy-efficiency innovation, Binghamton, N.Y., Mayor Richard David answered, "LED lighting." The mayor, who was speaking on a panel last month at the annual Energy Efficiency Forum in Washington, D.C., had recently wrapped up a $4 million project that replaced the city's roughly 7,000 streetlights with energy-efficient LED fixtures.

David is far from alone in admiring LEDs. Their remarkable efficiency has made them extremely popular among eco-advocates as well as cash-strapped municipalities looking to save on long-term costs. It's estimated that about 10 percent of the country's streetlights are now outfitted with light-emitting diodes. In the case of Binghamton, the new streetlights will reduce carbon dioxide emissions by 3 million pounds a year -- the equivalent of getting 301 cars off the road -- and will save the city $5.2 million in electricity and $1 million in maintenance costs over 15 years.

But by working to prevent one kind of pollution, cities have inadvertently exacerbated another: light pollution.

Binghamton's new LED fixtures shine six to seven times brighter than traditional streetlights. According to the American Medical Association (AMA), the bright, white light cast off is bad for a person's health and for the environment. In June, the AMA declared LED streetlights a public health risk. According to the group, the strong bluish tint, which appears white to the naked eye, interferes with the production of the hormone melatonin, causing sleep disorders in humans. Studies further suggest that excessive exposure to LED light at night increases the risk for obesity, diabetes, cardiovascular disease and cancer. LEDs also confuse nocturnal species, disrupt migratory birds and, according to scientists in the United Kingdom, could cause spring to come earlier -- or, at least, trick plants into thinking that spring is coming earlier.

But all LEDs aren't a problem. Rather, it's the type that's the issue. Because they're less expensive, cities have generally opted to install "white" LEDs. That's the kind, says the AMA, that impacts sleeping patterns and makes it harder to see clearly because of glare. Instead, the AMA recommends adopting LEDs with a yellow tint.

The AMA's statement last month already has one city reconsidering LEDs. Officials in Eugene, Ore., which just finished converting nearly 5,000 streetlights to LEDs, said they'll review their program. Public Works spokesman Brian Richardson told the local newspaper that while it's "still too new for us to be able to make any decisions, we will evaluate the guidance statement and determine the best direction to proceed."

Even before the AMA released its warning, cities were already running into protests from residents who felt LEDs were too bright. In 2014, only a month after installing white LED streetlights, Davis, Calif., spent hundreds of thousands of dollars switching to a warmer LED fixture after a loud outcry from residents.

Similarly, Phoenix is in the middle of outfitting all 90,000 of its streetlights with LEDs. But complaints from residents about the harsh, white lights led the city to conduct a survey that wrapped up last month. Phoenix now says it'll consider installing yellow LEDs instead.

The AMA also recommends ensuring streetlights are directed downward and shielded. Right now, "a lot of [lighting] is unshielded, which means that it's allowed to go in all directions, including up into the sky where it doesn't do anybody any good," said Paul Bogard, author of *The End of Night: Searching for Natural Darkness in an Age of Artificial Light*.

Several cities and states have laws that mandate how brightly a place should be lit and how it should be lit. Measures like those, as well as best practices and other resources on combating light pollution, are catalogued by the International Dark-Sky Association, which Bogard recommends as a valuable clearinghouse for any government interested in more information. "Light isn't the problem," says Bogard. "It's how we're using it."

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(338-339)

LED streetlights may contribute to 'serious health conditions' says AMA, prompting cities to re-evaluate

By Amelia Taylor-Hochberg | Sep 26, '16 1:16 PM EST

LED lights used in a public courtyard. Image via pixabay.com

> *high-intensity LED streetlights ... emit unseen blue light that can disturb sleep rhythms and possibly increase the risk of serious health conditions, including cancer and cardiovascular disease. [...]*
>
> *Some [researchers] noted that exposure to the blue-rich LED outdoor lights might decrease people's secretion of the hormone melatonin. Secreted at night, melatonin helps balance the reproductive, thyroid and adrenal hormones and regulates the body's circadian rhythm of sleeping and waking.* — washingtonpost.com

While the American Medical Association cautions cities to re-evaluate their use of high-intensity LED lights for health reasons, others have pointed out that most televisions and computers also emit the blue light wavelength found to be potentially harmful. Aside from human health concerns, LEDs are also "a major contributor" to anthropogenic light pollution in the night sky.

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AMA Report Affirms Human Health Impacts from LEDs

on JUNE 21, 2016

This photo shows the divide between East and West Berlin that is still visible at night from space. On the left are the gas lamps of the West and on the right, the orange high-pressure sodium lamps of the East, with a stark contrast between them. The image is a powerful reminder that lighting choices made by city planners are long lasting.

A groundbreaking report recently released by the American Medical Association (AMA) Council on Science and Public Health affirms known and suspected impacts to human health and the environment caused by light emitting diodes (LEDs) that emit excessive amounts of blue light.

The AMA report, titled "Human and Environmental Effects of Light Emitting Diode Community Lighting," unanimously approved by representatives of the Association's entire membership, supports concerns raised by the International Dark-Sky Association for more than five years. The report presents significant implications for the ongoing, worldwide transition to LEDs as the outdoor lighting technology of choice.

"The AMA's study not only provides additional rigorous scientific evidence to buttress IDA's longstanding efforts to raise awareness of the potential hazards of blue-rich light, but also speaks to the bold leadership that the medical community has consistently demonstrated on this critical human health and environmental issue," IDA Executive Director J. Scott Feierabend noted.

IDA's 2010 white paper, "Visibility, Environmental, and Astronomical Issues Associated with Blue-Rich White Outdoor Lighting," detailed the threats associated with exposure to blue-rich white light sources.

While the AMA report supports the use of LED lighting in order to reduce energy consumption and the use of fossil fuels, it recognizes that some LED lights are harmful. The report details findings from an increasing body of scientific evidence that implicates exposure to blue-rich white light at night to increased risks for cancer, diabetes and cardiovascular disease.

Not only is blue-rich white LED street lighting five times more disruptive to our sleep cycle than conventional street lighting, according to the report, but recent large surveys have documented that brighter residential nighttime lighting is associated with reduced sleep, impaired daytime functioning and a greater incidence of obesity.

As a result of a potential risk to public health from excess blue light exposure, the AMA report encourages attention to optimal design and engineering features when converting from existing lighting technologies to LED. These include requiring properly shielded outdoor lighting, considering adaptive controls that can dim or extinguish light at night, and limiting the correlated color temperature (CCT) of outdoor lighting to 3000 Kelvin (K) or lower. Color temperature is a measure of the spectral content of light, and higher CCT values indicate a greater amount of blue light that a fixture emits.

In 2014, IDA revised its Fixture Seal of Approval (FSA) guidelines to limit blue light emission by outdoor lighting by lowering the acceptable color temperature for approved lighting products to 3000K or below. The IDA FSA program provides third-party certification for lighting that minimize glare and light pollution, and reduce light trespass.

The AMA findings also underscore the fact that detrimental effects of blue-rich LED lighting are not limited to humans. “Other species are just as vulnerable to disruption of their circadian rhythms as are humans, and often more so,” explained Travis Longcore, Ph.D., Assistant Professor of Architecture, Spatial Sciences, and Biological Sciences at the University of Southern California. “Those impacts and others can be reduced by limiting blue-light emissions. Policy makers, government officials, and the American public now have the science and the imprimatur of the AMA to insist that LED installations be designed to reduce impacts on wildlife and human health.”

In 2009 the AMA unanimously adopted a resolution endorsing the use of fully shielded street lighting to minimize nighttime glare, and in 2012 it released a comprehensive report expanding its position on glare and addressing the impact of light at night on human health. The 2016 report represents the first time the organization has focused specifically on LED technology.

“The AMA has a long history and strong record of developing sound, science-based policy on lighting and human health, and adoption of these guidelines builds on that tradition,” explained Dr. Mario Motta, report coauthor and former IDA board member, and past president of the Massachusetts Medical Society. “Our hope is that municipalities will use the report’s guidelines when considering the adoption of LED street lighting, making their communities safer for both humans and wildlife.”

The AMA announcement comes on the heels of the recent publication of the “World Atlas of Artificial Night Sky Brightness,” a groundbreaking study cautioning that street lighting and outdoor lighting retrofits using 4000K lamps could result in a 2.5-fold increase in lighting pollution. The finding is significant both for lighting retrofits in industrialized economies, as well as first-time lighting installations in economies beginning the transition to industrialization.

“This is a timely and important policy statement by the AMA,” said Richard Stevens, Ph.D., a cancer epidemiologist at the University of Connecticut School of Medicine and coauthor of the report. “As with most new technology, everyone is enamored at first because it’s so great and does so much for us, but the downsides eventually become apparent. Electric light has great attributes, but we now realize, when poorly used and abused, there are also many problems.”

You Can Make a Difference

The publication of the AMA report and the “World Atlas” provide a great opportunity to contact your public officials about combating light pollution. Learn how.

TOWN OF HIGHLANDS STREETLIGHT PETITION

Blue-white LED streetlights will not save very much money. Compared to the cost to health, and well-being they may wind up costing money. Humans and animals are not designed to be exposed to daylight frequencies at night.

The town's lighting choices should be based on existing and emerging science about the negative effects of blue light on human health and the environment. This includes increased cancer risk, unpleasant glare and intensity, and damaging effects on the eye's retina, sleep quality, hormones and the well-being of wildlife.

The town should maintain our yellow sodium lights and replace broken mercury lights with them as the town did before. The yellow sodium lights provide clear visibility in all weather without being too bright and contain no harmful daylight frequencies.

Right now, when a light breaks, O&R replaces it with a blue-white LED light. Individuals should have the right to tell O&R they want the same yellow light if their streetlight breaks.

Meanwhile, the Town should commit to investigating the less harmful orange-amber LED lights (less harmful than blue-white LED lights) as this technology improves over time. Then we can consider whether they are a better solution than the existing yellow sodium vapor lights.

Name	Street Address	email (optional)	phone (optional)
1. Margaret J Wort	21 Drew Rd	jeanwo[illegible]aol.com	
2. R E McConnell	30 Franklin St		8454462266
3. Joseph W. Gentile III			518-653-8601
4. [illegible] D'T[illegible]	38 Bellevue		
5. Alaina Seney	32 Cherry St		
6. [illegible]	78 Forest Hill Rd F.M. NY		
7. Noreen [illegible]	30 Wildwood Rdg Ft Montgomery		
8. [illegible]	43 Cozzens Ave HF NY		
9. Lauren Gables	149 Canterbury Rd. NY		
10. Charisse Jackson		Rissybaby7@aol.com	

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	Name	Street Address	email (optional)	phone (optional)
1.	Stan Goldblatt	60 Weyant Rd		
2.	Alexandra Hammill	4 Kreiger Rd.		
3.	[illegible]	23 Kreiger Rd		
4.	[illegible]	11 Laurel Ln. HF NY.		
5.	Joseph [illegible]	14 Jacla Ln NY		
6.	[illegible]	29 Cozzens Ave		
7.	Karen Wilson	104 Canterbury Rd.		
8.	Rod Wilson	104 Canterbury Rd.		
9.	[illegible]	33 Montgomery Rd		
10.	James Craven	65 mine dock rd.		

2

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	Name	Street Address	email (optional)	phone (optional)
1.	Conner Craven	40 Mearns AVe	conner.craven91@gmail.com	
2.	Leon Foltz	121 Fort Montgomery		
3.	Sharon Baker	23 Ondaora Park, Highland Falls NY		
4.	Donald Baker	23 Ondaora Park, High Falls, NY.		
5.	Carrie Richardson	21 Kleitz Highland Falls		
6.	Melissa Nolan	33 Drew Ave Highland falls		
7.	Brenda Gallardo	160 old State Rd HF		
8.	Gabrielle Gallardo	160 Old State Rd HF		
9.	Darrell Shimshoni	106 Forest Hill Rd.		
10.	Steven Walker	106 Forest Hill Rd.		

3

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	Name	Street Address	email (optional)	phone (optional)
1.	[illegible]	114 Owens Farm Rd [illegible]		
2.	Marianne Ramos	50 Cosbom Hill Rd		516 641 0387
3.	Dome Raffy	77 Weyant Rd		914-262-8788
4.	John [illegible]	101 Canterbury Rd.		
5.	M. Marcello	7 Bridge Terrace		845-664-3068
6.	[illegible]	54 Weyant Rd		914-319-5803
7.	Mari Carmen Afis	6 Deer Run Trail		845-258-0570
8.	Alberto Baruti	16 Lakeview Drive		845-652-3636
9.	Kenya Otey	8 Saint Marks Place		
10.	Anton Grim	17 River Crest		845-507-2122

4

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Name	Street Address	email (optional)	phone (optional)
1. [illegible]	28 South St		
2. Walter K Willi	116 Canterbury Rd		
3. Tiffany Raport	22 RIVERCREST RD		
4. [illegible]	20 St. MARKS Place		
5. [illegible]	210 Canterbury rd		
6. Joe Planck	20 Cherry St, Ft Montgomery		
7. Denise Delaney	96 Firefighters Mem Dr Ft Montgomery		
8. James Voltaire	PO Box 736 30 Canterbury Rd. Fort Montgomery NY 10922		
9. Clint McKinley	PO Box 74 Ft. Montgomery NY 10922		
10. Jim McCabe	P.O. 298 Ft. Montgomery NY 10922		

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	Name	Street Address	email (optional)	phone (optional)
1.	Don MacLeod	14 Grove Place		
2.	Bernard Cassidy	17 Drew Rd.		
3.	[illegible]	18 Overlook Pl		
4.	[illegible] Buchholz	7 Highland Ave.		
5.	[illegible]	11 Fulton Rd		
6.	John Mayer	5 Wildwood Ridge, FM		
7.	JARED TAGAND	74 FIREFIGHTER MEMORIAL DR		
8.	Robert [illegible]	50 Dry Creek Rd. FM		
9.	Diana Molinile	50 Dry Creek Road, F.M.		
10.	[illegible] Shilebr	25 Kirkman WAY, F.M.		

6

TOWN OF HIGHLANDS STREETLIGHT PETITION

Blue-white LED streetlights will not save very much money. Compared to the cost to health, and well-being they may wind up costing money. Humans and animals are not designed to be exposed to daylight frequencies at night.

The town's lighting choices should be based on existing and emerging science about the negative effects of blue light on human health and the environment. This includes increased cancer risk, unpleasant glare and intensity, and damaging effects on the eye's retina, sleep quality, hormones and the well-being of wildlife.

The town should maintain our yellow sodium lights and replace broken mercury lights with them as the town did before. The yellow sodium lights provide clear visibility in all weather without being too bright and contain no harmful daylight frequencies.

Right now, when a light breaks, O&R replaces it with a blue-white LED light. Individuals should have the right to tell O&R they want the same yellow light if their streetlight breaks.

Meanwhile, the Town should commit to investigating the less harmful orange-amber LED lights (less harmful than blue-white LED lights) as this technology improves over time. Then we can consider whether they are a better solution than the existing yellow sodium vapor lights.

	Name	Street Address	email (optional)	phone (optional)
1.	Jeffrey D. Peterson	PO Box 188 23 Dry Creek	jdp0510@gmail	
2.	Catharine M Sheldon		Coardens4353@aol.com	446 4353
3.	[illegible]	P.O. Box 211		
4.	James Garrett	P.O. Box 211		
5.	[illegible]	PO Box 709		
6.	Kyle D Wallace	PO Box 334		
7.	[illegible]	PO Box 334		
8.	[illegible]			
9.	[illegible]	78 FOREST HILL RD		
10.	R.W. [illegible]	Box 484		

7

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	Name	Street Address	email (optional)	phone (optional)
1.	Victor Campagna	5 Fa Hi. Rd		446-3595
2.	Susan Salazar	POB 787 Ft.M.		
3.	Karen Parashkevov	POB 787		
4.	Rose Ott	POB 575		
5.	Guy Yoon	PO B 304		
6.	[illegible]	PO. Box 279 Ft M.		
7.	Greg Dyson	PO Box 817 Ft Montgomery		
8.	Karen Dyson	PO Box 817 F.M.		
9.	P Cl[illegible]	31 Dry Creek Rd		
10.	Trish K[illegible]	" " "		

8

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Name	Street Address	email (optional)	phone (optional)
1. Susan Crandall	8 Eagle Crest		
2. [illegible]	6 Eagle Crest		
3. [illegible] Mulhare	4 Deer Run Trail		
4. [illegible]	2 Deer Run Trail		
5. [illegible]	105 Weyant Road		
6. [illegible]	"		
7. Karan Mazonheimer	94 Weyant Rd.		914) 837-9522
8. Kathy Ripa	34 Bridge Terr, FM, NY 10922		
9. JAMES Ripa	34 Bridge Terr. FM NY 10922		
10. Katharine [illegible]	28 Owens Farm Road FM, NY 10922		

9

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Name	Street Address	email (optional)	phone (optional)
1. Thomas Kwietniak	34 Dry Creek Road	tkwietniak@yahoo.com	
2. KEITH KWIETNIAK	34 DRY CREEK RD		
3. Elaine McCann	30 Franklin St. Ft Montgomery		
4. [illegible]	94 Weyant Ft M.		
5. Jennifer Pushlar	83 Weyant Pl. F.M.	jennifer.pushlar@gmail.com	
6. [illegible]	117 FOREST HILL RD FM.		
7. [illegible]	"	"	
8. [illegible]	"	"	
9. [illegible] Cassano	26 Fawnwood LN.		
10. Camille Cassano	26 Fawnwood Ln		

10

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Name	Street Address	email (optional)	phone (optional)
1. Robert Shaffer 22 Fawnwood Lane Fort Montgomery NY 10922			
2. Cathy McCutchen 23 Beattie Pond Rd Fort Montgomery NY 10922			
3. Pamela Mayer 5 Wildwood Ridge Fort Montgomery NY 10922			
4. Kirk Manning 13 Wildwood Ridge Fort Montgomery NY 10920			
5. Vincent J. Rush 71 Wildwood Ridge Ft Montgomery 10922			
6. Patrice Biehle 41 Wildwood Ridge Ft. Mont, NY 10922			
7. Chris Kelly 30 Wildwood Ridge Fort Montgomery, N.Y. 10922			
8. Paul J. Pizzaccio 25 wildwood ridge Fort Mont, NY 10922			
9. K Pizzaccio 25 Wildwood ridge FM NY 10922			
10. Ben Briello 35 Torne Rd.			

11

Exhibit 4 NYPA email re: Orange LED lights (354-355)

RE: NYPA program info.

From: Scott, Jesse (jesse.scott@nypa.gov)

To: deborah_kopald@ymail.com

Date: Sunday, July 21, 2019, 07:50 PM EDT

No orange LEDs in neighborhoods.

> **From:** Deborah Kopald <deborah_kopald@ymail.com>
> **Sent:** Friday, July 19, 2019 6:54 PM
> **To:** Scott, Jesse <Jesse.Scott@nypa.gov>
> **Subject:** Re: NYPA program info.
>
> in a neighborhood?
>
> On Friday, July 19, 2019, 05:35:25 PM EDT, Scott, Jesse <Jesse.Scott@nypa.gov> wrote:
>
> No we cannot install orange LEDs on a roadway.
>
> Jesse
>
> On Jul 19, 2019, at 4:35 PM, Deborah Kopald <deborah_kopald@ymail.com> wrote:
>
>> What if we want an Orange LED light? can you accommodate?
>>
>> On Tuesday, July 16, 2019, 01:56:04 PM EDT, Scott, Jesse <Jesse.Scott@nypa.gov> wrote:

Jesse Scott

Manager, Customer Business Development

New York Power Authority

123 Main Street

White Plains, NY 10601

(914) 390-8107 (office)

(914) 265-0674 (cell)

Jesse.Scott@nypa.gov

www.nypa.gov

Page 4 News of the Highlands Friday, September 4, 2015

Dear Editor,

ESCO Energy services pitched a wireless dimmable LED streetlighting system to the village. Also, Mobilitie solicited the town to place cell transmitters on utility poles.

When wireless transmitting equipment is put at street level in close proximity to peoples' homes, businesses and areas they frequent, the radiation levels are much higher because radiation is mostly a factor of proximity to the transmitter -- more so than total power output. Putting radiation-emitting transmitters in the commons creates serious Constitutional violations, subjecting them to eventual removal.

In May, CBS News reported that 5 percent of the population are now intolerant to Wi-Fi (these power densities are also commensurate with being too close to a cell transmitter) and hence are functionally impaired. The 2008 amendments to the Americans with Disabilities Act (ADA) include functional impairments of the type people experience from too close proximity to wireless transmitters. While many Americans have not made the connection between symptoms and the sensitizing irritants, complaints to government agencies and the courts demanding accommodation have commenced including a lawsuit filed in August in U.S. District Court in Worcester, Mass.

Over two dozen international appeals by scientists to reduce wireless expansion have been made; the most recent one calls these exposures a public health crisis: https://www.emfscientist.org/. Also, the Harvard Safra Foundation Center for Ethics released a report that documents how the FCC, which is in charge of setting regulations, is wholly captured by the corporations it is supposed to regulate: http://ethics.harvard.edu/files/center-for-ethics/files/capturedagency_alster.pdf

The front line to correct this problem and heed the dire warnings lies with our local government officials.

Dimmable LED lights create high frequency transients and therefore line pollution that affects the human body. The wireless component of these systems can blanket streets with pulse-modulated microwave radiation; the least severe consequences would be perturbed sleep for some people, and the LED light itself is an irritant for some.

The street transmitter system used in San Francisco can create exposures to levels of radiation than are up to 138,000 times the outer boundary of the Building Biology Institute's lower threshold of severe concern and up to 230,000 times the amount of radiation found to cause sleeping disorders, depressive tendencies, concentration difficulties and cardiovascular problems in exposed subjects. (See: Oberfeld, G. et al. The Microwave Syndrome: Further Aspects of a Spanish Study. International Conference Proceedings, Kos, Greece, 2004.)

Please see charts and graphs, etc. backing up my claims here: http://wirelessrighttoknow.com/alerts/exhibits-for-streetlights-and-das-letter

Deborah Kopald

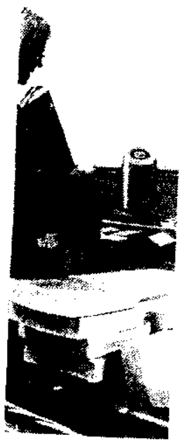

Photo by MJ Pitt
ghlands' Ruthie
ver 200 bags of

Dear MJ,

I really appreciate how the Village Board is run; they engage with people who raise questions and pro-actively work to get practical solutions.

Revisiting the issue of the wireless LED dimmable lights I wrote about two weeks ago and which was discussed at last week's Village Board meeting. (Exhibits and Letter are here: http://wirelessrighttoknow.com/alerts/exhibits-for-streetlights-and-das-letter/), there are three problems of varying degrees:

1) The LED lights may be too bright (they cause retinal toxicity and at the least could be too bright for those living on Main Street: people in cities have complained that the LEDs on police cruisers and highways can be irritating.)

2) The dimmability component cause line pollution including high frequency transients, harmonics, swells and swags. This pollution is a new concept for almost everyone, but it has to be understood as a clear and present danger to public health the way one would consider a chemical pollutant or black mold. Please review this powerpoint presentation from Stetzer Electric, one of the nation's leading experts, for more detailed explanations: http://media.stetzerelectric.com/Stetzerizer-Presentation.pptx

3) The wireless component to the system can flood the street with pulse-modulated microwaves such that those in certain buildings would have levels as if they were close by a cell tower.

The Village Board asked me to participate in future discussions with ESCO Energy Services to assess options. The problem with ESCO, like other new companies offering "solutions", is that the salesman told me he didn't know about specs and emissions. He promised to find the person in the company who could answer the questions but never did.

Often employees don't know the answers and the company management -- if they bother to answer-will trot out platitudes about emissions being within FCC limits, which allow the public to be irradiated up to a million times the lower boundary of severe concern identified by the International Institute for Building Biology and Ecology.

The line pollution issue is understood by only a few companies and the military, which has developed an expertise in filtering it, so as not to interfere with their equipment. (People need to be thinking about interference with human cells, not just our technical gadgets).

The village should not consider doing any business with a company that cannot or will not answer these questions. I discussed some legal issues in my last letter; ESCO likely will not be responsible post-sale.

Deborah Kopald

Dear MJ,

The other week, the Village announced they commissioned a request for proposal on new street-lighting, but fortunately added that they weren't committing to a project yet.

I would like to re-urge the village to stick with the current incandescent lights or if they want new lights, to use other incandescents that don't run off a wireless system.

I discussed the problems with LED lights and wireless system last fall and posted the exhibits and the original letter here: http://wireless-righttoknow.com/alerts/exhibits-for-streetlights-and-das-letter/

On June 14th, the American Medical Association (AMA) issued a policy position that states LED lighting can cause discomfort and disability through glare and retinal toxicity. http://www.ama-assn.org/ama/pub/news/news/2016/2016-06-14-community-guidance-street-lighting.page. They state:

"*High-intensity LED lighting designs emit a large amount of blue light that appears white to the naked eye and create worse nighttime glare than conventional lighting. Discomfort and disability from intense, blue-rich LED lighting can decrease visual acuity and safety, resulting in concerns and creating a road hazard.*

In addition to its impact on drivers, blue-rich LED streetlights operate at a wavelength that most adversely suppresses melatonin during night. It is estimated that white LED lamps have five times greater impact on circadian sleep rhythms than conventional street lamps. Recent large surveys found that brighter residential nighttime lighting is associated with reduced sleep times, dissatisfaction with sleep quality, excessive sleepiness, impaired daytime functioning and obesity."

The AMA goes on to suggest that if LED lights are used that they be shielded and dimmed during off-peak use. As previously discussed, dimmable LED lights create electromagnetic pollution, so the best course of action is not to use them at all.

The policy statement also talks about the detrimental effects on wildlife.

To the people who live on Main Street, I say, please pay attention to the AMA position. Once LED lights are put on Main Street, it will be costly and difficult to sue for diminished "sleep quality, excessive sleepiness, impaired daytime functioning and obesity." Also, understand that melatonin is not just important for proper sleep but also for repair to fix DNA damage to prevent cancer.

As a general comment, by the time the AMA gets around to acknowledging a problem, the science behind it is incontrovertible, so if they issue a warning, you can take it to the bank that something poses a real health risk.

To the village, I say not only "don't fix it if it ain't broke", but don't break it when it didn't need to be fixed to begin with.

Deborah Kopald

MJ,

It is dismaying to read that Bill Edsall wants to "fix" a problem that does not exist by creating new problems and wasting taxpayer dollars in the process through another proposed Wi-Fi and lights scheme.

The current lights in the town are sufficiently bright and have not been a source of complaints. Furthermore they utilize natural light. LED lights would light up the town like a runway. To get a glimpse, go to the McDonald's south parking lot in the evening to see how bright these lights would be. As I have documented in previous letters, they are known to cause retinal toxicity and dimmable LED lights cause EMF pollution on wiring.

Bill has been resistant to hearing from townspeople who have said that cell towers need to go in appropriate areas and that there is a real issue regarding radiation emissions even if that cannot be the reason for citing decision due to preemption. Every few years we repeat this to him, and he acts as if he has never heard it before. Public Wi-Fi will expose people to more radiation than they would get from cell towers.

No preemption exists with this optional Wi-Fi and light scheme. Furthermore, it will create violations of the Fair Housing Act and the Americans with Disabilities Act if rolled out as he proposes. In 2007, a toxicologist produced a report for then San Francisco Mayor Gavin Newsome warning of the public health hazard city-wide Wi-Fi would create:

Recently, Maryland's Children's Environmental Health and Protection Advisory Council (CEHPAC) called for schools to be hard-wired. The international scientists whose work was the basis for IARC 2b carcinogenicity designation of cell phone radiation put out the Reykjavik Appeal which called for the removal of Wi-Fi in schools. (The former head of Microsoft Canada and the American Academy of Medicine echo this call).

Headed to publication to add to the wide body of literature on microwave radiation effects, biochemist Martin Pall has penned, "Wi-Fi as a Very Substantial Threat to Human Health". At the same time Sacramento Superior Court is forcing the CA Dept. of Health to release its squelched cell phone guidance and the 9th Circuit Court of Appeals rejected the industry's bid to squelch the city of Berkeley's cell phone warning law.

Given what is going on, no responsible municipal official should be promoting more rollouts of microwave radiation in public.

Deborah Kopald

LED lights

"Some people like them and some people don't." That's how Highland Falls Deputy Mayor Jim Ramus described the new lights Orange & Rockland has installed in several locations in the village.

"There are more to come, and they don't cost us a dime," he said of the new style of streetlights. "And they lower our electric costs."

LED lights shine more brightly -- and white -- than traditional light bulbs.

LED streetlights were discussed

By MARY JANE PITT

Town Councilman Richard Sullivan said at a recent Town Board meeting that he continues the work of former Councilman Bill Edsall with regards to changing to LED street lights in Fort Montgomery.

"I've been studying it," he said, "and think it may make more sense for bigger communities to buy streetlights than it would for us. But, there are programs within Orange & Rockland to replace old fixtures with LED fixtures as they die."

Edsall had looked at a program where the municipality buys the lights from the utility company and assumes all maintenance. Highland Falls had also looked at a similar program. There are programs in the state set up to do just that (NYSERDA's Mid-Hudson Street Light Consortium, for instance) with funding available to help.

But, while there are potential savings related to owning the lights instead of paying rent on them, Sullivan said, the town would need to also purchase a bucket truck to do that maintenance, as well as hire a dedicated linesman to take care of them.

He said savings would come way down the road, if at all.

"One size does not fit all," Deputy Supervisor June Gunza said.

Supervisor Bob Livsey added that he's not even completely sure that people in Fort Montgomery want the bright LED lights ... they are significantly brighter than traditional street lights.

"Maybe we like our 'country roads' the way they are," the supervisor said.

Dear Editor,

Thank the Town Board members who questioned the wisdom of the purchase and rollout of LED lights.

ANSES, the French Agency for Food, Environmental and Occupational Health & Safety states "The issues of most concern identified by the Agency concern the eye due to the toxic effect of blue light and the risk of glare."

The American Medical Association states "some LED lights are harmful when used as streetlights" and cites their negative effect on sleep quality. Blue light suppresses the production of melatonin, which is the hormone that the sleep-wake cycle. Depressed melatonin is linked with the development and promotion of breast and prostate cancer. Breast cancer is well known to be caused by high estrogen levels, and melatonin happens to be an aromatase inhibitor, which means it lowers estrogen.

The Harvard School of Public Health reported in 2015 that chronic exposure to blue light, which reaches deep into the eye, is also associated with retinal cell damage and age-related macular degeneration (AMD) and says that exposure to this kind of light at night is related to several types of cancer, diabetes, heart disease and obesity and in 2017 conducted a study that shows that exposure to residential outdoor light at night contributes to invasive breast cancer risk. This finding reinforced a 2008 Israeli study finding a 75% higher breast cancer risk in communities with LED lights versus those without these lights. A recent Spanish study reinforced the permanent damage to the eye from exposure to this light, which dilates pupils.

As bright as these lights are, Harvard sleep researcher Stephen Lockley notes, "Even dim light can interfere with a person's circadian rhythm and melatonin secretion. A mere eight lux -- a level of brightness exceeded by most table lamps and about twice that of a night light -- has an effect".

In Davis, California, city leaders spent $350,000 to replace hundreds of LED streetlights after residents complained a mere month after installation. Residents in Brooklyn have complained that it feels like a film crew is outside their apartment buildings.

And... a recent Netherlands study found LED lights were bleaching the paint on the works of Van Gogh and Cezanne.

Finally when the bulbs break, a hazmat cleanup is required because of the copper and nickel which the U.S. Agency for Toxic Substances and Disease Registry defines as toxic: also twenty percent of the population is allergic to nickel.

Deborah Kopald

LETTERS

Dear Editor,

A few months ago I wrote a lengthy letter about the serious problem with LED lights -- in sum- that Davis, Calif. spent $350K ripping them out after residents were irritated by them, ophthalmologists and optometrists have written memoranda asserting they are dangerous -- which were used to reject them in parts of Long Island.

Studies from Harvard and international universities show they damage the retina, cause sleep disorders and raise breast cancer risk by depressing melatonin.

The French say they should only be in industrial settings (they aren't apparently appropriate - even in museums, where they bleached a Van Gogh). The American Medical Association (AMA) came out against them. The U.S. federal government also recognizes they create a hazmat situation when they break.

Why is Town Board member Richie Sullivan championing them and bringing in industry to talk them up at the Town Board meeting on April 8th?

At any rate, the Town Board has offered to host Patricia Wood, executive director of Grassroots Environmental Education to present these risks. People can get the full story beyond the corporate advertorial that way.

Deborah Kopald

a

would like to thank Mayor Joe sharing Pearl Popper's poem. It a very endearing poem. The fact t she could share recognition of town so eloquently brings a ling of pride to our community. hank you Joe.

Anne Burley

---

ar Editor,

is letter addresses the article lished in the April 5 News, tled "Main St. symposium ned this month". It states that mayor is inviting local leaders organizations, as well as out-of-n agencies to a Main St. posium at 1 p.m. on Wednesday, l 24.

e article closes stating "those ing to attend should contact the or at 446-3400 ext 22".

n invitation letter addressed to nds of Highland Falls', he ks of the "village's unrealized ntial ... and we have had certain s that have held us back". He er states "a lack of vision, and limited resources have nted growth and transforma-. Also mentioned "was work-ith Hudson Design ... using 12 ously done studies". One has k, where have you been, Mr. r, having served over 22 years yor and you are now address-e numerous studies conducted years ago?

nyone who has been involved goings on in the village, it is ent that the many studies were d by his administrations. One say that he did not have the ght to realize the potential he of. Many residents wanted improvements, but they were ed from realizing the initiatives oposed, for whatever reason.

sponse to the invitation "those g to attend", a number of .... members of the community responded, but were informed that the meeting was closed and only those specifically invited by the mayor might attend; that the public would be advised of the results of the meeting at a later date -- which also means they would not have input.

I submit that many of the 'public'/taxpayers are very knowledgeable of past village goings on -- through time -- and may very well have participated "in some of the 12 previously done studies", be it the Glynwood or Marina studies or others.The out-of-town invitees are a very select group, many of which participated in the earlier marina or other studies, but they do not pay taxes in this community. In my view, keeping all but a few chosen citizens out of a very critical meeting pertaining to the future of the village is not only short-sighted, but insulting to the taxpayers of the village.

Hopefully the mayor will reverse his position and open the meeting to those concerned residents who would like to attend. I submit, they doubtless will contribute toward the end result.

Ray Devereaux

Dear MJ:

According to new research published in the journal Atmospheric Chemistry and Physics: despite significant improvements, 71,000 air pollution-related deaths in 2010 translates to one out of every 35 deaths in the U.S. that year -- as many as from traffic accidents and gun shootings combined.

In Europe, nearly 400,000 people a year die prematurely because of poor air quality according to the European Union.

I don't think a day goes by when there is a weather event on the news that I associate with climate change.

The stories about plastics in our oceans are heart breaking.

Monday April 22 is Earth Day: I ask the residents of our Town to take a moment and think about what we can each do to make a better future for our children and our planet.

Bill Edsall

Dear Editor,

Because I have not lived in Highland Falls for decades, I have refrained from responding to any of the letters to the editor, but Deborah Kopald's misrepresentations about LED bulbs need to be addressed.

Although most of her assertions are wrong or flimsy, her claim that the American MEdical Association "came out against them" is dead wrong. It also undercuts all of her other wild claims. The AMA supported LEDs.

Sunlight has its dangers. All or almost all artificial lights have problems. Unshielded red LEDs present unique problems. Almost all museums and galleries use soft, reflected light to minimize UV damage and use 'museum' glass to block UV rays.

I am the president of the 85-year-old Print Club of Albany and its Museum of Prints and Print Making and I know how to avoid UV rays. We have a collection of more than 18,000 prints and take very good care of them.

There is no debate that LEDs are vastly more energy efficient than compact flourescent lights, and LEDs do not contain mercury, like CFLs. Mercury is very harmful.

A GOOGLE search shows lot of articles with positives and negatives about LEDs, but the positives far outweigh the negatives, and the negatives can be mitigated.

Joe Galu

(I am not employed by any part of the LED industry.)

Dear Editor,

With reference to Joe Galu's letter, I reiterate the following:

In my December letter, I stated:

'The American Medical Association states "some LED lights are harmful when used as streetlights" and cites their negative effect on sleep quality. Blue light suppresses the production of melatonin, which is the hormone that the sleep-wake cycle relies upon. Depressed melatonin is linked with the development and promotion of breast and prostate cancer. Breast cancer is well known to be caused by high estrogen levels, and melatonin happens to be an aromatase inhibitor, which means it lowers estrogen.'

In my March letter, which refers to my December letter's arguments in brief, I said that the AMA came out against LED lights. While it was a simplification of what I wrote in December, it is an accurate statement in the context of using typical blue-white LED lights (which is the default LED streetlight). The AMA does say that if you are going to use them, use shielded ones and the lowest emissions; make no mistake they assert that most commercially sold LED lights are "harmful". So, Mr. Galu's claim that I am "dead wrong" is inaccurate.

He also confuses UV radiation (which is invisible) with the specific properties of blue-white light, which as documented is linked with sleep problems, retinal toxicity and breast cancer. (FYI, LED lights do emit some UV light).

There are many studies including some from Harvard documenting this. The town extended an invitation to Patti Wood of Grassroots Environmental Education to speak about LEDs. I will submit my own written report with citations.

Anyone with common sense and curiosity can read the literature and discuss their conclusions; they do not need to be a review editor in Frontiers in Public Health's Radiation and Health section as I am. However, if one doesn't read the studies, one cannot intelligently discuss the harm and certainly one cannot credibly claim this evidence does not exist.

As for Google, it has its limits, but if used properly, one can find the Washington Post's "Some Cities are Taking Another Look at LED lighting after AMA Warning".

This except is on point:

"These lights aren't just bad for us," said Mario Motta, one of the authors of the AMA report, "they're bad for the environment, too."'

My other claims in my letters also stand and are incontrovertibly supported by studies and substantiated reports.

Deborah Kopald

Dear Mary Jane

Many people have said that LED lights are energy efficient. The problem is, they are not people efficient.

A cheap light that causes eye damage, disrupts people's sleep patterns, contributes to rising rates of breast cancer (because it stimulates too much estrogen production), and is damaging to the health of people in our town who are sensitive to it, is not cheap, and is not efficient.

For myself, even looking at the little LED lights in electronic equipment feels like suddenly being stabbed in the eye with a laser.

I do not understand why, in this time of economic stress for so many people, we need to spend all this money on the latest thing, when the lights we have now work very well, and do not cause people health problems.

Consider that Montsanto was just successfully sued for billions of dollars for their product (Glyphosate) that caused cancer. Do we want lawsuits here from the women who live here who suddenly find that the town has an increased rate of breast cancer?

A lot of new technology ideas are terrific. LED lights are a new technology that looks good up front, and is terribly costly to our eyes, our bodies and our lives. It's a high price to pay for a few kilowatts of electricity. And the resulting medical costs will be brutally expensive.

Furthermore, it is absurd to think that the equivalent intensity/temperature of an LED streetlight is similar to the existing light, some people will still be affected by the LED's unnatural effects on the human eye and body.

Janet Wilkie

Send your letters to newsofthehighlands@gmail.com

Dear Editor,

It's time to celebrate America! Just a week until the 4th of July!

For the past 51 years our 4th of July has been an All-American celebration of our country, our community and our freedom. For the last 30 years I, along with the committee, have sought to make this a gigantic focus of all things that unite us as a community.

This year's theme is 'Our Community - One Mission - Working Together'. I would like to ask the community not to make many out-of-town plans on July 3 and 4. There will be lots to do here for all ages.

To the Committee: Your service is invaluable. For months you added the burden of huge events to your already busy schedules. The words pride and commitment only begin to describe you.

Two quotes I would like to end with: Helen Hayes, the first lady of American theater, would attend our celebration. She once said "here in Highland Falls is the best celebration in America". And Col. Dan Bruno, our 2009 grand marshal, said "simply the best of small town USA, with the biggest patriotic heart".

Being biased, of course they are right!

Joseph E. D'Onofrio
Mayor

Dear Editor,

I continue to maintain that the introduction of permanent sources of blue light to our environment is an environmental problem for both humans and animals and that we should not be worshipping at the altar of energy efficiency to the extent that we replace something safe for human physiology, with an unsafe irritant – in this case replacing a yellow-only light with sources of blue. Humans are not designed to be exposed to daylight frequencies at night. Sodium vapor or mercury lights mimic candlelight and fire and are preferable to the incandescents, the most natural source used indoors.

At Monday's Town Board meeting I provided many studies showing the negative effects of blue light on sleep, melatonin and cancer development; there is a reason why a plethora of articles have popped up warning people to limit or eliminate their exposure to this light before bedtime, including an article this week where a two-year old child's eyes were permanently damaged from exposure to blue light from a tablet.

There are orange/amber LEDs that have been rolled out in Flagstaff, Ariz. and are used in Yosemite National Park. I gave a link to specs for an orange LED light from Osram. I spoke to Neptun today and they are awaiting a demo chip from China that purports to eliminate any remaining traces of blue light.

The technology of LEDs is still evolving and can be made much safer. We should not commit to a NYPA-sponsored investment without investigating all alternatives, including considering maintaining what we now have and watching as the technology evolves and improves. I also provided specs for a low color-temperature blue light that is superior to the one NYPA is offering in terms of the reduction of this toxin.

NYPA's one size fits all offering used in Kingston and Nyack is not the best option for our town. I also urge a demonstration of lights - perhaps in the park next to Garrison pond where people can compare and contrast the lights' quality.

The level of safety should not be considered to be where the least number of people are irritated, but should be below that line as blue light is injuring people at levels where they are tolerating it.

Deborah Kopald

Basketball, streetlights, taxes & more

Busy meeting for Board

By MARY JANE PITT

The Town Board dealt with a handful of important topics at its meeting on Monday. The board has a busy summer ahead, because most of the issue remain unresolved as the board awaits more information before acting.

On the agenda were:

LED Lights

The board has sat through several presentations on the possibility of changing over streetlights in Fort Montgomery to LED lights. On Monday, Fort Montgomery's Deborah Kopald presented the board members with a 22 page report, urging them to not just go ahead with an LED lighting project because it will cost less.

"Money should not be the overwhelming factor," she said as she handed them a compilation of reports lamenting the "obnoxious blue lights". She noted that Fort Montgomery is "nestled in a state park" and LED lights would change the natural lighting the community now enjoys.

"It's us, it's the animals. We would all like a good night's sleep," she said.

Councilman Richard Sullivan, who has been investigating the switch to LED lights agreed that if a switch to new streetlights does happen, everyone agrees that lower end kelvin number lights would be used. But, he did add that right now the town pays about $45,000 a year for the electricity to run its streetlights.

"We'd expect to have a positive cash flow of about $3000 a year for the eight years we are paying off new lights," he said, "and then once we do own them, we'd pay $20,000 a year less for lighting."

Use of the Sacred Heart Gym

The town currently uses the Sacred Heart Church gymnasium for its lower-age youth basketball league in the winter, and for adult yoga classes. For that, the town pays Sacred Heart Parish $500 for the season.

see BUSY MEETING page 3

Busy meeting for Board...

continued from page 1

Recreation Director Aaron Falk said he'd like to continue to use it again this summer (July an August) for Friday night open gym and a youth theatre program, and asked the board permission to offer the Sacred Heart Parish $1500 to do that. He said he was not sure the church would accept the offer, noting it recently faced a very large expense in repairing its heating system in the old school building which houses the gym.

Councilman Tyrone King spoke in favor of the payment to the church, calling it "a pillar of the community that we need to support".

"The municipality should find ways to help strengthen them," King said, saying that he believes more use of the building will help it remain viable.

Tax Reduction

The board, via attorney Justin Rider, responded to a letter received by the board from the Village Board expressing concern in the town's willingness to reduce the assessment of Key Bank by $250,000. Rider explained that while the Town Board did vote to accept a proposal to lower the assessment for one year -- because the building is sitting empty right now -- the School Board still has not, so it is not a done deal yet.

Rider went on to say, however, that by coming to an agreement with Key Bank for the short term will eliminate court costs if the matter were to proceed into a tax certiorari case. As the agreement stands, he said, it will cost the town "less than $1250" in a tax refund to Key Bank, and the school district about $5000.

"The cost of a trial-ready appraisal alone could cost between $6000 and $8000," Rider said.

The letter from the Village Board, signed by Mayor Joe D'Onofrio, said: "The assessed value of the property today remains the same as the purchase price paid in 2012 -- $1,250,000. It has not been increased by (the assessor's) office, and in our opinion, should not be decreased by the Board of Assessment Review."

Parking Lot

Supervisor Bob Livsey suggested to the board that the 'unofficial' parking lot across from the Post Office in Fort Montgomery "is becoming abused", with commercial vehicles being parked there for long periods of time. He asked that Rider create a local law establishing the lot as a municipal lot, with rules and regulations, and then signage be put up. He said the parking lot is "getting lots of use, which is great -- hikers, people going to the churches -- but they can't use it if there are boats and trailers parked in it".

LETTERS

Send your letters to newsofthehighlands@gmail.com

Dear Editor,

My wife and I moved to Fort Montgomery from Brooklyn to raise our family. We love living nestled in a state park and the clean air and environment, relaxed pace of life and our pleasant and quiet neighbors.

In comparison, Brooklyn had a lot of pollution, including noise and light pollution.

We are adamantly against blue-white LED lights being installed. The orange and yellow lights in our neighborhood do not irritate the eyes and are pleasing. I also walk at night a lot and feel that the existing old lights provide enough illumination to see without being overly bright.

On one of the streets in my neighborhood, Canterbury Road, where lights had broken, they put in bright blue white LEDs as replacement. The contrast is glaring; the old lights are superior.

Talking to other people, I find many have similar complaints about blue-white LEDs inside their home. They strain the eyes both inside the home and out.

All blue-white LED lights are much brighter than the current lights they would be replacing.

I favor the status quo, but if the town is going to switch to LED lights, they should use something that mimics the current color, which would be an orange amber LED light.

I enjoy living here and don't want to see it turned into Brooklyn and lit up like a runway. We are better served living in harmony with nature and we shouldn't take something that works and create a new set of problems.

These blue-white LED lights mimic day light, which should not be introduced into such a beautiful nature setting. Introducing these lights to this environment would be a huge step backward.

Steven Walker

With vote, a move toward LED lights

Town Board acted on Monday

By MARY JANE PITT

With a 4-0 vote on Monday evening, the Town Board has set in motion a plan to replace the existing mercury vapor and sodium vapor streetlights in Fort Montgomery with LED lights.

The motion made was to have Councilman Richard Sullivan contact the New York Power Authority (NYPA) and begin the action of turning what's now a proposal into a contract for LED lighting for Fort Montgomery.

The vote was 4-0 because Councilman Tyrone King was absent from the meeting.

The move came after the board heard from a NYPA representative several months ago about a lighting project that could be done here -- financed by NYPA and immediately resulting in annual savings on the town's annual cost of electricity, Sullivan said. The board also heard from two different people -- Grassroots Environmental Education's Patti Wood and Fort Montgomery's Deborah Kopald -- about risks they say are associated with LED lights.

"And I'm aware that right now there is a petition being circulated in Fort Montgomery against the change," Sullivan said.

Sullivan noted that he knows the switchover probably won't be "smooth sailing".

"It's a different type of lighting, and sometimes change upsets people," he said.

Sullivan has spent the better part of a year researching the use of LED lights in communities, including visiting others who have made the switch. He's often urged other board members and community residents to do the same.

The first step in the process, he said, after a contract signing, will most likely be letting Orange and Rockland know that the town intends to take ownership of its utility poles.

;hts

@gmail.com

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ɔe this past week, ittle local business

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.vorite things right ıbly not the smart- write about store- tory in this week's the O'Dells occa- :.)

ıf a variety as The ry, chocolate chip, ter chip, chocolate lla swirl, coconut :olate chip, orange y, vanilla bean and :at way to cool off m. That flavor also sicles at my grand-

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LETTERS

Send your letters to newsofthehighlands@gmail.com

Dear Editor,

The Town Board still doesn't get it.

With little time spent, 110 people signed a petition stating they do not want blue white LED lights. That includes the O&R slow replacement schedule -- people want to keep the existing yellow and orange lights and have the town investigate orange-amber LED lights.

The Town has been very clear long before they voted that they will be seeking the blue-white LED's irrespective of any evidence or public opinion presented to them. Damn the torpedoes, people will get used to it!

What I have heard repeatedly from people of all ages is that they don't like indoor LED lights, are irritated by the new LED headlights, are annoyed by neighbors' LED floodlights and that "the Town doesn't listen and will do whatever they want".

The Town signed a pre-contract to deal with NYPA that could create fees of 27.5% for the project and additional audit fees. The supervisor would not allow discussion of this pre-contract after failing to properly list it on the agenda and then cancelled public comment saying they were going into executive session. It was therefore also not surprising to hear from people regarding the futility of trying to oppose things at meetings.

The Town's point person on climate change, Ms. Anderson, suggested that NYPA be allowed to do a pilot. What she did not understand then was that NYPA is not offering the color temperature lights that the people of Fort Montgomery, who will be saddled with this project, are demanding and that the Town isn't interested in a pilot, they want to move ahead permanently.

The Town also passed a resolution, with no notice, that may be an ex post facto justification to take certain actions to reduce climate change. Ms. Anderson asked to write a $75K grant to do a study, a large amount (out of a $6M budget) that one councilperson rightly questioned.

Since the meeting, Ms. Anderson, who does not live in Fort Montgomery, now takes the Town Board's position with a new argument that there is not uniformity of light color in the Fort.

A climate change accounting should consider negative externalities of technologies proposed as well as carbon sinks; I hope she can reconsider these issues; otherwise the Town should appoint someone who can do this analysis properly and in a cost-effective way.

Barring a change of course, the voters should elect new representatives.

Deborah Kopald

NEWS BRIEFS

[redacted] On the Agenda

[redacted] Village Board

[redacted] e Village Board [redacted] meet at 7 p.m. on [redacted] nday, August 5 at [redacted] lage Hall.

Chamber meeting

[redacted] The Highlands Cham- [redacted] ber of Commerce will [redacted] meet at 4 p.m. on Thursday, Aug. 8 at Thayer Gate Deli.

Code enforcement

Philip Hannawalt has been hired as the town's new part-time Code Enforcement officer. The provisional hiring (pending Civil Service approval) began on August 1. He'll be paid $23 per hour.

New A/C

The Village Board has approved the spending of $4850 for a new air conditioning unit for the second floor meeting room of Villa...

LED streetlight process begins

Livsey can sign contract

By MARY JANE PITT

The Town Board authorized Supervisor Bob Livsey to sign a 27 page contract with the New York Power Authority last week -- it's a "starting point" with the utility company to make the switch over to LED streetlights.

The contract he will be signing does not include any financial specifics on the project, nor any specifics on the types of lights that will eventually be installed.

"This is just the basic contract -- a 'customer project commitment' -- that allows you to start negotiating," Town Attorney Justin Rider said. "For the next contract you'll have ironed out the particulars."

While the motion to allow Livsey to sign the contract was in the midst of being adopted (all four board members in attendance voted yes), Fort Montgomery's Deborah Kopald was in the audience loudly encouraging the board not to move forward with the project.

"Nobody I've talked to wants these lights, Bob," she said, as the motion passed.

Night...

continued from page 1A

safer, more caring places to live. National Night Out enhances the relationship between neighbors and law enforcement while bringing back a true sense of community. Furthermore, it provides a great opportunity to bring police and neighbors together under positive circumstances."

More information on the national effort is available at https://natw.org/

New 9W reflectors

Will help keep road safe

Assemblyman...

Exhibit 6a Email from Justin Rider, Esq. Town Attorney July 22, 2019 (373)

Fw: FOIL Request and previous FOILS

Deborah Kopald <deborah_kopald@hotmail.com>
Mon 7/22/2019 3:57 PM
To: Steven Walker <me@iamwalker.com>

1 attachments (593 KB)
Town of Highlands_ES_MCRA_2019_encrypted_ 7-15-19.pdf;

Deborah, attached is the Master Agreement. It does not contain the particulars for moving forward on LED

M. Justin Rider, Esq.
RIDER, WEINER & FRANKEL, P.C.
PO Box 2280 (mail address)
Newburgh, NY 12550

Exhibit 7a Email from Dr. Laura Fonken September 6, 2019
(374-375)

Experimental Neurology Study and email from toxicologist/pharmacologist co-author

From: Deborah Kopald (deborah_kopald@ymail.com)
To: blivsey@highlands-ny.gov; jgunza@highlands-ny.gov; rsullivan@highlands-ny.gov; rparry@highlands-ny.gov; tking@highlands-ny.gov
Cc: jrider@riderweiner.com
Date: Wednesday, September 11, 2019, 02:15 PM EDT

Dear Town Board,

Re: my letter to the paper last week, please see the attached study published in *Experimental Neurology*, as well as the below email from one of the co-authors, who is a toxicologist and pharmacologist at the University of Texas. The paper advises against blue-white LED lights in a hospital setting positing that they are a clear and present danger for patients. Please note Dr. Fonken's comment about their use as streetlights.

The first attachment is in manuscript form; the second is in published format and easier to read.

Sincerely,

Deborah

----- Forwarded Message -----
From: Fonken, Laura K <laura.fonken@austin.utexas.edu>
To: Deborah Kopald <deborah_kopald@ymail.com>
Sent: Thursday, September 5, 2019, 09:04:39 PM EDT
Subject: Re: blue white LED lights

Hi Deborah,

The International Dark Sky Association website has very helpful information on this topic (https://www.darksky.org/). The "lighting" section discusses suggestions and policies for improving lighting design in cities. I absolutely agree with you that blue-white LED lights are not the optimal design for streetlights.

Attached is a PDF of the requested article.

Please let me know if you have any additional questions.
Best,
Laura

Laura K. Fonken, Assistant Professor
Division of Pharmacology and Toxicology
University of Texas at Austin
Tel: (512) 232-8331
Web: http://sites.utexas.edu/fonken/
Email: laura.fonken@austin.utexas.edu

Fonken et al, Experimental Neuro, 2019.pdf
11.2MB

Experimental Neurology Dim Light at night impairs recovery.pdf
2.4MB

Exhibit 7b Dim light at night impairs recovery from global cerebral ischemia (376-388)

Experimental Neurology 317 (2019) 100–109

Contents lists available at ScienceDirect

Experimental Neurology

journal homepage: www.elsevier.com/locate/yexnr

Research paper

Dim light at night impairs recovery from global cerebral ischemia

Laura K. Fonken*, Tracy A. Bedrosian[1], Ning Zhang[2], Zachary M. Weil, A. Courtney DeVries[2], Randy J. Nelson[2]

Department of Neuroscience, Wexner Medical Center, The Ohio State University, Columbus, OH 43210, USA

ARTICLE INFO

Keywords:
Circadian
Light pollution
Cardiac arrest
Microglia
Neuroinflammation
Cytokines

ABSTRACT

Nighttime lighting is one of the great conveniences of modernization; however, there is mounting evidence that inopportune light exposure can disrupt physiological and behavioral functions. Hospital patients may be particularly vulnerable to the consequences of light at night due to their compromised physiological state. Cardiac arrest/cardiopulmonary resuscitation (CA) was used to test the hypothesis in mice that exposure to dim light at night impairs central nervous system (CNS) recovery from a major pathological insult. Mice exposed to dim light at night (5 lx) had higher mortality in the week following cardiac arrest compared to mice housed in dark nights (0 lx). Neuronal damage was significantly greater in surviving mice exposed to dim light at night after CA versus those housed in dark nights. Dim light at night may have elevated neuronal damage by amplifying pro-inflammatory pathways in the CNS; Iba1 immunoreactivity (an indication of microglia activation) and pro-inflammatory cytokine expression were elevated in mice exposed to dim light at night post-CA. Furthermore, selective inhibition of IL-1β or TNFα ameliorated damage in mice exposed to dim light at night. The effects of light at night on CA outcomes were also prevented by using a wavelength of nighttime light that has minimal impact on the endogenous circadian clock, suggesting that replacing broad-spectrum nighttime light with specific circadian-inert wavelengths could be protective. Together, these data indicate that exposure to dim light at night after global cerebral ischemia increases neuroinflammation, in turn exacerbating neurological damage and potential for mortality.

1. Introduction

The ability to artificially illuminate the night is one of the greatest conveniences of modernization. However, there is mounting evidence that chronic exposure to light at night can have negative health consequences including increasing the risk for developing cancer, diabetes, obesity, and heart disease (Bedrosian et al., 2016; Fonken and Nelson, 2014; Lunn et al., 2017; Stevens and Zhu, 2015). In contrast, the potential health consequences of acute exposure to light at night remain underexplored. Patients recovering in hospitals may be particularly vulnerable to inopportune light exposure as circadian disruption and sleep/wake disturbances are common after trauma (for examples see (Ayalon et al., 2007; Gaudet et al., 2018a; Gaudet et al., 2018b; Giannoccaro et al., 2013; Jain et al., 2004). We selected the cardiac arrest/cardiopulmonary resuscitation (CA) mouse model of global cerebral ischemia to test the hypothesis that light at night increases neuronal vulnerability because light at night creates a pro-inflammatory neuroenvironment (Bedrosian et al., 2013b; Fonken and Nelson, 2013) and inflammation is an important factor influencing the evolution of neurological damage after cerebral ischemia (Eltzschig and Eckle, 2011).

Global cerebral ischemia damages the central nervous system (CNS), affecting patient survival, as well as long-term cognitive performance and psychological health in survivors. Reducing mortality and minimizing CNS damage to improve patient outcome are essential goals of cardiovascular and cerebrovascular research. Importantly, the majority of permanent CNS damage resulting from cerebral ischemia is mediated by secondary processes that evolve over the first several hours to days after ischemic injury (Eltzschig and Eckle, 2011; Fu et al., 2015; Iadecola and Anrather, 2011). Although several mechanisms contribute to damage following ischemic injury, including energetic failure, excitotoxicity, and oxidative damage (reviewed in (Eltzschig and Eckle, 2011)) manipulation of inflammatory responses are considered a prime target for improving recovery. Following cerebral ischemia, an

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Received 27 July 2018; Received in revised form 12 December 2018; Accepted 12 February 2019
Available online 26 February 2019
0014-4886/

inflammatory response is triggered by activation of microglia and astrocytes with a corresponding upregulation of pro-inflammatory cytokines (Iadecola and Anrather, 2011). In particular, interleukin-1beta (IL-1β) and tumor necrosis factor alpha (TNFα) are pro-inflammatory cytokines that are upregulated within hours following global cerebral ischemia (Saito et al., 1996; Weil et al., 2008) and may remain elevated for weeks (Espinosa-Garcia et al., 2017; Norman et al., 2011), with the potential to exacerbate injury (Fu et al., 2015). The hippocampus is particularly vulnerable to delayed damage following global cerebral ischemia in both animal models (Kirino, 1982) and humans (Horn and Schlote, 1992; Petito et al., 1987). Hippocampal damage is a proxy for overall recovery, as increased hippocampal damage is associated with elevated mortality and increased behavioral deficits following global ischemia (Espinosa-Garcia et al., 2017; Neigh et al., 2009; Neigh et al., 2004; Norman et al., 2010). The trajectory of damage is likely determined within the first several hours after resuscitation, as the inflammatory response takes shape (Eltzschig and Eckle, 2011). Thus, if the recovery environment alters the inflammatory response to cerebral ischemia, then it may play an important role in influencing the extent of neuronal damage that develops following cerebral ischemia.

In particular, hospital lighting warrants examination as a factor that may influence patient recovery because light at night, to which ICU patients are commonly exposed (Durrington et al., 2017), has the potential to dysregulate circadian rhythms and thereby shift the CNS inflammatory mileu (Fonken et al., 2015; Fonken and Nelson, 2013). Light is the most potent entraining signal for the mammalian circadian clock (suprachiasmatic nuclei; SCN): extrinsic light information is conveyed from the retina to the SCN via the retinohypothalamic tract. Light input to the SCN coordinates internal signals, synchronizing daily physiological rhythms to the external light-dark cycle (Reppert and Weaver, 2002). Circadian rhythms are important for optimizing homeostatic functions, including those associated with the immune system (Lange et al., 2010). Indeed, several weeks of exposure to 5 lx of dim light at night (dLAN) elevates expression of pro-inflammatory cytokines in the brains of otherwise healthy rodents (Bedrosian et al., 2013b). However, environmental factors may influence inflammation much more rapidly; a recent laboratory study of healthy, young adults demonstrated that inverting behavioral and environmental cycles for as little as three days was sufficient to significantly increase serum concentrations of high sensitivity c-reactive protein (hsCRP; a marker of systemic inflammation) and pro-inflammatory cytokines (Morris et al., 2016). Therefore, if dim light at night promotes inflammation, then it could exacerbate outcome from CA. We hypothesized that light exposure at night would potentiate injury following CA in male mice. Consistent with our hypotheses, exposure to light at night following CA enhanced acute cytokine responses and increased neuronal death. Moreover, the effects of light at night were ameliorated by selective inhibition of IL-1β or TNFα or the use of a wavelength of nighttime light that does not activate photosensitive retinal ganglion cells.

2. Methods

2.1. Animals

8-week old male Swiss Webster mice (~30 g; Charles River, Kingston, NY) were housed in a temperature- and humidity-controlled vivarium and provided ad libitum access to food and water. Mice were left unmanipulated for > 1 week to recover from the effects of shipping and adjust to a 14:10 light/dark (LD) cycle prior to experimental manipulations. All experimental procedures were conducted in accordance with Guide for the Care and Use of Laboratory Animals and approved by the Ohio State University Institutional Animal Care and Use Committee. Efforts were made to minimize animal use and discomfort.

2.2. Cardiac arrest and cardiopulmonary resuscitation procedure

Mice were anesthetized with 3% isoflurane in air, intubated, and maintained thereafter on 1.5% isoflurane. Mice were ventilated a tidal volume of 150 µL at a respiratory rate of 160 breaths/min. Head and body temperature were monitored with temperature probes. A PE10 catheter was placed into the right jugular vein for epinephrine (EPI) and potassium chloride (KCl) administration. Blood pressure was monitored through a cannula inserted into the right femoral artery and connected to a blood pressure transducer (Columbus, Instruments). Mice were stabilized for 10 min and blood pressure and temperature recorded at 1 min intervals (Fig. S1). Following the 10 min acclimation, body and tail (but not head) temperature were lowered by circulating cold water through a coil system beneath the mouse to induce peripheral hypothermia restricting damage to the CNS during the CA/CPR procedure. CA was induced with an injection of KCL (50 µl, 0.5 M, 4 °C) into the jugular catheter and the mouse was disconnected from the ventilator. Once a body temperature of 27 °C was reached after approximately 4 min of arrest slow re-warming via a heat lamp and thermal blanket began. After 7 min 45 s of arrest, mice were reattached to the ventilator and 100% oxygen at a tidal volume of 150 µL and a respiratory rate of 160 breaths/min was ventilated. After 8 min of arrest, CPR was initiated with an injection of EPI (16 µg in 0.6 ml saline, 37 °C) into the jugular catheter and chest compressions (300/min); 0.5 µg injections of EPI were administered until the mouse resuscitated (with a maximal dose of 32 µg). Mice were maintained on 100% oxygen for 25 min after return of spontaneous circulation and catheters were removed and incisions sutured.

2.3. Lighting manipulations

Following a monitored post-operative recovery period (approximately 2 h), mice were either placed back in dark night housing room (control LD; 14 h 150 lx: 10 h 0 lx) or mice were placed in a room with a dim light at night cycle (dLAN; 14 h 150 lx: 10 h 5 lx). Both the bright and dim lights were from fluorescent light sources and consisted of 'cool white' light composed of wavelengths distributed across the visible spectrum including blue wavelengths, and light intensity was measured inside the animal cage. In the experiment involving dim red light, 5 lx of 636 nm red light was provided.

2.4. Tissue collection for staining

Seven days following the cardiac arrest/cardiopulmonary resuscitation or sham surgery, surviving mice were individually brought into a procedure room, anesthetized with isoflurane vapors and a blood sample was collected via the retro-orbital sinus. Mice then received a lethal injection of sodium pentobarbital and were perfused transcardially with ice-cold 0.1 M PBS followed by 50 ml of 4% paraformaldehyde. Brains were post-fixed overnight, cryoprotected in 30% sucrose, frozen on crushed dry ice, and stored at −80 °C. 14 µm brain sections were sliced at −22 °C using a cryostat and thaw mounted onto Super Frost Plus slides (Fisher, Hampton, NH). Sections were taken in a series of 10 slides so that all slides contained non-consecutive sections for analysis and slides were stored at −20 °C until stained with Fluoro-Jade C (FJ-C) or Iba1 using procedures already established in our lab (Weil et al., 2009). *Fluoro-Jade C*. Cell death was quantified by labeling degenerating neurons with the fluorescein derivative FJ-C (Millipore, Temecula, CA). Mounted sections were thoroughly dried on a slide warmer, immersed in a basic ethanol solution (80% EtOH with 1% NaOH) and rinsed with 70% ethanol followed by water. Slides were placed in a 0.06% potassium permanganate solution for 10 min and rinsed twice. Sections were simultaneously incubated in FJ-C (0.0001% in a 1% acetic acid solution) and counterstained with DAPI (Sigma, St. Louis). Slides were rinsed, dried, cleared in xylene, and then coverslipped with DPX (Sigma). FJ positive cells were counted in the CA1, CA3, and DG of both hippocampal (approximately −1.70 to −2.30 from Bregma, example of selected regions highlighted Fig. S2) hemispheres by a condition blind experimenter using a Nikon E800 microscope at 20× magnification. Cells were counted in two non-consecutive sections (sections were > 140 μm apart to avoid counting duplicate cells) and averaged. *Microglia*. Microglia were visualized using an Iba1 directed antibody. Slides were dried, rinsed in PBS, and blocked with bovine serum albumin (BSA). Slides were incubated at room temperature for 24 h with rabbit anti-Iba1 antibody (Wako, Richmond, VA) diluted 1:1000 in PBS containing 0.1% Triton-X and BSA. Slides were rinsed and incubated with biotinylated goat anti-rabbit secondary antibody (11,000; Vector Labs, Burlingame, CA) for 1 h. Sections were quenched in H_2O_2 in methanol, rinsed, and treated with Elite ABC reagent for 60 min (Vector). Sections were rinsed, developed with DAB (Vector), rinsed, dehydrated, cleared, and coverslipped. Staining for each experiment was performed in a single batch in order to minimize variation in staining intensity. Photomicrographs of the hippocampus (approximately −1.70 to −2.30 from Bregma, see Fig. S2) were taken with a Nikon E800 microscope at 20× using Neurolucida software (Microbrightfield, Burlington, VT). Immunoreactive regions in the captured images were assessed using thresholding with an ROI box (dimensions and size of ROI box was the same for individual regions) around the region of interest with Image J software (NIH). Thresholding was performed within a limited range on individual images and no sharpening filters or other image processing methods were applied. Images were captured and analyzed by a researcher blind to treatment group in two non-consecutive sections for each animal and averaged (total of 4 images per region for each animal when accounting for images from left and right hemisphere).

2.5. Cytokine expression

A separate cohort of mice that underwent CA or sham procedures was used for detection of hippocampal cytokine gene expression using quantitative real-time PCR (qPCR) at 6 h and 24 h timepoints post-surgery. Mice were anesthetized with isoflurane vapors, blood was drawn via the retro-orbital sinus, and mice were rapidly decapitated. Brains were removed and the hippocampus was dissected out and immersed in RNALater stabilizing solution. RNA was subsequently extracted from hippocampal samples using a homogenizer (Ultra-Turrax T8, IKAWorks, Wilmington, NC) and an RNeasy Mini Kit (Qiagen). RNA was then reverse transcribed into cDNA with M-MLV Reverse Transcriptase enzyme (Invitrogen) according to the manufacturer's protocol. Pro-inflammatory cytokine expression for IL-1β, IL-6, and TNFα was determined using inventoried primer and probe assays (Applied Biosystems, Foster City, CA) on an ABI 7500 Fast Real Time PCR System using Taqman® Universal PCR Master Mix. Relative gene expression of individual samples run in duplicate was calculated by comparison to a relative standard curve and standardized by comparison to 18S rRNA signal.

2.6. Administration of cytokine inhibitors

An indwelling cannula was inserted into the left lateral ventricle (cannula position: +0.02 posterior and −0.95 lateral to bregma, extending 2.75 mm below the skull; Plastics One, Roanoke, VA) of anesthetized mice using a stereotaxic apparatus three days prior to CA or sham surgeries. Two hours following CA, mice received a 2 μL injection of either a vehicle solution (artificial cerebral spinal fluid, aCSF), mouse IL-6 neutralizing antibody (IL-6na; 10 ng), a monoclonal TNF antibody (Infliximab; IFX; 0.2 μg), or recombinant mouse IL-1 receptor antagonist (IL-1RA; 3.6 μg) based on pre-assigned group and were then placed back in their respective lighting conditions. Doses were based on prior intracerebroventricular administration of these compounds in mouse (Arruda et al., 2011; Craft and DeVries, 2006; Karelina et al., 2009; Sun et al., 2018). Cannula placement was verified on Iba1 stained tissue.

2.7. Corticosterone radioimmunoassay

Within 30 min of collection, blood samples were centrifuged at 3000g for 30 min at 4 °C. Plasma was collected and stored at −80 °C until assayed. The samples were assayed using and I^{125} corticosterone kit (MP Biomedicals, Solon, OH). The standard curve was run in triplicate and samples in duplicate. All samples within an experiment were run in a single assay.

2.8. Statistical analyses

Statistical comparisons among groups were conducted using ANOVA. In the case of significant differences ($p < .05$), a post-hoc Tukey's test was conducted. When conditions of normality or equal variance were not met, the data were log transformed. Above statistical tests were conducted using Prism GraphPad and StatView Software v. 5.0.1. Survival plots were graphed using Kaplan-Meier survival plot in Prism. Differences were considered statistically significant when $p < .05$. Information on experimental group sizes are included in Supplemental Table 1.

3. Results

3.1. Dim light at night increases hippocampal damage following CA

Male Swiss Webster mice were acclimated to a standard light/dark cycle and then underwent 8 min of CA or the sham procedure toward the end of the light phase (see Fig. 1A for experimental outline and Fig. S1 for surgical measures; sham groups n = 8, CA-LD n = 16, CA-dLAN n = 27). A larger number of animals were included in the CA groups to compensate for increased mortality (see Supplemental Table 1 for more information on group sizes). Following the procedures, mice either remained in the LD cycle or were transferred to a dim light at night cycle. As anticipated, there was 100% survival in both sham groups. Among the CA mice, mortality in the dLAN group was double that of mice exposed to dark nights, indicating that post-ischemic exposure to dim light at night may compromise cardiac arrest survival (Fig. 1b). Furthermore, cardiac arrest caused a reduction in body weight but only in mice exposed to dim light at night ($p < .05$; Fig. 1c).

Damage to hippocampal neurons was assessed in rodents that survived to one week after the CA or sham procedures via staining for Fluoro-JadeC (FJC), a marker for degenerating neurons. The hippocampus was selected because it is particularly vulnerable to global ischemia damage and damage to the hippocampus is a good proxy for overall outcome (Horn and Schlote, 1992; Kirino, 1982; Norman et al., 2010; Petito et al., 1987). FJC staining was uniformly low among sham mice (Fig. 1d–f), and significantly elevated among mice that underwent CA ($p < .05$; Fig. 1d–h). Moreover, mice exposed to dLAN during recovery from CA had significantly more neuronal damage in the hippocampus than mice exposed to dark nights ($p < .05$; Fig. 1d–h).

3.2. Dim light at night alters acute inflammatory status

The neuroinflammatory response following global ischemia is established early and modulates neuronal damage (Fu et al., 2015; Iadecola and Anrather, 2011; Weil et al., 2009). Brain tissue was collected 24 h after CA or sham procedures, i.e., after a single night of post-ischemic dLAN or LD. Hippocampi were collected and processed for quantitative real time PCR (q-PCR) analyses of pro-inflammatory cytokines (n = 6–8/group; see Fig. 2a for experimental outline and Supplemental Table 1 for information on group sizes). As expected, TNFα, IL-1β, and interleukin-6 (IL-6) gene expression were elevated among CA as compared to sham mice ($p < .05$; Fig. 2b). Moreover, the single night of exposure to dLAN following CA was sufficient to upregulate the expression of TNFα, compared to mice exposed to a dark night ($p < .05$; Fig. 2b). There were no differences in hippocampal cytokine

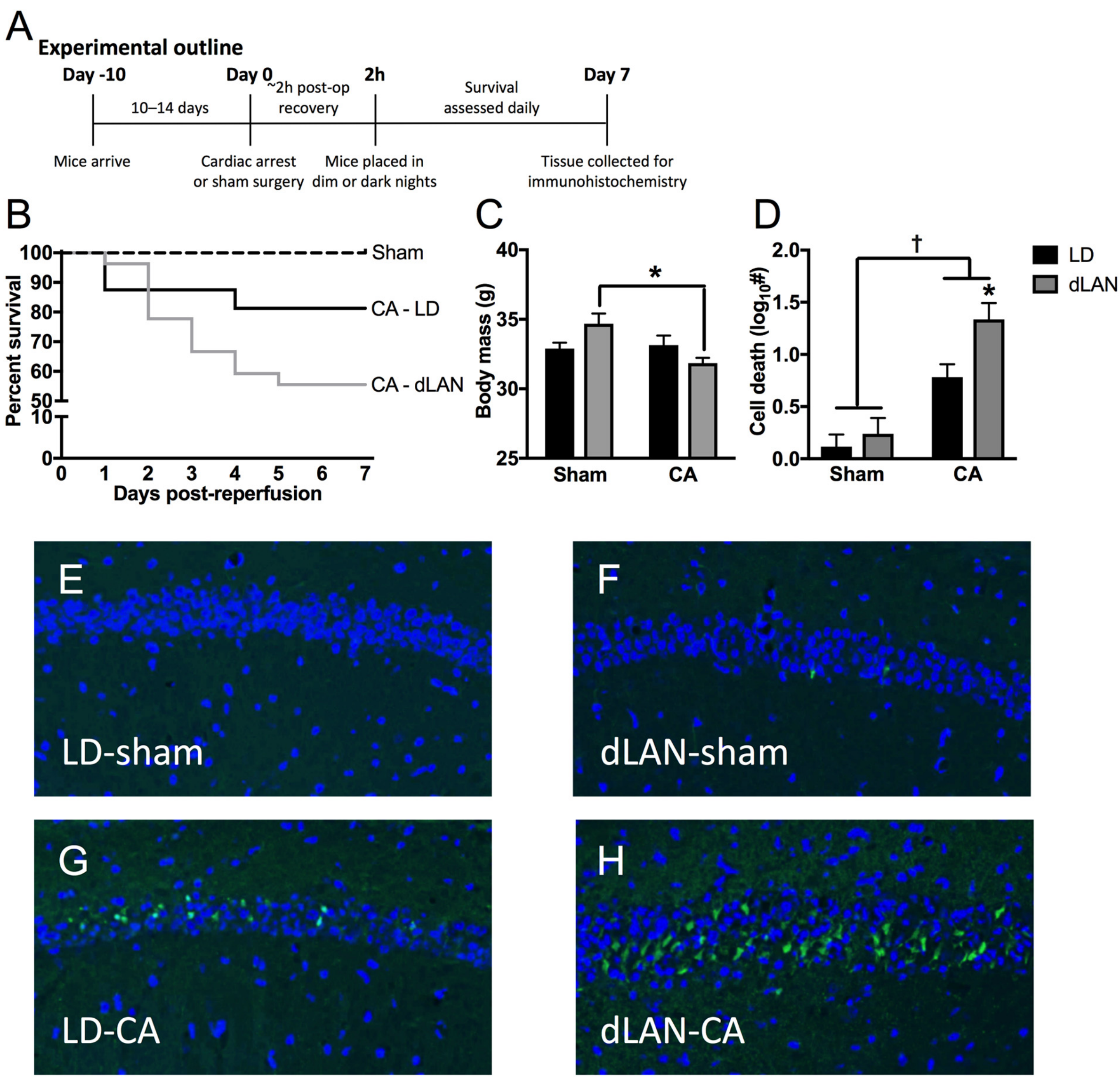


Fig. 1. Dim light at night (dLAN) impairs recovery from a cardiac arrest and cardiopulmonary resuscitation (CA). (a) Experimental outline for Fig. 1. Groups included n = 8–27 starting and n = 8–15 surviving; see Supplemental Table 1). (b) Kaplan Meier curve illustrates short-term mortality during the first week following cardiac arrest/CPR (CA). (c) dLAN exposure reduced body mass in mice that underwent the CA procedure. (d) dLAN exacerbates CA induced neuronal damage in the hippocampus, as indicated by increased Fluoro-JadeC (FJC) staining relative to LD. Representative FJC stained sections (20×) from the CA1 region of the hippocampus: (e) Sham-dark night (LD-sham) (f) Sham-dim light at night (dLAN-sham) (g) CA-dark night (CA-LD) and (h) CA-dLAN at one week following the CA/sham procedure. Data were analyzed using a two-way ANOVA with Tukey's post hoc test. The data in panel b represents mean ± SEM; the dagger represents a significant main effect ($p < .05$) between sham and CA, while the asterick indicates a significant difference ($p < .05$) between CA-LD and CA-dLAN.

gene expression between dLAN and LD mice that underwent the sham procedure ($p > .05$).

Importantly, changes in hippocampal cytokine expression may occur relatively rapidly after placement in dim light at night. The increase in TNFα expression becomes apparent soon after the onset of the dark phase: there was already a significant increase in post-CA TNFα expression among dLAN as compared to LD mice at 6 h post-CA and after only 4 h of dim light exposure during the typical dark phase of the light cycle ($n = 4$/group, $p < .05$; Fig. 2c).

The effects of dLAN on CA-induced neuroinflammation do not appear to be due to changes in corticosteroid concentrations; there were no differences in corticosterone concentrations between CA or sham groups at 24 h ($n = 6–8$/group; $p > .05$; Fig. 2d). Moreover, an investigation of corticosterone concentration at 6 h intervals following CA did not reveal any significant differences between the CA-dLAN and CA-LD groups during the first 24 h of recovery ($n = 4$/group; $p > .05$; Fig. S3).

3.3. Inhibition of selective pro-inflammatory cytokines ameliorates light-induced damage

Although several mechanisms contribute to damage following ischemic injury, including energetic failure, excitotoxicity, and oxidative stress, manipulation of inflammatory responses are considered a prime target for prevention of damage (Fu et al., 2015; Iadecola and Anrather, 2011). Following ischemic brain damage both selective targeting of specific cytokines and non-selective (e.g., minocycline) inhibition of pro-inflammatory cytokines ameliorate damage, improving recovery and behavioral outcomes (Espinosa-Garcia et al., 2017; Mizushima et al., 2002; Neigh et al., 2009; Yrjanheikki et al., 1998). Because our results indicate that dLAN elevates pro-inflammatory cytokines in the hippocampus of mice that have undergone a CA procedure, we

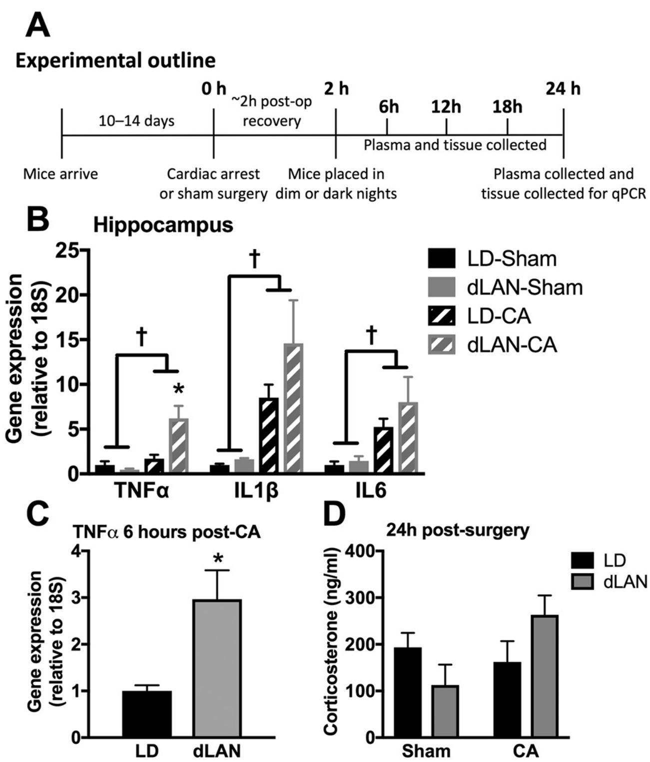


Fig. 2. CA-induced pro-inflammatory cytokine elevations are exacerbated in the hippocampus of dLAN mice. (a) Outline for experiments in Fig. 2 (n = 6–8/group; see supplemental Table 1). (b) Hippocampal TNFα, IL-1β, and IL-6 mRNA concentrations are increased 24 h following CA relative to sham; furthermore, TNFα expression is potentiated by exposure to dLAN as compared to LD following CA in mice. (c) TNFα expression is elevated as early as 6 h post-CA in the CA-dLAN group versus the CA-LD group (n = 4/group), this time point coincides with ~4 h of exposure to dLAN. (d) Serum corticosterone concentrations at 24 h were not altered by either CA or light at night (n = 6–8/group). There were no significant group differences in IL-1β or IL-6 at this early time point. Gene expression was assessed via RT-PCR and is presented as fold increase relative to a housekeeping gene (18S). The data are graphed as mean ± SEM; a dagger symbol represents a significant main effect ($p < .05$) between sham and CA, while an asterisk indicates a significant difference ($p < .05$) between CA-LD and CA-dLAN.

hypothesized that selective inhibition of pro-inflammatory cytokines would improve outcome following CA-dLAN. Three days prior to the CA procedure, mice were implanted with a cannula directed at the lateral ventricle. Two hours following CA, mice were administered a single 2 µL ICV injection of either vehicle (artificial cerebrospinal fluid; aCSF), mouse IL-6 neutralizing antibody (IL-6na; 10 ng), TNF monoclonal antibody (infliximab; IFX; 0.2 µg), or recombinant mouse IL-1 receptor antagonist (IL-1RA; 3.6 µg) (n = 8–10/group; see experimental outline in Fig. 3a). Doses were based on prior intracerebroventricular administration of these compounds in mouse (Arruda et al., 2011; Craft and DeVries, 2006; Karelina et al., 2009; Sun et al., 2018). Hippocampal damage was evaluated using Fluoro-JadeC as described above. There was no significant effect of the cytokine inhibition on survival ($p > .05$, Fig. 3b), although group numbers may have been insufficient for detecting differences in survival. However, both IL-1RA and IFX decreased hippocampal damage compared to aCSF treatment among CA-dLAN mice ($p < .05$; Fig. 3c), producing levels of FJC staining that were similar to CA-LD mice treated with the vehicle ($p > .05$). In contrast, treatment with IL-6na did not ameliorate hippocampal neuronal damage associated with CA-dLAN.

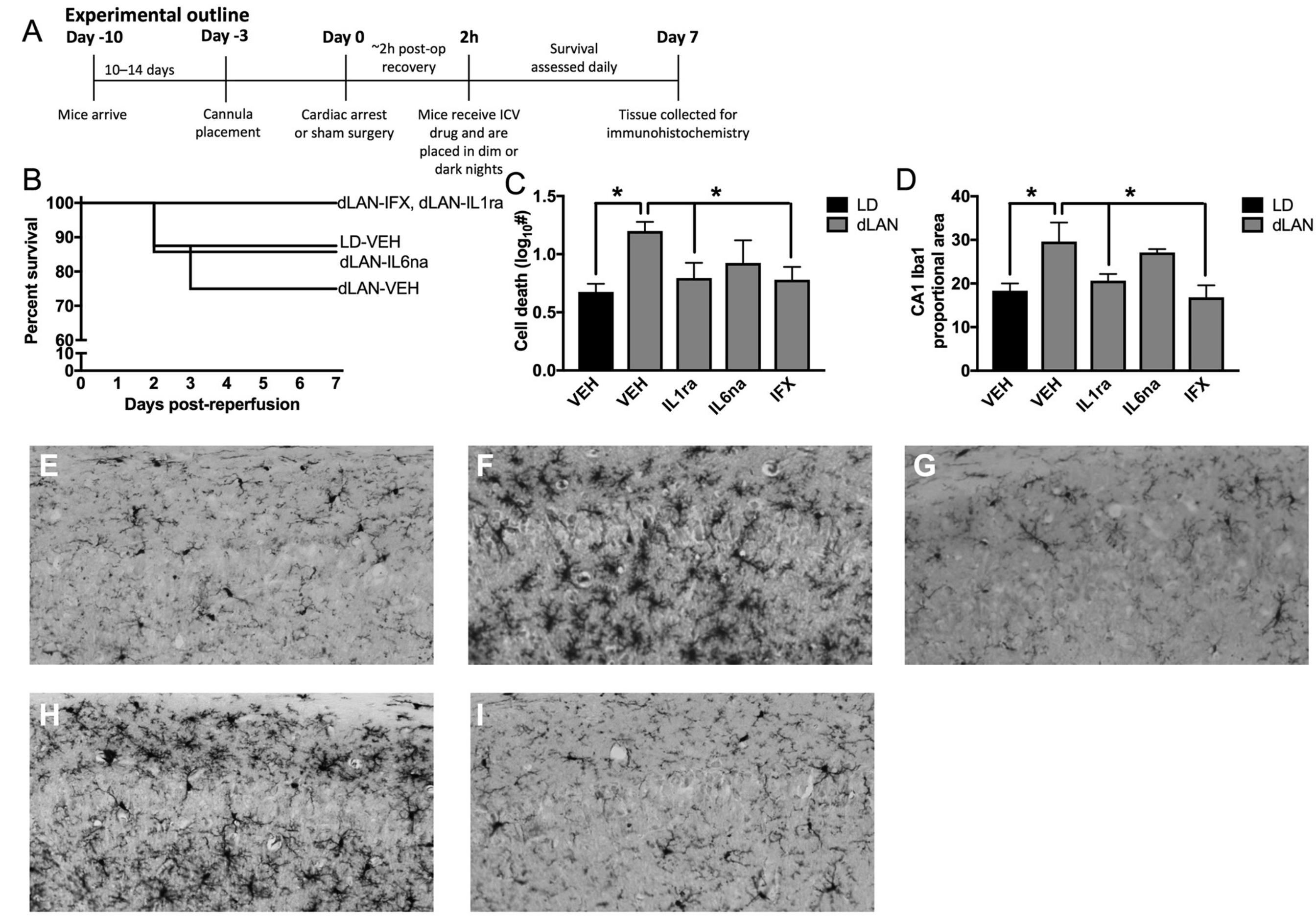
Histological analysis revealed a similar pattern for Iba1 proportional area, which is often used as an index of neuroinflammation. Brain tissue was labeled with Iba-1, an antibody directed against microglia; increased Iba-1 surface area is suggestive of microglial activation (Donnelly et al., 2009). Microglia are the resident CNS myeloid cell and a dominant source of pro-inflammatory cytokines following cerebral ischemia. Perturbations of the neuroenvironment can induce microglial activation, resulting in altered morphology and secretion of pro-inflammatory mediators (Graeber, 2010; Nimmerjahn et al., 2005). Significantly elevated Iba1 proportional area in the CA1, CA2, and CA3 subfields of the hippocampus were apparent among the CA-dLAN mice treated with the vehicle (aCSF) relative to the CA-LD mice treated with the vehicle ($p < .05$; Fig. 3d-j and Fig. S4). Furthermore, treatment of CA-dLAN mice with IL-1RA or IFX reduced Iba1 proportional area in the CA1 and CA2 ($p < .05$; Fig. 3d–j and Fig. S4) relative to the CA-dLAN mice treated with vehicle. Furthermore, Iba1 expression in CA-dLAN mice treated with IL-1RA or IFX did not differ from CA-LD mice treated with the vehicle in any of the hippocampal subfields quantified. In contrast, CA-dLAN mice treated with IIL-6na had comparable Iba1 staining in the CA1 as compared to CA-dLAN mice treated with the vehicle, while levels of Iba1 proportional area in the CA2 and CA3 regions were intermediate between vehicle treated CA-dLAN and CA-LD mice.

3.4. Alternative spectra of lighting minimize light-induced damage

The intrinsically photosensitive retinal ganglion cells (ipRGCs) that project to the master circadian pacemaker in the SCN contain melanopsin and are most responsive to the blue region of the visible light spectrum ranging from 450 to 485 nm (Berson et al., 2002); these wavelengths are present in broad spectrum white light, such as natural sunlight and the majority of indoor lighting. Longer wavelengths of lighting, such as red light, do not activate ipRGCs, and therefore minimally influence the circadian system (Brainard et al., 2008; Figueiro and Rea, 2010). Thus, we hypothesized that the use of a wavelength of nighttime light that does not activate the ipRGCs would not exacerbate ischemic outcome. An important caveat to this experiment, however, is mice also lack a long wavelength cone and thus have more limited detection of red wavelength light in general. As in the previous studies, the mice were acclimated to the LD light cycle [14 h light (150 lx): 10 h dark (0 lx)]. Following CA, mice either remained in LD, or were placed in dLAN [14 h light (150 lx): 10 h dim light (5 lx; 6500 K cool white light- containing blue wavelengths)] or a dim red light at night cycle [rLAN; 14 h light (150 lx): 10 h dim red (5 lx, 636 nm)] (n = 12/group). This experiment followed the same timeline as Fig. 1a.

Mice exposed to dim white light at night as compared to dark nights had increased mortality ($p = .05$); however, mice exposed to dim red light at night did not differ from LD or dLAN groups ($p > .05$; Fig. 4a). FJC staining revealed a significant increase in neuronal damage in the hippocampus among the CA-dLAN group compared to both the CA-LD and CA-rLAN groups ($p < .05$; Fig. 4b, d-f). In contrast, hippocampal neuronal damage among CA-rLAN mice was similar to CA-LD mice ($p > .05$). A similar pattern emerged from Iba-1 staining; CA-dLAN mice exhibited an increase in Iba1 proportional area in multiple hippocampal subfields compared to both CA-LD and CA-rLAN conspecifics ($p < .05$; Fig. 4c, g–j and Fig. S5), whereas the rLAN group did not differ from the CA-LD group in any of the comparisons ($p > .05$; Fig. 4c, g–j and Fig. S5).

To corroborate the histological assessment of neuroinflammation, hippocampal pro-inflammatory cytokine expression was assessed 24 h after CA (n = 7–8/group). This time point allowed exposure to a single night of post-ischemic dark, dim white light or dim red light. Exposure to dLAN significantly elevated hippocampal TNFα and IL-6 gene expression compared to both LD and rLAN ($p < .05$; Fig. 4k). dLAN also significantly increased IL-1β gene expression compared to rLAN ($p < .05$; Fig. 4k). Exposure to rLAN did not significantly alter pro-inflammatory cytokine expression compared to LD ($p > .05$).



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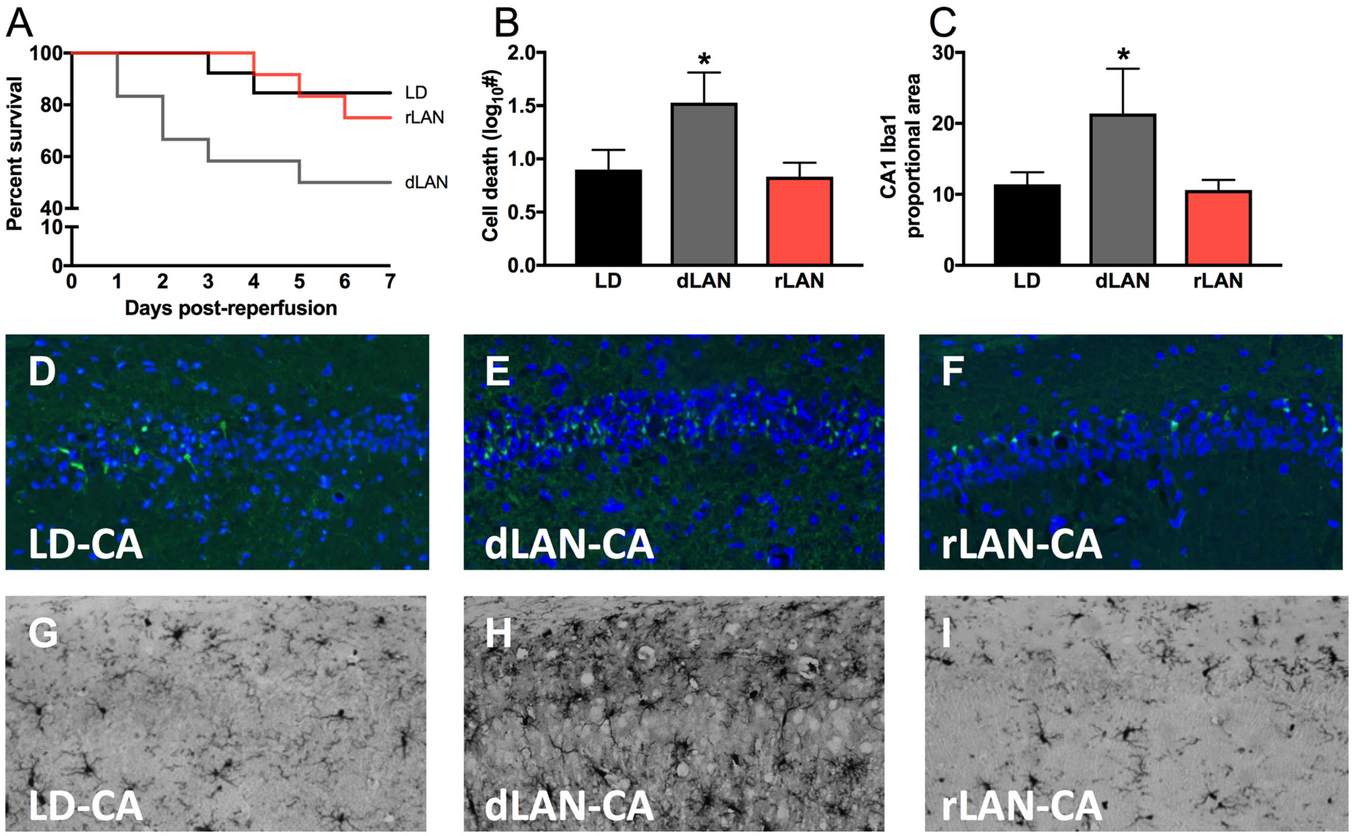
	LD - Veh	dLAN - Veh	dLAN - IL1ra	dLAN - IL6na	dLAN - IFX	p value
CA1	18.3 +/- 1.7*	29.6 +/- 4.4	20.6 +/- 1.5*	27.1 +/- 0.8	16.8 +/- 2.8*	p < 0.05
CA2	15.0 +/- 1.5*	24.7 +/- 3.8	17.7 +/- 2.1	16.9 +/- 2.0	13.5 +/- 2.3*	p < 0.05
CA3	13.5 +/- 1.4*	22.2 +/- 2.6	15.4 +/- 2.3	18.1 +/- 1.5	14.6 +/- 2.5	p < 0.05
DG	18.1 +/- 1.4	27.6 +/- 3.2	18.3 +/- 2.4	20.7 +/- 2.2	17.3 +/- 5.3	p = 0.179

Fig. 3. Selective inhibition of specific pro-inflammatory cytokines attenuates inflammation and neuronal cell death following CA and dLAN. (a) Experimental outline for Fig. 3 (n = 8–10/group, see Supplemental Table 1). (b) Kaplan Meier curve of mice treated with TNFα, IL-1β or IL-6 inhibitors 2 h following CA and directly prior to placement in dLAN. (c) Treatment of mice in the dLAN group with the TNFα or IL-1β inhibitor reduced neuronal damage (FJC stain) and (d) inhibited proportional area of Iba1 staining at one week after CA relative to the dLAN vehicle treated mice. Representative photomicrographs of microglial staining with Iba1 in the CA1 region of the hippocampus (20×) in mice treated with (e) LD-Veh (f) dLAN-Veh (g) dLAN-IL-1RA (h) dLAN-IL-6ab or (i) dLAN-IFX. (j) Table provides proportional area of Iba1 staining in subregions of the hippocampus as an indication of microglial activation. The data in panels b, c, and i are provided as mean ± SEM; Groups that differ from dLAN-VEH are marked with asterisks in the graphs ($p < .05$).

4. Discussion

In terms of productivity, safety, and convenience, there are many tangible benefits to the ability to illuminate the night. However, nighttime light exposure is not innocuous for human health. There is a growing literature linking long-term nighttime light exposure to maladaptive health conditions, including heart disease, metabolic disorders, and cancer (Bedrosian et al., 2016; Fonken and Nelson, 2014; Lunn et al., 2017). The current study provides evidence in a mouse model, that acute exposure to light at night also may be detrimental if it coincides with recovery from ischemic brain injury. Indeed, light at night reshapes the physiological response to cerebral ischemia, resulting in increased neuronal damage in mice (Fig. 1). Hippocampal cell death is a proxy for overall recovery after global ischemia as increased hippocampal damage is associated with elevated mortality and memory deficits, as well as impaired affective responses (Espinosa-Garcia et al., 2017; Neigh et al., 2009; Neigh et al., 2004; Norman et al., 2010). This is significant because intensive care units, where critically ill cardiovascular patients recover, tend to be well-lit at night. Patients are often exposed to light several times per night (Durrington et al., 2017; Lunn et al., 2017) and even patients whose eyelids are closed may be affected by the light intrusion (Robinson et al., 1991).

Exposure to light at night may exacerbate damage following CA by amplifying pro-inflammatory responses. A single night of dim light exposure directly following resuscitation from CA elevated hippocampal pro-inflammatory cytokine mRNA expression as compared to total darkness during the night. Changes in neuroinflammatory dynamics likely occur rapidly following placement in dim light as TNFα



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	LD	dLAN	rLAN	p value
CA1	11.4 +/- 1.7*	21.4 +/- 6.3	10.6 +/- 1.4*	p < 0.05
CA2	12.8 +/- 1.4*	29.1 +/- 8.2	11.9 +/- 2.7*	p < 0.05
CA3	10.7 +/- 1.3	13.7 +/- 2.4	10.8 +/- 1.7	p = 0.42
DG	11.4 +/- 2.9*	25.8 +/- 5.0	11.4 +/- 1.8*	p < 0.05

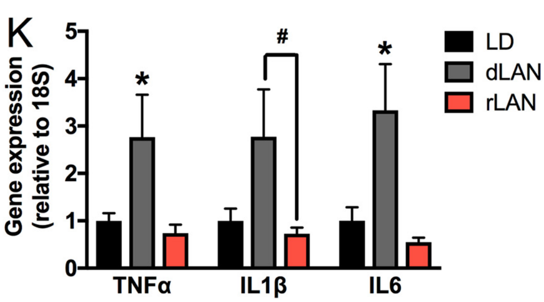

Fig. 4. Manipulation of lighting wavelength minimizes light at night induced damage following CA. The experimental outline in Fig. 4 followed the same timing as Fig. 1a (n = 12/group, 6–10 surviving, see Supplemental Table 1). (a) Kaplan Meier curve illustrating survival of mice exposed to dark nights (LD), dim light at night (dLAN), or red light at night (rLAN) following CA. (b) the dLAN group had significantly greater neuronal damage (FJC staining) and (c) increased proportional area of Iba1 staining in the hippocampus at one week after CA than either the CA-LD or CA-rLAN groups; the CA-LD or CA-rLAN groups did not differ significantly in either of these measures. Representative photomicrographs of FJC staining in the CA1 region of the hippocampus (20×) one week after CA in the (d) LD, (e) dLAN, and (f) rLAN groups. Representative photomicrographs of Iba1 staining in the CA1 region of the hippocampus (20×) one week after CA in the (g) LD, (h) dLAN, and (i) rLAN groups. (j) Table providing proportional area of Iba1 staining in subregions of the hippocampus as an indication of microglial activation. (k) Gene expression of TNFα, IL-1β, and IL-6 is significantly elevated in the hippocampus 24 h following CA in the CA-dLAN group relative to the rLAN group and CA-LD groups (n = 7–8/group). Gene expression was assessed via qPCR and is presented as fold increase relative to a housekeeping gene (18S). The data are provided as mean ± SEM; an asterisk represents a significant difference between dLAN and both other groups ($p < .05$), whereas a pound sign (#) indicates the dLAN group only significantly differs from the rLAN group ($p < .05$). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

mRNA expression in the hippocampus is elevated as early as 4 h after exposure to dLAN. At these acute time points, dim light exposure appeared to specifically amplify inflammation after injury as there were no significant differences between the sham-LD and sham-dLAN groups. However, chronic exposure to dim light at night may induce neuroinflammatory changes in the absence of injury; several weeks of exposure to dim light at night increases the expression of pro-inflammatory cytokines in the hippocampus of otherwise healthy rodents (Bedrosian et al., 2013b).

Pro-inflammatory cytokines, such as TNFα, are known to contribute to damage after cerebral ischemia (Lambertsen et al., 2012). Thus, these early changes in the inflammatory response caused by dLAN may causally alter the trajectory of recovery, resulting in increased neuronal damage. Indeed, inhibition of either TNFα or IL-1 signaling among CA-dLAN mice significantly reduced Iba1 + proportional area and neuronal damage relative to vehicle treated CA-dLAN mice. Thus, two bodies of evidence point to a role of increased inflammatory responses in mediating elevated neuronal damage among the CA-dLAN mice: (1) both pro-inflammatory cytokine gene expression and neuronal damage were elevated after exposure to dLAN relative to LD, and (2) treatment with IL-1RA or IFX prevented the exacerbation of neuronal damage and increases in Iba1 + proportional area observed among vehicle treated CA-dLAN mice. In contrast to inhibition of TNFα or IL-1, blocking IL-6 signaling with an IL-6 neutralizing antibody did not reduce cell death or Iba1 staining. The IL-6 neutralizing antibody dose was based on prior work (Karelina et al., 2009), however, it is possible that higher concentrations of IL-6 neutralizing antibody would prove more effective. Of note, lower levels of mortality occurred in this experiment compared to the other two experiments that measured 7-day survival. This may have occurred for several reasons. For example, there are typically small variations in survival between experimental cohorts that may relate to differences in animals provided by the vendor, variations in reagents used for the procedure, noise levels in the colony/surgical suite, etc. Additionally, the cannula implantation may have induced inflammation in the CNS causing inflammatory pre-conditioning, which is a known protective factor against ischemic brain injury (for example, see Garcia-Bonilla et al., 2018). Furthermore, this experiment may have included insufficient group sizes for detecting survival. Overall, targeting inflammatory pathways can prevent damage from cerebral ischemia in mice maintained in standard lighting conditions (Lambertsen et al., 2012). Because this is well established, mice maintained in dark nights were not included in these experiments in order to reduce animal use.

Microglia may be a cellular source of elevated inflammation in mice exposed to dim light at night. The proportional area of Iba1 staining, an indication of microglia activation, was elevated in the hippocampus of mice exposed to light at night as compared to dark nights following CA. Furthermore, inhibiting pro-inflammatory pathways with IFX and IL-1RA reduced Iba1 staining throughout the hippocampus and minimized cell death. However, other cellular sources such as neurotoxic reactive astrocytes and/or infiltrating immune cells may contribute to the proinflammatory cytokine response (Liddelow et al., 2017; Lindsberg et al., 2010).

Dim light at night may induce neuroinflammatory changes through several potential mechanisms. First, light at night may suppress nocturnal melatonin secretion. Melatonin exhibits anti-inflammatory properties and can alleviate CNS inflammation (Zhao et al., 2015). However, Swiss Webster mice likely lack appreciable levels of melatonin (Tosini and Menaker, 1998). Second, light at night may elevate neuroinflammation through disturbing sleep (Stenvers et al., 2016). Sleep alterations are associated with CNS inflammation (Bellesi et al., 2017). However, other studies have reported no sleep disturbances in response to dLAN (Borniger et al., 2013). Third, nighttime light exposure may alter circadian clock mechanisms in immune cells. Microglia express circadian timekeeping machinery (Fonken et al., 2015) and previous work suggest chronic exposure to dLAN exacerbates microglia pro-inflammatory responses (Fonken and Nelson, 2013). Chronic exposure to dim light at night reduces the amplitude of PER1 and PER2 rhythms in the SCN is mice and hamsters (Bedrosian et al., 2013a; Fonken et al., 2013). Moreover, dim light exposure is associated with disruption in clock gene expression in extra-SCN tissues such as liver (Fonken et al., 2013). The effects of exposure to a single night of 5 lx of dim light at night on clock gene expression has not been evaluated in the SCN or extra-SCN clocks. Future studies could determine whether dim light at night alters clock gene expression and/or behavior, and whether CA renders mice more susceptible to the disruptive effects of dLAN.

Although pharmacological intervention reduced the detrimental effects of dLAN on CA-induced microglial activation and neuronal damage, an alternative approach to improving CA outcome is to modify the physical qualities of the nighttime light to prevent increased neuroinflammation. Indeed, here we show that nighttime red light of the same illuminance as the dim white light did not exacerbate CA-induced neuronal damage or increase Iba1 staining in mice. These data are consistent with studies reporting that red light at night does not affect other aspects of physiology and behavior in humans or other animals to the same extent as broad spectrum white light that contains blue wavelengths (Figueiro and Rea, 2010). The effects of nighttime light may be mediated by the suprachiasmatic nucleus or "master circadian clock", which receives input from melanopsin containing ipRGCs in the retina. The ipRCGs are activated by blue light (~480 nm, found in outdoor and most indoor lighting, especially fluorescent lights), but are generally unaffected by long wavelength light, such as red light. However, a major limitation to this work is that red light at 5 lx is a much lower energy and dimmer than white light. Thus, future experiments should address whether a higher intensity red light source is also protective against light-associated damage following ischemic energy. Furthermore, mice may not be the optimal model to study the effects of red light: the mouse M-cone is most sensitive to light around 510 nm, suggesting none of the retinal pigments in mouse are maximally sensitive to the 636 nm red light (Hattar et al., 2003).

Although these studies were conducted in nocturnal rodents, they may have important implications for diurnal species. Indeed, the effect of light on entraining the circadian system and inhibition of melatonin is similar between nocturnal and diurnal animals (Challet, 2007). Furthermore, our prior work indicates that exposure to dim light at night is an equally potent facilitator of inflammation in diurnal rodents (Fonken et al., 2011). One benefit to using a nocturnal rodent in these experiments is that sleep disruption was likely not a potential confound (Borniger et al., 2013).

One additional note about this work is that experiments were conducted in young adult mice (8 weeks of age) and cardiac arrest in humans typically occurs in older individuals. The circadian system and immune system change over the course of an animal's lifespan. Aged animals typically exhibit lower amplitude molecular and behavioral circadian rhythms and slower re-entrainment of rhythms following light induced phase shifts (Davidson et al., 2008; Sellix et al., 2012). This suggests that light at night may have differential effects in a young versus aged animal. Furthermore, the neuroimmune system changes with age. Microglia tend to become more reactive or "primed" with age. Primed microglia exhibit hyperinflammatory responses upon immune activation that can exacerbate pathology (Fonken et al., 2018). Future work should address whether aging leads to increased vulnerability to the disruptive effects of light at night on physiology and behavior.

In sum, the mouse data presented here indicates that exposure to light at night, a common occurrence in hospital rooms, may compromise recovery from cerebral ischemia by exacerbating neuroinflammation. Reducing post-ischemic neuroinflammation among mice exposed to dLAN, prevented the increase in neuronal damage otherwise associated with dLAN. If the effects of white light at night are replicated in cardiovascular patients, then these results could have important implications for the design of lighting in clinical settings and could apply to a broad number of conditions and medical procedures that involve ischemia and inflammation, such as stroke, cardiovascular artery bypass graft, sickle cell disease, sleep apnea, and organ transplant.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.expneurol.2019.02.008.

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Author contribution statement

LFK, ACD, RJN contributed to the experimental design. NZ performed the surgical procedures. LFK, TAB, RJN, and ZMW collected and analyzed the data. All authors contributed to the writing and editing of the manuscript.

Conflict of interest statement

The authors have no conflicts of interest to report. All authors concur with the submission of this manuscript and none of the data have been previously reported or are under consideration for publication elsewhere.

The following are the supplementary data related to this article.

References

Arruda, A.P., Milanski, M., Coope, A., Torsoni, A.S., Ropelle, E., Carvalho, D.P., Carvalheira, J.B., Velloso, L.A., 2011. Low-grade hypothalamic inflammation leads to defective thermogenesis, insulin resistance, and impaired insulin secretion. Endocrinology 152, 1314–1326.

Ayalon, L., Borodkin, K., Dishon, L., Kanety, H., Dagan, Y., 2007. Circadian rhythm sleep disorders following mild traumatic brain injury. Neurology 68, 1136–1140.

Bedrosian, T.A., Galan, A., Vaughn, C.A., Weil, Z.M., Nelson, R.J., 2013a. Light at night alters daily patterns of cortisol and clock proteins in female Siberian hamsters. J. Neuroendocrinol. 25, 590–596.

Bedrosian, T.A., Weil, Z.M., Nelson, R.J., 2013b. Chronic dim light at night provokes reversible depression-like phenotype: possible role for TNF. Mol. Psychiatry 18, 930–936.

Bedrosian, T.A., Fonken, L.K., Nelson, R.J., 2016. Endocrine effects of circadian disruption. Annu. Rev. Physiol. 78, 109–131.

Bellesi, M., de Vivo, L., Chini, M., Gilli, F., Tononi, G., Cirelli, C., 2017. Sleep loss promotes astrocytic phagocytosis and microglial activation in mouse cerebral cortex. J. Neurosci. 37, 5263–5273.

Berson, D.M., Dunn, F.A., Takao, M., 2002. Phototransduction by retinal ganglion cells that set the circadian clock. Science 295, 1070–1073.

Borniger, J.C., Weil, Z.M., Zhang, N., Nelson, R.J., 2013. Dim light at night does not disrupt timing or quality of sleep in mice. Chronobiol. Int. 30, 1016–1023.

Brainard, G.C., Sliney, D., Hanifin, J.P., Glickman, G., Byrne, B., Greeson, J.M., Jasser, S., Gerner, E., Rollag, M.D., 2008. Sensitivity of the human circadian system to short-wavelength (420-nm) light. J. Biol. Rhythm. 23, 379–386.

Challet, E., 2007. Minireview: entrainment of the suprachiasmatic clockwork in diurnal and nocturnal mammals. Endocrinology 148, 5648–5655.

Craft, T.K., DeVries, A.C., 2006. Role of IL-1 in poststroke depressive-like behavior in mice. Biol. Psychiatry 60, 812–818.

Davidson, A.J., Yamazaki, S., Arble, D.M., Menaker, M., Block, G.D., 2008. Resetting of central and peripheral circadian oscillators in aged rats. Neurobiol. Aging 29, 471–477.

Donnelly, D.J., Gensel, J.C., Ankeny, D.P., van Rooijen, N., Popovich, P.G., 2009. An efficient and reproducible method for quantifying macrophages in different experimental models of central nervous system pathology. J. Neurosci. Methods 181, 36–44.

Durrington, H.J., Clark, R., Greer, R., Martial, F.P., Blaikley, J., Dark, P., Lucas, R.J., Ray, D.W., 2017. 'In a dark place, we find ourselves': light intensity in critical care units. Intensive Care Med. Exp. 5, 9.

Eltzschig, H.K., Eckle, T., 2011. Ischemia and reperfusion—from mechanism to translation. Nat. Med. 17, 1391–1401.

Espinosa-Garcia, C., Sayeed, I., Yousuf, S., Atif, F., Sergeeva, E.G., Neigh, G.N., Stein, D.G., 2017. Stress primes microglial polarization after global ischemia: therapeutic potential of progesterone. Brain Behav. Immun. 66, 177–192.

Figueiro, M.G., Rea, M.S., 2010. The effects of red and blue lights on circadian variations in cortisol, alpha amylase, and melatonin. Int. J. Endocrinol. 2010, 829351.

Fonken, L.K., Nelson, R.J., 2013. Mice exposed to dim light at night exaggerate inflammatory responses to lipopolysaccharide. Brain Behav. Immun. 34, 159–163.

Fonken, L.K., Nelson, R.J., 2014. The effects of light at night on circadian clocks and metabolism. Endocr. Rev. 35, 648–670.

Fonken, L.K., Haim, A., Nelson, R.J., 2011. Dim light at night increases immune function in nile grass rats, a diurnal rodent. Chronobiol. Int. 29, 26–34.

Fonken, L.K., Aubrecht, T.G., Melendez-Fernandez, O.H., Weil, Z.M., Nelson, R.J., 2013. Dim light at night disrupts molecular circadian rhythms and increases body weight. J. Biol. Rhythm. 28, 262–271.

Fonken, L.K., Frank, M.G., Kitt, M.M., Barrientos, R.M., Watkins, L.R., Maier, S.F., 2015. Microglia inflammatory responses are controlled by an intrinsic circadian clock. Brain Behav. Immun. 45, 171–179.

Fonken, L.K., Frank, M.G., Gaudet, A.D., Maier, S.F., 2018. Stress and aging act through common mechanisms to elicit neuroinflammatory priming. Brain Behav. Immun. 73, 133–148.

Fu, Y., Liu, Q., Anrather, J., Shi, F.D., 2015. Immune interventions in stroke. Nat. Rev. Neurol. 11, 524–535.

Garcia-Bonilla, L., Brea, D., Benakis, C., Lane, D.A., Murphy, M., Moore, J., Racchumi, G., Jiang, X., Iadecola, C., Anrather, J., 2018. Endogenous protection from ischemic brain injury by preconditioned monocytes. J. Neurosci. 38, 6722–6736.

Gaudet, A.D., Fonken, L.K., Ayala, M.T., Bateman, E.M., Schleicher, W.E., Smith, E.J., D'Angelo, H.M., Maier, S.F., Watkins, L.R., 2018a. Spinal cord injury in rats disrupts the circadian system. eNeuro 5 (6) (ENEURO. 0328-0318.2018).

Gaudet, A.D., Fonken, L.K., Ayala, M.T., D'Angelo, H.M., Smith, E.J., Bateman, E.M., Schleicher, W.E., Maier, S.F., Watkins, L., 2018b. Spinal cord injury in rats dysregulates diurnal rhythms of fecal output and liver metabolic indicators. J. Neurotrauma.

Giannoccaro, M.P., Moghadam, K.K., Pizza, F., Boriani, S., Maraldi, N.M., Avoni, P., Morreale, A., Liguori, R., Plazzi, G., 2013. Sleep disorders in patients with spinal cord injury. Sleep Med. Rev. 17, 399–409.

Graeber, M.B., 2010. Changing face of microglia. Science 330, 783–788.

Hattar, S., Lucas, R.J., Mrosovsky, N., Thompson, S., Douglas, R.H., Hankins, M.W., Lem, J., Biel, M., Hofmann, F., Foster, R.G., Yau, K.W., 2003. Melanopsin and rod-cone photoreceptive systems account for all major accessory visual functions in mice. Nature 424, 76–81.

Horn, M., Schlote, W., 1992. Delayed neuronal death and delayed neuronal recovery in the human brain following global ischemia. Acta Neuropathol. 85, 79–87.

Iadecola, C., Anrather, J., 2011. The immunology of stroke: from mechanisms to translation. Nat. Med. 17, 796–808.

Jain, S., Namboodri, K.K., Kumari, S., Prabhakar, S., 2004. Loss of circadian rhythm of blood pressure following acute stroke. BMC Neurol. 4 (1).

Karelina, K., Norman, G.J., Zhang, N., Morris, J.S., Peng, H., DeVries, A.C., 2009. Social isolation alters neuroinflammatory response to stroke. Proc. Natl. Acad. Sci. U. S. A. 106, 5895–5900.

Kirino, T., 1982. Delayed neuronal death in the gerbil hippocampus following ischemia. Brain Res. 239, 57–69.

Lambertsen, K.L., Biber, K., Finsen, B., 2012. Inflammatory cytokines in experimental and human stroke. J. Cereb. Blood Flow Metab. 32, 1677–1698.

Lange, T., Dimitrov, S., Born, J., 2010. Effects of sleep and circadian rhythm on the human immune system. Ann. N. Y. Acad. Sci. 1193, 48–59.

Liddelow, S.A., Guttenplan, K.A., Clarke, L.E., Bennett, F.C., Bohlen, C.J., Schirmer, L., Bennett, M.L., Munch, A.E., Chung, W.S., Peterson, T.C., Wilton, D.K., Frouin, A., Napier, B.A., Panicker, N., Kumar, M., Buckwalter, M.S., Rowitch, D.H., Dawson, V.L., Dawson, T.M., Stevens, B., Barres, B.A., 2017. Neurotoxic reactive astrocytes are induced by activated microglia. Nature 541, 481–487.

Lindsberg, P.J., Strbian, D., Karjalainen-Lindsberg, M.L., 2010. Mast cells as early responders in the regulation of acute blood-brain barrier changes after cerebral ischemia and hemorrhage. J. Cereb. Blood Flow Metab. 30, 689–702.

Lunn, R.M., Blask, D.E., Coogan, A.N., Figueiro, M.G., Gorman, M.R., Hall, J.E., Hansen, J., Nelson, R.J., Panda, S., Smolensky, M.H., Stevens, R.G., Turek, F.W., Vermeulen, R., Carreon, T., Caruso, C.C., Lawson, C.C., Thayer, K.A., Twery, M.J., Ewens, A.D., Garner, S.C., Schwingl, P.J., Boyd, W.A., 2017. Health consequences of electric lighting practices in the modern world: a report on the National Toxicology Program's workshop on shift work at night, artificial light at night, and circadian disruption. Sci. Total Environ. 607-608, 1073–1084.

Mizushima, H., Zhou, C.J., Dohi, K., Horai, R., Asano, M., Iwakura, Y., Hirabayashi, T., Arata, S., Nakajo, S., Takaki, A., Ohtaki, H., Shioda, S., 2002. Reduced postischemic apoptosis in the hippocampus of mice deficient in interleukin-1. J. Comp. Neurol. 448, 203–216.

Morris, C.J., Purvis, T.E., Hu, K., Scheer, F.A., 2016. Circadian misalignment increases cardiovascular disease risk factors in humans. Proc. Natl. Acad. Sci. U. S. A. 113, E1402–E1411.

Neigh, G.N., Kofler, J., Meyers, J.L., Bergdall, V., La Perle, K.M., Traystman, R.J., DeVries, A.C., 2004. Cardiac arrest/cardiopulmonary resuscitation increases anxiety-like behavior and decreases social interaction. J. Cereb. Blood Flow Metab. 24, 372–382.

Neigh, G.N., Karelina, K., Glasper, E.R., Bowers, S.L., Zhang, N., Popovich, P.G., DeVries, A.C., 2009. Anxiety after cardiac arrest/cardiopulmonary resuscitation: exacerbated by stress and prevented by minocycline. Stroke 40, 3601–3607.

Nimmerjahn, A., Kirchhoff, F., Helmchen, F., 2005. Resting microglial cells are highly dynamic surveillants of brain parenchyma in vivo. Science 308, 1314–1318.

Norman, G.J., Zhang, N., Morris, J.S., Karelina, K., Berntson, G.G., DeVries, A.C., 2010.

Social interaction modulates autonomic, inflammatory, and depressive-like responses to cardiac arrest and cardiopulmonary resuscitation. Proc. Natl. Acad. Sci. U. S. A. 107, 16342–16347.
Norman, G.J., Morris, J.S., Karelina, K., Weil, Z.M., Zhang, N., Al-Abed, Y., Brothers, H.M., Wenk, G.L., Pavlov, V.A., Tracey, K.J., Devries, A.C., 2011. Cardiopulmonary arrest and resuscitation disrupts cholinergic anti-inflammatory processes: a role for cholinergic alpha7 nicotinic receptors. J. Neurosci. 31, 3446–3452.
Petito, C.K., Feldmann, E., Pulsinelli, W.A., Plum, F., 1987. Delayed hippocampal damage in humans following cardiorespiratory arrest. Neurology 37, 1281–1286.
Reppert, S.M., Weaver, D.R., 2002. Coordination of circadian timing in mammals. Nature 418, 935–941.
Robinson, J., Bayliss, S.C., Fielder, A.R., 1991. Transmission of light across the adult and neonatal eyelid in vivo. Vis. Res. 31, 1837–1840.
Saito, K., Suyama, K., Nishida, K., Sei, Y., Basile, A.S., 1996. Early increases in TNF-alpha, IL-6 and IL-1 beta levels following transient cerebral ischemia in gerbil brain. Neurosci. Lett. 206, 149–152.
Sellix, M.T., Evans, J.A., Leise, T.L., Castanon-Cervantes, O., Hill, D.D., DeLisser, P., Block, G.D., Menaker, M., Davidson, A.J., 2012. Aging differentially affects the re-entrainment response of central and peripheral circadian oscillators. J. Neurosci. 32, 16193–16202.
Stenvers, D.J., van Dorp, R., Foppen, E., Mendoza, J., Opperhuizen, A.L., Fliers, E., Bisschop, P.H., Meijer, J.H., Kalsbeek, A., Deboer, T., 2016. Dim light at night disturbs the daily sleep-wake cycle in the rat. Sci. Rep. 6, 35662.
Stevens, R.G., Zhu, Y., 2015. Electric light, particularly at night, disrupts human circadian rhythmicity: is that a problem? Philos. Trans. R. Soc. Lond. Ser. B Biol. Sci. 370.
Sun, Q., Zhang, G., Chen, R., Li, R., Wang, H., Jiang, A., Li, Z., Kong, L., Fonken, L.K., Rajagopalan, S., Sun, Q., Liu, C., 2018. Central IKK2 inhibition ameliorates air pollution mediated hepatic glucose and lipid metabolism dysfunction in mice with type II diabetes. Toxicol. Sci. 164 (1), 240–249.
Tosini, G., Menaker, M., 1998. The clock in the mouse retina: melatonin synthesis and photoreceptor degeneration. Brain Res. 789, 221–228.
Weil, Z.M., Norman, G.J., Barker, J.M., Su, A.J., Nelson, R.J., Devries, A.C., 2008. Social isolation potentiates cell death and inflammatory responses after global ischemia. Mol. Psychiatry 13, 913–915.
Weil, Z.M., Karelina, K., Su, A.J., Barker, J.M., Norman, G.J., Zhang, N., Devries, A.C., Nelson, R.J., 2009. Time-of-day determines neuronal damage and mortality after cardiac arrest. Neurobiol. Dis. 36, 352–360.
Yrjanheikki, J., Keinanen, R., Pellikka, M., Hokfelt, T., Koistinaho, J., 1998. Tetracyclines inhibit microglial activation and are neuroprotective in global brain ischemia. Proc. Natl. Acad. Sci. U. S. A. 95, 15769–15774.
Zhao, L., An, R., Yang, Y., Yang, X., Liu, H., Yue, L., Li, X., Lin, Y., Reiter, R.J., Qu, Y., 2015. Melatonin alleviates brain injury in mice subjected to cecal ligation and puncture via attenuating inflammation, apoptosis, and oxidative stress: the role of SIRT1 signaling. J. Pineal Res. 59, 230–239.

American Association for the Advancement of Science: Human-Made Noise and Nighttime Lighting

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Date: Saturday, November 9, 2019, 07:06 AM EST

Interestingly, I found this conference announcement from the American Association of Science on **Human-Made Noise and Nighttime Lighting** 2015- it applies to a "T" to recent issues of concern and my efforts in this Town. I have also linked to the abstracts for the 3 individual speakers. The speaker's from the National Park Service talk was called "**Predicting Sound and Light levels at Large Spatial Scales**"; the next speaker's talk was called "**Going Global: Individual to Community-Level Responses to Noise and Light**" and the third was "**Social Science and Citizen Science to Inform Sound and Light Management**".

I ask the Town to get copies of the written talks and slides (I will reach out to the speakers as well and review them)- fyi, I have one of the replacement LED lights outside my house now from O&R and it is God-awful. The orange light was preferable, as I documented scientifically and aesthetically. The new light is too sharp- carries a way further so it winds up streaming down the hillside into my windows which is not appreciated.

It is fitting that this conference was put on by the American Association for the Advancement of Science. Science and public policy is what I am about and what I believe the signatories to my petition (that I was able to circulate for a few weeks before my life was upended and I was flushed out by noise) are about.

The hostility to science by Town government needs to be re-thought. The thinking around noise and light and the hostility I have received at both the noise hearing and at a private meeting also have to stop. It is 1950's thinking and not in keeping with what is known about these topics today.

Monday, 16 February 2015: 9:45 AM-11:15 AM
Room LL21E (San Jose Convention Center)

Artificial night lighting and loud, human-made sounds are increasingly prominent features in urban and rural areas across the globe. Because sensory systems are the primary means by which organisms interact with their environment, these evolutionarily novel stimuli have the potential to drastically alter the biology and ecology of diverse taxa, including humans. New evidence suggests that these sensory stimuli represent strong forces influencing human well-being and the behavior and distributions of animals. This symposium provides an appraisal of knowledge to date and discusses new insights resulting from innovative approaches to studying noise and night lighting as global change. Specifically, speakers will present new efforts to predict and map noise and night lighting at a continental scale, describe the breadth of ecological and human responses to these stimuli, and illustrate how citizen scientists can be important components to research and adaptive management. The panel will highlight the importance of the sensory environment to human and natural systems and demonstrate how research programs that integrate innovative mobile technologies, citizen scientists, and researchers from separate disciplines can reveal and produce otherwise unachievable insights and educational outcomes.

Organizer: *Clinton D. Francis, California Polytechnic State University*

Moderator: *Bora Zivkovic, North Carolina Wesleyan College*

Speakers:

***Kurt M. Fristrup**, National Park Service Division of Natural Sounds and Night Skies*
Predicting Sound and Light Levels at Large Spatial Scales

***Clinton D. Francis**, California Polytechnic State University*
Going Global: Individual to Community-Level Responses to Noise and Light

***Derrick Taff**, Pennsylvania State University*
Social Science and Citizen Science To Inform Sound and Light Management

The individual talk abstracts are here:

Predicting Sound and Light Levels at Large Spatial Scales

Monday, 16 February 2015: 9:45 AM-11:15 AM
Room LL21E (San Jose Convention Center)

***Kurt M. Fristrup**, National Park Service Division of Natural Sounds and Night Skies, Fort Collins, CO*

The National Park Service created models of sound level and night sky conditions for the coterminous U. S. to assess resource conditions in national parks and adjacent landscapes. These models generalize measurements taken from hundreds of sites spanning the range of geographic and ecological conditions found in park units. These data show that most people live in environments where night skies and soundscapes are profoundly degraded, and that noise and light pollution issues span much of the continent. For example, noise elevates median background sound levels by more than 3 decibels in 62% of the coterminous U. S. National parks and other protected natural areas are also affected, though many still present opportunities to enjoy pristine night skies and long intervals free from noise. Collaborative conservation efforts that extend beyond park boundaries will be required to conserve natural sensory environments for future generations.
https://aaas.confex.com/aaas/2015/webprogram/Paper14833.html

Going Global: Individual to Community-Level Responses to Noise and Light

Monday, 16 February 2015: 9:45 AM-11:15 AM
Room LL21E (San Jose Convention Center)

***Clinton D. Francis**,California Polytechnic State University, San Luis Obispo, CA*

The acoustic environment and natural cycle of day and night are of fundamental importance to countless species. Yet two prominent and underappreciated features of anthropogenic environmental change, noise and artificial light, are creating acoustic condition and light regimes that are highly novel across the globe. These stimuli can compromise the sensory systems by interfering with organisms' abilities to obtain, interpret and respond to environmental cues and alter biological clocks. Here we summarize the weight of current evidence that indicates that these aspects of human-induced environmental change can be powerful forces that require greater attention by biologists. We show that anthropogenic noise can drastically reduce avian diversity, disrupt avian physiological systems and behavior and alter several ecological interactions among community members. Similarly, at the individual level, we present evidence that exposure to light at night has several behavioral and physiological effects that can trigger reduced biological function and possibly reduced longevity. Despite these clear responses by individuals, whether and how light at night alters population and community dynamics remains unknown. We conclude by presenting new findings from a continental analysis demonstrating the relevance of the sensory environment to birds.
https://aaas.confex.com/aaas/2015/webprogram/Paper14832.html

Social Science and Citizen Science To Inform Sound and Light Management

Monday, 16 February 2015: 9:45 AM-11:15 AM
Room LL21E (San Jose Convention Center)

***Derrick Taff**, Pennsylvania State University, University Park, PA*

Citizen science can offer a unique structure for adaptive management, particularly of dispersed environmental features as found in residential systems. The knowledge-production capacity of citizen science makes it an overlooked, yet fundamental property of social-ecological systems. Based on a meta-analysis of broader impacts reported in the literature, we identify best practices for project design to enable adaptive management.

https://aaas.confex.com/aaas/2015/webprogram/Paper15973.html

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> On Saturday, October 12, 2019, 05:58:55 PM EDT, Deborah Kopald <deborah_kopald@ymail.com> wrote:

The noise hearing is Monday @ 6 p.m. Note 6, not 7.

On Saturday, September 28, 2019, 09:35:35 PM EDT, Deborah Kopald <deborah_kopald@ymail.com> wrote:

Dear Town Board and Interested Town of Highlands Residents,

This website was mentioned to me by NYC noise expert Dr. Arline Bronzaft- as I had mentioned about hearing a noisy lawnmower in a part of the street I hadn't been in on a while -- I have subsequently learned that towns have started demanding that people use certain electric lawnmowers and gardening tools to both make the sound less loud and unpleasant and eliminate diesel exhaust fumes all in one fell swoop.

Such a policy would also meet the town's mandate to **reduce greenhouse gas emissions**, simultaneously- a kill-two-birds with one stone policy!

https://www.quietcommunities.org/

Their mission statement reads, "Our mission is to transition landscape maintenance to **low noise, zero emissions** practices with positive solutions to protect the health of workers, children, the public and the environment. We provide research, education, outreach, and solutions, working collaboratively with communities, businesses, schools, and government agencies. Quiet Communities is a program of the non-profit organization, Quiet Communities, Inc."

Given that some people may own the noisy, diesel exhaust spewing ones- those could be restricted to a very limited time period to minimize greenhouse gas effects and annoyance of diesel exhaust and noise. Residents could be incentived to purchase green equipment that is also quiet. This could be done with a tax credit against local taxes to facilitate the conversion. Or it could just be mandated as is being done elsewhere to fulfill the mandate of the town's global warming resolution, stat.

Dr. Bronzaft also mentioned that the city of New York requires notification to neighbors of projects- I've discussed this issue previously and will do so in my formal remarks.

Also- regarding ongoing comments about low frequency noise impacts, to underscore how much of a nuisance this environmental pollutant is, I would like to point out that this type of noise which comes from motors and construction equipment is also emitted by wind turbines, which have been known to drive people from their homes. Low frequency noise covers a spectrum of frequencies and is audible to and/or felt by many, though not all.

These sites from Australia and Ireland (the latter is a paper by biomedical engineer Mariana Alves-Pereira, "Infrasound and low-frequency noise- does it affect human health?") discuss the same problem:

https://waubrafoundation.org.au/

http://www.engineersjournal.ie/2018/01/23/ilfn-infrasound-low-frequency-noise-turbine-health/

This is why provisions in the NYC code forcing silencers on certain machines should be under consideration.

To reiterate, it is 2019, soon to be 2020. It is a new era where people work from home and spend more time there and an era where towns pass resolutions reducing global warming impacts. Fortunately both these and noise impacts can be addressed together by some policies.

I continue to urge meaningful change and not just a consideration of what hours to work (which should be negotiated by all, but should also be limited from the current free-for-all to respect the fact that people work out of their homes in today's day and age, and some must be at home because they are disabled, elderly, or some combination thereof.

Again, we are one of the only places with no noise ordinance at all. "Incremental" change is not enough.

Sincerely,

Deborah

Exhibit 8b Abstract for AAAS session "Social Science and Citizen Science To Inform Sound and Light Management"
(391-392)

AAAS 2015 ANNUAL MEETING
INNOVATIONS, INFORMATION, AND IMAGING

Social Science and Citizen Science To Inform Sound and Light Management

Monday, 16 February 2015: 9:45 AM-11:15 AM
Room LL21E (San Jose Convention Center)

***Derrick Taff**, Pennsylvania State University, University Park, PA*

Citizen science can offer a unique structure for adaptive management, particularly of dispersed environmental features as found in residential systems. The knowledge-production capacity of citizen science makes it an overlooked, yet fundamental property of social-ecological systems. Based on a meta-analysis of broader impacts reported in the literature, we identify best practices for project design to enable adaptive management.

See more of: Human-Made Noise and Nighttime Lighting
See more of: Behavioral and Social Sciences
See more of: Symposia

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Meeting Information

When:
12 - 16 February 2015
Where:
Where: San Jose, CA

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AAAS

Exhibit 8c AAAS session “Going Global: Individual to Community-Level Responses to Noise and Light” (393-394)

AAAS 2015 ANNUAL MEETING
INNOVATIONS, INFORMATION, AND IMAGING

Going Global: Individual to Community-Level Responses to Noise and Light

Monday, 16 February 2015: 9:45 AM-11:15 AM
Room LL21E (San Jose Convention Center)

Clinton D. Francis*, California Polytechnic State University, San Luis Obispo, CA*

The acoustic environment and natural cycle of day and night are of fundamental importance to countless species. Yet two prominent and underappreciated features of anthropogenic environmental change, noise and artificial light, are creating acoustic condition and light regimes that are highly novel across the globe. These stimuli can compromise the sensory systems by interfering with organisms’ abilities to obtain, interpret and respond to environmental cues and alter biological clocks. Here we summarize the weight of current evidence that indicates that these aspects of human-induced environmental change can be powerful forces that require greater attention by biologists. We show that anthropogenic noise can drastically reduce avian diversity, disrupt avian physiological systems and behavior and alter several ecological interactions among community members. Similarly, at the individual level, we present evidence that exposure to light at night has several behavioral and physiological effects that can trigger reduced biological function and possibly reduced longevity. Despite these clear responses by individuals, whether and how light at night alters population and community dynamics remains unknown. We conclude by presenting new findings from a continental analysis demonstrating the relevance of the sensory environment to birds.

See more of: Human-Made Noise and Nighttime Lighting
See more of: Behavioral and Social Sciences
See more of: Symposia

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Where: San Jose, CA

AAAS

AAAS 2015 ANNUAL MEETING
INNOVATIONS, INFORMATION, AND IMAGING

Predicting Sound and Light Levels at Large Spatial Scales

Monday, 16 February 2015: 9:45 AM-11:15 AM
Room LL21E (San Jose Convention Center)

Kurt M. Fristrup*, National Park Service Division of Natural Sounds and Night Skies, Fort Collins, CO*

The National Park Service created models of sound level and night sky conditions for the coterminous U. S. to assess resource conditions in national parks and adjacent landscapes. These models generalize measurements taken from hundreds of sites spanning the range of geographic and ecological conditions found in park units. These data show that most people live in environments where night skies and soundscapes are profoundly degraded, and that noise and light pollution issues span much of the continent. For example, noise elevates median background sound levels by more than 3 decibels in 62% of the coterminous U. S. National parks and other protected natural areas are also affected, though many still present opportunities to enjoy pristine night skies and long intervals free from noise. Collaborative conservation efforts that extend beyond park boundaries will be required to conserve natural sensory environments for future generations.

See more of: Human-Made Noise and Nighttime Lighting
See more of: Behavioral and Social Sciences
See more of: Symposia

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Meeting Information

When:
12 - 16 February 2015
Where:
Where: San Jose, CA

Light pollution is driving the INSECT APOCALYPSE,luring moths to their deaths, making bugs more visible to predators; Light pollution has diverse impacts on...

From: Deborah Kopald (deborah_kopald@ymail.com)

To: blivsey@highlands-ny.gov; jgunza@highlands-ny.gov; tking@highlands-ny.gov; rparry@highlands-ny.gov; rsullivan@highlands-ny.gov; sussman1@frontiernet.net; jpatterson@highlands-ny.gov; lpeterson@highlands-ny.gov; deborah_kopald@ymail.com

Cc: jsun1166@yahoo.com; frugalgardenerny@gmail.com; crownprincejosh@aol.com; pckinney3@gmail.com; bobbie@bobbiefallon.com; gardens4353@aol.com; pondside@earthlink.com; john.blanc@usma.edu; jmagee721@gmail.com; bernardpcassidy@aol.com; kingkdamon@gmail.com; marianmichaels@yahoo.com; mayermom3@hotmail.com; kirkmanning@hotmail.com; cszevin@gmail.com; ktk@us.ibm.com; tkwietniak@yahoo.com; jennifer.pushlar@gmail.com; akena@me.com; mileskristy@hotmail.com; jrplanck@gmail.com; melissaanolan@gmail.com; thecaptainsails@gmail.com; nugitive@gmail.com; musiccoach40@gmail.com; rissybaby7@gmail.com; marissa.marotta@gmail.com; abrunwasser@gmail.com; eaglfire@gmail.com; frankcassano9@gmail.com; janetwilkiephd@yahoo.com; momamac5@aol.com; walter@bestweb.net; crescensioc@aol.com; bklyn29@earthlink.net; hudsonvalleybirder@yahoo.com; gfciesla@verizon.net; holtpaula10@msn.com; beasnest10@aol.com; goldphoto@juno.com; guys1gals3@yahoo.com; khs117@aol.com; jbliotta@aol.com; jeanwort@aol.com; rjmbam53@aol.com; ltrubenbachekg@aol.com; eflowoman@aol.com; rbuchholz@hvc.rr.com; cleary33@verizon.net; jreilly@rcls.org; parashk@hvc.rr.com; brewss@aol.com; campcosmo@hvc.rr.com; mslapp@hvc.rr.com; vanzetta@netzero.net; 4tietze@msn.com; ganobrien@verizon.net; sslewis4@aol.com; hsuelou@aol.com; chazandsyl@aol.com; jjpdoo@aol.com; nela.pratts45@aol.com; jooklife5000@aol.com; walla872@aol.com; litrainman21884@aol.com; me@iamwalker.com; jamesdisalvo@yahoo.com; mindy.kimball@westpoint.edu; lizdipierro@aol.com; ataylor1@hvc.rr.com; lkmilsom@gmail.com; irena.kelly.workroom@gmail.com; dwojciechowski@hvc.rr.com; holly@thegarrisonhouse.com; lovelyann74@gmail.com; amcten@yahoo.com; jane.capizzano@wpaog.org; sallyprah@aol.com; cmill1047@aol.com; aesflash@hvc.rr.com; scroot@aol.com; ruthoke@aol.com; danielleshim@gmail.com; newsofthehighlands@gmail.com

Date: Friday, November 22, 2019, 06:26 PM EST

Light pollution is driving the INSECT APOCALYPSE, scientists claim — from luring moths to their deaths to making bugs more visible to predators

- **Experts reviewed over 200 studies into the impacts of artificial light on bugs**
- **Light pollution has diverse impacts on insects that can shake entire food webs**
- **It is feared that 40 per cent of creepy-crawlies could go extinct within decades**
- **Researchers encourage people to reduce their use of artificial light at night**
- **https://www.dailymail.co.uk/sciencetech/article-7715309/Light-pollution-driving-INSECT-APOCALYPSE-scientists-claim.html**

Light pollution is driving the INSECT APOCALYPSE, scientists claim

Light pollution is driving the INSECT APOCALYPSE, scientists claim

Ian Randall

Declining insect numbers are having knock on effects to the global ecosystem - such as reducing North American b...

On Saturday, November 9, 2019, 07:23:12 AM EST, Deborah Kopald <deborah_kopald@ymail.com> wrote:

Here is the link to the overall conference which got omitted from my last note: https://aaas.confex.com/aaas/2015/webprogram/Session9641.html

I also went back into the email and took the liberty of highlighting major points in the abstracts which emphasize **how degraded light and noise conditions impact longevity and reduce functionality, how important the sensory environment is, and how citizens are taking the lead in improving these conditions**. **(**Apparently, these people are getting respect at conferences in California. I get hostility, told to move to Montana and an uncontrolled mob in Town Hall that has been brainwashed into saying I am un-neighborly as well as oblique threats made to me personally for demanding the few existing rules there are be adhered to.**)**

--

On Saturday, November 9, 2019, 07:06:50 AM EST, Deborah Kopald <deborah_kopald@ymail.com> wrote:

Interestingly, I found this conference announcement from the American Association of Science on **Human-Made Noise and Nighttime Lighting** 2015- it applies to a "T" to recent issues of concern and my efforts in this Town. I have also linked to the abstracts for the 3 individual speakers. The speaker's from the National Park Service talk was called "**Predicting Sound and Light levels at Large Spatial Scales**"; the next speaker's talk was called "**Going Global: Individual to Community-Level Responses to Noise and Light**" and the third was "**Social Science and Citizen Science to Inform Sound and Light Management**".

I ask the Town to get copies of the written talks and slides (I will reach out to the speakers as well and review them)- fyi, I have one of the replacement LED lights outside my house now from O&R and it is God-awful.

The orange light was preferable, as I documented scientifically and aesthetically. The new light is too sharp- carries a way further so it winds up streaming down the hillside into my windows which is not appreciated.

It is fitting that this conference was put on by the American Association for the Advancement of Science. Science and public policy is what I am about and what I believe the signatories to my petition (that I was able to circulate for a few weeks before my life was upended and I was flushed out by noise) are about.

The hostility to science by Town government needs to be re-thought. The thinking around noise and light and the hostility I have received at both the noise hearing and at a private meeting also have to stop. It is 1950's thinking and not in keeping with what is known about these topics today.

Monday, 16 February 2015: 9:45 AM-11:15 AM
Room LL21E (San Jose Convention Center)

Artificial night lighting and loud, human-made sounds are increasingly prominent features in urban and rural areas across the globe. Because sensory systems are the primary means by which organisms interact with their environment, these evolutionarily novel stimuli have the potential to drastically alter the biology and ecology of diverse taxa, including humans. New evidence suggests that these sensory stimuli represent strong forces influencing human well-being and the behavior and distributions of animals. This symposium provides an appraisal of knowledge to date and discusses new insights resulting from innovative approaches to studying noise and night lighting as global change. Specifically, speakers will present new efforts to predict and map noise and night lighting at a continental scale, describe the breadth of ecological and human responses to these stimuli, and illustrate how citizen scientists can be important components to research and adaptive management. The panel will highlight the importance of the sensory environment to human and natural systems and demonstrate how research programs that integrate innovative mobile technologies, citizen scientists, and researchers from separate disciplines can reveal and produce otherwise unachievable insights and educational outcomes.

Organizer: *Clinton D. Francis, California Polytechnic State University*

Moderator: *Bora Zivkovic, North Carolina Wesleyan College*

Speakers:

***Kurt M. Fristrup**, National Park Service Division of Natural Sounds and Night Skies*
Predicting Sound and Light Levels at Large Spatial Scales

***Clinton D. Francis**, California Polytechnic State University*
Going Global: Individual to Community-Level Responses to Noise and Light

***Derrick Taff**, Pennsylvania State University*
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https://aaas.confex.com/aaas/2015/webprogram/Paper14833.html

Going Global: Individual to Community-Level Responses to Noise and Light

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https://aaas.confex.com/aaas/2015/webprogram/Paper14832.html

Social Science and Citizen Science To Inform Sound and Light Management

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Room LL21E (San Jose Convention Center)

***Derrick Taff**, Pennsylvania State University, University Park, PA*

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https://aaas.confex.com/aaas/2015/webprogram/Paper15973.html

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On Saturday, October 12, 2019, 05:58:55 PM EDT, Deborah Kopald <deborah_kopald@ymail.com> wrote:

The noise hearing is Monday @ 6 p.m. Note 6, not 7.

On Saturday, September 28, 2019, 09:35:35 PM EDT, Deborah Kopald <deborah_kopald@ymail.com> wrote:

Dear Town Board and Interested Town of Highlands Residents,

This website was mentioned to me by NYC noise expert Dr. Arline Bronzaft- as I had mentioned about hearing a noisy lawnmower in a part of the street I hadn't been in on a while -- I have subsequently learned that towns have started demanding that people use certain electric lawnmowers and gardening tools to both make the sound less loud and unpleasant and eliminate diesel exhaust fumes all in one fell swoop.

Such a policy would also meet the town's mandate to **reduce greenhouse gas emissions**, simultaneously- a kill-two-birds with one stone policy!

https://www.quietcommunities.org/

Their mission statement reads, "Our mission is to transition landscape maintenance to **low noise, zero emissions** practices with positive solutions to protect the health of workers, children, the public and the environment. We provide research, education, outreach, and solutions, working collaboratively with communities, businesses, schools, and government agencies. Quiet Communities is a program of the non-profit organization, Quiet Communities, Inc."

Given that some people may own the noisy, diesel exhaust spewing ones- those could be restricted to a very limited time period to minimize greenhouse gas effects and annoyance of diesel exhaust and noise. Residents could be incentived to purchase green equipment that is also quiet. This could be done with a tax credit against local taxes to facilitate the conversion. Or it could just be mandated as is being done elsewhere to fulfill the mandate of the town's global warming resolution, stat.

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Again, we are one of the only places with no noise ordinance at all. "Incremental" change is not enough.

Sincerely,

Deborah

Light pollution is driving the INSECT APOCALYPSE, scientists claim — from luring moths to their deaths to making bugs more visible to predators

- **Experts reviewed over 200 studies into the impacts of artificial light on bugs**
- **Light pollution has diverse impacts on insects that can shake entire food webs**
- **It is feared that 40 per cent of creepy-crawlies could go extinct within decades**
- **Researchers encourage people to reduce their use of artificial light at night**

By IAN RANDALL FOR MAILONLINE
PUBLISHED: 12:16 EDT, 22 November 2019 | **UPDATED:** 14:27 EDT, 22 November 2019

Light pollution is helping to drive the so-called 'insect apocalypse', experts warn, contributing to fears that 40 per cent of all bug species will be lost within decades.

Artificial light at night can impact insects in various ways, from driving them elsewhere to changing their development and life cycles.

Declining insect numbers are having knock on effects to the global ecosystem — such as reducing North American bird numbers by 3 billion in the last 50 years.

The researchers note, however, that light pollution is — compared with other man-made environmental problems — relatively easy to address.

They encourage people to reduce their reliance on artificial lighting where possible and dim or filter outside light sources where not.

Scroll down for video

'Artificial light at night impacts nocturnal and diurnal insects through effects on development, movement, foraging, reproduction and predation risk,' the researchers note in their paper.

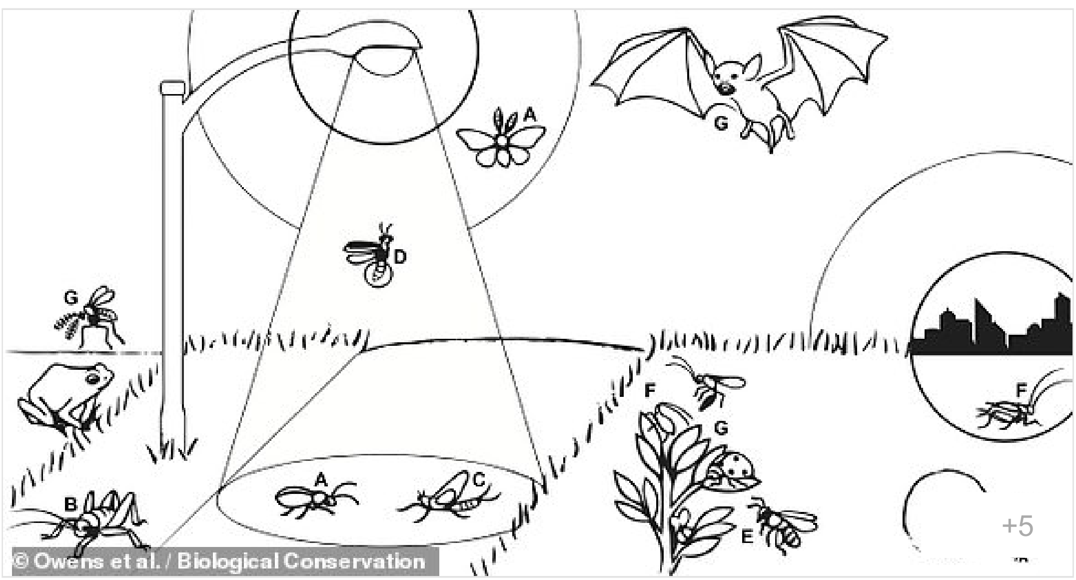
Because of light pollution's broad impact, it provides a threat that transcends individual insect species.

For example, experts believe that declining insect numbers are directly related to the loss of around 3 billion birds that feed on bugs in the US and Canada since 1970.

'We also emphasise that artificial light at night is not merely a subcategory of urbanisation,' the researchers added.

'The ecological consequences of light pollution are not limited to urban and suburban centres, but widespread along roadways and around protected areas.'

HOW ARE DIFFERENT INSECTS AFFECTED BY LIGHT POLLUTION?



Artificial light at night can impact insects in various ways, from driving them elsewhere to changing their development and life cycles

A. Moths and beetles are fatally attracted to artificial light sources.

B. In contrast, some insects like weta avoid light, driving them away.

E. Daytime pollinators like bees end up extending their active hours later into the evening, while nocturnal insects are forced to emerge later.

F. Aphids and crickets suffer altered development and life cycles that are

C. Mayflies end up confused and lay eggs on non-aquatic flat surfaces.

D.Natural light sources can be obscured by artificial lights. This prevents dung beetles from navigating by the stars and glowing insects like fireflies from attracting mates and warding off predators.

regulated by light.

G. These disturbed biological cycles eventually lead to mismatches among interconnected species and food webs, with cascading effects. Light can make certain insects easier for predators to spot and eat, as well.

SOURCE: **Owens et al. / Biological Conservation**

'Just as was the case for early **climate change** science, we have to take the Insect Apocalypse seriously,' said the Zoological Lighting Institute's James Karl Fischer.

'If we really hope to prevent a terrible situation from getting worse, these issues should not be avoided.'

'Insects are lynch-pins of the environment and necessary for other kinds of animals to survive; and a diversity of insects is crucial to maintaining our own food supply.'

Declining insect numbers are having knock on effects to the global ecosystem — such as reducing North American bird numbers by 3 billion in the last 50 years

The authors have a number of simple recommendations to help protect insects from light pollution — beyond the obvious of turning off non-essential illumination.

Outdoor lights can also be shielded, filtered or dimmed, they note.

They also caution that certain monochromatic LED lights presently come with a number of environmental drawbacks — such as their potential for generating ultrasound emissions that can also disturb various insects.

The researchers note, however, that light pollution is — compared with other man-made environmental problems — relatively easy to address

'The amount of personal control we have here gives us a bit of hope,' said Dr Fischer.

'It is an easy matter to eliminate, reduce or change the ecologically devastating artificial lighting in and on our homes, schools, businesses if we want to, simply by turning off exterior lights.'

'But we have to want to, and be willing to explore alternatives to the functions those lights currently serve.'

The full findings of the study were published in the journal **Biological Conservation**.

LIGHT POLLUTION IS ARTIFICIAL LIGHT THAT IS EXCESSIVE, OBTRUSIVE AND WASTEFUL

Light pollution, also known as photopollution, is the presence of anthropogenic light in the night environment.

Artificial light that's excessive, obtrusive and ultimately wasteful is called light pollution, and it directly influences how bright our night skies appear.

With more than nine million streetlamps and 27 million offices, factories, warehouses and homes in the UK, the quantity of light we cast into the sky is vast.

While some light escapes into space, the rest is scattered by molecules in the atmosphere making it difficult to see the stars against the night sky. What you see instead is 'Skyglow'.

The increasing number of people living on earth and the corresponding increase in inappropriate and unshielded outdoor lighting has resulted in light pollution—a brightening night sky that has obliterated the stars for much of the world's population.

Most people must travel far from home, away from the glow of artificial lighting, to experience the awe-inspiring expanse of the Milky Way as our ancestors once knew it.

Light pollution is excessive and inappropriate artificial light. While some light escapes into space, the rest is scattered by molecules in the atmosphere making it difficult to see the stars against the night sky. What you see instead is 'Skyglow'

The negative effects of the loss of this inspirational natural resource might seem intangible.

But a growing body of evidence links the brightening night sky directly to measurable negative impacts on human health and immune function, on adverse behavioural changes in insect and animal populations, and on a decrease of both ambient quality and safety in our nighttime environment.

Astronomers were among the first to record the negative impacts of wasted lighting on scientific research, but for all of us, the adverse economic and environmental impacts of wasted energy are apparent in everything from the monthly electric bill to global warming.

Read more:
Light pollution is a driver of insect declines - ScienceDirect

Biological Conservation
Volume 241, January 2020, 108259

Short communication

Light pollution is a driver of insect declines

Avalon C.S. Owens [a], Précillia Cochard [b], Joanna Durrant [c], Bridgette Farnworth [d], Elizabeth K. Perkin [e], Brett Seymoure [f]

Show more

https://doi.org/10.1016/j.biocon.2019.108259

Highlights

- Artificial light at night
- Recent research addresses global loss of insect biodiversity without including ALAN.
- ALAN causes insect declines due to affecting insect movement, foraging, reproduction, and predation.
- Insect biodiversity loss can be mitigated with better informed lighting practices.

Abstract

Insects around the world are rapidly declining. Concerns over what this loss means for food security and ecological communities have compelled a growing number of researchers to search diverse insect species, as well as its positive effect on insectivore predation. We conclude with a discussion of how artificial lights can be tuned to reduce their impact on vulnerable populations. ALAN is unique among anthropogenic habitat disturbances in that it is fairly easy to ameliorate, and leaves behind no residual effects. Greater recognition of the ways in which ALAN affects insects can help conservationists reduce or eliminate one of the major drivers of insect declines.

Previous Next

Keywords

ALAN; Light pollution; Skyglow; Insect apocalypse; Insect declines; Insect conservation

1. Introduction

Over the last two decades, rese

biomass (Dirzo et al., 2014; Pot

Germany (Hallmann et al., 201

2019), Sweden (Franzén and Jo

al., 2009; Wilson et al., 2018), P

Hallwachs, 2019). This alleged

amount of public concern: insects are a critical component of all terrestrial and freshwater food webs (Baxter et al., 2005; van Veen et al., 2006) and provide important ecosystem services (Schowalter et al., 2018). Their absence would have devastating consequences for life on this planet. If insect decline is indeed a global phenomenon (see Wagner, 2019), the question then becomes: What is the problem, and how can we best address it? One recent review of insect decline has sought to identify the main causes by ranking potential drivers in order of their frequency of mention within relevant literature (Sánchez-Bayo and Wyckhuys, 2019). The authors found, as indeed have we, that habitat loss, chemical pollution (especially pesticide use), invasive species, and climate change are the most well-described threats to insect persistence. However, we do not agree that relative degree of scientific consideration reflects importance in this case. Instead we posit that "diurnal bias"—a preference among ecologists for studying daytime phenomena (Gaston, 2019)—has led insect conservationists to overlook another widespread habitat disturbance, pollutant, and method of insect control: artificial light at night (ALAN).

and Honda, 2013); around the 1950s, light traps became popular among entomologists for use in surveying insect biodiversity (Leather, 2015). More recently, as lighting technology has advanced and the cost per unit of brightness declined, both the intensity and quantity of artificial light installations have increased worldwide (Kyba, 2018; Kyba et al., 2017; Tsao et al., 2010). Modern light pollution is no longer confined to urban centers, but radiates outwards through the atmosphere and along road networks that run into or around otherwise pristine areas (Gaston et al., 2015; Gaston and Holt, 2018; Guetté et al., 2018). Since 1992, levels of light pollution have doubled in high biodiversity areas, and are likely to continue to rise (Koen et al., 2018; Kyba et al., 2017). By 2014, over 23% of the land surface of the planet experienced artificially elevated levels of night sky brightness (Falchi et al., 2016); by comparison, agricultural crops cover approximately 12% (FAO, 2012). Insect conservationists now frequently lament, as do we, the dearth of insects to be found swarming around artificial lights (*e.g.* Janzen and Hallwachs, 2019), yet rarely consider that the lights themselves may be an issue.

Artificial light at night is a potent evolutionary trap (Schlaepfer et al., 2002; Altermatt and Ebert, 2016; Hopkins et al., 2018). Most anthropogenic disturbances have natural analogs: the climate has warmed before, habitats have fragmented, species have invaded new ranges, and new pesticides (also known as plant daily cycle of light and dark, th constant. Until now (Altermatt adaptations to ALAN. And so s others for unclear reasons pere injury, exhaustion, or predatio impact of an artificial light source will depend on its intensity, direction, spectral distribution (Elvidge et al., 2010), and flicker rate (Inger et al., 2014), as well as the time of day and structure of nearby surfaces (Horváth et al., 2009; Szaz et al., 2015), the light output of most common fixtures is more than enough to radically disturb the entire habitat of small-bodied animals such as insects. Insects that manage to escape the cone of light beneath a fixture can still be affected by skyglow, which emanates far beyond urban centers at levels sufficient to obscure or alter vital environmental cues including polarized moonlight, starlight, moon phase, and daylength (Davies et al., 2013b; Kyba et al., 2011a; 2011b).

A growing body of research demonstrates that ALAN can impact the fitness of plants and animals (Bennie et al., 2016; Gaston et al., 2013), and more recent reviews have catalogued its broadscale effects on insects in particular (Desouhant et al., 2019; Grubisic et al., 2018; Owens and Lewis, 2018; Seymoure, 2018). Some estimates suggest that one third of insects attracted to stationary

Hublin, 1983; see also Cantelo et al., 1972). Insects that escape immediate death may still become trapped in a "light sink," unable to engage in behaviors vital to fitness (van Langevelde et al., 2017). The potential for individual deaths to compound into large-scale declines (Kokko and Sutherland, 2001) has been borne out by the results of a 30 year survey of Dutch macromoths (van Langevelde et al., 2018), during which time positively phototactic and nocturnal species underwent steeper declines than diurnal species not attracted to light. A similar survey of macromoths in the UK and Ireland found greater losses at light polluted sites (Wilson et al., 2018), even after controlling for urbanization (Bates et al., 2014), and that nocturnal species once again underwent disproportionate declines (Coulthard et al., 2019). However, a small number of studies have found disproportionate declines in day-active insect species instead (Franzén and Johannesson, 2007).

One complicating factor is the fact that temporal niche partitioning between diurnal and nocturnal species has become less extreme in response to human activity (Ditchkoff et al., 2006; Gaynor et al., 2018; Levy et al., 2019). At the same time, deforestation and habitat fragmentation have reduced the availability of dark refuges for all species (reviewed in Seymoure, 2018). If ALAN is contributing to a worldwide decline of entomofauna, insects that occupy open habitats should be more threatened than those

more so than fossorial species-

and Johannesson, 2007; Guerr

Sánchez-Bayo and Wyckhuys, 2

with light in mind.

We argue here that ALAN impa[...]

alike in ways both related and unrelated to flight-to-light behavior (Fig. 1). ALAN can cause immediate behavioral change, or more complex behavioral expression of physiological changes induced by external timekeeping signals (*i.e.Zeitgebers*); both changes may be triggered by certain wavelengths of light only. ALAN can also interact with other anthropogenic disturbances such as climate change or noise pollution in complex ways (McMahon et al., 2017; Miller et al., 2017; Walker et al., 2019). For example, pollinator insects pushed from agricultural fields to road verges by pesticides will be more exposed to streetlights and vehicle headlights (Phillips et al., 2019). Impacts on single species will have downstream effects on other members of the food web, the outcome of which can be extremely difficult to predict (Sanders and Gaston, 2018). To keep this review in scope, we focus here on the way in which ALAN impacts several vital fitness-related behaviors of insects on the individual level. We also discuss some of the potential consequences for insect populations, many of which are just now becoming apparent (Table 1)

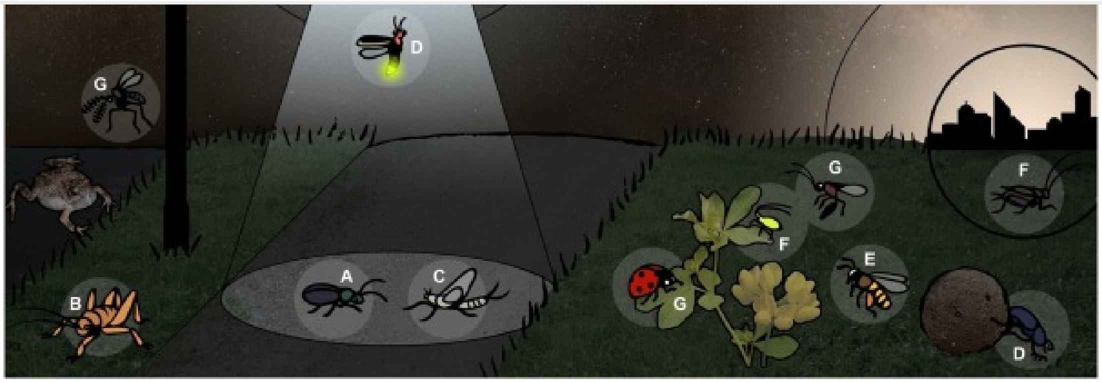


Fig. 1. Both local sources of artificial light (**left**) and diffuse skyglow (**right**) can impact the physiology, behavior, and fitness of insects. Positively phototactic insects, including macromoths and beetles, exhibit a “fatal attraction” to ALAN (**A**), while negatively phototactic insects such as weta avoid it (**B**). ALAN also amplifies polarized light pollution, causing mayflies and other aquatic insects to oviposit on non-aquatic flat surfaces (**C**). ALAN obscures natural nocturnal light sources (**D**), including the astr
bioluminescent signals produc
and reproductive success in th
activity and rest (*E*), causing di
into the evening, while fully n
these repeated perturbations h
and aphids (**F**). The resulting phenological mismatches between host plants, predators, and prey will have cascading effects on pollination success, host-parasite interactions, and eventually entire food webs (**G**). Textures modified from Creative Commons Attribution 2.0 Generic licensed images (Wikimedia Commons, Flickr; Milky Way: John Fowler; túngara frog: Geoff Gallice; Townsend's big-eared bat: National Parks Service).

Table 1. Examples of the effects of ALAN on vital fitness-related behaviors in diverse insect taxa. **RESPONSE to ALAN** adapted from Owens and Lewis (2018): positive and negative phototaxis refer to impulsive movement towards or away from a light source; spatial disorientation connotes an impaired ability to navigate due to altered environmental cues; temporal disorientation arises from the disruption of circadian rhythms; altered recognition refers to the impact of additional

BEHAVIOR	RESPONSE to ALAN	FITNESS COST	EXAMPLE TAXON	citation(s)
development	*temporal disorientation*	juvenile insects exposed to ALAN experience accelerated, slowed, or impaired growth	field crickets	Durrant et al., 2018*
	positive phototaxis	insects caught in the orbit of artificial lights are trapped, unable to advance or retreat	macromoths	Somers-Yeates et al., 2013*
	negative phototaxis	insects that avoid moving through or around lit areas are unable to effectively disperse	aquatic insects	Perkin et al., 2014a,b*
movement	***spatial disorientation***	ALAN obscures orientational cues such as the moon or stars, and thus impedes navigation	sand hoppers	Ugolini et al., 2005
	temporal disorientation	ambient illumination inhibits nocturnal activity, including locomotion, in night-active insects	leafhoppers	Shi et al., 2017*
	positive phototaxis	inse[illegible] do r[illegible]		
	negative phototaxis	inse[illegible] capi[illegible]		
foraging	***temporal disorientation***	insects that shift to new temporal niches are physiologically unprepared to forage therein	dung beetles	Caveney et al., 1995
	altered recognition	unnatural spectra obscure the visual signals insects use to identify food sources or hosts	parasitoid wasps	Cochard et al., 2017*
	indirect effects	the impact of ALAN on plant growth decreases food availability for herbivorous insects	pea aphids	Bennie et al., 2018a*
reproduction	***sex-biased phototaxis***	disproportionate attraction to ALAN skews the effective sex ratio in insect populations	winter moths	van Geffen et al., 2015b*
	temporal disorientation	physiological effects of ALAN lead to sterility or decreased fecundity of adult reproductives	fruit flies	McLay et al., 2017*

predation	***positive phototaxis***	insects trapped around or under artificial lights are vulnerable to exploitation by predators	giant water bugs	Yoon et al., 2010*
	altered recognition	unnatural spectra obscure aposematic coloration and/or camouflage in prey insects	*Heliconius* butterflies	Seymoure, 2016*
	indirect effects	increased illumination allows visually guided insectivores to hunt more effectively	lady beetle prey	Miller et al., 2017*

2. Movement

Large-scale seasonal migration and small-scale daily movements in pursuit of food or habitat both play a crucial role in maintaining the fitness of insect species (Hammock and Wetzel, 2013; Rankin, 1985), and are necessary to the recovery of at-risk metapopulations (Schultz et al., 2019). The attractive and repulsive effects of discrete sources of artificial light are well known to prevent natural patterns of movement (Allema et al., 2012) and alter the distribution of insects in a landscape away from the evolv al., 2017; Manríquez et al., 201 repercussions of "fatal attracti Lines of closely spaced streetli to the movement of positively Eisenbeis, 2006), effectively fra the drift rates of negatively phototactic immature aquatic insects are significantly lower in the presence of riverside lighting (Henn et al., 2014; Perkin et al., 2014a), and their adult forms prevented from moving between streams or colonizing new streams (Perkin et al., 2014b).

Nocturnal light signals serve an important role in the orientation of many insect species (reviewed in Foster et al., 2018; Owens and Lewis, 2018). For example, *Scarabaeus satyrus* dung beetles use the stars and dim patterns of polarized starlight to efficiently navigate away from dung piles (Dacke et al., 2013), while *Talitrus saltator* sand hoppers maintain a route parallel to the shoreline on their nightly excursions by moving with respect to the moon (Ugolini et al., 2005). These signals can be partially or fully obscured in light polluted habitats (Davies et al., 2013b; Kyba et al., 2011a; 2011b); lunar signals also face competition from overhead sources of artificial light (*e.g.* streetlights; Sotthibandhu and Baker, 1979). Upwelling light (*e.g.* path lighting) can further disorient flying insects such as wasps and dragonflies that maintain a horizontal position

3. Foraging

Artificial light at night can interfere with efficient acquisition of food, vital to the developmental and reproductive success of insects (Wenninger and Landolt, 2011), in several ways. Diurnal and crepuscular insects that move their foraging activity into the "night light niche" (Garber, 1978) must endure cold stress (Caveney et al., 1995; Urbanski et al., 2012), while nocturnal insects that continue to forage alongside may experience reduced rates of growth due to increased competition and/or what is effectively a reduction in their spatial niche (Duarte et al., 2019). Insects avoid profitable foraging patches under illumination due to perceived (Skutelsky, 1996) or actual increases in their risk of predation by invertebrate (Heiling, 1999; Miller et al., 2017), avian (Dwyer et al., 2013, and mammalian insectivores (Rydell, 2006). For example, the reduced presence of tree (*Hemideina thoracica*) and cave (Rhaphidophoridae sp.) weta at artificially illuminated sites is thought to be in avoidance of geckos and other nocturnal predators (Farnworth et al., 2018).

Nocturnal insects that postpone foraging until their habitat is sufficiently dark (Dreisig, 1980) are likely to be negatively affected by a reduction in temporal niche (Tierney et al., 2017). For example, in laboratory environ[...]
several moth species (van Lang[...]
less food under ALAN, and gro[...]
(*Arachnocampa tasmaniensis*) ext[...]
(Merritt and Clarke, 2013), and[...]
pollinators that delay their nig[...]
to become desynchronized from their food plants, especially in cases where flower opening is cued by temperature instead of light (Seymoure, 2018; Somanathan et al., 2008; van Doorn and Van Meeteren, 2003). Differences in the environmental cues used to guide development of insects and their food plants result in increasingly exaggerated desynchronization over the course of the growing season (Forrest and Thomson, 2011; Laube et al., 2014) and decrease pollinator effectiveness (Rafferty and Ives, 2012).

Artificial light at night might also cause unexpected trophic cascades through its effects on plants (Bennie et al., 2016; Schroer et al., 2019) or insect natural enemies (see Predation). For example, ALAN stunts the growth of larval cutworms (*Apamea sordens*) by increasing the cuticle toughness of their smooth brome host plants (Grenis and Murphy, 2018). By decreasing the flower abundance of pea plants (Bennie et al., 2018a, 2016), ALAN has also been shown to impact pea aphids (*Acyrthosiphon pisum*) (Bennie et al., 2018b) as well as the parasitoid wasps (*Aphidius* to decrease the rate at which parasitoid wasps encounter their pea aphid hosts (Cochard et al., 2017; 2019a, 2019b). Finally, ALAN can incapacitate positively phototactic insects such as giant water bugs (*Lethocerus deyrolli;*Choi et al., 2009; Yoon et al., 2010) and macromoths (Somers-Yeates et al., 2013) that might otherwise spend the evening engaged in foraging activities, including nocturnal pollination (Knop et al., 2017; Macgregor et al., 2015).

4. Reproduction

ALAN can delay or eliminate the window of time during which night-active insects engage in courtship and mating (Dreisig, 1975; Lall, 1993; Li et al., 2019). The corn earworm moth (*Helicoverpa zea*) never mates when ambient light levels are above that produced by a quarter moon (Agee, 1969), and other strictly nocturnal insects are likely similarly sensitive, but understudied. The insects that manage to maintain a nightly routine within light polluted habitats may still have difficulty locating suitable mates. Firefly beetles are one unique example: the courtship of most fireflies requires the exchange of bioluminescent signals, which are obscured or inhibited by artificial illumination (Firebaugh and Haynes, 2016; Owens et al., 2018) to the point that receptive *Lampyris noctiluca* females perched underneath streetlights are never visited by male conspecifics (Ineichen and Rüt the streetlights to attract males conspecifics: male crepuscular reflects the purplish light of du of a different spectral composi

ALAN can also impact the reproductive success of insects directly through its various effects on development and physiology (Honnen et al., 2016). Exposure to constant light is known to sterilize males (Bebas et al., 2001; Giebultowicz et al., 1990), suppress female sex pheromones (Fatzinger, 1973; van Geffen et al., 2015a), and interfere with oviposition in moths (Nemfc, 1971; Yamaoka and Hirao, 1981) – likely a result of its disruption of the circadian timing of reproductive development or behavior. Similarly, exposure to dim ALAN decreases the fecundity of *Drosophila melanogaster* (McLay et al., 2017). Exposure to different ratios of blue or red light at night significantly alters the sex ratio of parasitoid wasps (Cochard et al., 2019a, 2019b), and may impact other insect species as well. The effective sex ratio of surviving reproductives can be further altered by the differential impacts of ALAN on behavior: for example, male tree weta avoid illuminated areas but female tree weta do not (Farnworth et al., 2018), and female winter moths (*Operophtera brumata*) avoid illuminated tree trunks (van Geffen et al., 2015b). In general, female moths tend to be less strongly attracted to artificial lights than males of the same species

5. Predation

Insects that become caught in the orbit of artificial lights can be readily exploited by insectivores. This may be why predatory arthropods tend to be disproportionately represented in illuminated habitats (Davies et al., 2017, 2012; Eccard et al., 2018; Manfrin et al., 2017), just as insectivorous bats (Jung and Kalko, 2010; Minnaar et al., 2015; Russo et al., 2019; Rydell, 2006), rats (Yoon et al., 2010), shorebirds (Dwyer et al., 2013), geckos (Zozaya et al., 2015) and cane toads (González-Bernal et al., 2016) are often found feeding around artificial lights. Orb-web spiders prefer to build their webs near artificial lights, where they net more prey (Czaczkes et al., 2018; Heiling, 1999; Yuen and Bonebrake, 2017). Diurnal predators such as jumping spiders (Frank, 2009; Wolff, 1982) and anoles (Garber, 1978) have also been described hunting for insects at lights at night (Manfrin et al., 2018), while birds are known to feed on aquatic insects trapped by polarized light pollution (Robertson et al., 2010). In general, prey insects do not appear able to defend against the increased predation pressure. To the contrary, a wide variety of moth species willingly approach streetlights monitored by foraging bats (Acharya and Fenton, 1999), where they are less able to execute their normal evasive flight behavior (Minnaar et al., 2015; Svensson and Rydell, 1998).

Predators do not only benefit f also the increased visibility, wh including some birds (Dwyer e Other invertebrate predators n visually oriented lady beetles (use non-visual cues to hunt (Miller et al., 2017). When light levels are too bright, however, some predatory and parasitoid insects themselves succumb to its suppressive effects on foraging behavior (Eccard et al., 2018; Sanders et al., 2018, 2015). Finally, alterations to the intensity and spectra of the nocturnal light environment can interfere with visual signals, which play an important role the predator-prey arms race. The aposematic glows of larval fireflies (Branham and Wenzel, 2003; Leavell et al., 2018) and the aposematic coloration of *Heliconius* butterflies (Seymoure, 2016) are likely to become less apparent under ALAN, as these and other warning signals have evolved to maximize visibility within particular natural light environments. Camouflage has also evolved within environments illuminated solely by natural sources (Davies et al., 2013a; Delhey and Peters, 2017), and could become ineffectual when viewed under ALAN. In some cases, intelligent predators given the opportunity to observe insects perched beneath artificial lights may become better at recognizing them in natural light environments (Frank, Artificial light at night can interfere with the development of immature insects by directly inhibiting or promoting nocturnal or diurnal foraging activity (see **Foraging**), or by interfering with the production of a suite of endocrine hormones (Ouyang et al., 2018; Russart and Nelson, 2018a) and the processes that they regulate, including circadian rhythms (Aulsebrook et al., 2018; Dominoni et al., 2016) and metabolic function (Gaston et al., 2017; Marcheva et al., 2013). One insect hormone particularly affected by environmental light – especially short wavelength light (Aubé et al., 2013; Lampel et al., 2005) – is melatonin. Melatonin is an active antioxidant (Durrant et al., 2019; Jones et al., 2015; Tan et al., 2010) and key biological signal (Hardeland and Poeggeler, 2003), which is primarily produced in darkness and suppressed by blue light. Its daily oscillation helps to regulate circadian rhythms of activity as well as circannual photoperiodism (Desouhant et al., 2019; Evans et al., 2007; Tan et al., 2010).

Previous research into the circadian rhythms of insects has used regimens of constant darkness or light to elucidate the fitness costs of total arrhythmicity (Winfree, 1974), which include impaired immune function, reduced fecundity, and a shorter lifespan (Durrant et al., 2015; Kouser and Palaksha Shakunthala, 2014). Other subtler fitness costs may arise from the mistiming of crucial life history events. For example, many insect species synchronize certain developmental activities with p
eclose before dawn when ambi
while intertidal midges (*Ponto*
(Neumann, 1989; Soong et al.,
intertidal midges to drown.

Artificially lengthened photop
juveniles, including locusts (*Locusta migratoria;* Tanaka et al., 1993) and thrips (*Megalurothrips sjostedti;* Ekesi et al., 1999), while accelerating the development of multivoltine lady beetles (*Coelophora saucia*; Omkar and Pathak, 2006), aphids (*Megoura viciae;* Kehoe et al., 2018) and flower bugs (*Orius sauteri;* Wang et al., 2013). By effectively lengthening photoperiod, and potentially suppressing melatonin production, ALAN prolongs juvenile development in black field crickets (*Teleogryllus commodus;* Durrant et al., 2018), but accelerates development in orb-web spiders (*Eriophora biapicata;* Willmott et al., 2018). Short-wavelength light speeds up the pupal development of cabbage moths (*Mamestra brassicae;* van Geffen et al., 2014), while red light has no effect. ALAN also causes aphids that exhibit seasonal polyphenism to maintain their summer form well into autumn (Sanders et al., 2015), and horse-chestnut leafminers (*Cameraria ohridella*) to undergo more generations per season (Schroer et al. 2019); both of these changes likely lead to cold stress. Whether ALAN slows or speeds development in a certain species is ultimately

7. Recommendations

We still have yet to fully understand how diverse insect taxa respond to artificial light of varying spectral composition, intensity, polarization, and flicker. To make matters more complicated, old fashioned bulb types often release large amounts of heat (Elvidge et al., 2010), while some modern LED fixtures emit ultrasonic frequencies that could have compounding effects on insect fitness (John Swaddle, *pers. comm.*). A combination of insect electroretinography and thoughtfully controlled behavioral studies (Cronin et al., 2014) may reveal ways of reducing the ecological consequences of ALAN on insects while still maintaining sufficient levels of nighttime illumination for human safety and enjoyment. In general, efforts to mitigate ALAN driven declines in insect diversity and biomass should take a spectral, spatial, and temporal approach (Bruce-White and Shardlow, 2011).

Monochromatic LEDs can be engineered to produce light of any desired spectral composition (Pimputkar et al., 2009). Therefore, once we know the specific wavelength affinities of insects, we can in theory design lights with minimal output in the wavelengths that most affect insect fitness. Many insects are capable of perceiving ultraviolet wavelengths, but are fairly insensitive to red, deep red, and infrared (Briscoe

or red) tends to induce relative

(Donners et al., 2018; Longcore

the least suppressive effect on

and Nelson, 2018b), which may

(Desouhant et al., 2019; Do et a

2012). However, the spectral needs of certain insect (Bek, 2013; Pacheco et al., 2016; Spoelstra et al., 2015; van Langevelde et al., 2017) and non-insect taxa such as plants, fish, and birds (Bennie et al., 2016; Dominoni, 2015; Seymoure et al., 2019) do not always align. Furthermore, many monochromatic LED fixtures on the market today are so bright, with such a broad full width at half maximum (FWHM, a measure of the proportion of photons emitted on either side of the peak wavelength), that their color as stated is not particularly relevant.

In many cases, it is far easier, quicker, and cheaper to shield, dim, or turn off a light source than it is to find the particular bulb type or narrow bandpass filter that makes its emissions visible to humans alone. Spatial mitigation of ALAN must involve the installation of proper shielding, but shielding alone is insufficient: it may block glare at human eye level and reduce atmospheric skyglow, but it will not prevent downwelling light from affecting insects in the immediate habitat; stationary insects, including pond-dwelling aquatic species and most female fireflies, ecotourist hotspots, path lights might be shielded from the top *and* the bottom to minimize their impact on nearby biodiversity. Increased understanding of how insects are affected by "invisible" qualities of light including polarization (Egri et al., 2017; Száz et al., 2016) and flicker rate (Barroso et al., 2017; Inger et al., 2014; Shields, 1989) can further inform the design of low-impact fixtures as well as their surrounding surfaces. Finally, temporal approaches comprising motion activation and/or automatic timers that extinguish lights when they are not needed, or when vulnerable species are likely to be most affected (*e.g.* during the two month long courtship season of the common glow-worm; (Gardiner, 2011), can greatly improve insect survivorship.

8. Conclusion

Some estimates predict that one million species, including up to 40% of insects, will go extinct within the next several decades (IPBES, 2019; Sánchez-Bayo and Wyckhuys, 2019). It is urgent therefore that we seek to identify the range of threats that insects face, and understand how to best address them. In light of the evidence presented above, we strongly believe that ALAN—in combination with habitat loss, chemical pollution, invasive species, and climate change—is driving insect declines. The relative lack of research into its ecological impact is likely a reflection of diurnal bias (Gaston, 2019),
light is the source of all life on
animal taxa, and an environme
all of evolutionary history. Ant
predicted to affect all life that l

In this paper we have summarized numerous studies demonstrating the ways in which ALAN impacts nocturnal and diurnal insects through effects on movement, foraging, reproduction, predation risk, and development. We would like to emphasize that ALAN is not merely a subcategory of urbanization: the ecological consequences of light pollution are not limited to urban and suburban centers, but widespread along roadways and around protected areas. Although there is obviously no single cause of insect declines, each threat identified is an opportunity for better informed management practices. Furthermore, unlike other potential drivers of insect declines, ALAN is relatively straightforward to reverse, and doing so could greatly reduce insect losses immediately. Our aim in sharing our perspective is thus to urge policy makers and land managers to incorporate the known consequences of ALAN into their insect conservation agendas. Meanwhile, more research is needed to further document the role of ALAN in insect declines, as well as to engineer more insect friendly lighting technology.

References

Acharya and Fenton, 1999 L. Acharya, M.B. Fenton
Bat attacks and moth defensive behaviour around street lights
Can. J. Zool., 77 (1999), pp. 27-33
View Record in Scopus Google Scholar

Agee, 1969 H.R. Agee
Mating behavior of bollworm moths
Ann. Entomol. Soc. Am., 62 (1969), pp. 1120-1122
CrossRef View Record in Scopus Google Scholar

Altermatt et al., 2009 F. Altermatt, A. Baumeyer, D. Ebert
Experimental evidence for male biased flight-to-light behavior in two moth species
Entomol. Exp. Appl., 130 (2009), pp. 259-265
CrossRef View Record in Scopus Google Scholar

Altermatt and Ebert, 2016 F. A
Reduced flight-to-light
pollution
Biol. Lett., 12 (2016), 10.
Google Scholar

Aubé et al., 2013 M. Aubé, J. Roby, M. Kocifaj
Evaluating potential spectral impacts of various artificial lights on melatonin suppression, photosynthesis, and star visibility
PLoS One, 8 (2013), Article e67798
CrossRef Google Scholar

Aulsebrook et al., 2018 A.E. Aulsebrook, T.M. Jones, R.A. Mulder, J.A. Lesku
Impacts of artificial light at night on sleep: a review and prospectus
J Exp Zool A Ecol Integr Physiol, 329 (2018), pp. 409-418
CrossRef View Record in Scopus Google Scholar

Barroso et al., 2017 A. Barroso, I. Haifig, V. Janei, I. da Silva, C. Dietrich, A.M. Costa-Leonardo
Effects of flickering light on the attraction of nocturnal insects

H. Young
Garden and landscape-scale correlates of moths of differing conservation status: significant effects of urbanization and habitat diversity
PLoS One, 9 (2014), Article e86925
CrossRef Google Scholar

Baxter et al., 2005 C.V. Baxter, K.D. Fausch, W. Carl Saunders
Tangled webs: reciprocal flows of invertebrate prey link streams and riparian zones
Freshw. Biol., 50 (2005), pp. 201-220
CrossRef View Record in Scopus Google Scholar

Beavis, 1995 I.C. Beavis
The first light trap, 1st century AD
Entomol. Rec. J. Var., 107 (1995), p. 155
View Record in Scopus Google Scholar

Bebas et al., 2001 P. Bebas, B. Cymborowski, J.M. Giebultowicz
Circadian rhythm of sperm release in males of the cotton leafworm, Spodoptera littoralis: in vivo and in vitro stu
J. Insect Physiol., 47 (20
Article Download

Bek, 2015 R.J. Bek
Investigating the Impa
worm, Lampyris noctilu
University of Leeds (2015)
Google Scholar

Bennie et al., 2018a J. Bennie, T.W. Davies, D. Cruse, F. Bell, K.J. Gaston
Artificial light at night alters grassland vegetation species composition and phenology
J. Appl. Ecol., 55 (2018), pp. 442-450
CrossRef View Record in Scopus Google Scholar

Bennie et al., 2016 J. Bennie, T.W. Davies, D. Cruse, K.J. Gaston
Ecological effects of artificial light at night on wild plants
J. Ecol., 104 (2016), pp. 611-620
CrossRef View Record in Scopus Google Scholar

Berry et al., 2011 R.P. Berry, W.T. Wcislo, E.J. Warrant
Ocellar adaptations for dim light vision in a nocturnal bee
J. Exp. Biol., 214 (2011), pp. 1283-1293
CrossRef View Record in Scopus Google Scholar

Boggs and Inouye, 2012 C.L. Boggs, D.W. Inouye
A single climate driver has direct and indirect effects on insect population dynamics
Ecol. Lett., 15 (2012), pp. 502-508
CrossRef View Record in Scopus Google Scholar

Bosch et al., 2010 J. Bosch, F. Sgolastra, W.P. Kemp
Timing of eclosion affects diapause development, fat body consumption and longevity in Osmia lignaria, a univoltine, adult-wintering solitary bee
J. Insect Physiol., 56 (2010), pp. 1949-1957
Article Download PDF View Record in Scopus Google Scholar

Branham and Wenzel, 2003 M.A. Branham, J.W. Wenzel
The origin of photic be
(Coleoptera: lampyrida
Cladistics, 19 (2003), pp.
Article Download

Briscoe and Chittka, 2001 A.D
The evolution of color vision in insects
Annu. Rev. Entomol., 46 (2001), pp. 471-510
CrossRef View Record in Scopus Google Scholar

Bruce-White and Shardlow, 2011 C. Bruce-White, M. Shardlow
A Review of the Impact of Artificial Light on Invertebrates
Buglife-The Invertebrate Conservation Trust (2011)
Google Scholar

Buckley et al., 2017 L.B. Buckley, A.J. Arakaki, A.F. Cannistra, H.M. Kharouba, J.G. Kingsolver
Insect development, thermal plasticity and fitness implications in changing, seasonal environments
Integr. Comp. Biol., 57 (2017), pp. 988-998
CrossRef View Record in Scopus Google Scholar

Caveney et al., 1995 S. Caveney, C.H. Scholtz, P. McIntyre
Patterns of daily flight activity in onitine dung beetles (Scarabaeinae: onitini)
Oecologia, 103 (1995), pp. 444-452
View Record in Scopus Google Scholar

Choi et al., 2009 H. Choi, H. Kim, J.G. Kim
Landscape analysis of the effects of artificial lighting around wetland habitats on the giant water bug Lethocerus deyrollei in Jeju Island
J. Ecol. Field Biol., 32 (2009), 10.5141/JEFB.2009.32.2.083
Google Scholar

Cochard et al., 2019a P. Cochard, T. Galstian, C. Cloutier
The influence of light environment on host colour preference in a parasitoid wasp
Ecol. Entomol. (2019)
Google Scholar

Cochard et al., 2019b P. Cochard, T. Galstian, C. Cloutier
The proportion of blue
photoperiod in greenho
Biol. Control, 133 (2019
Article Download

Cochard et al., 2017 P. Cochar
Light environments differently affect parasitoid wasps and their hosts' locomotor activity
J. Insect Behav., 30 (2017), pp. 595-611
CrossRef View Record in Scopus Google Scholar

Conrad et al., 2003 K.F. Conrad, I.P. Woiwod, J.N. Perry
East Atlantic teleconnection pattern and the decline of a common Arctiid moth
Glob. Chang. Biol., 9 (2003), pp. 125-130
View Record in Scopus Google Scholar

Coulthard et al., 2019 E. Coulthard, J. Norrey, C. Shortall, W.E. Harris
Ecological traits predict population changes in moths
Biol. Conserv., 233 (2019), pp. 213-219
Article Download PDF View Record in Scopus Google Scholar

Cutler et al., 1995 D. Cutler, R. Bennett, R. Stevenson, R. White
Feeding behavior in the nocturnal moth Manduca sexta is mediated mainly by blue receptors, but where are they located in the retina?
J. Exp. Biol., 198 (1995), pp. 1909-1917
View Record in Scopus Google Scholar

Czaczkes et al., 2018 T.J. Czaczkes, A.M. Bastidas-Urrutia, P. Ghislandi, C. Tuni
Reduced light avoidance in spiders from populations in light-polluted urban environments
Naturwissenschaften, 105 (2018), p. 64
Google Scholar

Dacke et al., 2013 M. Dacke, E. Baird, M. Byrne, C.H. Scholtz, E.J. Warrant
Dung beetles use the Milky Way for orientation
Curr. Biol., 23 (2013), pp. 298-300
Article Download PDF View Record in Scopus Google Scholar

Dauchy et al., 2016 R.T. Dauchy, M.A. Wren-Dail, A.E. Hoffman, J.P. Hanifin, B. Warfield, G.C. Brainard, S.M. Hill, V.P.
Effects of daytime expo
nighttime melatonin ar
physiology
Comp. Med., 66 (2016),
View Record in Scopus

Davies et al., 2017 T.W. Davies, J. Bennie, D. Cruse, D. Blumgart, R. Inger, K.J. Gaston
Multiple night-time light-emitting diode lighting strategies impact grassland invertebrate assemblages
Glob. Chang. Biol. (2017), 10.1111/gcb.13615
Google Scholar

Davies et al., 2012 T.W. Davies, J. Bennie, K.J. Gaston
Street lighting changes the composition of invertebrate communities
Biol. Lett., 8 (2012), pp. 764-767
CrossRef View Record in Scopus Google Scholar

Davies et al., 2013a T.W. Davies, J. Bennie, R. Inger, N.H. de Ibarra, K.J. Gaston

Artificial light alters natural regimes of night-time sky brightness
Sci. Rep., 3 (2013), p. 1722
Google Scholar

Degen et al., 2016 T. Degen, O. Mitesser, E.K. Perkin, N.-S. Weiß, M. Oehlert, E. Mattig, F. Hölker
Street lighting: sex-independent impacts on moth movement
J. Anim. Ecol., 85 (2016), pp. 1352-1360
CrossRef View Record in Scopus Google Scholar

Delhey and Peters, 2017 K. Delhey, A. Peters
Conservation implications of anthropogenic impacts on visual communication and camouflage
Conserv. Biol., 31 (2017), pp. 30-39
CrossRef View Record in Scopus Google Scholar

Desouhant et al., 2019 E. Desouhant, E. Gomes, N. Mondy, I. Amat
Mechanistic, ecological, and evolutionary consequences of artificial light at night for insects: review and pros
Entomol. Exp. Appl., 16
CrossRef View Record

Dillon and Dillon, 2002 M. Di
Artificial sunshine: a so
National Trust. (2002)
Google Scholar

Dirzo et al., 2014 R. Dirzo, H.S. Young, M. Galetti, G. Ceballos, N.J.B. Isaac, B. Collen
Defaunation in the anthropocene
Science, 345 (2014), pp. 401-406
CrossRef View Record in Scopus Google Scholar

Ditchkoff et al., 2006 S.S. Ditchkoff, S.T. Saalfeld, C.J. Gibson
Animal behavior in urban ecosystems: modifications due to human-induced stress
Urban Ecosyst., 9 (2006), pp. 5-12
CrossRef View Record in Scopus Google Scholar

Dominoni, 2015 D.M. Dominoni

Dominoni et al., 2016 D.M. Dominoni, J.C. Borniger, R.J. Nelson
Light at night, clocks and health: from humans to wild organisms
Biol. Lett., 12 (2016), Article 20160015
CrossRef Google Scholar

Do et al., 2009 M.T.H. Do, S.H. Kang, T. Xue, H. Zhong, H.-W. Liao, D.E. Bergles, K.-W. Yau
Photon capture and signalling by melanopsin retinal ganglion cells
Nature, 457 (2009), pp. 281-287
CrossRef View Record in Scopus Google Scholar

Donners et al., 2018 M. Donners, R.H.A. van Grunsven, D. Groenendijk, F. van Langevelde, J.W. Bikker, T. Longcore, E. Veenendaal
Colors of attraction: modeling insect flight to light behavior
J Exp Zool A Ecol Integr Physiol, 329 (2018), pp. 434-440
CrossRef View Record in Scopus Google Scholar

Dreisig, 1980 H. Dreisig
The importance of illumination level in the daily onset of flight activity in nocturnal moths
Physiol. Entomol., 5 (19
CrossRef View Record

Dreisig, 1975 H. Dreisig
Environmental control
fireflies (Coleoptera: lampyridae)
Oecologia, 18 (1975), pp. 85-99
View Record in Scopus Google Scholar

Duarte et al., 2019 C. Duarte, D. Quintanilla-Ahumada, C. Anguita, P.H. Manríquez, S. Widdicombe, J. Pulgar, E.A. Silva-Rodriguez, C. Miranda, K. Manríquez, P.A. Quijón
Artificial light pollution at night (ALAN) disrupts the distribution and circadian rhythm of a sandy beach isopod
Environ. Pollut. (2019), 10.1016/j.envpol.2019.02.037
Google Scholar

Durrant et al., 2018 J. Durrant, L.M. Botha, M.P. Green, T.M. Jones
Artificial light at night prolongs juvenile development time in the black field cricket, Teleogryllus commodus

cricket, Teleogryllus commodus
Insect Sci. (2019), 10.1111/1744-7917.12665
Google Scholar

Durrant et al., 2015 J. Durrant, E.B. Michaelides, T. Rupasinghe, D. Tull, M.P. Green, T.M. Jones
Constant illumination reduces circulating melatonin and impairs immune function in the cricket Teleogryllus commodus
PeerJ, 3 (2015), p. e1075
CrossRef Google Scholar

Dwyer et al., 2013 R.G. Dwyer, S. Bearhop, H.A. Campbell, D.M. Bryant
Shedding light on light: benefits of anthropogenic illumination to a nocturnally foraging shorebird
J. Anim. Ecol., 82 (2013), pp. 478-485
CrossRef View Record in Scopus Google Scholar

Eccard et al., 2018 J.A. Eccard, I. Scheffler, S. Franke, J. Hoffmann
Off-grid: solar powered LED illumination impacts epigeal arthropods
Insect Conserv. Divers.,
Google Scholar

Egri et al., 2017 Á. Egri, D. Szá
Method to improve the
distracting light polluti
R. Soc. Open Sci., 4 (201
CrossRef Google Scholar

Eisenbeis, 2006 G. Eisenbeis
Artificial night lighting and insects: attraction of insects to streetlamps in a rural setting in Germany
C. Rich, T. Longcore (Eds.), Ecological Consequences of Artificial Night Lighting, Island Press, Washington, D.C (2006), pp. 281-304
View Record in Scopus Google Scholar

Ekesi et al., 1999 S. Ekesi, N.K. Maniania, I. Onu
Effects of temperature and photoperiod on development and oviposition of the legume flower thrips, Megalurothrips sjostedti
Entomol. Exp. Appl., 93 (1999), pp. 149-155

CrossRef View Record in Scopus Google Scholar

Evans et al., 2007 J.A. Evans, J.A. Elliott, M.R. Gorman
Circadian effects of light no brighter than moonlight
J. Biol. Rhythms, 22 (2007), pp. 356-367
CrossRef View Record in Scopus Google Scholar

Falchi et al., 2016 F. Falchi, P. Cinzano, D. Duriscoe, C.C.M. Kyba, C.D. Elvidge, K. Baugh, B.A. Portnov, N.A. Rybnikova, R. Furgoni
The new world atlas of artificial night sky brightness
Sci. Adv., 2 (2016), Article e1600377
CrossRef Google Scholar

Fao, 2012 F.A. Fao
FAOSTAT Online Statistical Service
Food and Agriculture Organization of the United Nations (2012)
Google Scholar

Farnworth et al., 2018 B. Farn
Photons and foraging:
not female, New Zealan
Environ. Pollut., 236 (20
Article Download

Fatzinger, 1973 C.W. Fatzinge
Circadian rhythmicity of sex pheromone release by dioryctria abietella (Lepidoptera: pyralidae (Phycitinae)) and the effect of a diel light cycle on its precopulatory behavior
Ann. Entomol. Soc. Am., 66 (1973), pp. 1147-1153
CrossRef View Record in Scopus Google Scholar

Firebaugh and Haynes, 2016 A. Firebaugh, K.J. Haynes
Experimental tests of light-pollution impacts on nocturnal insect courtship and dispersal
Oecologia. (2016), 10.1007/s00442-016-3723-1
Google Scholar

Forrest and Thomson, 2011 J.R.K. Forrest, J.D. Thomson
An examination of synchrony between insect emergence and flowering in Rocky Mountain meadows

Outline Download Share Export

Google Scholar

Fox et al., 2014 R. Fox, T.H. Oliver, C. Harrower, M.S. Parsons, C.D. Thomas, D.B. Roy
Long-term changes to the frequency of occurrence of British moths are consistent with opposing and synergistic effects of climate and land-use changes
J. Appl. Ecol., 51 (2014), pp. 949-957
CrossRef View Record in Scopus Google Scholar

Frank, 2009 K.D. Frank
Exploitation of artificial light at night by a diurnal jumping spider
Peckhamia. (2009)
Google Scholar

Frank, 2006 K.D. Frank
Effects of artificial night lighting on moths
C. Rich, T. Longcore (Eds.), Ecological Consequences of Artificial Night Lighting, Island Press, Washington, D.C (2006), pp. 305-344
View Record in Scopus

Frank, 1988 K.D. Frank
Impact of outdoor light
J. Lepid. Soc., 42 (1988),
View Record in Scopus

Franzén and Johannesson, 2007 M. Franzén, M. Johannesson
Predicting extinction risk of butterflies and moths (Macrolepidoptera) from distribution patterns and species characteristics
J. Insect Conserv., 11 (2007), pp. 367-390
CrossRef View Record in Scopus Google Scholar

Garber, 1978 S.D. Garber
Opportunistic feeding behavior of Anolis cristatellus (Iguanidae: reptilia) in Puerto Rico
Trans. Kans. Acad. Sci., 81 (1978), p. 79
CrossRef View Record in Scopus Google Scholar

Gardiner, 2011 T.A. Gardiner
Glowing, Glowing, Gone? The Plight of the Glow-worm in Essex

Access tl

Outline Download Share Export

Southeast. Nat., 9 (2010), pp. 427-434
CrossRef View Record in Scopus Google Scholar

Gaston, 2019 K.J. Gaston
Nighttime ecology: the "Nocturnal problem" revisited
Am. Nat., 193 (2019), pp. 481-502
CrossRef View Record in Scopus Google Scholar

Gaston et al., 2013 K.J. Gaston, J. Bennie, T.W. Davies, J. Hopkins
The ecological impacts of nighttime light pollution: a mechanistic appraisal
Biol. Rev. Camb. Philos. Soc., 88 (2013), pp. 912-927
CrossRef View Record in Scopus Google Scholar

Gaston et al., 2017 K.J. Gaston, T.W. Davies, S.L. Nedelec, L.A. Holt
Impacts of artificial light at night on biological timings
Annu. Rev. Ecol. Evol. Syst., 48 (2017), pp. 49-68
CrossRef View Record in Scopus Google Scholar

Gaston et al., 2015 K.J. Gaston, J.P. Duffy, J. Bennie
Quantifying the erosion
Conserv. Biol., 29 (2015)
CrossRef View Record

Gaston and Holt, 2018 K.J. Ga
Nature, extent and ecol
J. Appl. Ecol. (2018), 10.1111/1365-2664.13157
Google Scholar

Gaynor et al., 2018 K.M. Gaynor, C.E. Hojnowski, N.H. Carter, J.S. Brashares
The influence of human disturbance on wildlife nocturnality
Science, 360 (2018), pp. 1232-1235
CrossRef View Record in Scopus Google Scholar

Giebultowicz et al., 1990 J.M. Giebultowicz, R.L. Ridgway, R.B. Imberski
Physiological basis for sterilizing effects of constant light in Lymantria dispar
Physiol. Entomol., 15 (1990), pp. 149-156
CrossRef View Record in Scopus Google Scholar

Goodman, 1965 L.J. Goodman
The role of certain optomotor reactions in regulating stability in the rolling plane during flight in the desert locust, Schistocerca gregaria
J. Exp. Biol., 42 (1965), pp. 385-407
View Record in Scopus Google Scholar

Grenis and Murphy, 2018 K. Grenis, S.M. Murphy
Direct and indirect effects of light pollution on the performance of an herbivorous insect
Insect Sci. (2018), 10.1111/1744-7917.12574
Google Scholar

Grenis et al., 2015 K. Grenis, B. Tjossem, S.M. Murphy
Predation of larval Lepidoptera in habitat fragments varies spatially and temporally but is not affected by light pollution
J. Insect Conserv., 19 (2015), pp. 559-566
CrossRef View Record in Scopus Google Scholar

Grubisic et al., 2018 M. Grubi
Insect declines and agr
Ann. Appl. Biol., 173 (20
CrossRef View Record

Guerra Alonso et al., 2019 C.B
Livestock areas with ca
Chaco forest
Insect Conserv. Divers., 12 (2019), pp. 296-308
CrossRef View Record in Scopus Google Scholar

Guetté et al., 2018 A. Guetté, L. Godet, M. Juigner, M. Robin
Worldwide increase in Artificial Light At Night around protected areas and within biodiversity hotspots
7
Biol. Conserv., 223 (2018), pp. 97-103
Article Download PDF View Record in Scopus Google Scholar

Hallmann et al., 2017 C.A. Hallmann, M. Sorg, E. Jongejans, H. Siepel, N. Hofland, H. Schwan, W. Stenmans, A. Müller, H. Sumser, T. Hörren, D. Goulson, H. de Kroon

Outline Download Share Export

Hammock and Wetzel, 2013 B.G. Hammock, W.C. Wetzel
The relative importance of drift causes for stream insect herbivores across a canopy gradient
Oikos, 122 (2013), pp. 1586-1593
CrossRef View Record in Scopus Google Scholar

Hardeland and Poeggeler, 2003 R. Hardeland, B. Poeggeler
Non-vertebrate melatonin
J. Pineal Res., 34 (2003), pp. 233-241
View Record in Scopus Google Scholar

Heiling, 1999 A.M. Heiling
Why do nocturnal orb-web spiders (Araneidae) search for light?
Behav. Ecol. Sociobiol. (Print), 46 (1999), pp. 43-49
View Record in Scopus Google Scholar

Henn et al., 2014 M. Henn, H. Nichols, Y. Zhang, T.H. Bonner
Effect of artificial light on the drift of aquatic insects in urban central Texas streams
J. Freshw. Ecol., 29 (2014
CrossRef View Record

Honnen et al., 2016 A.-C. Hor
Sex-specific gene expre
artificial light at night
BMC Genomics, 17 (2016), p. 22
Google Scholar

Hopkins et al., 2018 G.R. Hopkins, K.J. Gaston, M.E. Visser, M.A. Elgar, T.M. Jones
Artificial light at night as a driver of evolution across urban-rural landscapes
Front. Ecol. Environ., 114 (2018), p. 8951
View Record in Scopus Google Scholar

Horváth et al., 2009 G. Horváth, G. Kriska, P. Malik, B. Robertson
Polarized light pollution: a new kind of ecological photopollution
Front. Ecol. Environ., 7 (2009), pp. 317-325
CrossRef View Record in Scopus Google Scholar

Ineichen and Rüttimann, 2012 S. Ineichen, B. Rüttimann

Inger et al., 2014 R. Inger, J. Bennie, T.W. Davies, K.J. Gaston
Potential biological and ecological effects of flickering artificial light
PLoS One, 9 (2014), Article e98631
CrossRef Google Scholar

IPBES, 2019 IPBES
S. Díaz, J. Settele, E.S. Brondizio, H.T. Ngo, M. Guèze, J. Agard, A. Arneth, P. Balvanera, K.A. Brauman, S.H.M. Butchart, K.M.A. Chan, L.A. Garibaldi, K. Ichii, J. Liu, S.M. Subramanian, G.F. Midgley, P. Miloslavich, Z. Molnár, D. Obura, A. Pfaff, S. Polasky, A. Purvis, J. Razzaque, B. Reyers, R. Roy Chowdhury, Y.J. Shin, I.J. Visseren-Hamakers, K.J. Willis, C.N. Zayas (Eds.), Summary for Policymakers of the Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, IPBES secretariat, Bonn, Germany (2019)
Google Scholar

Janzen and Hallwachs, 2019 D.H. Janzen, W. Hallwachs
Perspective: where might be many tropical insects?
Biol. Conserv., 233 (2019), pp. 102-108
Article Download

Jarvis, 2018 B. Jarvis
The Insect Apocalypse
The New York Times (2
Google Scholar

Johansen et al., 2011 N.S. Johansen, I. Vänninen, D.M. Pinto, A.I. Nissinen, L. Shipp
In the light of new greenhouse technologies: 2. Direct effects of artificial lighting on arthropods and integrated pest management in greenhouse crops
Ann. Appl. Biol., 159 (2011), pp. 1-27
CrossRef View Record in Scopus Google Scholar

Jones et al., 2015 T.M. Jones, J. Durrant, E.B. Michaelides, M.P. Green
Melatonin: a possible link between the presence of artificial light at night and reductions in biological fitness
Philos. Trans. R. Soc. Lond., B, Biol. Sci., 370 (2015), 10.1098/rstb.2014.0122
Google Scholar

Jung and Kalko, 2010 K. Jung, E.K.V. Kalko

Shifting daylength regimes associated with range shifts alter aphid-parasitoid community dynamics
Ecol. Evol., 147 (2018), p. 381
View Record in Scopus Google Scholar

Kelley et al., 2019 J.L. Kelley, N.J. Tatarnic, G.E. Schröder-Turk, J.A. Endler, B.D. Wilts
A dynamic optical signal in a nocturnal moth
Curr. Biol. (2019), 10.1016/j.cub.2019.07.005
0
Google Scholar

Knop et al., 2017 E. Knop, L. Zoller, R. Ryser, C. Gerpe, M. Hörler, C. Fontaine
Artificial light at night as a new threat to pollination
Nature. (2017), 10.1038/nature23288
Google Scholar

Koen et al., 2018 E.L. Koen, C. Minnaar, C.L. Roever, J.G. Boyles
Emerging threat of the
Glob. Chang. Biol., 24 (2
View Record in Scopus

Kokko and Sutherland, 2001 I
Ecological traps in char
behaviourally mediated
Evol. Ecol. Res., 3 (2001), pp. 603-610
Google Scholar

Konvička et al., 2016 M. Konvička, J. Beneš, O. Čížek, T. Kuras, I. Klečková
Has the currently warming climate affected populations of the mountain ringlet butterfly, Erebia epiphron (Lepidoptera: nymphalidae), in low-elevation mountains?
Eur. J. Entomol. (2016), 10.14411/eje.2016.036
Google Scholar

Kouser and Palaksha Shakunthala, 2014 S. Kouser, V. Palaksha Shakunthala
Study on fitness of Drosophila melanogaster in different light regimes
Biol. Rhythm Res., 45 (2014), pp. 293-300
CrossRef View Record in Scopus Google Scholar

Kyba, 2018 C.C.M. Kyba
Is light pollution getting better or worse?
Nat. Astron. (2018), 10.1038/s41550-018-0402-7
Google Scholar

Kyba et al., 2017 C.C.M. Kyba, T. Kuester, A. Sánchez de Miguel, K. Baugh, A. Jechow, F. Hölker, J. Bennie, C.D. Elvidge, K.J. Gaston, L. Guanter
Artificially lit surface of Earth at night increasing in radiance and extent
Sci. Adv., 3 (2017), Article e1701528
CrossRef Google Scholar

Kyba et al., 2011a C.C.M. Kyba, T. Ruhtz, J. Fischer, F. Hölker
Cloud coverage acts as an amplifier for ecological light pollution in urban ecosystems
PLoS One, 6 (2011), Article e17307
CrossRef Google Scholar

Kyba et al., 2011b C.C.M. Kyba, T. Ruhtz, J. Fischer, F. Hölker
Lunar skylight polariza
J. Geophys. Res., 116 (20
Google Scholar

Lall, 1993 A.B. Lall
Action spectra for the i
active firefly Photinus s
2
J. Insect Physiol., 39 (1993), pp. 123-127
Article Download PDF View Record in Scopus Google Scholar

Lampel et al., 2005 J. Lampel, A.D. Briscoe, L.T. Wasserthal
Expression of UV-, blue-, long-wavelength-sensitive opsins and melatonin in extraretinal photoreceptors of the optic lobes of hawk moths
Cell Tissue Res., 321 (2005), pp. 443-458
CrossRef View Record in Scopus Google Scholar

Laube et al., 2014 J. Laube, T.H. Sparks, N. Estrella, J. Höfler, D.P. Ankerst, A. Menzel
Chilling outweighs photoperiod in preventing precocious spring development
Glob. Chang. Biol., 20 (2014), pp. 170-182

(Accessed 8.22.19)
(2015)
Google Scholar

Leavell et al., 2018 B.C. Leavell, J.J. Rubin, C.J.W. McClure, K.A. Miner, M.A. Branham, J.R. Barber
Fireflies thwart bat attack with multisensory warnings
Sci. Adv., 4 (2018)
eaat6601
Google Scholar

Levy et al., 2019 O. Levy, T. Dayan, W.P. Porter, N. Kronfeld-Schor
Time and ecological resilience: can diurnal animals compensate for climate change by shifting to nocturnal activity?
Ecol. Monogr., 89 (2019), Article e01334
CrossRef Google Scholar

Lind et al., 2017 O. Lind, M.J. Henze, A. Kelber, D. Osorio
Coevolution of colorati
Philos. Trans. R. Soc. Lo
Google Scholar

Lister and Garcia, 2018 B.C. L
Climate-driven decline
Proc. Natl. Acad. Sci. U.
CrossRef View Record in Scopus Google Scholar

Li et al., 2019 X. Li, X. Jia, H. Xiang, H. Diao, Y. Yan, Y. Wang, R. Ma
The effect of photoperiods and light intensity on mating behavior and reproduction of Grapholita molesta (Lepidoptera: tortricidae)
Environ. Entomol. (2019), 10.1093/ee/nvz066
Google Scholar

Longcore et al., 2018 T. Longcore, A. Rodríguez, B. Witherington, J.F. Penniman, L. Herf, M. Herf
Rapid assessment of lamp spectrum to quantify ecological effects of light at night
J Exp Zool A Ecol Integr Physiol. (2018), 10.1002/jez.2184
Google Scholar

Farias, C. Duarte
Light pollution reduces activity, food consumption and growth rates in a sandy beach invertebrate
Environ. Pollut., 218 (2016), pp. 1147-1153
Article Download PDF View Record in Scopus Google Scholar

Macgregor et al., 2017 C.J. Macgregor, D.M. Evans, R. Fox, M.J.O. Pocock
The dark side of street lighting: impacts on moths and evidence for the disruption of nocturnal pollen transport
Glob. Chang. Biol., 23 (2017), pp. 697-707
CrossRef View Record in Scopus Google Scholar

Macgregor et al., 2015 C.J. Macgregor, M.J.O. Pocock, R. Fox, D.M. Evans
Pollination by nocturnal Lepidoptera, and the effects of light pollution: a review
Ecol. Entomol., 40 (2015), pp. 187-198
CrossRef View Record in Scopus Google Scholar

Manfrin et al., 2018 A. Manfri
Dietary changes in pred ecosystem
Oikos. (2018)
Google Scholar

Manfrin et al., 2017 A. Manfrin, ... Wohlfahrt, M. Monaghan, F. Hölker
Artificial light at night affects organism flux across ecosystem boundaries and drives community structure in the recipient ecosystem
Front. Environ. Sci. Eng. China, 5 (2017), p. 61
Google Scholar

Manríquez et al., 2019 P.H. Manríquez, M.E. Jara, M.I. Diaz, P.A. Quijón, S. Widdicombe, J. Pulgar, K. Manríquez, D. Quintanilla-Ahumada, C. Duarte
Artificial light pollution influences behavioral and physiological traits in a keystone predator species, Concholepas concholepas
Sci. Total Environ. (2019), 10.1016/j.scitotenv.2019.01.157
Google Scholar

McKay et al., 2017 L.K. McKay, M.P. Green, T.M. Jones
Chronic exposure to dim artificial light at night decreases fecundity and adult survival in Drosophila melanogaster
J. Insect Physiol., 100 (2017), pp. 15-20
Article Download PDF View Record in Scopus Google Scholar

McMahon et al., 2017 T.A. McMahon, J.R. Rohr, X.E. Bernal
Light and noise pollution interact to disrupt interspecific interactions
Ecology. (2017), 10.1002/ecy.1770
Google Scholar

Merritt and Clarke, 2013 D.J. Merritt, A.K. Clarke
The impact of cave lighting on the bioluminescent display of the Tasmanian glow-worm Arachnocampa tasmaniensis
J. Insect Conserv., 17 (2013), pp. 147-153
CrossRef View Record in Scopus Google Scholar

Meyer and Sullivan, 2013 L.A. Meyer, S.M.P. Sullivan
Bright lights, big city: i riparian invertebrate flu
Ecol. Appl., 23 (2013), pp
CrossRef View Record

Miller et al., 2017 C.R. Miller, Ives
Combined effects of night warming and light pollution on predator-prey interactions
Proc. Biol. Sci., 284 (2017), 10.1098/rspb.2017.1195
Google Scholar

Miller et al., 2015 J.R. Miller, C.G. Adams, P.A. Weston, J.H. Schenker
Trapping of Small Organisms Moving Randomly: Principles and Applications to Pest Monitoring and Management
Springer, Cham (2015)
Google Scholar

Miller-Rushing et al., 2010 A.J. Miller-Rushing, T.T. Høye, D.W. Inouye
The effects of phenological mismatches on demography
Philos. Trans. R. Soc. Lond., B, Biol. Sci., 365 (2010), pp. 3177-3186

J. Appl. Ecol., 52 (2015), pp. 522-531
CrossRef View Record in Scopus Google Scholar

Nemfc, 1971 S.J. Nemfc
Effects of lunar phases on light-trap collections and populations of bollworm moths
J. Econ. Entomol., 64 (1971), pp. 860-864
CrossRef Google Scholar

Neumann, 1989 D. Neumann
Circadian components of semilunar and lunar timing mechanisms
J. Biol. Rhythms, 4 (1989), pp. 285-294
View Record in Scopus Google Scholar

Ouyang et al., 2018 J.Q. Ouyang, S. Davies, D. Dominoni
Hormonally mediated effects of artificial light at night on behavior and fitness: linking endocrine mechanisms with function
J. Exp. Biol., 221 (2018), 10.1242/jeb.156893
Google Scholar

Owens and Lewis, 2018 A.C.S.
The impact of artificial
Ecol. Evol., 8 (2018), pp.
CrossRef View Record

Owens et al., 2018 A.C.S. Owe
Short- and mid-wavelength artificial light influences the flash signals of Aquatica ficta fireflies (Coleoptera: Lampyridae)
PLoS One, 13 (2018), Article e0191576
CrossRef Google Scholar

Pacheco et al., 2016 Y.M. Pacheco, G.J. Martin, S.M. Bybee
On the phototactic response of rwandan Diaphanes motschulsky (Coleoptera: lampyridae) to a trap with a 630Nm red light
Coleopt. Bull., 70 (2016), pp. 559-561
CrossRef View Record in Scopus Google Scholar

Patent 4808, 1846 Patent 4808, U.S., 1846. Improvement in lanterns for destroying insects. US Patent. 4808.

Insect Conserv. Divers., 11 (2018), pp. 58-71
CrossRef View Record in Scopus Google Scholar

Pawson et al., 2009 S.M. Pawson, M.S. Watt, E.G. Brockerhoff
Using differential responses to light spectra As a monitoring and control tool for Arhopalus ferus (Coleoptera: cerambycidae) and other exotic wood-boring pests
J. Econ. Entomol., 102 (2009), 10.1603/029.102.0112
Google Scholar

Perkin et al., 2014a E.K. Perkin, F. Hölker, K. Tockner
Artificial light as a disturbance to light-naïve streams. Freshwater
(2014)
Google Scholar

Perkin et al., 2014b E.K. Perkin, F. Hölker, K. Tockner
The effects of artificial lighting on adult aquatic and terrestrial insects
Freshw. Biol. (2014)
Google Scholar

Phillips et al., 2019 B.B. Philli
Road verges support po
traffic and summer cutt
J. Appl. Ecol. (2019), 10.1
Google Scholar

Pimputkar et al., 2009 S. Pimputkar, J.S. Speck, S.P. DenBaars, S. Nakamura
Prospects for LED lighting
Nat. Photonics, 3 (2009), p. 180
CrossRef View Record in Scopus Google Scholar

Potocký et al., 2018 P. Potocký, A. Bartoňová, J. Beneš, M. Zapletal, M. Konvička
Life-history traits of Central European moths: gradients of variation and their association with rarity and threats
Insect Conserv. Divers., 11 (2018), pp. 493-505
CrossRef View Record in Scopus Google Scholar

Potts et al., 2010 S.G. Potts, J.C. Biesmeijer, C. Kremen, P. Neumann, O. Schweiger, W.E. Kunin
Global pollinator declines: trends, impacts and drivers

Widespread losses of pollinating insects in Britain
Nat. Commun., 10 (2019), p. 1018
Google Scholar

Rafferty and Ives, 2012 N.E. Rafferty, A.R. Ives
Pollinator effectiveness varies with experimental shifts in flowering time
Ecology, 93 (2012), pp. 803-814
CrossRef View Record in Scopus Google Scholar

Rankin, 1985 M.A.R. Rankin
Migration: Mechanisms and Adaptive Significance, Contributions in Marine Science, v. 27, suppl. Marine Science Institute, the University of Texas at Austin, Port Aransas, Tex (1985)

Robertson et al., 2018 B.A. Robertson, I.A. Keddy-Hector, S.D. Shrestha, L.Y. Silverberg, C.E. Woolner, I. Hetterich, G. Horvath
Susceptibility to ecological traps is similar among closely related taxa but sensitive to spatial isolation
Anim. Behav., 135 (2018), pp. 77-84
Article Download

Robertson et al., 2010 B. Robe
Glass buildings as bird
pollution
Acta Zool. Academ. Sci.
View Record in Scopus Google Scholar

Russart and Nelson, 2018a K.L.G. Russart, R.J. Nelson
Artificial light at night alters behavior in laboratory and wild animals
J Exp Zool A Ecol Integr Physiol. (2018), 10.1002/jez.2173
Google Scholar

Russart and Nelson, 2018b K.L.G. Russart, R.J. Nelson
Light at night as an environmental endocrine disruptor
Physiol. Behav., 190 (2018), pp. 82-89
Article Download PDF View Record in Scopus Google Scholar

Russo et al., 2019 D. Russo, F. Cosentino, F. Festa, F. De Benedetta, B. Pejic, P. Cerretti, L. Ancillotto

Bats and their insect prey at streetlights
C. Rich, T. Longcore (Eds.), Ecological Consequences of Artificial Night Lighting, Island Press, Washington, D.C (2006)
Google Scholar

Sánchez-Bayo and Wyckhuys, 2019 F. Sánchez-Bayo, K.A.G. Wyckhuys
Worldwide decline of the entomofauna: a review of its drivers
Biol. Conserv., 232 (2019), pp. 8-27
Article Download PDF View Record in Scopus Google Scholar

Sanders and Gaston, 2018 D. Sanders, K.J. Gaston
How ecological communities respond to artificial light at night
J Exp Zool A Ecol Integr Physiol. (2018), 10.1002/jez.2157
Google Scholar

Sanders et al., 2018 D. Sanders, R. Kehoe, D. Cruse, F.J.F. van Veen, K.J. Gaston
Low levels of artificial light at night strengthen top-down control in insect food web
Curr. Biol., 28 (2018), pp. 2474-2478
e3
View Record in Scopus

Sanders et al., 2015 D. Sanders
Veen, K.J. Gaston
Artificial nighttime ligh
Sci. Rep., 5 (2015), p. 152
View Record in Scopus Google Scholar

Santos et al., 2010 C.D. Santos, A.C. Miranda, J.P. Granadeiro, P.M. Lourenço, S. Saraiva, J.M. Palmeirim
Effects of artificial illumination on the nocturnal foraging of waders
Acta Oecol., 36 (2010), pp. 166-172
Article Download PDF View Record in Scopus Google Scholar

Saunders, 2012 D.S. Saunders
Insect photoperiodism: seeing the light
Physiol. Entomol., 37 (2012), pp. 207-218
CrossRef View Record in Scopus Google Scholar

Desynchronizations in bee-plant interactions cause severe fitness losses in solitary bees
J. Anim. Ecol., 87 (2018), pp. 139-149
CrossRef View Record in Scopus Google Scholar

Schlaepfer et al., 2002 M.A. Schlaepfer, M.C. Runge, P.W. Sherman
Ecological and evolutionary traps
Trends Ecol. Evol., 17 (2002), pp. 474-480
Article Download PDF View Record in Scopus Google Scholar

Schowalter et al., 2018 T.D. Schowalter, J.A. Noriega, T. Tscharntke
Insect effects on ecosystem services—introduction
Basic Appl. Ecol., 26 (2018), pp. 1-7
Article Download PDF View Record in Scopus Google Scholar

Schultz et al., 2019 C.B. Schultz, N.M. Haddad, E.H. Henry, E.E. Crone
Movement and demography of At-Risk butterflies: building blocks for conservation
Annu. Rev. Entomol., 64 (2019), pp. 167-184
CrossRef View Record

Seymoure, 2018 B.M. Seymou
Enlightening butterfly
butterfly behavioral eco
Insects, 9 (2018), 10.339
Google Scholar

Seymoure, 2016 B.M. Seymoure
Heliconius In A New Light: The Effects of Light Environments on Mimetic Coloration, Behavior, and Visual Systems (Ph.D.)
Arizona State University (2016)
Google Scholar

Seymoure et al., 2019 B.M. Seymoure, C. Linares, J. White
Connecting spectral radiometry of anthropogenic light sources to the visual ecology of organisms
J. Zool., 329 (2019), p. 465
View Record in Scopus Google Scholar

Adult tea green leafhoppers, Empoasca onukii (Matsuda), change behaviors under varying light conditions
PLoS One, 12 (2017), Article e0168439
CrossRef Google Scholar

Shimoda and Honda, 2013 M. Shimoda, K.-I. Honda
Insect reactions to light and its applications to pest management
Appl. Entomol. Zool., 48 (2013), pp. 413-421
CrossRef View Record in Scopus Google Scholar

Shortall et al., 2009 C.R. Shortall, A. Moore, E. Smith, M.J. Hall, I.P. Woiwod, R. Harrington
Long-term changes in the abundance of flying insects
Insect Conserv. Divers., 2 (2009), pp. 251-260
CrossRef Google Scholar

Skutelsky, 1996 O. Skutelsky
Predation risk and state-dependent foraging in scorpions: effects of moonlight on foraging in the scorpio
Anim. Behav., 52 (1996),
Article Download

Somanathan et al., 2008 H. So
Visual ecology of India
J. Comp. Physiol. A Neu
CrossRef View Record in Scopus Google Scholar

Somers-Yeates et al., 2013 R. Somers-Yeates, D. Hodgson, P.K. McGregor, A. Spalding, R.H. Ffrench-Constant
Shedding light on moths: shorter wavelengths attract noctuids more than geometrids
Biol. Lett., 9 (2013), Article 20130376
CrossRef Google Scholar

Soong et al., 2011 K. Soong, Y.J. Lee, I.H. Chang
Short-lived intertidal midge Pontomyia oceana have semilunar eclosion rhythm entrained by night light
Mar. Ecol. Prog. Ser., 433 (2011), pp. 121-130
CrossRef View Record in Scopus Google Scholar

Spoelstra et al., 2015 K. Spoelstra, R.H.A. van Grunsven, M. Donners, P. Gienapp, M.E. Huigens, R. Slaterus, F. Berendse, M.E. Visser, E. Veenendaal
Experimental illumination of natural habitat—an experimental set-up to assess the direct and indirect ecological consequences of artificial light of different spectral composition
Philos. Trans. R. Soc. Lond., B, Biol. Sci., 370 (2015), Article 20140129
CrossRef View Record in Scopus Google Scholar

Streinzer et al., 2019 M. Streinzer, N. Roth, H.F. Paulus, J. Spaethe
Color preference and spatial distribution of glaphyrid beetles suggest a key role in the maintenance of the color polymorphism in the peacock anemone (Anemone pavonina, Ranunculaceae) in Northern Greece
J. Comp. Physiol. A Neuroethol. Sens. Neural. Behav. Physiol. (2019), 10.1007/s00359-019-01360-2
Google Scholar

Šustek, 1999 Z. Šustek
Light attraction of carabid beetles and their survival in the city centre
Biologia Bratislava, 43 (
View Record in Scopus

Svensson and Rydell, 1998 A.N
Mercury vapour lamps
spp.; Geometridae)
Anim. Behav., 55 (1998), pp. 223-226
Article Download PDF View Record in Scopus Google Scholar

Szaz et al., 2015 D. Szaz, G. Horvath, A. Barta, B.A. Robertson, A. Farkas, A. Egri, N. Tarjanyi, G. Racz, G. Kriska
Lamp-lit bridges as dual light-traps for the night-swarming mayfly, Ephoron virgo: interaction of polarized and unpolarized light pollution
PLoS One, 10 (2015), Article e0121194
CrossRef Google Scholar

Száz et al., 2016 D. Száz, D. Mihályi, A. Farkas, Á. Egri, A. Barta, G. Kriska, B. Robertson, G. Horváth

Tanaka et al., 1993 S. Tanaka, T. Hakomori, E. Hasegawa
Effects of daylength and hopper density on reproductive traits in a Japanese population of the migratory locust, Locusta migratoria L. J
Insect Physiol., 39 (1993)
Google Scholar

Tan et al., 2010 D.-X. Tan, R. Hardeland, L.C. Manchester, S.D. Paredes, A. Korkmaz, R.M. Sainz, J.C. Mayo, L. Fuentes-Broto, R.J. Reiter
The changing biological roles of melatonin during evolution: from an antioxidant to signals of darkness, sexual selection and fitness
Biol. Rev. Camb. Philos. Soc., 85 (2010), pp. 607-623
View Record in Scopus Google Scholar

Thakurdas et al., 2009 P. Thakurdas, S. Sharma, K. Vanlalhriatpuia, B. Sinam, M. Chib, A. Shivagaje, D. Joshi
Light at night alters the parameters of the eclosion rhythm in a tropical fruit fly, Drosophila jambulina
Chronobiol. Int., 26 (2009), pp. 1575-1586
CrossRef View Record

Théry et al., 2008 M. Théry, S.
Dusk light environmen horned beetle
Behav. Ecol., 19 (2008), p
CrossRef View Record in Scopus Google Scholar

Tierney et al., 2017 S.M. Tierney, M. Friedrich, W.F. Humphreys, T.M. Jones, E.J. Warrant, W.T. Wcislo
Consequences of evolutionary transitions in changing photic environments
Aust. Entomol., 56 (2017), pp. 23-46
CrossRef View Record in Scopus Google Scholar

Tsao et al., 2010 J.Y. Tsao, H.D. Saunders, J.R. Creighton, M.E. Coltrin, J.A. Simmons
Solid-state lighting: an energy-economics perspective
J. Phys. D Appl. Phys., 43 (2010), 10.1088/0022-3727/43/35/354001
Google Scholar

Ugolini et al., 2005 A. Ugolini, V. Boddi, L. Mercatelli, C. Castellini

Rapid adaptive evolution of photoperiodic response during invasion and range expansion across a climatic gradient
Am. Nat., 179 (2012), pp. 490-500
CrossRef View Record in Scopus Google Scholar

Väisänen and Hublin, 1983 R. Väisänen, C. Hublin
The effect of continuous light trapping on moth populations: a mark-recapture experiment on Hydraecia petasitis (Lepidoptera, Noctuidae)
Notulae Entomologicae, 63 (1983), pp. 187-191
View Record in Scopus Google Scholar

van Doorn and Van Meeteren, 2003 W.G. van Doorn, U. Van Meeteren
Flower opening and closure: a review
J. Exp. Bot., 54 (2003), pp. 1801-1812
View Record in Scopus Google Scholar

van Geffen et al., 2015a K.G. van Geffen, A.T. Groot, R.H.A. Van Grunsven, M. Donners, F. Berendse, E.M. Veenendaal
Artificial night lighting
Ecol. Entomol., 40 (2015
CrossRef View Record

van Geffen et al., 2015b K.G. v
Berendse, E.M. Veenend
Artificial light at night inhibits mating in a Geometrid moth
Insect Conserv. Divers., 8 (2015), pp. 282-287
CrossRef View Record in Scopus Google Scholar

van Geffen et al., 2014 K.G. van Geffen, R.H.A. van Grunsven, J. van Ruijven, F. Berendse, E.M. Veenendaal
Artificial light at night causes diapause inhibition and sex-specific life history changes in a moth
Ecol. Evol., 4 (2014), pp. 2082-2089
View Record in Scopus Google Scholar

van Langevelde et al., 2018 F. van Langevelde, M. Braamburg-Annegarn, M.E. Huigens, R. Groendijk, O. Poitevin, J.R. van Deijk, W.N. Ellis, R.H.A. van Grunsven, R. de Vos, R.A. Vos, M. Franzén, M.F.W. DeVries

Fjell
Artificial night lighting inhibits feeding in moths
Biol. Lett., 13 (2017), 10.1098/rsbl.2016.0874
Google Scholar

van Strien et al., 2019 A.J. van Strien, C.A.M. van Swaay, W.T.F.H. van Strien-van Liempt, M.J.M. Poot, M.F. WallisDeVries
Over a century of data reveal more than 80% decline in butterflies in the Netherlands
Biol. Conserv., 234 (2019), pp. 116-122
Article Download PDF View Record in Scopus Google Scholar

van Veen et al., 2006 F.J.F. van Veen, R.J. Morris, H.C.J. Godfray
Apparent competition, quantitative food webs, and the structure of phytophagous insect communities
Annu. Rev. Entomol., 51 (2006), pp. 187-208
View Record in Scopus Google Scholar

Villalobos Jiménez and de, 2017 G. Villalobos Jiménez, J. de
The Impacts of Urbanis
Damselflies (Insecta: O
University of Leeds (201
Google Scholar

Wagner, 2019 D.L. Wagner
Global insect decline: Comments on Sánchez-Bayo and Wyckhuys (2019)
Biol. Conserv. (2019), 10.1016/j.biocon.2019.03.005
Google Scholar

Walker et al., 2019 W.H. Walker, O.H. Meléndez-Fernández II, R.J. Nelson, R.J. Reiter
Global climate change and invariable photoperiods: a mismatch that jeopardizes animal fitness
Ecol. Evol., 310 (2019), p. 456
View Record in Scopus Google Scholar

Wang et al., 2013 S. Wang, X.L. Tan, J.P. Michaud, F. Zhang, X. Guo
Light intensity and wavelength influence development, reproduction and locomotor activity in the predatory flower bug Orius sauteri (Poppius) (Hemiptera: anthocoridae)
Biocontrol, 58 (2013), pp. 667-674

J. Insect Sci., 11 (2011), p. 161
Google Scholar

White, 2018 P.J.T. White
An aerial approach to investigating the relationship between Macromoths and artificial nighttime lights across an urban landscape
J. Agric. Urban Entomol. (2018), pp. 1-14
View Record in Scopus Google Scholar

Willmott et al., 2018 N.J. Willmott, J. Henneken, C.J. Selleck, T.M. Jones
Artificial light at night alters life history in a nocturnal orb-web spider
PeerJ, 6 (2018), p. e5599
CrossRef Google Scholar

Wilson et al., 2018 J.F. Wilson, D. Baker, J. Cheney, M. Cook, M. Ellis, R. Freestone, D. Gardner, G. Geen, R. Hemming, D. Hodgers, S. Howarth, A. Jupp, N. Lowe, S. Orridge, M. Shaw, B. Smith, A. Turner, H. Young
A role for artificial night-time lighting in long-term changes in populations of 100 widespread macro-mot
J. Insect Conserv. (2018)
Google Scholar

Winfree, 1974 A.T. Winfree
Suppressing drosophila
Science, 183 (1974), pp. 970-972
View Record in Scopus Google Scholar

Wolff, 1982 R.J. Wolff
Nocturnal activity under artificial lights by the jumping spider Sitticus fasciger
Peckhamia, 2 (1982), p. 32
View Record in Scopus Google Scholar

Yamaoka and Hirao, 1981 K. Yamaoka, T. Hirao
Mechanisms of ovipositional behaviour in Bombyx mori: time-gating and accumulation of the internal factor
Int. J. Invertebr. Reprod., 4 (1981), pp. 169-180
CrossRef Google Scholar

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Yuen and Bonebrake, 2017 S.W. Yuen, T.C. Bonebrake
Artificial night light alters nocturnal prey interception outcomes for morphologically variable spiders
PeerJ, 5 (2017), p. e4070
CrossRef Google Scholar

Zozaya et al., 2015 S.M. Zozaya, R.A. Alford, L. Schwarzkopf
Invasive house geckos are more willing to use artificial lights than are native geckos: house geckos and artificial lights
Austral Ecol., 40 (2015), pp. 982-987
CrossRef View Record in Scopus Google Scholar

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Light pollution ruins teen sleep and may contribute to mental disorders, study says

By Sandee LaMotte, CNN

Updated 12:17 PM ET, Wed July 8, 2020

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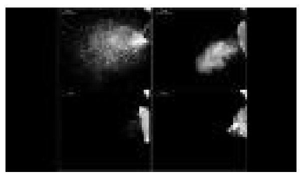

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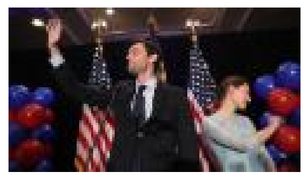

Jon Ossoff awaiting Covid-19 test results after wife tests positive

C hi si d

(CNN) — Hey sleepyheads -- have you been turning off or covering up all your smartphone and computer lights in your bedroom at night?

Blocking indoor light to keep your body in sleep mode is one of the first things any sleep expert will tell you to do for better sleep. Now, you may want to use light-blocking curtains at your bedroom windows as well -- especially for any children in your home.

A new study, published Wednesday in the journal JAMA Psychiatry, finds adolescents who live in areas with high levels of outdoor artificial light at night get less sleep and are more likely to have a mood disorder than teens who live with low levels of outdoor light.

Research has long studied the association between indoor artificial light and mental health, but few studies have looked at the impact of outdoor artificial light, especially in teens, making this the first study of its kind, the authors said, with "potentially long-term implications for mental and physical health."

"Although environmental light exposure is only one factor in a more complex network of influences on sleep and behavior, it is likely to be an important target for prevention and

interventions in adolescent health," said co-author Kathleen Merikangas, a senior investigator and chief of the Genetic Epidemiology Research Branch at the National Institute of Mental Health, in a statement.

Poor sleep in teens

When our internal 24-hour body clock, called our circadian

Related Article: Less dream-stage REM sleep linked to higher risk of death, study says

weakened immune system, weight gain, a lack of libido and a higher risk of diabetes, stroke, cardiovascular disease, dementia and some cancers.

Disruptions to sleep and circadian rhythms are also linked to certain mental disorders, including bipolar disorder, mood swings, paranoia and anxiety.

Secretion of the sleep hormone melatonin begins at dark. Research has found that the body will slow or stop melatonin production if exposed to light.

Although preteens and teens need more than nine hours of sleep a night, they are the least likely to get enough rest, partly due to today's technology lures of social media and smartphones and late-to-bed habits.

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More than 90% of high school students in the United States are chronically sleep-deprived, with 20% getting fewer than five hours a night, according to a Sleep in America poll.

According to a study from the US Centers for Disease Control and Prevention, sleep deprivation sets teens up to engage in more risky behavior, such as drinking, texting while driving or not wearing a seat belt or helmet, compared with those who get at least nine hours a night.

Previous studies on teen sleep found that fewer than eight hours a night was also associated with obesity, migraines, sexual activity, substance abuse, lack of exercise, feelings of depression and thoughts of suicide.

More than 10,000 teens studied

The new study collected data on mental health issues and sleep patterns from more than 10,000 teens participating in the National Comorbidity Survey Adolescent Supplement, the first government study designed to capture a nationally representative estimate of the types and prevalence of mental disorders in American teens.

Related Article: 10 commandments for better sleep

The study analyzed data on adolescents between the ages 13 and 18 that was recorded between 2001 and 2004. Teens filled out sleep and mental health questionnaires, and the results were cross-referenced with average artificial light levels for their homes collected via satellite images.

Not only did teens in cities with higher levels of artificial outdoor light go to bed later and sleep less, they also were more likely to have a mood or anxiety disorder. Specifically, teens exposed to higher light levels were more likely to be diagnosed with bipolar disorder or a specific phobia, the study found.

Related Article: Craving carbs and sleeping badly while social distancing? Here's how to cope

There was a racial and social-economic disparity as well, the study found. Levels of nighttime artificial light varied according to factors such as population density and socioeconomic status -- teens from immigrant or racial or ethnic minority groups who lived in lower income families were more likely to live in areas with high levels of outdoor light at night.

"These findings illustrate the importance of joint consideration of both broader environmental-level and individual-level exposures in mental health and sleep research," said study author Diana Paksarian, a postdoctoral research fellow at the National Institute of Mental Health, in a statement.

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JAMA Psychiatry | Original Investigation

Association of Outdoor Artificial Light at Night With Mental Disorders and Sleep Patterns Among US Adolescents

Diana Paksarian, PhD; Kara E. Rudolph, PhD; Emma K. Stapp, PhD; Gideon P. Dunster, PhD; Jianping He, MS; Daniel Mennitt, PhD; Samer Hattar, PhD; Joan A. Casey, PhD; Peter James, ScD; Kathleen R. Merikangas, PhD

Supplemental content

IMPORTANCE Indoor nighttime light exposure influences sleep and circadian rhythms and is known to affect mood-associated brain circuits in animals. However, little is known about the association between levels of nighttime outdoor light and sleep and mental health in the population, especially among adolescents.

OBJECTIVE To estimate associations of outdoor artificial light at night (ALAN) with sleep patterns and past-year mental disorder among US adolescents.

DESIGN, SETTING, AND PARTICIPANTS This population-based, cross-sectional study of US adolescents used the National Comorbidity Survey–Adolescent Supplement, a nationally representative cross-sectional survey conducted from February 2001 through January 2004. A probability sample of adolescents aged 13 to 18 years was included. Analyses were conducted between February 2019 and April 2020.

EXPOSURES Levels of outdoor ALAN, measured by satellite, with means calculated within census block groups. ALAN values were transformed into units of radiance (nW/cm^2/sr).

MAIN OUTCOMES AND MEASURES Self-reported habitual sleep patterns (weeknight bedtime, weeknight sleep duration, weekend bedtime delay, and weekend oversleep) and past-year mood, anxiety, behavior, and substance use disorders, measured via an in-person structured diagnostic interview. Parent-reported information was included in behavior disorder diagnoses.

RESULTS Among 10 123 adolescents (4953 boys [51.3%]; mean [SE] age, 15.2 [0.06] years [weighted]; 6483 for behavior disorder outcomes), ALAN was positively associated with indicators of social disadvantage, such as racial/ethnic minority status (median [IQR] ALAN: white adolescents, 12.96 [30.51] nW/cm^2/sr; Hispanic adolescents: 38.54 [47.84] nW/cm^2/sr; non-Hispanic black adolescents: 37.39 [51.88] nW/cm^2/sr; adolescents of other races/ethnicities: 30.94 [49.93] nW/cm^2/sr; $P < .001$) and lower family income (median [IQR] ALAN by family income-to-poverty ratio ≤1.5: 26.76 [52.48] nW/cm^2/sr; >6: 21.46 [34.38] nW/cm^2/sr; $P = .005$). After adjustment for several sociodemographic characteristics, as well as area-level population density and socioeconomic status, this study found that higher ALAN levels were associated with later weeknight bedtime, and those in the lowest quartile of ALAN reported the longest weeknight sleep duration. Those in the highest quartile of ALAN went to bed 29 (95% CI, 15-43) minutes later and reported 11 (95% CI, 19-2) fewer minutes of sleep than those in the lowest quartile. ALAN was also positively associated with prevalence of past-year mood and anxiety disorder: each median absolute deviation increase in ALAN was associated with 1.07 (95% CI, 1.00-1.14) times the odds of mood disorder and 1.10 (95% CI, 1.05-1.16) times the odds of anxiety disorder. Further analyses revealed associations with bipolar disorder (odds ratio [OR], 1.19 [95% CI, 1.05-1.35]), specific phobias (OR, 1.18 [95% CI, 1.11-1.26]), and major depressive disorder or dysthymia (OR, 1.07 [95% CI, 1.00-1.15]). Among adolescent girls, differences in weeknight bedtime by ALAN (third and fourth quartiles vs first quartile) were greater with increasing years since menarche (F_3, 8.15; $P < .001$).

CONCLUSIONS AND RELEVANCE In this study, area-level outdoor ALAN was associated with less favorable sleep patterns and mood and anxiety disorder in adolescents. Future studies should elucidate whether interventions to reduce exposure to ALAN may positively affect mental and sleep health.

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Disturbances in daily rhythms of sleep and activity have long been observed in individuals with mental disorders, especially mood disorders.[1] This association is thought to be bidirectional, and not simply because of an effect of mental disorder on daily rhythms. For example, prospective high-risk studies have identified sleep disturbances as an early antecedent of bipolar disorder.[2] A longitudinal community study of youths demonstrated prospective bidirectional associations between sleep problems and anxiety disorder, with sleep problems associated with subsequent anxiety disorder and vice versa.[3] Furthermore, among people with bipolar disorder, disturbances to behavioral rhythms often precede mood episodes,[4] and changes in activity levels were found to drive changes in mood over time.[5]

Daily rhythms are primarily driven by the light-dark cycle, which is the body's major source of information about the time of day.[6] The secretion of melatonin begins at dark and is strongly inhibited by exposure to light. Light is also the primary driver of the innate circadian rhythms of cellular and genetic processes. Light information is transmitted through retinal pathways to the suprachiasmatic nucleus, which acts as the body's central clock and helps to synchronize peripheral clocks with the environment. It is thought that exposure to light at night increases disease risk by contributing to dysregulation and desynchronization of behavioral and biological daily rhythms.[7,8]

In 2012, the American Medical Association issued a policy statement[9,10] citing concerns about the health outcomes of nighttime lighting, including mood disorders. Multiple lines of evidence support the idea that aberrant light exposure may negatively affect mood. Studies using animal models have shown that light affects depressionlike and anxietylike behaviors and have begun to elucidate neural mechanisms for these outcomes.[11-13] In addition, human studies measuring exposure to indoor artificial light at night (ALAN) have documented associations with mental health.[14-17] Moreover, light therapy has long been used as a treatment for mood disorder.[18,19]

In addition to individual-level indoor exposure, exposure to outdoor ALAN at the contextual level may influence mental health. Several community-based and population-based studies have demonstrated associations between outdoor ALAN and sleep patterns.[20-24] ALAN has also gained attention as a risk factor for chronic diseases, particularly cancer and obesity.[20,25,26] To our knowledge, only 1 prior study[27] has focused on the association between outdoor ALAN and mental health at the population level. This study, conducted among a representative sample of South Korean adults, showed that those living in districts with higher levels of outdoor ALAN were more likely to report depressive symptoms and suicidal ideation or attempt.[27] In the current study, we leverage data from a nationally representative sample of US adolescents to estimate associations of outdoor ALAN with sleep patterns and mental disorder, including broad disorder classes as well as individual disorders, in the past year. We focus on adolescents because of evidence that mental disorders commonly emerge during adolescence[28] and evidence from animal studies that indicates that early exposure to ALAN may have long-lasting effects.[29,30] As a secondary aim, we assessed whether associations differed by sex and age (among adolescent boys) or pubertal maturation (among adolescent girls).[31,32]

Key Points

Question Are levels of outdoor artificial light at night associated with adolescent sleep patterns and past-year mental disorder?

Findings In a cross-sectional, nationally representative survey of US adolescents, higher levels of outdoor artificial light at night, measured via satellite, were associated with later weeknight bedtimes; those in the lowest quartile of nighttime light reported the longest weeknight sleep durations. Adolescents in areas with greater levels of nighttime light also had higher prevalence of past-year mood and anxiety disorders.

Meaning Future studies of adolescent mental and sleep health should consider contextual-level measures of light at night, in addition to individual-level exposure.

Methods

Sample

We used data from the National Comorbidity Survey-Adolescent Supplement (NCS-A), a nationally representative cross-sectional survey of adolescents residing in the contiguous US that was conducted from February 2001 through January 2004.[33] A complex sampling design with dual household and school sampling frames was used. Adolescents in the NCS-A were sampled from across the US, from the same counties as adults in the NCS-Replication, a nationally representative survey of US adults.[34] A total of 10 123 adolescents aged 13 to 18 years participated, with an overall response rate of 75.6%. In-person interviews assessing mental disorders and a range of individual, familial, and contextual characteristics were administered in adolescents' homes by trained lay interviewers.[35] In addition, parents or guardians were mailed a parent self-administered questionnaire (PSAQ), data from which are available for 6483 adolescents. The NCS-A's procedures were approved by the human subjects committees of Harvard Medical School and the University of Michigan. Written informed consent and assent were obtained from parents and adolescents, respectively. This study was determined not human subjects research by the National Institutes of Health Office of Institutional Review Board Operations.

Measures

Mental Disorder

Mental disorders were assessed during in-person interviews using a modified version of the World Health Organization Composite International Diagnostic Interview version 3.0, a fully structured, lay-administered instrument that generates psychiatric diagnoses according to *DSM-IV* criteria.[35-37] Here we considered 4 broad classes of past-year mental disorder: mood (major depressive disorder, dysthymia, and bipolar I and II disorders), anxiety (agoraphobia without panic, specific phobia, social phobia, generalized anxiety disorder, panic disorder, posttraumatic stress disorder, and separation anxiety dis-

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order), substance use (alcohol and drug abuse and dependence), and behavior (conduct disorder, oppositional defiant disorder, and attention-deficit/hyperactivity disorder). Mood, anxiety, and substance use disorder diagnoses were based on adolescent interviews alone. To maximize validity, diagnoses of conduct disorder and oppositional defiant disorder were based on both adolescent and parent reports, combined using an *or* rule at the symptom level, while diagnoses of attention-deficit/hyperactivity disorder were based on parent reports alone.[38,39]

Sleep Patterns

During the interview, adolescents were asked what time they usually go to bed on weeknights and weekends, and how many hours of sleep they usually get on weeknights and weekends. From this, we derived 4 sleep patterns: weeknight bedtime, weeknight sleep duration, weekend bedtime delay (weekend bedtime minus weeknight bedtime), and weekend oversleep (weekend sleep duration minus weeknight sleep duration). The first 2 measures captured mean sleep patterns, while the second 2 captured day-to-day variability in sleep patterns. These patterns have been studied previously in association with mental health and contextual exposures in the NCS-A.[40-42]

Adolescent-reported sleep patterns contained anomalous reports that were likely spurious (eg, a weekend sleep duration of 24 hours). To mitigate the influence of spurious reports, observations outside of 3 SDs were omitted prior to calculating sleep patterns (weeknight bedtime: 223 individuals; weeknight sleep duration: 62 individuals; weekend bedtime: 400 individuals; weekend sleep duration: 63 individuals). Total rates of missingness were 2.5% (n = 252) for weeknight bedtime, 1.0% (n = 105) for weeknight sleep duration, 7.1% (n = 719) for weekend bedtime delay, and 2.3% (n = 233) for weekend oversleep. The larger proportion of missingness for weekend bedtime delay was in part because of omission of observations from 251 adolescents who reported going to bed at noon on weekends. Sensitivity analyses that (1) included all reports and (2) recoded bedtimes of noon as midnight did not meaningfully change the results and are presented in the eTable 3 and eTable 4 in the Supplement.

Outdoor ALAN

Outdoor ALAN information was derived from satellite imagery data maintained by the National Oceanic and Atmospheric Administration's Earth Observation Group.[43] Data are from the US Defense Meteorological Satellite Program's Operational Linescan System Nighttime Lights Time Series, which provides annual composite estimates based on continuous sampling of the Earth's surface with daily global coverage. These composites are based on observations that exclude clouds, sunlight, moonlight, glare, and brief events, such as fires.[44] We used the Defense Meteorological Satellite Program Global Radiance Calibrated Nighttime Lights high-dynamic range data, which captures increased variability within urban and suburban areas.[45] Data were from the year 2000 and available at a resolution of approximately 1 km^2. Mean ALAN levels for each census block group in the US according to the 2000 decennial census were calculated using ArcGIS (ESRI). ALAN values were transformed into units of radiance (nW/cm^2/sr). This information was linked to participants in the NCS-A based on their census block group of residence. A census block group is a subdivision of a census tract, contains between 600 and 3000 people, and is the smallest geographical unit for which the US census collects sample data.

Covariates

Individual-level covariates included age, sex, race/ethnicity, parental education, number of siblings, number of biological parents, family income-to-poverty ratio, and immigrant generation. All covariates were categorized as in **Table 1**, except for age, which was modeled continuously. Area-level covariates included county-level urbanicity, region, population density, and socioeconomic status (SES). Population density (people/km^2) was from the 2000 US census at the block group level. Census tract-level SES was measured using an index[46] that has been used in large epidemiologic studies and applied previously in the NCS-A.[47] It is derived from 6 indicators (median household income; percentage of households receiving interest, dividend, or rental income; median value of owner-occupied housing units; percentage of adults 25 years and older who completed high school; percentage of adults 25 years and older who completed college; and percentage of the persons 16 years and older with employment who held executive, managerial, or professional occupations; Table 1) that are standardized and summed to create a normally distributed summary score. Forty-eight adolescents (0.5%) lived in census tracts with missing SES indicators. Age at menarche was assessed among adolescent girls by self-report and subtracted from current age to derive years since menarche as a measure of pubertal maturation.

Statistical Analysis

First, we estimated the median and interquartile range (IQR) of ALAN by sociodemographic characteristics. Second, we estimated associations between ALAN and sleep patterns using linear regression. ALAN was modeled in quartiles to allow for nonlinearity. Third, we used binary and multinomial logistic regression to estimate odds ratios (ORs) and 95% CIs for the associations between ALAN and past-year mental disorder classes. ALAN was modeled as continuous in these models, as exploratory analyses revealed that apparent nonlinearity was attributable to the most extreme values of ALAN. ALAN was standardized using the median absolute deviation from the median.[48] Fourth, where associations with disorder classes were observed, we performed post hoc analyses to identify associations with individual disorders. Multinomial logistic regression was used to compare each disorder of interest with a consistent reference group while accounting for associations with other disorders. Three levels of model adjustment were used: age and sex only (model 1), additional adjustment for all sociodemographic covariates (model 2), and additional adjustment for continuous area-level SES and quadratic population density (model 3). Fifth, for outcomes of sleep patterns and mental disorder classes, we performed post hoc analyses testing for interactions of ALAN with sex and age (among adolescent boys) or years since menarche (among adolescent girls),

Table 1. Median and Interquartile Range of Outdoor Artificial Light at Night, by Participant, Family, and Area-Level Characteristics[a]

Characteristic	No. (%)	Light at night, nW/cm^2/sr, median (IQR)	*P* value
Age, y			
13	1652 (15.2)	18.10 (42.55)	.14
14	2218 (21.0)	24.08 (43.07)	
15	1887 (20.5)	18.68 (36.70)	
16	2010 (21.0)	19.62 (37.67)	
17	1758 (16.8)	24.13 (41.08)	
18	598 (5.4)	29.15 (42.09)	
Sex			
Female	5170 (48.8)	21.84 (40.40)	.49
Male	4953 (51.3)	20.80 (40.27)	
Race/ethnicity			
Hispanic	1914 (14.4)	38.54 (47.84)	<.001
Non-Hispanic black	1953 (15.1)	37.39 (51.88)	
Other race/ethnicity	622 (5.0)	30.94 (49.93)	
Non-Hispanic white	5634 (65.6)	12.96 (30.51)	
Urbanicity			
Metropolitan	4508 (47.5)	37.35 (47.80)	<.001
Other urban	3304 (37.6)	13.95 (27.82)	
Nonurban	2311 (14.9)	2.12 (3.74)	
Region			
Northeast	1868 (18.1)	33.34 (75.18)	<.001
Midwest	2776 (23.3)	23.57 (37.56)	
South	3434 (36.0)	10.79 (28.91)	
West	2045 (22.6)	28.96 (46.78)	
Parental education			
Less than high school	1684 (15.5)	29.97 (55.71)	<.001
High school graduation	3081 (29.7)	16.32 (44.11)	
Some college	1998 (19.4)	21.87 (41.02)	
College graduation	3360 (35.3)	19.84 (31.20)	
Family income-to-poverty ratio			
≤1.5	1717 (14.7)	26.76 (52.48)	.005
>1.50 to ≤3	2023 (19.1)	23.23 (44.98)	
>3.0 to ≤6	3101 (31.9)	17.96 (38.69)	
>6	3282 (34.3)	21.46 (34.38)	
No. of biological parents			
0	971 (9.3)	22.07 (40.89)	<.001
1	3797 (35.7)	25.61 (46.35)	
2	5355 (55.0)	18.48 (36.60)	
No. of siblings			
1	483 (5.5)	21.51 (42.36)	<.001
2	2569 (28.4)	18.67 (37.59)	
3	2633 (26.5)	20.13 (38.25)	
≥4	4438 (39.6)	24.06 (44.46)	

(continued)

Table 1. Median and Interquartile Range of Outdoor Artificial Light at Night, by Participant, Family, and Area-Level Characteristics[a] (continued)

Characteristic	No. (%)	Light at night, nW/cm^2/sr, median (IQR)	*P* value
Nativity			
Not born in US	591 (6.5)	40.49 (45.00)	<.001
1 or 2 Parents not born in US	1533 (13.4)	33.30 (51.16)	
1 to 4 Grandparents not born in US	1298 (13.3)	27.01 (43.89)	
Other	6701 (66.8)	14.58 (34.09)	
Area-level SES score quintile			
First (lowest)	2015 (16.5)	41.74 (57.24)	<.001
Second	2025 (20.1)	13.86 (43.69)	
Third	2006 (19.4)	7.96 (35.57)	
Fourth	2022 (20.5)	18.45 (31.71)	
Fifth (highest)	2007 (23.5)	24.07 (27.12)	
Area-level population density quintile			
First (lowest)	2026 (19.0)	1.78 (1.33)	<.001
Second	2023 (20.6)	7.20 (8.96)	
Third	2025 (20.2)	24.76 (21.26)	
Fourth	2024 (20.5)	36.60 (28.03)	
Fifth (highest)	2025 (19.8)	68.15 (52.02)	

Abbreviations: IQR, interquartile range; SES, socioeconomic status.

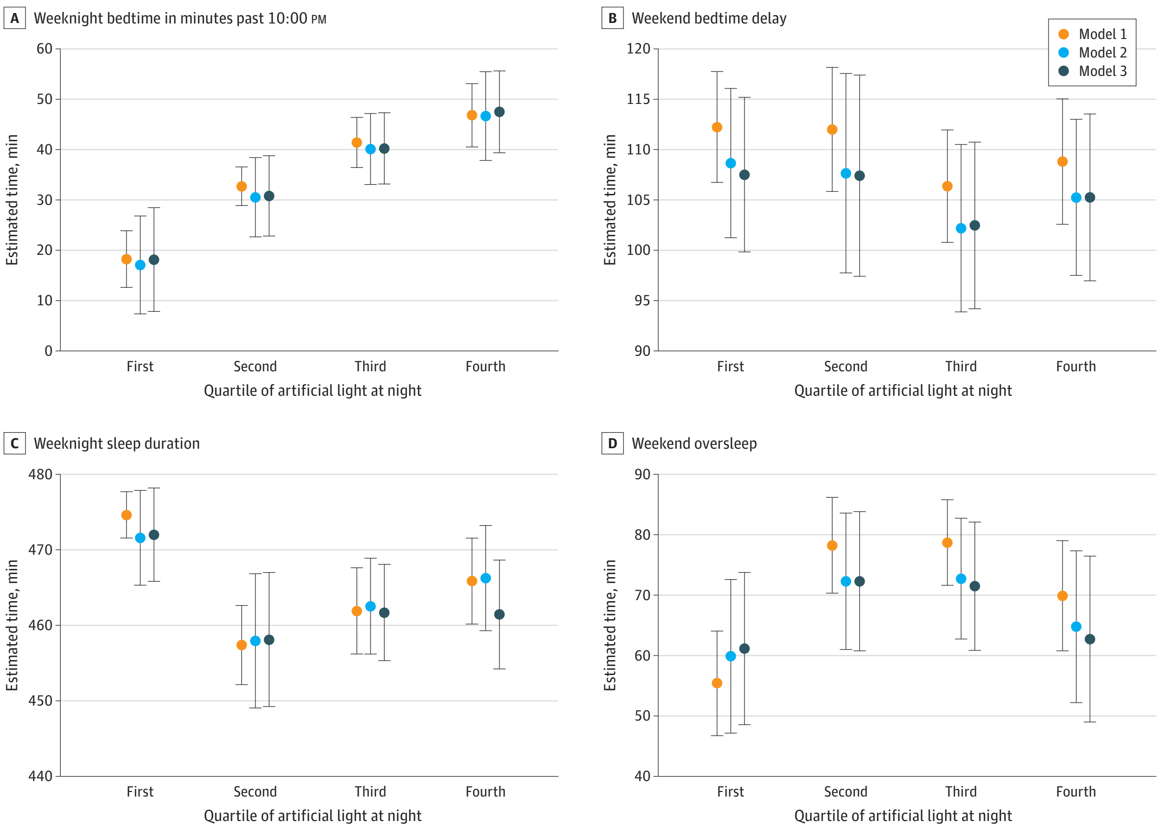
[a] Artificial light at night is measured in nanowatts. The *P* values are from *F* tests from binary and multinomial logistic regressions with demographic characteristics as the dependent variables and light at night as the independent variable. Area-level SES scores were derived from 6 census indicators: median household income; percentage of households receiving interest, dividend, or rental income; median value of owner-occupied housing units; percentage of adults 25 years or older who completed high school; percentage of adults 25 years or older who completed college; and percentage of persons 16 years and older with employment who are in executive, managerial, or professional occupations.

by adding multiplicative interaction terms to model 3. Finally, we performed a sensitivity analysis controlling for season of interview. Analyses accounted for the complex sampling design and survey weights.[49] Variances were estimated using Taylor series linearization. Because of the relatively low rates of missingness, missing data were handled via model-wise deletion. Analyses were conducted using SAS version 9.4 (SAS Institute) from February 2019 to April 2020.

Results

A total of 10 123 adolescents aged 13 to 18 years participated (4953 boys [51.3%]; 5634 non-Hispanic white individuals [65.6%]; mean [SE] age, 15.2 [0.06] years [weighted]), with data from the parent self-administered questionnaire available for 6483 adolescents. Median values of ALAN, by individual and area-level characteristics, are presented in Table 1. Levels of ALAN differed according to every covariate except age and sex. ALAN levels were lowest for non-Hispanic white adolescents (median

Figure. Adjusted Mean Sleep Patterns by Quartiles of Outdoor Artificial Light at Night Among US Adolescents



Weeknight bedtime is in minutes past 10:00 PM. Model 1 is adjusted for age and sex. Model 2 is additionally adjusted for race/ethnicity, family income, parental education, family structure, nativity, region, and urbanicity. Model 3 is additionally adjusted for census block group–level population density and census tract–level socioeconomic status. Sample sizes reflect those in eTable 1 in the Supplement. Forty-eight adolescents missing values for area-level socioeconomic status were not included in model 3. In model 3, artificial light at night was associated with weeknight bedtime and weeknight sleep duration (eTable 1 in the Supplement). Mean weeknight bedtime differed significantly between all quartiles of artificial light at night. Mean sleep duration did not differ significantly between the second through fourth quartiles of artificial light at night.

[IQR], 12.96 [30.51] nW/cm^2/sr; vs Hispanic adolescents: 38.54 [47.84] nW/cm^2/sr; non-Hispanic black adolescents: 37.39 [51.88] nW/cm^2/sr; adolescents of other races/ethnicities: 30.94 [49.93] nW/cm^2/sr; $P < .001$), increased monotonically with urbanicity (nonurban: 2.12 [3.74] nW/cm^2/sr; other urban: 13.95 [27.82] nW/cm^2/sr; metropolitan: 37.35 [47.80] nW/cm^2/sr; $P < .001$), and were highest in the Northeast (33.34 [75.18] nW/cm^2/sr vs the Midwest: 23/57 [37.56] nW/cm^2/sr; South: 10.79 [28.91] nW/cm^2/sr; and West: 28.96 [46.78] nW/cm^2/sr; $P < .001$). ALAN levels also differed by adolescent socioeconomic characteristics (eg, median [IQR] by family income-to-poverty ratio ≤1.5: 26.76 [52.48] nW/cm^2/sr; >6: 21.46 [34.38] nW/cm^2/sr; $P = .005$), family structure (eg, median [IQR] by number of biological parents: 0, 22.07 [40.89] nW/cm^2/sr; 2, 18.48 [36.60] nW/cm^2/sr; $P < .001$), and area-level SES (median [IQR]: first [lowest] quintile, 41.74 [57.24] nW/cm^2/sr; fifth [highest] quintile, 24.07 [27.12] nW/cm^2/sr; $P < .001$) and population density (median [IQR]: first [lowest] quintile, 1.87 [1.33]; fifth [highest] quintile, 68.15 [52.02]) (Table 1).

The **Figure** and eTable 1 in the Supplement show associations between quartiles of ALAN and sleep patterns. Adjusting for age and sex (model 1), ALAN was associated with weeknight bedtime (mean differences from lowest quartile of ALAN: second quartile, 14.47 [95% CI, 8.07-20.87] minutes; third quartile, 23.16 [95% CI, 15.33-31.00] minutes; highest quartile, 28.56 [95% CI, 18.82-38.30] minutes; $P < .001$), weeknight sleep duration (mean differences from lowest quartile of ALAN: second quartile, −17.24 [95% CI, −23.04 to −11.44] minutes; third quartile, −12.71 [95% CI, −19.29 to −6.13] minutes; highest quartile, −8.77 [95% CI, −15.29 to −2.24] minutes; $P < .001$), and weekend oversleep (mean differences from lowest quartile of ALAN: second quartile, 22.87 [95% CI, 10.73-35.00] minutes; third quartile, 23.31 [95% CI, 12.24-34.38] minutes; highest quartile, 14.50 [95% CI, 1.66-27.35] minutes; $P < .001$). Further adjustment for sociodemographic covariates reduced the magnitude of association with sleep duration (mean differences from lowest quartile of ALAN: second quartile, −13.65 [95% CI, −19.78 to −7.51] minutes; third quartile, −9.05

Table 2. Associations Between Outdoor Artificial Light at Night and Classes of Mental Disorder in the Past Year Among Adolescents[a]

Disorder class	Participants, No.	Model 1 OR (95% CI)[b]	Model 1 P value	Model 2 OR (95% CI)[c]	Model 2 P value	Model 3 OR (95% CI)[d]	Model 3 P value
Mood	1021	1.09 (1.03-1.14)	.002	1.08 (1.02-1.15)	.01	1.07 (1.00-1.14)	.04
Anxiety	1950	1.09 (1.04-1.15)	.002	1.08 (1.03-1.13)	.003	1.10 (1.05-1.16)	<.001
Substance	854	1.03 (0.94-1.12)	.57	1.04 (0.93-1.16)	.50	1.00 (0.90-1.11)	.96
Behavior	959	1.08 (0.98-1.21)	.13	1.07 (0.95-1.21)	.25	1.04 (0.93-1.17)	.46

Abbreviations: OR, odds ratio; SES, socioeconomic status.

[a] Artificial light at night was standardized using the median absolute deviation from the median. Numbers are unweighted. The sample size is 6483 for behavioral outcomes and 10 123 for other outcomes. Analyses accounting for comorbidity between mood and anxiety disorder showed that ORs did not significantly differ between those with mood disorder only, anxiety only, or both.

[b] Model 1 is adjusted for age and sex.

[c] Model 2 is additionally adjusted for race/ethnicity, family income, parental education, family structure, nativity, region, and urbanicity.

[d] Model 3 is additionally adjusted for area-level population density and socioeconomic status. Forty-eight adolescents missing values for area-level SES were not included in model 3.

Table 3. Associations Between Outdoor Artificial Light at Night and Past-Year Mood and Anxiety Disorders Among Adolescents[a]

Disorder	No.	Model 1 OR (95% CI)[b]	Model 1 P value	Model 2 OR (95% CI)[c,d]	Model 2 P value	Model 3 OR (95% CI)[d,e]	Model 3 P value
Bipolar disorder	246	1.11 (1.03-1.18)	.005	1.14 (1.05-1.24)	.002	1.19 (1.05-1.35)	.006
Major depressive disorder/dysthymia	775	1.11 (1.03-1.19)	.005	1.09 (1.01-1.18)	.04	1.07 (1.00-1.15)	.07
Agoraphobia without panic	192	1.23 (1.11-1.36)	<.001	1.18 (1.03-1.35)	.01	1.05 (0.89-1.24)	.57
Generalized anxiety	63	1.10 (0.95-1.27)	.21	1.01 (.83-1.22)	.95	0.93 (0.68-1.26)	.63
Social phobia	516	1.08 (1.02-1.14)	.005	1.05 (0.96-1.16)	.29	1.06 (0.96-1.18)	.25
Specific phobia	1244	1.11 (1.04-1.18)	.001	1.12 (1.05-1.18)	<.001	1.18 (1.11-1.26)	<.001
Panic disorder	191	1.04 (0.93-1.16)	.53	1.04 (0.90-1.21)	.57	1.07 (0.85-1.33)	.57
PTSD	292	0.95 (0.83-1.08)	.42	0.91 (0.76-1.08)	.26	0.93 (0.80-1.08)	.35
Separation anxiety	143	1.12 (0.97-1.29)	.13	1.00 (.842-1.19)	.99	1.06 (0.88-1.28)	.53

Abbreviations: ALAN, artificial light at night; OR, odds ratio; PTSD, posttraumatic stress disorder; SES, socioeconomic status.

[a] Estimates are from separate multinomial logistic regressions, with the exception of major depressive disorder/dysthymia and bipolar disorder, which were estimated in the same model. Those with no mood or anxiety disorder are the comparison group for each disorder. Numbers are unweighted. Artificial light at night was standardized using the median absolute deviation from the median. The ORs for bipolar disorder and major depressive disorder/dysthymia did not significantly differ from one another.

[b] Model 1 is adjusted for age and sex.

[c] Model 2 is additionally adjusted for race/ethnicity, family income, parental education, family structure, nativity, region, and urbanicity.

[d] In the multinomial regression (models 2 and 3) for specific phobia, ALAN was not associated with other anxiety disorders (model 3: OR, 1.01 [95% CI, 0.95-1.07]). Specific phobia was the only anxiety disorder for which this was true.

[e] Model 3 is additionally adjusted for area-level population density and socioeconomic status. Forty-eight adolescents missing values for area-level SES were not included in model 3.

[95% CI, −15.58 to −2.52] minutes; highest quartile, −5.34 [95% CI, −13.60 to 2.93] minutes; $P < .001$) and removed the association with weekend oversleep. Under full adjustment (model 3), bedtime was progressively later as the quartile of ALAN increased; those in the highest quartile of ALAN went to bed 29 (95% CI, 15-43) minutes later than those in the lowest quartile. Sleep duration was shorter among those in the 3 highest quartiles of ALAN compared to the lowest quartile; those in the highest quartile of ALAN reported 11 (95% CI, 2-19) fewer minutes of sleep than those in the lowest quartile.

Associations between continuous ALAN and the 4 classes of past-year mental disorder are presented in **Table 2**. ALAN was positively associated with mood and anxiety disorder under all 3 adjustments. Adjusting for all covariates, each median absolute deviation increase in ALAN was associated with 1.07 (95% CI, 1.00-1.14) times the odds of mood disorder and 1.10 (95% CI, 1.05-1.16) times the odds of anxiety disorder.

Table 3 presents post hoc analyses of individual mood and anxiety disorders. Adjusting for age and sex (model 1), ALAN was positively associated with major depressive disorder/dysthymia (odds ratio [OR], 1.11 [95% CI, 1.03-1.19]), bipolar disorder (OR, 1.11 [95% CI, 1.03-1.18]), agoraphobia (OR, 1.23 [95% CI, 1.11-1.36]), social phobia (OR, 1.08 [95% CI, 1.02-1.14]), and specific phobias (OR, 1.11 [95% CI, 1.04-1.16]). Under full adjustment (model 3), only the associations with bipolar disorder (OR, 1.19 [95% CI, 1.05-1.35]) and specific phobias (OR, 1.18 [95% CI, 1.11-1.26]) remained, although odds of major depressive disorder/dysthymia were elevated (OR, 1.07 [95% CI, 1.00-1.15]). The ORs for bipolar disorder and major depressive disorder/dysthymia did not significantly differ from one another (model 1: OR, 1.00 [95% CI, 0.90-1.11]; model 2: OR, 1.05 [95% CI, 0.93-1.17]; model 3: OR, 1.11 [95% CI, 0.96, 1.29]).

There was an interaction between ALAN and years since menarche among girls, for the outcome of weeknight bedtime (F_3, 8.15; $P < .001$; eTable 2 in the Supplement).

Estimates indicated that the difference in bedtime for those in 2 highest quartiles of ALAN compared with the lowest quartile was greater with increasing years since menarche (eFigure in the Supplement). Results of sensitivity analyses (eTables 3, 4, 5, and 6 in the Supplement) were similar to the main results.

Discussion

We found that contextual-level outdoor ALAN was associated with self-reported sleep patterns and past-year mental disorder among US adolescents. After adjusting for several sociodemographic characteristics as well as area-level population density and SES, we found that adolescents living in areas with higher levels of outdoor ALAN reported later weeknight bedtime, and those in the areas with the lowest levels had longer weeknight sleep duration. Adolescents in areas with higher outdoor ALAN also had higher odds of mood and anxiety disorders in the past year. Associations with mood disorders were present for both bipolar disorder and major depressive disorder/dysthymia, while associations with anxiety disorders were driven by specific phobias. Our results are consistent with the biological role of light as a driver of circadian rhythms[6] and with several studies,[20-24] including 1 study among adolescents, demonstrating effects of ALAN on sleep patterns. They also confirm the results of a prior study of the association between ALAN and mental health among adults,[27] supporting evidence from animal models that demonstrate an association of light with mood-associated behaviors.[13] To our knowledge, this is the first study to show associations between outdoor ALAN and *DSM*-defined mental disorders.

Disturbances in sleep and circadian rhythms are well-documented in mental disorders[1,50] and may be a mechanism linking ALAN to mental disorder risk. Prior work in the NCS-A demonstrated associations between sleep patterns and past-year mental disorder.[42] Prospective data will be required to assess whether sleep patterns mediate the association between ALAN and mental disorder. However, prior evidence points to sleep and circadian disturbances as antecedent and possibly causal factors in mental disorder onset, especially for mood disorder.[2,3,51,52] While ALAN was associated with both subtypes of mood disorders in our study, the association with bipolar disorder was especially statistically robust. This is consistent with abundant evidence that behavioral rhythms are a core feature of bipolar disorder.[53] For example, hypersensitivity of melatonin suppression in response to nighttime light exposure has been suggested as an endophenotype for bipolar disorder.[54]

Animal models provide evidence for biological pathways that may underlie the association between ALAN and mental disorder. In mice, the retinal ganglion cells that transmit light information to the suprachiasmatic nucleus also project to mood-associated brain structures, including the newly discovered perihabenular nucleus and regions of the hypothalamus and amygdala.[55,56] Exposure to dim light at night induces depressionlike behaviors in both nocturnal and diurnal rodents,[13] corroborating evidence for both indirect and direct pathways to mood (ie, pathways that do and do not include disruption to sleep and circadian rhythms).[13] Circadian rhythm disruption caused by ALAN could increase risk for mental disorder through a variety of mechanisms, including hypothalamic-pituitary-adrenal axis function, neurotransmission, and immune function.[57]

Some prior studies have suggested that effects of light may differ by sex, across the life course, and across puberty.[20,25,30-32] We found no evidence for differences by sex, consistent with a prior study of the association of light exposure with circadian function in adolescents.[32] We also did not find evidence for differences by age among adolescent boys. Among adolescent girls, the association between ALAN and bedtime was stronger among those who with a longer time since menarche. This may be explained by differences in light sensitivity, changes in personal light exposure, or both.[32]

We found that outdoor ALAN was strongly associated with several adolescent demographic and socioeconomic characteristics, including indicators of social disadvantage. For example, ALAN levels were higher among racial/ethnic minority adolescents, among adolescents from immigrant families, and among those with lower family incomes. Some prior studies of outdoor ALAN have noted differences according to sociodemographic characteristics.[20,23-25] The finding of social disparities in the distribution of outdoor ALAN among US adolescents implies that adolescents who face other sources of social disadvantage, especially those in urban settings, may also be exposed to greater levels of ALAN; this may represent an additional source of physiological stress.

To our knowledge, this is the first study to report associations between ALAN and mental disorders among adolescents, associations that have potentially long-term implications for mental and physical health. There is strong evidence for both homotypic and heterotypic continuity in mental disorder across the transition from adolescence to adulthood, especially between depression and anxiety.[58] Our finding that the association between ALAN and anxiety disorder was specific to specific phobias may be because of their greater prevalence, but could also be because of the developmental nature of the sample. Previous work from the World Mental Health Surveys showed that specific phobias are the factor most strongly associated with latent internalizing comorbidity and may therefore serve as a marker of youth at risk for progression to later psychopathology.[59] The associations we observed between ALAN and sleep patterns also have potential long-term health implications, in that suboptimal sleep patterns have been prospectively associated with adverse physical and mental health outcomes.[60-63] The importance of sleep health in other physical health outcomes, combined with known social disparities in sleep,[64] have prompted calls for more research into sleep as a potential mediator of social disparities in health.[65] Our results illustrate the potential utility of adopting this approach in mental health research.

Limitations

These findings should be interpreted in the context of the study's limitations and strengths. First, we lacked individual-level measures of light exposure, for which outdoor ALAN may not be a good proxy.[66,67] This includes both indoor and outdoor sources of ALAN, which may be influenced by the use of blackout shades and other factors that affect how much light enters the home. However, individual ALAN exposure may be more susceptible to reverse causation. In addition, as interventions to reduce indoor ALAN exposure become more widespread (eg, nighttime light filters on personal electronics, changes to indoor lighting), outdoor sources of ALAN may become more influential. Second, the NCS-A is cross-sectional. While reverse causation between ALAN and sleep or mental health outcomes seems unlikely, longitudinal data would enable assessment of temporal associations between ALAN, sleep, and mental disorder. Third, sleep patterns were measured subjectively. However, we have no reason to believe that the error in sleep measurement is correlated with ALAN exposure. Fourth, ALAN was measured slightly before NCS-A data collection and was aggregated to the census block-group level, which could result in misclassification in very large or small census block groups. However, additional analyses (not shown) indicated weak dilution of the association between ALAN and sleep duration for interviews conducted after 2001 that did not affect interpretation. Furthermore, because US Defense Meteorological Satellite Program measurements were taken at varying times of night, and over 1 year, their composites do not necessarily reflect the maximum ALAN in an area or allow examination of temporal patterns. On the other hand, ALAN was measured objectively and independently of the outcomes. Fifth, ALAN may be a proxy for economic activity[68] or other environmental exposures that are difficult to separate from ALAN in the context of a national epidemiologic study. However, as discussed, animal experiments demonstrate causal effects of ALAN on circadian rhythms and mood-associated behaviors. Sixth, we lacked measures of other personal, behavioral, and family characteristics that may influence sleep patterns,[69] which may explain the lack of association with weekend bedtime delay and oversleep. Seventh, we lacked geographic information on daylight, precluding a more complete characterization of 24-hour contextual light.[70,71] Eighth, our sample was not well suited to differentiating associations between ALAN and depression vs mania because of the infrequency of unipolar mania. Finally, patterns and sources of ALAN among adolescents may have changed since the NCS-A was conducted; the associations observed here may differ from what would be observed currently. However, the NCS-A provides the most current available data on prevalence of a wide array of *DSM* mental disorders among US adolescents.

Conclusions

In this study, we demonstrate that outdoor ALAN is associated with mental disorders and sleep patterns among US adolescents. These findings illustrate the importance of considering macrolevel indicators of light exposure in addition to individual-level light measures that are increasingly used in mental health and sleep research (eg, Figueiro et al,[17] Esaki et al,[72] and Obayashi et al[73]). Further research is needed to evaluate the role of other contextual and individual-level risk factors in the association between ALAN and mental disorder. Future studies should elucidate whether public interventions designed to reduce the brightness or spectral composition of outdoor nighttime lighting[74] could benefit mental and sleep health among youth, especially those who face other sources of social disadvantage. For example, studies investigating the effects of changes in street lighting could include health outcomes, such as sleep and mood, to weigh the benefits and perceived disadvantages[75] of such interventions.

ARTICLE INFORMATION

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Concept and design: Paksarian, Merikangas.
Acquisition, analysis, or interpretation of data: All authors.
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Administrative, technical, or material support: He, Mennitt, Casey, James, Merikangas.
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REFERENCES

1. Germain A, Kupfer DJ. Circadian rhythm disturbances in depression. *Hum Psychopharmacol*. 2008;23(7):571-585. doi:10.1002/hup.964

2. Duffy A, Goodday S, Keown-Stoneman C, Grof P. The emergent course of bipolar disorder: observations over two decades from the canadian high-risk offspring cohort. *Am J Psychiatry*. 2019; 176(9):720-729. doi:10.1176/appi.ajp.2018.18040461

3. Shanahan L, Copeland WE, Angold A, Bondy CL, Costello EJ. Sleep problems predict and are predicted by generalized anxiety/depression and oppositional defiant disorder. *J Am Acad Child*

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Adolesc Psychiatry. 2014;53(5):550-558. doi:10.1016/j.jaac.2013.12.029

4. Jackson A, Cavanagh J, Scott J. A systematic review of manic and depressive prodromes. *J Affect Disord*. 2003;74(3):209-217. doi:10.1016/S0165-0327(02)00266-5

5. Merikangas KR, Swendsen J, Hickie IB, et al. Real-time mobile monitoring of the dynamic associations among motor activity, energy, mood, and sleep in adults with bipolar disorder. *JAMA Psychiatry*. 2019;76(2):190-198. doi:10.1001/jamapsychiatry.2018.3546

6. Roenneberg T, Merrow M. The circadian clock and human health. *Curr Biol*. 2016;26(10):R432-R443. doi:10.1016/j.cub.2016.04.011

7. Cho Y, Ryu SH, Lee BR, Kim KH, Lee E, Choi J. Effects of artificial light at night on human health: a literature review of observational and experimental studies applied to exposure assessment. *Chronobiol Int*. 2015;32(9):1294-1310. doi:10.3109/07420528.2015.1073158

8. Karatsoreos IN, Bhagat S, Bloss EB, Morrison JH, McEwen BS. Disruption of circadian clocks has ramifications for metabolism, brain, and behavior. *Proc Natl Acad Sci U S A*. 2011;108(4):1657-1662. doi:10.1073/pnas.1018375108

9. Stevens RG, Brainard GC, Blask DE, Lockley SW, Motta ME. Adverse health effects of nighttime lighting: comments on American Medical Association policy statement. *Am J Prev Med*. 2013; 45(3):343-346. doi:10.1016/j.amepre.2013.04.011

10. Blask DE, Brainard G, Gibbons R, Lockley S, Stevens R, Motta ME. *Light Pollution: Adverse Health Effects of Nighttime Lighting, Report 4 Of The Council On Science And Public Health (A-12)*. American Medical Association; 2012.

11. Bedrosian TA, Nelson RJ. Influence of the modern light environment on mood. *Mol Psychiatry*. 2013;18(7):751-757. doi:10.1038/mp.2013.70

12. Bedrosian TA, Nelson RJ. Timing of light exposure affects mood and brain circuits. *Transl Psychiatry*. 2017;7(1):e1017. doi:10.1038/tp.2016.262

13. LeGates TA, Fernandez DC, Hattar S. Light as a central modulator of circadian rhythms, sleep and affect. *Nat Rev Neurosci*. 2014;15(7):443-454. doi:10.1038/nrn3743

14. Obayashi K, Saeki K, Iwamoto J, Ikada Y, Kurumatani N. Exposure to light at night and risk of depression in the elderly. *J Affect Disord*. 2013;151(1):331-336. doi:10.1016/j.jad.2013.06.018

15. Obayashi K, Saeki K, Kurumatani N. Bedroom light exposure at night and the incidence of depressive symptoms: a longitudinal study of the HEIJO-KYO Cohort. *Am J Epidemiol*. 2018;187(3): 427-434. doi:10.1093/aje/kwx290

16. Wallace-Guy GM, Kripke DF, Jean-Louis G, Langer RD, Elliott JA, Tuunainen A. Evening light exposure: implications for sleep and depression. *J Am Geriatr Soc*. 2002;50(4):738-739. doi:10.1046/j.1532-5415.2002.50171.x

17. Figueiro MG, Hunter CM, Higgins P, et al. Tailored lighting intervention for persons with dementia and caregivers living at home. *Sleep Health*. 2015;1(4):322-330. doi:10.1016/j.sleh.2015.09.003

18. Oldham MA, Ciraulo DA. Bright light therapy for depression: a review of its effects on chronobiology and the autonomic nervous system. *Chronobiol Int*. 2014;31(3):305-319. doi:10.3109/07420528.2013.833935

19. Terman M, Terman JS. Light therapy for seasonal and nonseasonal depression: efficacy, protocol, safety, and side effects. *CNS Spectr*. 2005; 10(8):647-663. doi:10.1017/S1092852900019611

20. Koo YS, Song JY, Joo EY, et al. Outdoor artificial light at night, obesity, and sleep health: cross-sectional analysis in the KoGES study. *Chronobiol Int*. 2016;33(3):301-314. doi:10.3109/07420528.2016.1143480

21. Patel PC. Light pollution and insufficient sleep: evidence from the United States. *Am J Hum Biol*. 2019;31(6):e23300. doi:10.1002/ajhb.23300

22. Vollmer C, Michel U, Randler C. Outdoor light at night (LAN) is correlated with eveningness in adolescents. *Chronobiol Int*. 2012;29(4):502-508. doi:10.3109/07420528.2011.635232

23. Xiao Q, Gee G, Jones RR, Jia P, James P, Hale L. Cross-sectional association between outdoor artificial light at night and sleep duration in middle-to-older aged adults: The NIH-AARP Diet and Health Study. *Environ Res*. 2020;180:108823. doi:10.1016/j.envres.2019.108823

24. Ohayon MM, Milesi C. Artificial outdoor nighttime lights associate with altered sleep behavior in the American general population. *Sleep*. 2016;39(6):1311-1320. doi:10.5665/sleep.5860

25. James P, Bertrand KA, Hart JE, Schernhammer ES, Tamimi RM, Laden F. Outdoor light at night and breast cancer incidence in the Nurses' Health Study II. *Environ Health Perspect*. 2017;125(8):087010. doi:10.1289/EHP935

26. Rybnikova NA, Haim A, Portnov BA. Does artificial light-at-night exposure contribute to the worldwide obesity pandemic? *Int J Obes (Lond)*. 2016;40(5):815-823. doi:10.1038/ijo.2015.255

27. Min JY, Min KB. Outdoor light at night and the prevalence of depressive symptoms and suicidal behaviors: a cross-sectional study in a nationally representative sample of Korean adults. *J Affect Disord*. 2018;227:199-205. doi:10.1016/j.jad.2017.10.039

28. Jones PB. Adult mental health disorders and their age at onset. *Br J Psychiatry Suppl*. 2013;54 (s54):s5-s10. doi:10.1192/bjp.bp.112.119164

29. Borniger JC, McHenry ZD, Abi Salloum BA, Nelson RJ. Exposure to dim light at night during early development increases adult anxiety-like responses. *Physiol Behav*. 2014;133:99-106. doi:10.1016/j.physbeh.2014.05.012

30. Cissé YM, Peng J, Nelson RJ. Dim light at night prior to adolescence increases adult anxiety-like behaviors. *Chronobiol Int*. 2016;33(10):1473-1480. doi:10.1080/07420528.2016.1221418

31. Chellappa SL, Steiner R, Oelhafen P, Cajochen C. Sex differences in light sensitivity impact on brightness perception, vigilant attention and sleep in humans. *Sci Rep*. 2017;7(1):14215. doi:10.1038/s41598-017-13973-1

32. Crowley SJ, Cain SW, Burns AC, Acebo C, Carskadon MA. Increased sensitivity of the circadian system to light in early/mid-puberty. *J Clin Endocrinol Metab*. 2015;100(11):4067-4073. doi:10.1210/jc.2015-2775

33. Kessler RC, Avenevoli S, Costello EJ, et al. National comorbidity survey replication adolescent supplement (NCS-A): II, overview and design. *J Am Acad Child Adolesc Psychiatry*. 2009;48(4):380-385. doi:10.1097/CHI.0b013e3181999705

34. Kessler RC, Berglund P, Chiu WT, et al. The US National Comorbidity Survey Replication (NCS-R): design and field procedures. *Int J Methods Psychiatr Res*. 2004;13(2):69-92. doi:10.1002/mpr.167

35. Merikangas KR, Avenevoli S, Costello EJ, Koretz D, Kessler RC. National comorbidity survey replication adolescent supplement (NCS-A): I, background and measures. *J Am Acad Child Adolesc Psychiatry*. 2009;48(4):367-379. doi:10.1097/CHI.0b013e31819996f1

36. Kessler RC, Akiskal HS, Angst J, et al. Validity of the assessment of bipolar spectrum disorders in the WHO CIDI 3.0. *J Affect Disord*. 2006;96(3):259-269. doi:10.1016/j.jad.2006.08.018

37. Kessler RC, Avenevoli S, Green J, et al. National comorbidity survey replication adolescent supplement (NCS-A): III, concordance of DSM-IV/CIDI diagnoses with clinical reassessments. *J Am Acad Child Adolesc Psychiatry*. 2009;48(4): 386-399. doi:10.1097/CHI.0b013e31819a1cbc

38. Cantwell DP, Lewinsohn PM, Rohde P, Seeley JR. Correspondence between adolescent report and parent report of psychiatric diagnostic data. *J Am Acad Child Adolesc Psychiatry*. 1997;36(5): 610-619. doi:10.1097/00004583-199705000-00011

39. Grills AE, Ollendick TH. Issues in parent-child agreement: the case of structured diagnostic interviews. *Clin Child Fam Psychol Rev*. 2002;5(1): 57-83. doi:10.1023/A:1014573708569

40. Paksarian D, Rudolph KE, He JP, Merikangas KR. School start time and adolescent sleep patterns: results from the U.S. National Comorbidity Survey—adolescent supplement. *Am J Public Health*. 2015;105(7):1351-1357. doi:10.2105/AJPH.2015.302619

41. Rudolph KE, Shev A, Paksarian D, et al. Environmental noise and sleep and mental health outcomes in a nationally representative sample of urban US adolescents. *Environ Epidemiol*. 2019;3 (4):e056. doi:10.1097/EE9.0000000000000056

42. Zhang J, Paksarian D, Lamers F, Hickie IB, He J, Merikangas KR. Sleep patterns and mental health correlates in US adolescents. *J Pediatr*. 2017;182: 137-143. doi:10.1016/j.jpeds.2016.11.007

43. NOAA Earth Observation Group. Version 4 DMSP-OLS nighttime lights time series. Published 2020. Accessed May 29, 2020. https://ngdc.noaa.gov/eog/dmsp/downloadV4composites.html

44. NOAA Earth Observation Group. Version 4 DMSP-OLS nighttime lights time series readme. Published 2020. Accessed May 29, 2020. https://ngdc.noaa.gov/eog/gcv4_readme.txt

45. Hsu FC, Baugh KE, Ghosh T, Zhizhin M, Elvidge CD. DMSP-OLS radiance calibrated nighttime lights time series with intercalibration. *Remote Sens (Basel)*. 2015;7(2):1855-1876. doi:10.3390/rs70201855

46. Diez-Roux AV, Kiefe CI, Jacobs DR Jr, et al. Area characteristics and individual-level socioeconomic position indicators in three population-based epidemiologic studies. *Ann Epidemiol*. 2001;11(6): 395-405. Published correction appears in *Ann Epidemiol*.2001;30(4):924. doi:10.1016/S1047-2797(01)00221-6

47. Rudolph KE, Stuart EA, Glass TA, Merikangas KR. Neighborhood disadvantage in context: the influence of urbanicity on the association between neighborhood disadvantage and adolescent emotional disorders. *Soc Psychiatry Psychiatr Epidemiol*. 2014;49(3):467-475. doi:10.1007/s00127-013-0725-8

48. Greenland S, Maclure M, Schlesselman JJ, Poole C, Morgenstern H. Standardized regression coefficients: a further critique and review of some alternatives. *Epidemiology*. 1991;2(5):387-392. doi:10.1097/00001648-199109000-00015

49. Kessler RC, Avenevoli S, Costello EJ, et al. Design and field procedures in the US National Comorbidity Survey Replication Adolescent Supplement (NCS-A). *Int J Methods Psychiatr Res*. 2009;18(2):69-83. doi:10.1002/mpr.279

50. Ford DE, Kamerow DB. Epidemiologic study of sleep disturbances and psychiatric disorders: an opportunity for prevention? *JAMA*. 1989;262(11):1479-1484. doi:10.1001/jama.1989.03430110069030

51. Murray G, Harvey A. Circadian rhythms and sleep in bipolar disorder. *Bipolar Disord*. 2010;12(5):459-472. doi:10.1111/j.1399-5618.2010.00843.x

52. Soehner AM, Bertocci MA, Levenson JC, et al. Longitudinal associations between sleep patterns and psychiatric symptom severity in high-risk and community comparison youth. *J Am Acad Child Adolesc Psychiatry*. 2019;58(6):608-617. doi:10.1016/j.jaac.2018.09.448

53. Gonzalez R. The relationship between bipolar disorder and biological rhythms. *J Clin Psychiatry*. 2014;75(4):e323-e331. doi:10.4088/JCP.13r08507

54. Hallam KT, Olver JS, Chambers V, Begg DP, McGrath C, Norman TR. The heritability of melatonin secretion and sensitivity to bright nocturnal light in twins. *Psychoneuroendocrinology*. 2006;31(7):867-875. doi:10.1016/j.psyneuen.2006.04.004

55. Hattar S, Kumar M, Park A, et al. Central projections of melanopsin-expressing retinal ganglion cells in the mouse. *J Comp Neurol*. 2006;497(3):326-349. doi:10.1002/cne.20970

56. Fernandez DC, Fogerson PM, Lazzerini Ospri L, et al. Light affects mood and learning through distinct retina-brain pathways. *Cell*. 2018;175(1):71-84.e18. doi:10.1016/j.cell.2018.08.004

57. McClung CA. How might circadian rhythms control mood? Let me count the ways.... *Biol Psychiatry*. 2013;74(4):242-249. doi:10.1016/j.biopsych.2013.02.019

58. Copeland WE, Adair CE, Smetanin P, et al. Diagnostic transitions from childhood to adolescence to early adulthood. *J Child Psychol Psychiatry*. 2013;54(7):791-799. doi:10.1111/jcpp.12062

59. Kessler RC, Ormel J, Petukhova M, et al. Development of lifetime comorbidity in the World Health Organization world mental health surveys. *Arch Gen Psychiatry*. 2011;68(1):90-100. doi:10.1001/archgenpsychiatry.2010.180

60. Zhai L, Zhang H, Zhang D. Sleep duration and depression among adults: a meta-analysis of prospective studies. *Depress Anxiety*. 2015;32(9):664-670. doi:10.1002/da.22386

61. Sivertsen B, Lallukka T, Salo P, et al. Insomnia as a risk factor for ill health: results from the large population-based prospective HUNT study in Norway. *J Sleep Res*. 2014;23(2):124-132. doi:10.1111/jsr.12102

62. Gangwisch JE, Malaspina D, Babiss LA, et al. Short sleep duration as a risk factor for hypercholesterolemia: analyses of the National Longitudinal Study of Adolescent Health. *Sleep*. 2010;33(7):956-961. doi:10.1093/sleep/33.7.956

63. Wong MM, Brower KJ. The prospective relationship between sleep problems and suicidal behavior in the National Longitudinal Study of Adolescent Health. *J Psychiatr Res*. 2012;46(7):953-959. doi:10.1016/j.jpsychires.2012.04.008

64. Jackson CL, Redline S, Emmons KM. Sleep as a potential fundamental contributor to disparities in cardiovascular health. *Annu Rev Public Health*. 2015;36:417-440. doi:10.1146/annurev-publhealth-031914-122838

65. Laposky AD, Van Cauter E, Diez-Roux AV. Reducing health disparities: the role of sleep deficiency and sleep disorders. *Sleep Med*. 2016;18:3-6. doi:10.1016/j.sleep.2015.01.007

66. Huss A, van Wel L, Bogaards L, et al. Shedding some light in the dark—a comparison of personal measurements with satellite-based estimates of exposure to light at night among children in the Netherlands. *Environ Health Perspect*. 2019;127(6):67001. doi:10.1289/EHP3431

67. Rea MS, Brons JA, Figueiro MG. Measurements of light at night (LAN) for a sample of female school teachers. *Chronobiol Int*. 2011;28(8):673-680. doi:10.3109/07420528.2011.602198

68. Mellander C, Lobo J, Stolarick K, Matheson Z. Night-time light data: A good proxy measure for economic activity? *PLoS One*. 2015;10(10):e0139779. doi:10.1371/journal.pone.0139779

69. Johnson DA, Billings ME, Hale L. Environmental determinants of insufficient sleep and sleep disorders: implications for population health. *Curr Epidemiol Rep*. 2018;5(2):61-69. doi:10.1007/s40471-018-0139-y

70. Bauer M, Glenn T, Alda M, et al. Influence of light exposure during early life on the age of onset of bipolar disorder. *J Psychiatr Res*. 2015;64:1-8. doi:10.1016/j.jpsychires.2015.03.013

71. Smolensky MH, Sackett-Lundeen LL, Portaluppi F. *Nocturnal Light Pollution and Underexposure to Daytime Sunlight: Complementary Mechanisms of Circadian Disruption and Related Diseases*. Taylor & Francis; 2015.

72. Esaki Y, Kitajima T, Obayashi K, Saeki K, Fujita K, Iwata N. Light exposure at night and sleep quality in bipolar disorder: the APPLE cohort study. *J Affect Disord*. 2019;257:314-320. doi:10.1016/j.jad.2019.07.031

73. Obayashi K, Saeki K, Kurumatani N. Association between light exposure at night and insomnia in the general elderly population: the HEIJO-KYO cohort. *Chronobiol Int*. 2014;31(9):976-982. doi:10.3109/07420528.2014.937491

74. Maierová L. Public lighting, public health, 2018; VII Lighting Conference of the Visegrad Countries (Lumen V4), Trebic. Published 2018. Accessed June 5, 2020. https://ieeexplore.ieee.org/abstract/document/8521032

75. Green J, Perkins C, Steinbach R, Edwards P. Reduced street lighting at night and health: a rapid appraisal of public views in England and Wales. *Health Place*. 2015;34:171-180. doi:10.1016/j.healthplace.2015.05.011

Arencibia, Stephanie (Molly)

From:	Laino, Jeffrey <Jeffrey.Laino@nypa.gov>
Sent:	Tuesday, April 9, 2019 9:23 AM
To:	Richard Sullivan
Cc:	Luteran, Kevin
Subject:	RE: [EXTERNAL]Presentation
Attachments:	Sample 2017 MCRA - Statewide 07242017.pdf; NYPA Street Lighting Authorization to Proceed.pdf

Good Morning Richie,
Thank you for the email, it was my pleasure to present the NYPA street lighting proposal to the Supervisor and Council members last night. I hope all their questions were answered but please reach out to me if any additional questions arise.
I am attaching the Authorization to Proceed and a sample Master Cost Recovery Agreement(MCRA). These are the 2 documents NYPA will need executed in order to begin the project implementation. I will have the contracting unit at NYPA email you an executable version of the MCRA upon request.
What do you think the timeline is for the Town to make a decision on moving forward with the project?
Let me know if there is anything else you need and please send me a link to any news articles regarding the project.
Thank you and looking forward to working with you.

Jeff Laino
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-----Original Message-----
From: Richard Sullivan <rsullivan@highlands-ny.gov>
Sent: Tuesday, April 9, 2019 5:37 AM
To: Laino, Jeffrey <Jeffrey.Laino@nypa.gov>
Cc: Luteran, Kevin <Kevin.Luteran@nypa.gov>
Subject: [EXTERNAL]Presentation

____

CAUTION â€" External Email

Suspicious? Click Report Phishing on Outlook toolbar. For Mobile forward to (abuse@nypa,gov)

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Jeff,
Not sure if Kevin is your associate, subordinate, or supervisor, but I wanted to let you know you were concise, germane , well poised and delivered a very well received workup, thank you.
Just a bit on the Village of Highland Falls- in 2016 there was a different team in place, they had an electrician as a trustee who invited NYPA to implement a similar program , but once removed from power, the current team , who I like, ended that effort.
I did speak with the village liaison to streetlights yesterday, and the village has over 250 lights, O and R is changing 7 per year , that would be a lame 30 year effort, and savings would be barely recognized. O and R does have some deal where for an extra $169 per light they will do more per year, and thatâ€™s about all I know about their program, or lack thereof.
So as a good neighbor I kept the village out of it, I tried contacting their Point man since late Feb., no response until yesterday so the citizens you met last night will be charged with the task of inviting/ pressuring the village to participate, either way that is a separate body of government .
I / we look forward to advancing this effort, and with a trustworthy body like NYPA , and the issue of maintenance after ownership being addressed by NYPA and included in your workup, I believe this will be at least plausible, hopefully executable project, and again thank you. When the local paper does an article on this (this Thursday), Iâ€™ll share an online copy if you desire.
Have a great day, Richie

Sent from my iPad

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ANDREW M. CUOMO
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GIL C. QUINIONES
President and Chief Executive Officer

April 5, 2019

Supervisor Bob Livsey
Town of Highlands
254 Main Street
Highland Falls NY 10928

RE: Energy Services Program
Authorization to Proceed with turn-key street light project
Town of Highlands– LED Street Lighting

Dear Supervisor Livsey,

The New York Power Authority (NYPA) is excited to support the Town of Highlands in identifying and implementing a comprehensive street lighting upgrade. Improving the existing street lights is a widely used and effective strategy to achieve the goal of reducing energy consumption, lowering utility costs, and improving light quality throughout the community.

Consistent with the Master Cost Recovery Agreement, NYPA provides a turn-key solution to upgrade the Town of Highlands's existing street lights to energy efficient LED technology. NYPA is pleased to offer these services to replace approximately 167 existing street light fixtures with new high efficient LED technology.

By signing below, the Town of Highlands authorizes NYPA to proceed with the full turn-key solution of the LED street lighting project, which includes the final design report, conducting bids for materials and installation labor, providing construction management, and commissioning the final project. When the design and bidding is completed, you will receive an Initial Customer Installation Commitment (ICIC) for your review and signature. At this point, if you choose to proceed to project implementation all development costs will be rolled into the overall project. Conversely, should you decide not to proceed with the implementation of the project, the Town of Highlands agrees to reimburse NYPA for all costs incurred up to the termination date for the development, design and bidding of the project. The cost of developing the design and for bidding the materials and labor will be determined during the next phase. NYPA will be fully transparent through this process and provide complete documentation as to how it determined all project costs.

By signing below, affirm that you agree to these conditions:

NEW YORK STATE OF OPPORTUNITY. | NY Power Authority

Joseph Rende	
(Name, printed)	(Name, printed)
Senior Director, Customer Business Development	
(Title)	(Title)
(Signature)	(Signature)
(Date)	(Date)

Master Cost Recovery Agreement No. ____________________
Effective Date: ____________________

ENERGY SERVICES PROGRAM

MASTER COST RECOVERY AGREEMENT

BETWEEN

POWER AUTHORITY OF THE STATE OF NEW YORK

AND

[CUSTOMER]

ENERGY SERVICES PROGRAM
MASTER COST RECOVERY AGREEMENT

This Master Cost Recovery Agreement (this "Master Agreement"), dated as of this _____ day of _________, 2017, is entered into by and between POWER AUTHORITY OF THE STATE OF NEW YORK, a corporate municipal instrumentality of the State of New York with offices located at 123 Main Street, White Plains, New York 10601 ("Authority") and _____________________________, a __________________ with offices located at _____________________________ ("Customer").

WHEREAS, Public Authorities Law §1005(17) permits the Authority, as deemed feasible and advisable by the Trustees, to finance and design, develop, construct, implement, provide and administer energy-related projects, programs and services for any public entity and certain other specified entities; and

WHEREAS, the Trustees have authorized the establishment of the Authority's Energy Services Program ("ESP") to include, among other things, energy efficiency projects and services, clean energy technology projects and services and high-performance and sustainable building projects and services (including technologies that reduce air and other pollution and conserve materials and resources such as water); and the construction, installation and/or operation of facilities or equipment done in connection with any such projects, programs or services; and

WHEREAS, Public Authorities Law §1005(17) permits Customer, a public entity, to enter into an energy services contract with the Authority for such energy-related projects, programs and services as authorized by Public Authorities Law; and

WHEREAS, Authority and Customer desire to work together to develop and implement Projects contemplated under the ESP and to enter into this Master Agreement as more particularly set forth herein.

NOW, THEREFORE, Authority and Customer (sometimes referred to herein collectively as the "Parties" and individually as a "Party"), in consideration of the mutual covenants and conditions contained herein and in these recitals, hereby agree as follows:

DEFINITIONS

The following definitions apply for all purposes of this Master Agreement:

"Advisory Services" means the consulting services provided by Authority or Service Providers to assist Customer in its efforts to reduce energy consumption and associated operations and maintenance costs, to realize environmental benefits, including but not limited to the reduction of air pollution; to conserve natural resources; and/or facilitate the use of clean energy sources at Customer's Facilities.

"Advisory Services Terms and Conditions" means the additional terms and conditions set forth in Exhibit C applicable to Advisory Services Projects provided by Authority or Service Provider to Customer hereunder.

"Ancillary Documents" means documents, other than this Master Agreement and the Customer Project Commitment (and documents that modify them, such as Change Orders and Contingent Work Orders), covering information necessary for the implementation of a specific Project, such as authorizations, Substantial Completion and Operation Transfer Reports, Milestone Completion Reports and Final Inspection Reports, etc.

"Authority's Authorized Representative" means an individual designated by Authority in accordance with Section 10.1(b) to coordinate a Project on behalf of Authority and to communicate with Customer concerning such Project.

"Authority Implemented Work" means Work undertaken by Authority for Customer as more fully set forth in a CPC (subject to the terms and conditions of this Master Agreement and any applicable Transaction Document) through the services of qualified Service Providers or Subproviders engaged by Authority.

"Authority Material Handling Fee" is a fee applied by the Authority to the cost of materials purchased directly by the Authority for a Project, where applicable, to reimburse the Authority for procurement, material handling, storage and/or restocking. The amount of such fee, when applicable to a Project, will be set forth in the CPC, as superseded by the Final CPC.

"Authority Program Fee" mean Authority's fee applicable to each Project. Details of the Authority Program Fee will be set forth in the Compensation Schedule, attached hereto as Exhibit A, and the amount of such fee will be set forth in the CPC, as superseded by the Final CPC.

"Background Intellectual Property Rights" means Intellectual Property Rights of a Party owned, controlled, acquired, developed, invented, generated, authored, conceived or reduced to practice prior to the date of this Master Agreement, or acquired parallel to and independent of this Master Agreement or any Transaction Documents entered into under this Master Agreement.

"Capital Project" is a Project involving the design, construction, installation and/or modification of facilities and/or equipment in Customer's Facility.

"Capital Project Terms and Conditions" means the additional terms and conditions set forth in Exhibit B applicable to Capital Projects provided by Authority or Service Provider to Customer hereunder.

"Change Order" is a Transaction Document that memorializes a modification to the CPC that cannot be made by Contingency Work Order, setting forth agreed-upon additions, deletions or revisions to the Work, and the cost and/or time impact to the Project.

"Compensation Schedule" is a schedule attached hereto as Exhibit A setting forth details about the Authority Program Fee and other relevant Project costs, where applicable, for the different services offered by Authority under this Master Agreement.

"Contingency Work Order" is a Transaction Document that memorializes the Authority's use of the Project Contingency for a Project, such use to be reflected on subsequent CPCs that are executed for the particular Project.

"Customer's Authorized Representative" means an individual designated by Customer in accordance with Section 10.1(a), to coordinate a Project on behalf of Customer and to assist Authority, its Service Providers and Subproviders with the implementation of the Project.

"Customer Project Commitment" or "CPC" is a Transaction Document containing terms and conditions for one or more specific Projects at a Customer's Facility(ies) that includes, at a minimum, the location of Customer's Facility, a detailed scope of Work (including a description of milestones, if any), the projected Project costs and any specific payment terms applicable to the Project.

"Debris" shall mean unregulated materials removed from a Customer Facility and unsuitable for further use.

"Environmental Laws" means all current and future federal, state and local laws (including common law), treaties, regulations, rules, ordinances, codes, decrees, judgments, directives, orders (including consent orders), environmental permits, and obligations and other requirements imposed by any "Governmental Authority" (as defined herein), including New York State Department of Environmental Conservation ("NYS DEC") Technical Administrative Guidance Memoranda and other guidance documents issued or published by any Governmental Authority, in each case, relating to pollution, protection of the environment, natural resources, or protection of human health and safety from conditions in the environment, the presence, "Release" (as defined herein) of, threatened Release of, or exposure to, "Hazardous Substances" (as defined herein), or to the generation, manufacture, processing, distribution, use, treatment, storage, transport, recycling or handling of, or arrangement for such activities with respect to, Hazardous Substances.

"Environmental Liabilities" means all liabilities, obligations, damages, losses, claims, actions, suits, judgments, orders, fines, penalties, fees, expenses, and costs, relating to environmental conditions or activities, including (i) Remediation costs, engineering costs, environmental consultant and expert fees, laboratory fees, permitting fees, investigation costs, defense costs, and reasonable attorneys' fees and expenses; (ii) any claims, demands, and causes of action relating to or resulting from any personal injury (including wrongful death), property damage (real or personal) or natural resource damage; and (iii) any penalties, fines or costs associated with the failure to comply with any Environmental Law.

"Energy Services Program" or "ESP" includes energy efficiency projects and services; clean energy technology projects and services; high-performance and sustainable building programs and services (including technologies that reduce air and other pollution, conserve materials and resources such as water); and the construction, installation and/or operation of facilities or equipment done in connection with any such project, programs and services.

"Facility" means the building, structure or premises owned and/or operated by Customer that may benefit from Customer's participation in Authority's ESP Program.

"Final CPC" means the document that reflects the final reconciliation of Project costs and all amendments to the CPC that is issued by Authority to Customer upon completion of the Work for a Project.

"Final Inspection Report" means the report, if any, to be executed by Authority and Customer after completion of a Project.

"Hazardous Substances" means (i) any petroleum, petroleum products or byproducts, and all other regulated hydrocarbons (including without limitation, petrochemicals and crude oil), or any fraction thereof, coal ash, radon gas, asbestos, asbestos-containing material, urea formaldehyde, polychlorinated biphenyls, chlorofluorocarbons, and other ozone-depleting substances; and (ii) any chemical, material, substance, product or waste (including thermal discharges and hazardous waste) that is prohibited, limited, or regulated by or pursuant to any Environmental Laws.

"Intellectual Property Rights" means any and all intellectual property rights, including, but not limited to rights in any and all of the following: (i) technical information and know-how; (ii) discoveries, improvements, enhancements, upgrades, inventions, (whether or not patentable); (iii) patents, patent applications, patent disclosures, and any other patentable subject matter; (iv) copyrights, applications to register copyrights, works of authorship and any other copyrightable works; (v) trademarks, trade names, trade dresses, brand names, logos and similar marks; (vi) any sketches, drawings, outlines, drafts; (vii) computer software (including source code, executable code, databases, data and related documentation); (viii) trade secrets and know-how; and (ix) all improvements or modifications to any of the foregoing.

"Labor Cost" is that portion of the Total Reimbursement Costs for installation labor performed by Service Provider and Subprovider in connection with the Work performed in connection with a Project pursuant to a CPC based on this Master Agreement. Such costs will be detailed in each CPC.

"Long-Term Repayment Obligation" means the obligation of Customer to repay Authority in accordance with and subject to the terms of a loan agreement after conversion of a Short-Term Repayment Obligation.

"Material Cost" is that portion of the Total Reimbursement Costs related to equipment, materials and supplies in connection with the Work performed in connection with a Project pursuant to a CPC based on this Master Agreement. Such costs will be detailed in each CPC.

"Milestone Completion Report" means a document generated by Authority or Service Provider that identifies a milestone(s) satisfactorily completed during the progress of a Project or phase of a Project (i.e., design, construction, or otherwise), signifies Customer's concurrence with the completion of such milestone and represents Customer's authorization to proceed to the next milestone or phase of the Work, as applicable.

"Other Agreement" means any stand-alone agreements entered into between the Parties at any time, including, without limitation, non-disclosure agreements, privacy agreements, or grant agreements, but shall not include any Master Cost Recovery Agreement, Energy Efficiency Services Agreement or other agreements governing services under the ESP entered into by the Parties prior to the execution of this Master Agreement.

"Project" means any project or service undertaken through Authority's ESP pursuant to a CPC based on this Master Agreement.

"Project Contingency" means a defined budget to be utilized at the Authority's discretion in accordance with Section 2.3 hereof for, among other things, unexpected costs and expenses that may arise during the performance of a Project (usually calculated as a percentage of Material Cost and Labor Cost).

"Release" means any actual or threatened release, spill, emission, emptying, escape, leaking, dumping, injection, pouring, deposit, disposal, discharge, dispersal, leaching, or migration into the environment or within any building, structure, facility, or fixture and/or the exacerbation of any preexisting condition of Hazardous Substances.

"Remediation" means the investigation (including any feasibility studies or reports), cleanup, removal, abatement, transportation, disposal, treatment (including in-situ treatment), management, stabilization, neutralization, collection, or containment of Hazardous Substances and any Release(s), that may be required to satisfy Environmental Laws, in each case, including, without limitation, any closure, restoration or monitoring, operations and maintenance activities, including any engineering or institutional controls, that may be required by any Governmental Authority after the completion of such investigation, study, cleanup, removal, transportation, disposal, treatment, neutralization, collection, or containment activities as well as the performance of any and all obligations imposed by any Governmental Authority in connection with such investigation, cleanup, removal, transportation, disposal, treatment (including in situ treatment), management, stabilization, neutralization, collection, or containment (including any such obligation that may be imposed pursuant to an Environmental permit or a consent order).

"Service Provider(s)" means a third party provider of goods and/or services that Authority, acting as the contracting entity, contracts with through its procurement policies, procedures and guidelines to perform Work in connection with a Project at Customer Facilities.

"Service Provider Fees" means the costs associated with the payment to Service Providers, its Subproviders and other third party professionals for Work performed with respect to a specific Project. Service Provider Fees will be detailed in each CPC.

"Short-Term Interest" is a cost component of the Total Reimbursement Costs of a Project representing the costs incurred by the Authority in connection with financing the delivery of a Project during the time within which such funds remain unpaid by Customer.

"Short-Term Repayment Obligation" refers to Customer's obligation to reimburse Authority for the costs of delivering a Project, as identified in the Final CPC.

"Short-Term Repayment Obligation Maturity Date" means the date set forth in the Final CPC, no later than ninety (90) days following the approval of the Final CPC.

"Specific Subject Matter" shall mean intellectual property rights, Authority's liability and limitation thereof, Project warranties, and amendments to this Master Agreement and/or any Transaction Documents.

"Subprovider(s)" refers to individuals or entities retained by the Service Provider(s) to perform all or part of the Work.

"Substantial Completion and Operation Transfer Report" is a document signed by the Parties signifying that the equipment and/or facilities installed at the Project have been inspected, tested and accepted by Customer.

"Third Party" means any utility company, permit agency, governmental authority having jurisdiction over a Project, any contractor or service provider hired by Customer, or any other third party that is not a Service Provider or Subprovider but is, directly or indirectly, involved in or whose approval is required in connection with, a Project and not under contract, directly or indirectly, with the Authority.

"Total Annual Energy Savings" is the estimated net reduction in Customer's annual usage of (a) energy service, (b) other utilities including, but not limited to, water and sewer, and (c) any related operation or maintenance savings, if applicable, resulting from the installation of one or more energy conservation measures in accordance with this Master Agreement.

"Total Reimbursement Costs" is the sum of all of the costs of a Project as set forth in the CPC and Final CPC, including, but not limited to, to the extent applicable to such Project: (1) Material Cost; (2) Labor Cost; (3) the amount of the Project Contingency applied as a Project cost; (4) Service Provider Fees; (5) Authority Program Fee; (6) Short-Term Interest; and (7) other Project-related costs and expenses.

"Transaction Document(s)" means with respect to a Project, this Master Agreement and any related Customer Project Commitment and any document that modify them, such as Change Orders and Contingency Work Orders.

"Waste" refers to waste PCBs (as defined by the United States Environmental Protection Agency ("USEPA") in 40 CFR Part 761) and hazardous waste (as defined by the USEPA in 40 CFR Part 261 and the NYS DEC in 6 NYCRR Part 371) as well as other material regulated for purposes of release, reuse, disposal, or recycling (e.g. CFCs, ethylene glycol, mercury, oil, asbestos), which form a part of the equipment removed from Customer Facilities due to implementing the Work. Disposal of such Waste shall be conducted in accordance with the provisions set forth in Article IV.

"Work" means the services performed for Customer for a selected Customer Facility pursuant to this Master Agreement and the other Transaction Documents for a Project. The scope of Work shall be described in the CPC, as amended by subsequent Change Orders, Contingency Work Orders, and the Final CPC.

ARTICLE I

SCOPE AND APPLICATION OF AGREEMENT; ORDER OF PRECEDENCE

1.1 Transaction Documents. In connection with each Project, the Parties will, either concurrently with or subsequently to this Master Agreement, enter into one or more Customer Project Commitments, or similar memoranda, that define a specific Project(s) and the costs and fees associated with such Project, and associated Ancillary Documents. Except as otherwise expressly set forth therein, all Transaction Documents, upon execution by the Parties, shall be

governed by the terms and conditions of this Master Agreement. Each Transaction Document shall contain a specific reference to this Master Agreement and CPC, as applicable. This Master Agreement does not obligate Authority to accept requests for Projects issued by Customer or obligate any Party to enter into a CPC.

1.2 Entire Agreement. Subject to the provisions of Section 1.4 below, with respect to a Project, this Master Agreement (including Exhibits A, B, and C and any other exhibits, schedules or appendices hereto) and any Transaction Document which specifically references a Project, constitute the entire agreement between Authority and Customer concerning such Project, and supersedes all prior negotiations, representations, contracts and agreements concerning such Project.

1.3 Conflict and Order of Precedence. In the event of a conflict between the terms of this Master Agreement and the terms and conditions set forth in another Transaction Document, or between the terms of two or more Transaction Documents in effect for a Project, the order of precedence shall be a follows: (i) the terms of the CPC for such Project (as amended by Contingency Work Orders and/or Change Orders and as superseded by the Final CPC) but solely with respect to the price (i.e., the Project's Total Reimbursement Costs), payment terms, and scope of Work (including description of milestones) of the Project; (ii) the terms of this Master Agreement; (iii) the remaining terms of the Project CPC; and (iv) the terms of any Ancillary Document. Notwithstanding the foregoing, the Parties agree that with respect to Specific Subject Matters, if the terms of a Transaction Document concerning a Specific Subject Matter are more favorable to Authority than the respective terms set forth in this Master Agreement, the more favorable terms of the Transaction Document shall prevail with respect to the Project to which it relates. (By way of example, if a Transaction Document includes a term that disclaims any warranties by Authority (or Service Provider) for Work performed, such term would prevail over the warranties set forth in Section 7.1. hereof.)

1.4 Other Agreements. This Master Agreement supersedes all Master Cost Recovery Agreements, Energy Services Agreements or other agreements governing services under the ESP entered into by the Parties prior to the execution of this Master Agreement. Notwithstanding the foregoing, this Master Agreement does not supersede and does not apply to any Other Agreements existing between Customer and Authority. Any projects which Authority has undertaken or undertakes at Customer Facilities pursuant to such Other Agreements, or under prior Energy Services Agreements under which projects remain incomplete as of the date of this Master Agreement, shall be governed by those agreements and related documents, unless otherwise agreed in writing. Termination of this Master Agreement shall have no effect on the Other Agreements which will remain in full force and effect according to their respective terms.

1.5 Amendments. This Master Agreement and any other Transaction Document executed in connection herewith may be amended only in writing signed by an authorized officer or designee of Authority and Customer.

ARTICLE II

GENERAL PROJECT STRUCTURE

2.1 Customer Project Commitment or CPC. For each Project undertaken under this Master Agreement, the parties will enter into one or more CPC(s), each of which will state the specific terms and conditions applicable to such Project, segregating the Project into logical phases to be performed consecutively. Each CPC will include, at a minimum, the phasing plan setting forth how the Project will proceed, the location of Customer's Facility, scope of Work, (including description of milestones, if any), projected Total Reimbursement Costs, and payment terms.

The Authority is not obligated to commence any Work for a particular Project unless or until a CPC is executed by Authority and Customer. Notwithstanding the foregoing, the Parties may agree to expedite the commencement of a portion of the Work associated with a particular Project prior to the execution of a CPC provided that the Parties memorialize such agreement prior to the commencement of such Work in a writing that sets forth the specific items of Work to be commenced and the associated cost of such Work. In such event, Customer agrees to bear the costs of any Work undertaken by Authority or its Service Providers for Customer in preparation for or with respect to such Project or potential Project even if no CPC is ultimately executed.

2.2 Final CPC. As soon as practicable following completion of the Work and receipt of all invoices associated with a Project, Authority will generate a Final CPC which will include all Contingency Work Orders, and all agreed-upon Change Orders, if any. The Final CPC will reconcile the Total Reimbursement Costs set forth in the CPC on the basis of Authority's actual costs and will supersede all prior CPCs. The Final CPC shall also describe the Project-specific terms for the Work completed at the Facility or Facilities, Customer's Short-Term Repayment Obligation, and the final repayment terms. Authority and Customer shall execute such Final CPC, which shall be "deemed executed" unless Customer disputes such Final CPC in writing within forty-five (45) days of the Authority's transmission thereof. If Customer timely disputes the Final CPC, then the Parties shall endeavor to resolve the dispute as expeditiously as possible in accordance with the procedures set forth in Section 11.2; provided, however, that Customer shall pay any undisputed amounts of Customer's Short-Term Repayment Obligations set forth in the Final CPC in accordance with Article V hereof.

2.3 Contingency Work Order. If unexpected costs and expenses arise during the performance of a Project, the Authority may utilize the Project Contingency, provided that (i) the scope modifications, if any, are consistent with the general nature of the Project; (ii) the modifications do not render the Project ineligible under the Authority's Energy Services Program requirements; and (iii) the cumulative increased Project costs do not exceed the Project Contingency. Contingency Work Orders may be utilized to account for, among other things, remedial work required due to design or construction omissions (whether remedial work is caused by omissions of Authority, its Service Providers or Customer) to the extent that the requirements set forth above are met. If the requirements for a Contingency Work Order are not met, Authority and Customer may negotiate a Change Order as described in Section 2.4 below.

As the Project Contingency is utilized, the Authority will issue a Contingency Work Order, which shall be effective upon issuance and automatically update the terms of the respective CPC without the need for express Customer approval. Any objections to the manner in which the Authority is utilizing the Project Contingency must be raised by the Customer in writing to the Authority within seven (7) days of the Authority's issuance of any such Contingency Work Order, or such other period of time identified in the Contingency Work Order. Failure to comply with this notice requirement by the Customer will be deemed a waiver of any claim that (i) the Project Contingency was used improperly; or (ii) that payment on account of such Contingency Work Order is disputed. Upon request, the Authority will provide Customer with periodic reports that establish an accounting of how the Project Contingency is being utilized.

2.4 Change Order. Any party to a CPC may at any time by written notice to the other party request modifications to the Work described in the executed CPC. Authority shall provide Customer with a written analysis of the effects of the requested modification(s) and, provided that the requested modification(s) do not materially alter the general scope of the Project, the Parties will negotiate a Change Order to the CPC. No Change Order shall take effect until it is approved within the time period specified in the Change Order by Authority and by Customer in accordance with Customer's procedures to authorize amendments to the CPC. In the event of a dispute over a request for a Change Order, Authority may elect to proceed with the Work in accordance with the scope of Work as set forth in the CPC (as revised by agreed-upon Change Orders and/or Contingency Work Orders), or the dispute may be treated under the provisions of Section 11.1 hereof.

2.5 Unforeseen Circumstances or Conditions. In the event that circumstances or conditions at Customer's Facility are encountered after a CPC is executed, that may require changes to the Project schedule and/or result in an increase to the Total Reimbursement Costs of the Project, Authority shall as soon as practicable notify Customer. The CPC shall be revised by a Contingency Work Order or a Change Order, as applicable, to incorporate necessary changes to the Project schedule, the scope of Work and/or any increase in the Total Reimbursement Costs, as a result of the existence of the unforeseen circumstance or condition. Customer shall assume any increase in costs as part of its Short-Term Repayment Obligation.

2.6 Third Party Obligations. The Authority shall not be held responsible for any action or failure to act of Customer, its officers, employees, agents, representatives or any Third Party, including, but not limited to, any delay in issuance or any non-issuance of a permit or approval necessary to perform or close out the Work under a Project. Any changes to the Project schedule or scope of Work or any increase in the Total Reimbursement Costs caused by such act or failure to act, shall be Customer's responsibility. If the Third Party conduct necessitates the issuance of a Change Order to compensate the Authority for any changes to the Project schedule, scope of Work or Total Reimbursement Costs resulting from such act or failure to act, Authority may suspend its Work on the Project until Customer approves such Change Order. If Customer fails to approve the Change Order within thirty (30) days of its issuance or the Project is suspended as a result for more than ninety (90) days, Authority, in its sole discretion, may terminate all Project Work and issue a Final CPC as provided in Section 3.4(d) below.

2.7 Execution and Disputes Regarding Reports. The execution of a Milestone Completion, Final Inspection, Substantial Completion and Operation Transfer Report or similar

report(s) shall not be unreasonably withheld by either Party, and the Parties shall endeavor to fully execute such report within thirty (30) days after its submittal to Customer or it shall be deemed executed unless it was disputed by Customer in writing within such thirty (30) day period. In the event of any disputes by Customer with respect to such report(s), the Parties shall endeavor to resolve such dispute as expeditiously as possible in accordance with Sec. 11.1 hereof.

2.8 Limitation on Work in Certain Premises. Absent the express written consent of Authority, no Work of any kind shall be performed in any premises of Customer used for private business use within the meaning of Section 141(b) of the U.S. Internal Revenue Code of 1986, as amended.

2.9 Eligibility Criteria. Projects will be undertaken on an individual basis in Customer's Facilities as deemed feasible and advisable by Authority and mutually agreed to by Authority and Customer. A Project will not proceed unless it satisfies (as determined by Authority in its sole discretion) Authority's requirements related to reduction in overall primary energy costs, energy conservation, results in environmental benefits and/or other requirements of the Authority's Energy Services Program, then in effect.

ARTICLE III

SUSPENSION AND TERMINATION OF PROJECTS

3.1 Suspension of Work.

(a) Suspension by Customer. Customer may direct Authority to suspend Work at any Customer Facility by written notice to Authority. Authority, and the Service Providers and Subproviders, will thereupon cease Work at that Facility as soon as practicable.

(b) Suspension by Authority. In addition to any other right by Authority to suspend Work on a Project set forth herein, Authority may suspend Work at any Customer Facility if any of the following occurs: (i) Customer fails to make payment to Authority when due; and such payment default continues for a period of ten (10) days after written notice thereof by Authority to Customer; (ii) circumstances or conditions at Customer's Facility are discovered after a CPC is executed which require changes to the Project and/or result in an increase to the Project's Total Reimbursement Costs that cannot be covered by the use of any remaining Project Contingency budgeted for the Project; (iii) a Third Party's act or failure to act causes a delay to the critical path of the Project schedule that continues for a period of thirty (30) days after written notice thereof by Authority to Customer; (iv) a delay caused by a Force Majeure event continues for a period of fifteen (15) consecutive days; (v) the existence of a hazard not caused by Authority or its Service Provider(s) that threatens the safety and protection of the site, its inhabitants or the public; or (vi) the existence of an unforeseen circumstance or condition the correction of which could reasonably be expected to (A) create an unreasonable risk for Authority or Service Provider not ordinarily associated with projects of similar size and scope (as determined by Authority); (B) create a threat to life or safety of the inhabitants or the public in general, or (C) violate applicable federal, state or local laws, regulations, codes or standards.

(c) Liability for Cost Increase as Result of Suspension. The suspension of Work by either Party pursuant to the provisions of this Section 3.1 may adversely impact the Project schedule, the scope of Work and/or the Total Reimbursement Costs. The CPC may be revised by a Contingency Work Order or Change Order, as applicable, to incorporate any necessary changes. Customer shall assume any increase in the Total Reimbursement Costs in full as part of its Short-Term Repayment Obligation unless the suspension was caused by the gross negligence or willful misconduct of Authority, its Service Provider or Subprovider, in which case Customer will not be responsible for any increase in the Total Reimbursement Costs to the extent such increase is caused by such gross negligence or willful misconduct.

(d) Resumption of Work After Suspension. In the event Work on a Project was suspended by a Party (whether pursuant to this Section 3.1 or otherwise), Authority and Customer have to agree in writing that Work shall resume before any Work on the Project can continue. In the event Work is suspended for more than ninety (90) days, Authority, in its sole discretion, may terminate Work for that Project and Authority shall issue a Final CPC as provided in Section 3.4(d) below.

3.2 Emergency. If an emergency results in or could reasonably be expected to result in personal injury or loss of life or damage or harm to property or public safety, Customer, acting in good faith in order to prevent, avoid or mitigate personal injury or loss of life or damage or harm to property or public safety may direct a Service Provider to suspend Work. Customer shall provide written notification to Authority of the suspension and events leading up to the suspension within eight (8) hours after the emergency has been stabilized. Sections 3.1(c) and (d) shall also be applicable to a suspension under this Section 3.2.

3.3 Termination of a Project. Authority may terminate a Project (and the related CPC) at any time upon thirty (30) days' prior written notice to Customer. In addition, the following incidents shall be deemed to immediately terminate a Project: (i) closure, abandonment, destruction or material damage to the Facility for which Project Work is being performed; (ii) reduction or elimination of energy savings or other modification to the Project that, in the Authority's opinion, renders the Project ineligible under the Authority's requirements for inclusion in its Energy Services Program , whether due to removal, by-passing or alteration of equipment or due to any unforeseen event; (iii) discovery of asbestos or other hazardous material in Customer's Facility that impedes the execution of the Work; and (iv) failure by Customer to make payment to Authority when due and such payment default continues for a period of thirty (30) days after written notice thereof by Authority to Customer.

3.4 Actions Upon Project Termination or Cancellation. In the event that a Project is canceled or terminated in whole or in part subsequent to execution of a CPC but prior to completion of such Project, Authority shall:

(a) Discontinue or direct Service Provider(s) to discontinue all Work and the placement of all orders for materials, equipment or labor otherwise required for the Project or terminated part of the Project, as applicable;

(b) Cancel or direct Service Provider to cancel all existing orders and subcontracts related to performance of the Project or terminated part of the Project, as applicable;

(c) Take actions reasonably necessary, or as directed by Customer in writing, for the protection and preservation of the Work and all Project-related equipment, materials and property within Authority's or Service Provider's possession and control; and

(d) Issue a Final CPC covering (i) that portion of the Total Reimbursement Cost (excluding the Authority Program Fee) actually incurred by Authority at or prior to such termination/cancellation both for the performed and for the terminated portion(s) of the Work (including, but not limited to, non-cancelable material and equipment not yet incorporated into the Work); (ii) the costs for any additional services performed by Authority or Service Provider pursuant to 3.4(c) hereof; (iii) any wind-down costs incurred by Authority and its Service Providers and Subproviders as a result of the termination/cancellation, along with Service Providers' and Subproviders' reasonable and customary overhead and profit on the Work not executed; and (iv) the Authority Program Fee. The Authority Program Fee for a Project that is terminated or canceled prior to completion shall be as set forth in the Compensation Schedule, unless otherwise agreed upon by the Parties in the CPC.

ARTICLE IV

ENVIRONMENTAL PROVISIONS

4.1 Hazardous Materials and Disposal of Waste and Debris.

(a) General Responsibilities. With respect to Authority Implemented Work, Authority shall require that Service Provider and/or Subprovider (as applicable) be responsible for environmental air monitoring and thoroughly cleaning the job site, including the removal of Waste and Debris generated as a result of a Project. Such removal may involve the management, transportation and disposal of Waste and Debris. If in the course of performing the scope of the Project Work as described in the CPC for any Authority Implemented Work, Authority encounters existing Hazardous Materials, including but not limited to Waste, any such materials shall be handled, transported and disposed of in accordance with applicable local, state and federal laws and regulations, as well as Authority's policies and procedures.

(b) Customer is Generator of Waste. The Customer acknowledges that, in accordance with USEPA and NYS DEC regulations, it is, and remains the Generator of, and holds title to, any Waste encountered during Work performed pursuant to this Master Agreement. If the Customer holds a Hazardous Waste "Generator Identification Number" for the specific site where work is being performed (as defined in Section 3010 of Subtitle C of RCRA), that number will be utilized for any and all hazardous waste disposal. If a Hazardous Waste "Generator Identification Number" does not exist, one may need to be obtained from the USEPA for each site from which Authority removes Waste. The Customer authorizes Authority, where required by USEPA and/or NYS DEC regulations, to apply in the name of the Customer for Hazardous Waste Generator Identification Numbers in order to dispose of Waste pursuant to this Master Agreement and to act as the contact Party for such applications. To the extent that the Customer is the generator of the Waste, a duly authorized representative of the Customer must sign such applications when requested by Authority. The Customer also authorizes Authority, where required by USEPA and/or NYS DEC regulations, to prepare, in the name of the Customer, any manifests or other forms required for the disposal of the Waste generated pursuant to activities under this Master

Agreement. A duly authorized representative of the Customer shall sign any manifests or other shipping records required to ship Waste offsite for disposal.

(c) Notification and Cost of Waste Disposal. With respect to Authority Implemented Work, Authority shall advise Customer (whenever possible, in advance of removal) where material determined to be Waste has been encountered which must be disposed of pursuant to USEPA and NYS DEC regulations. Authority shall keep the Customer fully informed of Authority's activities on its behalf and shall provide the Customer with copies of all applications and other materials provided or received in connection with actions taken pursuant to this authorization. The direct costs of Waste disposal will be included in the Final CPC. Any costs to Authority relating to the Project that may arise subsequent to the time the Final CPC is executed (or deemed executed) under present or future laws or regulations due to pollution, clean-up or otherwise at the site of disposal shall be borne by the Customer. If, however, such costs are due to the negligence or willful acts of Authority's Service Provider or Subprovider or due to the willful acts of Authority, the Customer shall not be responsible. With respect to Authority Implemented Work, Authority shall use reasonable diligence in overseeing the removal and disposal of Waste, shall maintain complete and accurate records thereof, and shall make those records available to the Customer upon request. In addition, any existing equipment determined by the Customer to be useful to the Customer may, at the Customer's request, be retained by the Customer and shall be the sole responsibility of the Customer.

(d) Customer Disposal of Waste. Notwithstanding the foregoing, the Customer shall have the option of disposing of Waste and Debris generated as a result of a Project at its own expense in accordance with all applicable local, state and federal laws and regulations, as well as Authority's policies and procedures.

4.2 Remediation. The Customer shall be responsible for the performance of any Remediation required under applicable local, state and federal Environmental Laws in order to address the existence or suspected existence of Hazardous Substances in, on, or under the job site that are discovered or encountered during Work performed and any Release or threatened Release in, on, under, over or migrating to, from or through the job site. The Customer shall promptly take all actions as are necessary to perform Remediation of any such Release or Discovery, and such other work as may be required by any Governmental Authority to safeguard the health, safety or welfare of any persons, the land and any improvements thereon or there under, from any Release or threatened Release or Discovery. In the case any Remediation is required, the Customer shall be responsible for restoring the affected portion or portions of the job site, together with any and all affected soil and groundwater, to the functional and topographical condition that existed prior to the Release and Remediation, as well as to the condition required by Environmental Laws, and as necessary to satisfy the requirements of any Governmental Authority exercising jurisdiction with respect to the job site for such Release or Discovery.

4.3 Environmental Indemnification. Customer shall be solely responsible for any and all loss, damage or injury to persons or property and for any cleanup costs associated with any site where Waste and Debris are disposed of or comes to be situated including, but not limited to, response and remedial costs. In addition, to the extent permitted by law, the Customer shall, or shall require its Service Provider and Subproviders to, at their sole cost and expense, indemnify, defend and hold harmless Authority and the State of New York against any loss, liability (including, without limitation, judgments, attorney's fees, court costs, penalties or fines), or expenses of any type (including, but not limited to, required corrective actions) which Authority or the State of New York incurs because of injury to, or death of any person, or on account of damage to property, or any other claim arising out of, in connection with, or as a consequence of (a) the disposition or use of retained equipment by the Customer or anyone for whose acts the Customer may be liable, and (b) any cleanup costs associated with any site where Waste and Debris are disposed of or come to be situated traceable to such Waste and Debris including, but not limited to, response and remedial costs.

ARTICLE V

RECOVERY OF COSTS/REPAYMENT OBLIGATION

5.1 Project Cost. Authority shall initially pay for and/or incur costs for all components of the Total Reimbursement Costs applicable to a Project at the selected Customer Facility. Customer agrees to pay the Authority the Total Reimbursement Costs specified in the respective CPC as reconciled by the Final CPC.

5.2 Total Reimbursement Costs. The following components of the Total Reimbursement Costs may be delineated in a CPC for a particular Project:

(a) Material Cost. The Material Cost represents the cost of materials, equipment, fixtures, tools, construction equipment and machinery, water, heat, utilities, transportation and other facilities necessary for the proper execution and completion of the Work, whether temporary or permanent and whether or not incorporated or to be incorporated into the Work.

(b) Labor Cost. The Labor Cost represents (i) the sum of all wages paid to skilled trade and craft workers, plus employee benefits, payroll taxes, insurance and related costs; or (ii) the fees paid to skilled trade and craft workers that are not employees, in each case as represented on the Service Providers' or Subproviders' invoice.

(c) Project Contingency. The Project Contingency, or a portion thereof, actually applied by the Authority to the Project as set forth in a Contingency Work Order.

(d) Service Provider Fees. The Service Provider Fees represent the costs associated with the payment of Service Providers, Subproviders and other third party professionals based on actual invoices, individual billing rates based on hourly increments, or a percentage fee applied to certain Project costs, plus reimbursable expenses;

(e) Authority Program Fee. The Authority Program Fee reimburses Authority for services provided by Authority during the implementation of a Project. The Authority Program Fee can be based on a percentage fee applied to certain Project costs, a lump sum fee, individual billing rates based on hourly increments and/or other fee arrangements identified in the Compensation Schedule.

(f) Short-Term Interest. Short-Term Interest reimburses the Authority for costs incurred in connection with financing the delivery of a Project. It is based on the underlying source of funds chosen by the Authority, in its sole discretion, to finance a Project during its implementation and may vary depending upon the actual financing product the Authority selects. In addition to the actual interest expense incurred by the Authority on the short-term debt issued for Project expenses, Short-Term Interest may include additional fees for administering the financing program including but not limited to costs incurred to secure liquidity facilities, remarketing services, purchase of an interest rate cap(s), issuing and payment agents and other financing related costs and credit premiums, if any.

(g) Other Project-Related Costs. Other Project-related costs may include Authority Material Handling Fee, Waste disposal costs, additional Project-specific insurance, surety bond costs, specialty services and other Project-specific costs not otherwise included in any of the above categories.

5.3 Billing. The specific billing method for each Project is set forth in the CPC and/or the long-term financing agreement associated with the particular Project. The final repayment amount due to the Authority will be the Total Reimbursement Costs as reconciled in a Final CPC to reflect adjustments to account for payments made or additional charges incurred by Customer and will constitute the Customer's Short-Term Repayment Obligation. In the event a Project is terminated before completion, Authority shall issue a Final CPC as provided in Section 3.4(d).

5.4 Payment.

(a) Payments. Customer shall pay any invoiced amounts to Authority within thirty (30) days of Customer's receipt of Authority's invoice. Any outstanding amounts not paid within such thirty (30) day period shall accrue additional Short-Term Interest until the date when payment is made in full. Such additional Short-Term Interest will be reflected on subsequent invoices and/or the Final CPC.

(b) Late Payment. Customer's final Short-Term Repayment Obligation shall be fully repaid on or before the Short-Term Repayment Obligation Maturity Date. Any amount due and unpaid on the Short-Term Repayment Obligation Maturity Date shall be subject to a late payment charge determined as the greater of (i) interest in accordance with the late payment rate set forth in State Finance Law §179(g); or (ii) the late charges payable under the terms of Authority's electric service, in accordance with provision 454.6 (b) of Authority's Rules and Regulations for Power Service, as such regulation may be amended from time to time. Authority, in its sole discretion, may waive the application of such late payment charge for a Project upon sufficient justification demonstrated by Customer.

5.5 Grants and Funding. Authority may pursue and apply for grants or other available funding for the respective Project, where applicable, when authorized by Customer. The Customer may assign the right to receive such grants or other available funding to the Authority, and the Authority may, at its sole discretion, accept such assignment. If Authority accepts such assignment, the Authority will apply the funds to reduce the Total Reimbursement Costs, provided the funds are actually received by the Authority by the Short Term Repayment Obligation Maturity Date.

5.6 Long-Term Financing for Capital Projects. Should Customer require financing to satisfy its Short Term Repayment Obligation for a Capital Project, the Customer may apply for permanent long-term financing through any of the financing products offered by the Authority to convert Customer's Short-Term Repayment Obligation to a Long-Term Repayment Obligation. Authority may agree to such financing, in its sole discretion. Regardless of whether the Customer elects to utilize any of the Authority's available financing products, the Customer is responsible for satisfying its Short Term Repayment Obligation within the time constraints set forth herein.

If the Customer is interested in any of the Authority's long-term financing products, it must indicate its interest by marking the appropriate section of the CPC for the design phase of a Capital Project. To be eligible for the Authority's long-term financing products, Customer must comply with the Authority's policies and procedures for long term repayment. If Customer's long-term financing application is approved by the Authority, the Parties' obligations with respect to long-term financing will be set out in a separate loan agreement with terms and conditions agreed to by the Parties. This long-term financing option will allow the Customer to convert the Short-Term Repayment Obligation to a Long-Term Repayment Obligation.

ARTICLE VI

INSURANCE REQUIREMENTS.

Authority's agreements with the Service Providers shall provide that the Service Provider or Subproviders shall obtain and maintain the policies of insurance with the identified limits set forth in Section 6.1, unless additional policies of insurance and/or higher limits are required under the applicable CPC. The costs of such insurance will be part of the Total Reimbursement Costs.

6.1 Insurance Requirements:

(a) Workers' Compensation (inclusive of New York State disability benefits) and Employer's Liability coverage;

(b) Commercial General Liability insurance policy, including Contractual Liability and Products/Completed Operations Liability coverages, with limits of not less than $2,000,000 per occurrence for bodily injury and not less than $2,000,000 for property damage, such policies naming Authority and the State of New York as additional insureds under the policy;

(c) Automobile Liability coverage with a minimum limit of $1,000,000 per accident; and

(d) if required under the applicable CPC:

(i) Pollution Liability, including coverage for asbestos abatement, with minimum limits of $1,000,000 per occurrence;

(ii) Professional Liability insurance with a minimum limit of $1,000,000; and

(iii) Builder's risk insurance in the amount of the estimated Total Reimbursement Cost to be issued on a replacement cost basis without optional deductibles and

will include the interests of Customer, Authority, and the Service Providers. Such insurance shall be maintained until final payment has been made by Customer to Authority.

6.2 Adjustments. The types of insurances required and/or policy limits listed in Sections 6.1 above may be adjusted as Customer and Authority deem appropriate in connection with a specific CPC. The form and sufficiency of each insurance policy required to be obtained hereunder by the Service Provider or Subprovider shall be subject to approval by Authority. Authority shall hold all Certificates of Insurance submitted to the Authority by its Service Providers and Subproviders with respect to any Project implemented under this Master Agreement.

6.3 Customer Insurance Requirements. With specific regard to the ESP equipment, for so long as any portion of Customer's Short-Term or Long-Term Repayment Obligation, as applicable, remains unpaid, Customer shall procure an all risk policy of insurance which will insure the equipment for full replacement cost value against loss while the equipment is in Customer's care, custody and control. The insurance policy shall name Authority and the State of New York as additional insured and loss payees, and shall contain a full waiver of subrogation against Authority, its agents, Service Providers, Subproviders and the State of New York. Customer shall also procure a Commercial General Liability insurance policy with minimum limits of $5,000,000 per occurrence for bodily injury and property damage naming Authority and the State of New York as additional insured. In lieu of obtaining all risk and commercial general liability insurance, Customer may request in writing to Authority to self-insure against risk of loss. Authority may approve or deny such request in its sole discretion. Customer agrees to provide any relevant documents or information requested by Authority in order for Authority to make the determination that Customer has sufficient resources to self-insure. The decision to self-insure will not relieve Customer of any of the obligations imposed herein and shall afford Authority the protection against loss and rights it would have received, if Customer had obtained such policies of insurance.

ARTICLE VII

WARRANTIES, DAMAGES, LIABILITY, ETC.

7.1 Service Provider's Warranty Requirements. Authority's agreements with its Service Providers shall provide that all Work performed and any materials provided by the Service Providers under the agreements shall be free from any defects. Such agreements shall further provide that any defective Work or materials identified within one (l) year after (i) execution (or deemed execution) by the Parties of a Substantial Completion and Operation Transfer Report or (ii) if no such report must be signed, completion of the Project, shall be promptly corrected, repaired, replaced, re-performed or otherwise remedied by the Service Provider and/or Subprovider(s) at no additional expense to Customer. Authority's agreements with Service Providers shall also provide that any manufacturers' warranties for equipment installed at Customer's Facilities be assigned to Customer.

Authority shall have no obligation to assist Customer with any warranty claims against a Service Provider or equipment manufacturer. Customer shall coordinate any warranty claims directly with the respective Service Provider or equipment manufacturer.

7.2 Authority Warranty Disclaimer. THE WARRANTY PROVIDED BY SERVICE PROVIDER AND THE ASSIGNED WARRANTIES OF THE EQUIPMENT MANUFACTURERS ARE EXPRESSLY IN LIEU OF ALL OTHER WARRANTIES. AUTHORITY EXPRESSLY EXCLUDES ALL OTHER WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, DESCRIPTION OR QUALITY NOT EXPRESSLY SET FORTH HEREIN, TO THE EXTENT PERMITTED BY LAW. NO AFFIRMATION OF AUTHORITY, BY WORDS OR ACTION, SHALL CONSTITUTE A WARRANTY. DESCRIPTIONS, SPECIFICATIONS, DRAWINGS, AND OTHER PARTICULARS FURNISHED TO CUSTOMER ARE ONLY ESTIMATES AND DO NOT CREATE A WARRANTY.

7.3 Projected Energy Savings. Authority and its Service Providers shall use their best efforts to prepare accurate engineering estimates. After energy efficiency Work is completed in Customer's Facility, it is the intent and expectation of the Parties that Customer's annual energy usage for that Facility shall not increase above the pre-installation level except due to changes in rates or increases in usage not related to the implementation of the ESP Work. Customer is responsible for providing Authority with accurate information concerning the operation of its Facility. Customer understands that the projected energy savings are based upon such Customer input. It is Customer's sole responsibility to ensure that the expected energy savings meet Customer's satisfaction at the time the CPC for a Project is executed.

AUTHORITY HEREBY DISCLAIMS ANY AND ALL LIABILITY FOR ANY ENERGY SAVINGS PROJECTED BY AUTHORITY OR OTHERWISE EXPECTED BY CUSTOMER THAT CANNOT BE ACHIEVED.

7.4 Uncontrollable Forces. Authority shall not be responsible for delays or failures in performance resulting from occurrences beyond its reasonable control including, but not limited to, acts of God, strikes, walkouts, acts of war, or any law, regulation, or action of any court or governmental authority, fire, malfunctions in communication lines or computer hardware, power failures, shipping or delivery delays or other events caused by those not party to this Master Agreement (including, without limitation, any Third Parties, and any Service Providers or Subproviders of Authority). In the event Authority or the Service Providers or Subproviders are unable to fulfill any obligations hereunder by reason of such uncontrollable forces, Customer will be notified in writing and the completion dates described in the CPC will be extended by the amount of additional time reasonably necessary to complete the Work. If necessary, Authority will issue a Contingency Work Order or a Change Order, as applicable.

7.5 Damages, Indemnification by Service Provider.

(a) Damages. Authority's agreements with the Service Providers shall include a provision that all damage of whatever nature resulting from the performance of the Work or resulting to the Work during its progress, from whatever cause shall be borne by the Service Provider, and all Work performed shall be solely at the Service Provider's risk until the Work has been finally inspected and accepted by Authority. The Service Provider, however, shall not be responsible for damages resulting from gross negligence or willful misconduct of officials or employees of Authority or Customer.

(b) Indemnification. Authority's agreements with the Service Providers will include a provision that to the extent permitted by law, the Service Provider shall assume the entire responsibility and liability for and defense of, and pay and indemnify, Authority, Customer, and the State of New York (where a Project undertaken for Customer is located on property of New York State), against any loss, damage, expense or liability and will hold each of them harmless from and pay any loss, damage, cost or expense (including without limitation, judgments, attorney's fees, and court costs) which Authority, Customer or the State of New York incur because of injury to or death of any person or on account of damage to property, or any claim arising out of, in connection with, or as a consequence of, the performance of the Work and/or any act or omission of the Service Provider or any of its Subproviders, employees, agents or anyone directly or indirectly employed by the Service Provider or anyone for whose acts the Service Provider may be liable.

7.6 Limitation of Authority's Liability.

(a) Obligation to Exhaust Remedies against Service Provider. In the event of any alleged Authority liability to Customer, Customer shall first pursue and exhaust all remedies in law against the Service Providers and Subproviders and under the insurance identified in Article VI above and carried by the Service Providers and Subproviders before making any claim or taking any action against Authority.

(b) Exclusion of Indirect, Incidental, Consequential Damages. To the fullest extent permitted by law, Authority shall not be liable to Customer, for any indirect, special, incidental, or consequential damages of any kind (including without limitation, any loss of property or equipment, loss of profits or revenue, loss of use of equipment or power systems, cost of capital, cost of purchased or replacement power or temporary equipment, including additional expenses incurred in using existing facilities) related to or arising in connection with this Master Agreement or any other Transaction Document executed in connection herewith, regardless of the form of action (whether in contract, tort or otherwise), even if Authority has been advised of the possibility of such damages.

(c) Total Liability Cap. The Parties agree that in no event shall Authority's total liability (whether in contract, tort or otherwise) for all claims relating to a Project exceed ten percent (10%) of the Total Reimbursement Costs for such Project set forth in the respective CPC.

(d) No Limitation of Service Provider/Subprovider Liability. Nothing in this Section 7.6 shall be construed as limiting the liability of a Service Provider or Subprovider to Authority or Customer in connection with the performance of such Service Provider's or Subprovider's Work on Customer's premises.

7.7 Customer's Responsibility for Project Equipment and Performed Work. Upon delivery at Customer's Facility, Customer shall be responsible for all damage to all Project materials, supplies and equipment of every description and all Work performed at Customer's site unless such damages are caused by Authority or its Service Providers or Subproviders.

ARTICLE VIII

INTELLECTUAL PROPERTY RIGHTS

8.1 Intellectual Property; Proprietary Information.

(a) Intellectual Property Rights. Neither Party shall acquire, directly or by implication, any ownership of any Background Intellectual Property Rights of the other Party. Each Party shall retain title to any Intellectual Property Rights developed, authored, conceived or reduced to practice independently and solely by that Party during the performance of this Master Agreement without the other Party's Background Intellectual Property Rights. Notwithstanding any of the foregoing, it is agreed by the Parties that Authority shall be the sole owner of all Intellectual Property Rights related to any Project which is jointly developed, invented or otherwise generated during the performance of this Master Agreement or any Transaction Document.

(b) Work Product; Proprietary Information. Unless and until Customer has repaid its Short-Term or Long-Term Repayment Obligation, as applicable, the Facility data, evaluations, design and other information produced by Authority or its Service Providers in connection with a Project shall be the property of Authority. Customer shall have the right to use any such proprietary information for the maintenance of Project installations in its Facilities. Upon payment in full by Customer, such information shall become the property of Customer. Any information identified as confidential which is exchanged by Authority and Customer shall be duly protected by the recipient to the extent permitted by law. It is understood that the Public Officers Law and other statutes and regulations regarding Freedom of Information may require the disclosure of information in certain situations.

ARTICLE IX

TERM AND TERMINATION

9.1 Term. This Master Agreement shall end on ____________ __, 2027, unless earlier terminated in writing by either Party in accordance with the terms of this Master Agreement.

9.2 Termination of Master Agreement. Unless otherwise provided in this Master Agreement, either Authority or Customer may terminate this Master Agreement at any time upon one hundred twenty (120) days' prior written notice to the other Party.

9.3 Pending Projects. Authority and Customer acknowledge that a Project implemented pursuant to a CPC executed during the Term of this Master Agreement may extend beyond the expiration or early termination of this Master Agreement. Provided that the Project was commenced pursuant to a CPC that was executed during the Term of this Master Agreement, then this Master Agreement will be extended, as it applies to such CPC only and for the sole purpose of completing the Project. The Project implemented pursuant to such CPC may continue until completed or otherwise terminated earlier pursuant to the terms and conditions of this Master Agreement.

9.4 Extension. This Master Agreement may be renewed at the end of the current term for an additional period, such additional period not to exceed a period equal to the original Term, to be mutually determined by the Parties in writing and signed by an authorized officer or designee of Authority and Customer.

ARTICLE X

GENERAL OBLIGATIONS OF THE PARTIES

10.1 Authorized Representatives.

(a) Customer's Authorized Representative. For each Project, Customer shall designate a Customer's Authorized Representative and shall inform Authority in writing accordingly. If Customer desires to change its Customer Authorized Representative, it must notify Authority in writing (in accordance with notice requirements set forth herein) at least five (5) business days prior to such change. Customer's Authorized Representative shall coordinate the Project on behalf of Customer and assist Authority and the Service Providers and Subproviders with the implementation of the Project in the selected Facilities of Customer. Customer's Authorized Representative shall be responsible to obtain all necessary approvals, authorizations, and signatures of Customer with respect to any CPC, Change Order, Final CPC and other Transaction Document.

(b) Authority's Authorized Representative. For each Project, Authority shall designate an Authority's Authorized Representative and shall inform Customer accordingly. Authority's Authorized Representative shall coordinate the Project on behalf of Authority and communicate with Customer. Authority will inform Customer of any changes to its Authorized Representative.

10.2 Authority Obligations. With respect to any Authority Implemented Work, Authority shall comply with the following:

(a) Reporting and Information. Authority shall keep Customer informed as to the progress of the Work and shall provide Customer with periodic reports of all activities by the Service Providers and Subproviders at Customer's Facilities. Authority and its Service Providers shall meet with representatives of Customer upon reasonable notice to discuss any matters concerning the Projects.

(b) Permits, Licenses, Authorizations. Authority shall require that the Service Providers and Subproviders obtain and maintain all permits, licenses and authorizations required to perform the Work in Customer's Facilities and that they will comply with all applicable local, state and federal laws, guidelines and regulations, including applicable local, state and federal building, fire and electrical codes and standards. Any costs associated with permits and licenses that must be obtained by Service Provider or Subprovider for a specific Project will be reflected in the Total Reimbursement Costs. Notwithstanding the foregoing, neither Authority nor Service Provider (or Subprovider) shall be responsible for closing out open permits obtained by Service Provider (or Subprovider) due to existing deficiencies or code violations in Customer's Facility which are outside the Project scope.

(c) Service Provider/Subprovider Performance. Authority shall require its Service Providers and Subproviders to comply with regulations governing access to and performance of the Work in the selected Customer Facilities and to perform such Work in such a manner as not to unreasonably interfere with Customer's business at the Facilities. Authority shall also require its Service Providers and Subproviders to comply with Customer's operational and safety requirements, which in certain instances may require substantial supervision and control over the site by Customer.

(d) Records. Authority's Service Providers shall maintain accurate records of Project Work for a period of six (6) years after completion of a Project.

10.3 Customer Obligations. With respect to any Project entered into in connection with this Master Agreement, Customer shall have the following rights and obligations:

(a) Right to Inspect. Customer and Customer's Authorized Representative may observe and inspect all Work in any of Customer's Facilities and shall have the right to attend all Project job meetings, upon written notice of its intent to attend a particular meeting.

(b) Attendance at Meetings. Upon reasonable request and notice from Authority or Service Provider, Customer shall attend meetings scheduled by Authority or Service Provider to discuss any Project-related matters.

(c) Site Rules and Regulations. Customer must promptly notify Authority of any site specific construction, safety, technical or other requirements and restrictions related to its Facility(ies) prior to the start and during the Project. If Customer becomes aware of any defect in the Work or any failure of Authority or the Service Provider or Subprovider to meet the respective Project requirements, the Customer shall give prompt notice to Authority.

(d) Access. Customer shall provide Authority and its Service Providers safe, proper and timely access to the Facility as necessary to perform the Work. Upon Authority's request, Customer's Authorized Representative will accompany Authority and its Service Providers to Customer Facilities. Customer shall promptly provide verbal and written notice of limitations or changes in site access.

(e) Permits and Licenses.

(i) Customer shall provide Authority or Service Provider with such assistance (including, but not limited to, all necessary information requested by Service Provider) as may be required for Authority or Service Provider to obtain all permits, licenses and authorizations necessary to perform the Work in accordance with all applicable local, state and federal laws, regulations, codes and standards applicable to the Facility.

(ii) Customer shall be responsible and shall hold all licenses, permits, authorizations and regulatory approvals necessary for the lawful conduct of its business as presently conducted, and shall comply with all applicable statutes, laws, ordinances, rules and regulations of all governmental bodies, agencies and subdivisions having, asserting or claiming jurisdiction over it, with respect to any part of the conduct of its business and corporate affairs.

(f) Project Equipment. As long as Customer's Short-Term or Long-Term Repayment Obligation, as applicable, remains outstanding, (i) Customer will keep all Project-related equipment free from any and all liens, claims, encumbrances, and the like; (ii) Customer will not grant a security interest in such equipment to any party without the prior written consent of Authority; (iii) the equipment will remain at the Facility site as designated in a CPC; (iv) Customer will not sell, offer for sale, transfer, or dispose of such equipment without notice to Authority; (v) Customer will not use or permit any person to use the equipment in a manner prohibited by law or in a manner which would void any manufacturer's warranty; (vi) Customer agrees to maintain the equipment in good order and repair at all times, and will not waste or destroy the equipment or any part of it; and (vii) Customer will keep the equipment insured in accordance with the requirements set forth in Section 6.3 hereof.

(g) Coordination. Customer shall be responsible for facilitating coordination with Third Parties as required. Furthermore, Customer shall promptly resolve any disputes or issues that arise with any Third Parties. Customer shall be responsible for any changes to the Project schedule, the scope of Work and/or the Total Reimbursement Costs resulting from any delays due to unresolved disputes or issues with Third Parties pursuant to Section 2.6 hereof.

(h) Review and Approval. Customer will promptly review any documents submitted to it by Authority requiring Customer's decision and shall render any required decision pertaining thereto without undue delay.

(i) Assistance; Timely Performance. Customer shall cooperate with Authority and its Service Providers and Subproviders and provide Authority with such other assistance as necessary to facilitate the performance of the Work. Customer shall perform all obligations set forth in this Master Agreement and any other Transaction Document in a timely manner so as to permit the orderly progress of the Projects. Authority shall not be responsible for any Project delays due to Customer's non-compliance with its obligations set forth herein or in a Transaction Document.

ARTICLE XI

MISCELLANEOUS

11.1 Disputes. In the event of any dispute regarding ESP Work at any Customer Facility, Work there may be suspended by Authority until the matter is resolved to the mutual satisfaction of the Parties in accordance with the procedures set forth in Section 11.2 hereof. In the event the Parties are unable to resolve any such dispute after good faith efforts, the Work at that Facility shall terminate and Authority shall issue a Final CPC as provided in Section 3.4(d) hereof.

11.2 Dispute Resolution. The Parties shall use good faith efforts to settle promptly all disputes arising under this Master Agreement or in connection with any ESP Work. In the event that any dispute, including but not limited to a billing dispute, a dispute regarding the quality of the Work, or a dispute regarding the interpretation of this Master Agreement, arises and cannot be resolved in the normal course of business by operating personnel within twenty (20) days after commencement of a dispute, either Party may give the other Party formal notice of the dispute in accordance with the notice requirements set forth herein. In the event that such notice is given,

the Parties shall attempt to resolve the dispute by negotiation between representatives who have the necessary authority to resolve the dispute in question. Within twenty (20) days after delivery of the notice, the receiving Party shall consider all information relevant to the dispute and shall submit to the other Party (in accordance with the notice requirements set forth herein) a proposal for resolution. Thereafter, the representatives shall confer in person or by telephone, promptly and no later than five (5) days after receipt of the proposal for resolution, to attempt to resolve the dispute. All reasonable requests for information by one Party to another Party will be honored. To the extent that disputes are not resolved pursuant to this process, the Parties reserve all rights under law or equity to seek and pursue remedies through the judicial process.

11.3 Publicity.

(a) Public Announcements. No marketing, publicity, promotion, social media, or advertising regarding this Master Agreement, or any Project undertaken pursuant to this Master Agreement, will be issued by Customer without Authority's prior written approval, which approval will not be unreasonably withheld. Any responses to news media inquiries or social media activities developed by Customer, related to this Master Agreement, or any Project undertaken pursuant to this Master Agreement, must be coordinated with Authority for review and approval prior to their release. Letters, speeches, news and/or press releases, articles for publication, website and social media postings, etc., related to this Master Agreement, or any Project undertaken pursuant to this Master Agreement, must be coordinated with Authority for review and approval prior to their release. Any and all communications, whether verbal, electronic or written, must be submitted to Authority's Corporate Communication Business Unit for prior review and approval. Customer agrees to abide by these terms regarding public announcements during the term of this Master Agreement and for a period of two (2) years following the expiration or termination of this Master Agreement.

(b) Signage. The parties agree that Authority may, at no cost to Customer, install and maintain appropriate publicity signage at or in the vicinity of a Project. Customer will cooperate with Authority, and/or any third-party vendor designated by Authority, by timely responding to any questions regarding the design, manufacture, installation and maintenance of the signage. Customer will provide ordinary maintenance to the signage and promptly notify Authority after Customer becomes aware of any damage that may occur to the signage. The publicity signage may include the identity of the Project, including a brief statement highlighting the Project, any applicable Authority program, New York State program or other initiative under which the Project is implemented and the identity of the parties supporting the Project, including those parties' respective logos. The publicity signage is intended to be placed in an area of Customer's designation with significant public visibility within close proximity to the Project. Authority will be responsible for removing the publicity signage upon the conclusion of a Project, or such earlier time as either Party deems it appropriate.

11.4 Notices. All notices permitted or required hereunder or in connection with any Transaction Document shall be in writing and transmitted either: (i) via certified or registered United States mail, return receipt requested; (ii) by personal delivery; (iii) by expedited delivery service; or (iv) by e-mail, with a copy sent via U.S. Mail.

Such notices shall identify the Master Agreement and the Transaction Document to which it relates, and be addressed as follows or to such different addresses as the Parties may from time-to-time designate in accordance herewith:

To Authority:
NEW YORK POWER AUTHORITY
PROCUREMENT DIVISION
Name: John Canale
Title: Vice President, Procurement
Address: 123 Main Street, 5th Floor, White Plains, NY 10601
E-Mail Address: john.canale@nypa.gov

with a copy to:
NEW YORK POWER AUTHORITY
LAW DEPARTMENT
Name: Debra Hopke, Esq.
Title: Principle Attorney
Address: 123 Main Street, 11th Floor, White Plains, NY 10601
E-Mail Address: debra.hopke@nypa.gov

To Customer:
[CUSTOMER NAME]
Name:
Title:
Address:
E-Mail Address:

Any such notice shall be deemed to have been given either at the time of personal delivery or, in the case of expedited delivery service or certified or registered United States mail, as of the date of first attempted delivery at the address and in the manner provided herein, or in the case of email, upon receipt. The Parties may, from time to time, specify any new or different address in the United States as their address for purpose of receiving notice under this Master Agreement (and any Transaction Document) by giving fifteen (15) days written notice to the other Party sent in accordance herewith. The Parties agree to mutually designate individuals as their respective representatives for the purposes of receiving notices under this Master Agreement.

11.5 No Waiver. The failure of any Party to insist upon strict adherence to any term of this Master Agreement or any Transaction Document executed in connection herewith on any occasion shall not be considered a waiver nor deprive that Party of the right thereafter to insist upon strict adherence to that term or any other term of this Master Agreement.

11.6 Assignment. This Master Agreement and any Transaction Document executed in connection herewith may not be assigned, transferred nor conveyed by either Party without the prior written consent of the other Party. Any attempted assignment, transfer or conveyance without such consent shall be entirely void ab initio and have no force or effect.

11.7 Governing Law; Venue. This Master Agreement (and any Transaction Document executed in connection herewith) and any and all disputes arising in connection herewith (whether in contract, tort or otherwise) shall be governed by and construed in accordance with the laws of the State of New York without giving effect to any choice or conflict of laws provision or rule that would cause the application of the laws of any jurisdiction other than New York. Any action at law, or in equity, for the enforcement of this Master Agreement (and any Transaction Document executed in connection herewith) or any dispute arising in connection herewith shall be instituted only in a court of competent jurisdiction located in the County of Albany, State of New York.

11.8 No Third Party Beneficiaries. Nothing contained in this Master Agreement shall, directly or indirectly, create a contractual relationship with, or give any claim or right of action in favor of, any third party (including, without limitation, any Service Provider or Subprovider) against Authority.

11.9 Severability. The invalidity or unenforceability of any provisions of this Master Agreement or of any Transaction Document executed in connection herewith shall not affect the validity or enforceability of any other provisions of this Master Agreement or Transaction Document, as applicable, which other provisions shall remain in full force and effect.

11.10 Survival of Provisions. The articles that contain provisions related to the following will survive the expiration, termination or completion of this Master Agreement: Conflict and Order of Precedence; Recovery of Costs and Repayment Obligation, Warranty, Damages, Liability, Ownership of Installed Work and Intellectual Property, Publicity; and Governing Law, Venue.

11.11 Not Construed Against Drafter. Authority and Customer acknowledge that they have read this Master Agreement, have had the opportunity to review it with an attorney of their respective choice, and have agreed to all its terms. Under these circumstances, Authority and Customer agree that the rule of construction that a contract be construed against the drafter shall not be applied in interpreting this Master Agreement and that in the event of any ambiguity in any of the terms or conditions of this Master Agreement, including any exhibits or schedules hereto, such ambiguity shall not be construed for or against any Party hereto on the basis that such Party did or did not author same.

11.12 Headings. The articles and section headings contained in this Master Agreement are for reference purposes only and shall not affect the meaning or interpretation of this Master Agreement.

11.13 Counterparts. This Master Agreement may be executed in counterparts via inked signature or electronic mark, each of which shall be deemed an original, but all of which together shall constitute one and the same instrument. The fully executed Master Agreement may be delivered using pdf or similar file type transmitted via electronic mail, cloud based server, e-signature technology or other similar electronic means.

(SIGNATURE PAGE FOLLOWS)

IN WITNESS WHEREOF, the parties hereto have duly executed this Master Agreement as of the effective date first written above.

POWER AUTHORITY OF THE STATE OF NEW YORK		[CUSTOMER]	
By:		By:	
Name:	John Canale	Name:	
Title:	Vice President, Procurement	Title:	
Date:		Date:	

Signature Page to Master Cost Recovery Agreement No. ______________

NEW YORK STATE OF OPPORTUNITY. | NY Power Authority

EXHIBIT A

STATEWIDE COMPENSATION SCHEDULE

As compensation for services rendered by the Authority under the Master Agreement, the Customer will pay the Authority Program Fee as set forth below.

A. CAPITAL PROJECTS

I. AUTHORITY PROGRAM FEE

For Capital Projects, the Authority Program Fee is calculated as a percentage of the cumulative sum of all costs related to a Project, including, but not limited to all Material Costs; Labor Costs; Service Provider Fees; the amount of the Project Contingency applied as a Project cost; and other Project-related costs and expenses. The Authority Program Fee is in addition to all such costs related to a Project. The Authority Program Fee percentage will be fixed upon execution of the CPC for the installation phase.

1. Authority Program Fee when Service Provider performs Work

The following table sets forth the Authority Program Fee where the Authority delivers a Project using one or more Service Providers to perform audit, design, construction management and/or installation.

Project Size (in millions)	Authority Program Fee
\$0 - \$3M	12.5%
\$3M - \$6M	12.0%
\$6M - \$12.5M	11.5%
\$12.5M - \$40M	11.0%
\$40M - \$60M	10.5%
> \$60M	10.0%

2. Authority Program Fee when Authority and Service Provider perform Work

The following table sets forth the Authority Program Fee where the Authority will be performing design and construction management with its own forces using one or more Service Providers to perform installation. If the Authority procures material directly in lieu of using one of its Service Providers, there will be an additional Material Handling Fee of 1.5% charged on the Material Cost of the Project.

Project Size (in millions)	Authority Program Fee
\$0 - \$3M	27.5%
\$3M - \$6M	27.0%
\$6M - \$12.5M	26.5%
\$12.5M - \$40M	26.0%

\$40M - \$60M	25.5%
> \$60M	25.0%

3. Authority Program Fee when Authority provides Audit Services Only

The Authority Program fee for providing Audit services not contemplated as part of a full project (i.e. design, construction management and/or installation) is calculated as twenty-five percent (25%) of the costs related to the Audit.

II. MILESTONE PAYMENTS

To the extent applicable, the Authority Program Fee will be paid on milestones as detailed in the CPC or as otherwise mutually agreed upon.

III. AUTHORITY FEE IN THE EVENT OF PROJECT TERMINATION

1. Termination at or after Audit Phase

If a Project is terminated at or after the audit phase, but prior to moving forward with any design or implementation, the Authority's Program Fee is calculated as twenty-five percent (25%) of the actual costs associated with such audit.

2. Termination during Design, Procurement or Installation Phase

If a Project is terminated in whole or part during the design, procurement or installation phase, the Authority's Program Fee for the Project will be the cumulative percentage value at the current milestone (as if it had been achieved) and calculated based on the estimated Project costs, including, but not limited to all Material Costs; Labor Costs; Service Provider Fees; the amount of the Project Contingency applied as a Project cost; and other Project-related costs and expenses up through the current milestone (as if it had been achieved). For the purposes of calculating the Authority's Program Fee, the then current milestone is assumed complete once the Project is canceled.

The following table sets forth the Authority Program Fee percentage segmented by milestone.

Milestone	% of Authority's Program Fee	Cumulative Authority Program Fee Percentage
30% Design	10%	10% + (audit cost)
90% Design	15%	25% + (audit cost)
100% Design & Bidding	15%	40% + (audit cost)
Construction CPC Preparation	10%	50% + (audit cost)
Construction (25% completion)	10%	60% + (audit cost)
Construction (50% completion)	15%	75% + (audit cost)

Construction (75% completion)	15%	90% + (audit cost)
Construction (100% completion)	10%	100% + (audit cost)

B. ADVISORY SERVICES PROJECTS

I. AUTHORITY PROGRAM FEE

The Authority Program Fee for the Advisory Services will be calculated according to one of the following methods as set forth in the CPC for the Project:

Time and Materials: The Authority's Program Fee maybe based on actual time and cost of material incurred by Authority or its Service Providers in connection with a Project based on rates defined in the Project CPC.

Lump Sum: The Authority's Program Fee may be based on the percentage complete of a lump sum or milestones defined in the Project CPC.

Unit Price: The Authority's Program Fee maybe based on the unit prices defined in the Project CPC.

Percent of Materials and Labor: The Authority's Program Fee maybe based on a percentage of Service Provider Material Costs and Labor Costs as defined in the Project CPC.

Other Mechanisms: The Authority's Program Fee may be based on an evolving cost recovery mechanisms not defined in this Master Agreement. If other mechanisms are selected, the Authority's Program Fee will be based on mutual Authority and Customer agreement and will be defined in the Project CPC.

II. PROJECT TERMINATION

If a Project is terminated in whole or part prior to completion of a Project, the Authority's Program Fee will be based on the Project costs incurred by Authority up until the date of termination. For the purposes of calculating the Authority's Program Fee, as applicable, the then current milestone is assumed complete once the Project is canceled.

NEW YORK STATE OF OPPORTUNITY. | NY Power Authority

EXHIBIT B

CAPITAL PROJECT TERMS AND CONDITIONS

1. Application. In addition to the terms and conditions set forth in the main body of this Master Agreement, these Capital Project Terms and Conditions shall apply to all Capital Projects provided by Authority or Service Provider to Customer under the Master Agreement.

2. Capital Project Services. Capital Projects are generally delivered through the services of qualified installation Service Providers or Subproviders under contract with the Authority. Capital Project services may include any or all of the following services (as more fully described below): audit, design, construction management, equipment procurement, installation, commissioning, disposal of Waste, financing and other Project related services required to install a Project.

3. Audit.

(a) Scope. After Customer has identified potential Projects for Authority's and Customer's consideration, Customer may request that Authority perform an audit of the Facility. The audit will help identify opportunities for implementing ESP measures and will be scheduled by Customer's Authorized Representative and/or the appropriate Facility manager. The scope of the audit will be set forth in a CPC which shall be executed by an authorized officer or designee of Authority and Customer prior to commencement of any audit Work. In some instances, the audit will involve a complete inventory of the systems which are currently used in normal operation, while in others a more targeted approach will be taken. The audit may also include an analysis of whether hazardous materials and Waste related to those systems are likely to be present or generated as a result of installing a Project.

(b) Audit Report. Based upon the results of the audit, a written report will be furnished to Customer. The report will include an estimate of the Total Reimbursement Costs as well as estimates of the potential Total Annual Energy Savings and environmental or sustainability benefits, as applicable, that Customer can reasonably expect through implementation of the recommendations made in the report. If, after analysis of the report by Authority and Customer, Authority, in its sole discretion, determines that the Project either (1) does not meet Authority's eligibility criteria, or (2) is not appropriate at such Facility, activity there will cease.

(c) Deferment of Total Reimbursement Costs for Audit Work. Upon completion of the audit Work, if Customer and Authority decide to proceed to the next phase, Customer and Authority will execute a CPC reflecting the scope of such next Project phase. By executing the CPC, Customer acknowledges its concurrence with the audit results. Subject to Authority's approval, Customer may request that payment of the Total Reimbursement Costs for the audit Work, be deferred and included in the Total Reimbursement Costs of the CPC for the next Project phase.

4. Project Design.

(a) General. If agreed upon by the Parties in a CPC, Authority shall prepare a Project design. Customer will be asked to review all aspects of the design and specifications. Where deemed appropriate by Authority and Customer, the Service Provider will arrange for geotechnical surveys (i.e., soil tests, borings, and related evaluations), surveys of the site (i.e., to determine physical characteristics of the site, such as utility locations), and/or demonstration installations (i.e., the installation of sample lighting fixtures or other equipment) of selected measures in Customer's Facility, all at Customer's sole risk.

(b) Milestones and Milestone Completion Reports. Authority will submit the Project design documents to the Customer at 30%, 60%, 90% and "final" design milestones, or according to the milestone schedule set forth in the respective CPC. Upon completion of each design milestone, Customer and Authority (or their duly authorized representatives) shall promptly review the design Work, or applicable portions thereof and Customer and Authority shall jointly sign a Milestone Completion Report. It shall be Customer's responsibility to determine that the proposed design meets Customer's needs.

(c) Deferment of Total Reimbursement Costs for Design Work. Unless otherwise set forth in the CPC for a Project, Authority may invoice the Customer for the Total Reimbursement Costs for the performed design Work through the milestone(s), if any, set forth in the CPC (plus any Total Reimbursement Costs incurred during the audit, if such costs were deferred and rolled over). Customer may request payment deferral if Customer approves Authority to proceed to the next milestone or the next Project phase. With Authority's approval, Customer's Short-Term Repayment Obligation will be deferred and rolled into the next milestone invoice, or at design completion, become part of the Total Reimbursement Costs of the CPC for the next Project phase.

(d) Ownership of Design Work Upon Early Termination. If Customer terminates the design Project prior to its completion, upon receipt of Customer's final payment, Authority will deliver to Customer all design plans and documents completed through the date of termination. Customer's use of such design plans and documents will be subject to any copyrights of the Authority and/or the designer. By using any incomplete or unfinished design plans and/or documents that have not been sealed with the licensed design professional's stamp upon delivery to Customer, Customer accepts full and complete responsibility for such design and further agrees to hold Authority harmless from its use of such incomplete or unfinished design plans and/or documents.

5. Procurement. After Authority and Customer agree on the Project's design and technical specifications, Authority or the Service Provider will competitively solicit, using the Authority's procurement guidelines, bids for the Work as set forth in the design documents. The resulting final design, specifications and bid price shall be incorporated into a CPC for the Project. Authority's contracts with its Service Providers will require compliance with the Authority's guidelines regarding the competitive solicitation of the services of Subproviders for Customer's Facilities, including the selection of minority and women-owned business enterprises. The services of Subproviders and equipment procurement will be obtained through a competitive bid process conducted by the Service Provider with Authority oversight. In the event Customer

decides not to proceed with the installation Project, Customer shall reimburse Authority for the costs of any Work undertaken by Authority and/or its Service Provider in connection with the procurement process and the associated cost and expense of same.

6. Installation.

(a) General. After Authority and Customer have entered into a CPC for installation Work, the Service Provider and/or its Subproviders will perform the Work pursuant to the design and technical specifications set forth in such CPC.

(b) Substantial Completion and Operation Transfer Report. After Customer has inspected, tested and accepted the Project equipment, or portion thereof, installed by the Service Provider, the Parties will execute a Substantial Completion and Operation Transfer Report for the completed portion of the Work signifying (i) that Customer accepts responsibility for operation and maintenance of the installed equipment, (ii) that the Project, or specified portion thereof, is substantially complete, and (iii) the commencement of any warranty period.

(c) Final Inspection Report. Upon completion of the Work, Customer and Authority (or their duly authorized representatives) shall promptly inspect the entire Facility, or applicable portions thereof. Authority or its Service Providers will confirm that the Work has been satisfactorily completed according to the provisions of this Master Agreement and the applicable CPC. Authority and Customer shall jointly sign a Final Inspection Report.

7. Maintenance and Post-Installation Audit. Authority will provide Customer with information regarding the maintenance of Project installations and recommendations for appropriate replacement equipment to be used in those installations to facilitate proper usage and, if applicable, energy savings at Customer's Facilities. After the Project installations are completed, Customer shall use reasonable efforts to see that such maintenance and materials instructions are followed at its Facilities. While any portion of the Customer's Short-Term Repayment Obligation remains outstanding, Authority may, upon reasonable notice to Customer, audit installations in Customer's Facilities to evaluate compliance with such maintenance and materials instructions.

8. Project Closeout for Capital Projects. Notwithstanding the terms set forth in the CPC or Final CPC, the Customer shall, within the time specified in the Final CPC, (a) repay the Short-Term Repayment Obligation or (b) convert the Short-Term Repayment Obligation to a Long-Term Repayment Obligation and enter long term repayment consistent with the Authority's policies and procedures. The Customer shall make payment of that portion of the Short-Term Repayment Obligation that is not converted to the Long-Term Repayment Obligation upon receipt of the Authority's invoice and in accordance with the terms of this Master Agreement. The Short Term Repayment Obligation, as set forth in the Final CPC, shall include the Authority's estimate of Short-Term Interest to be accrued between the issuance of the Final CPC and conversion to long term repayment.

9. Authority Obligations. In addition to the obligations otherwise set forth herein and the respective CPC, Authority shall require the Service Provider to adhere to the Project's design

and technical specifications as set forth in the CPC and minimize any interference with the normal operations at Customer's Facility.

10. Customer Obligations. In addition to the obligations otherwise set forth herein and the respective CPC, Customer shall promptly review all completed installations. Customer shall review and approve, as may be required, any corrective or restoration Work resulting from improper work by the Service Provider.

11. Customer-Supplied Equipment and/or Work. Customer and Authority may agree in the CPC for the provision of Customer materials and/or completion of Customer work in connection with a Project, independent of Authority. If so, then Customer shall be responsible for any changes to the Project schedule, scope of Work or any increase in the Total Reimbursement Costs caused by Customer due to non-delivery of Customer materials or non- or late performance of Customer work and Authority shall issue any necessary Contingency Work Order or Change Order, as applicable. Authority may suspend its Work on the Project until Customer approves such Change Order. Furthermore, if the Customer does not meet the Project schedule with respect to Customer materials and/or Customer work, Authority has the right to terminate the Project if the delay is not cured within fifteen (15) days of written notice thereof by Authority to Customer and turn it over to Customer for completion without any liability on the part of Authority.

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NEW YORK STATE OF OPPORTUNITY. | NY Power Authority

EXHIBIT C

ADVISORY SERVICES TERMS AND CONDITIONS

1. Application. In addition to the terms and conditions set forth in the main body of this Master Agreement, these Advisory Services Terms and Conditions shall apply to all Advisory Services Projects provided by Authority or Service Provider to Customer pursuant to the Master Agreement.

2. Advisory Services. Upon Customer's request, Authority may provide any or all of the Advisory Services described below. Advisory Services may be provided by Authority employees and/or Service Providers with expertise in the area as determined by Authority. Authority and Customer will cooperate in good faith during the performance of such Advisory Services.

3. Description of Services

(a) *Review*. Review of information provided by the Customer regarding, among other things, Customer's site conditions, future plans for modifications to facilities, operations and/or usage, historical utility data, any relevant strategic plans or initiatives, and other relevant requirements that are specific to Customer.

(b) *Meetings*. Participate in meetings and conference calls as mutually agreed upon by the parties as being in the best interests of the Project or as otherwise detailed in the Customer Project Commitment.

(c) *Site Observations*. Observe Customer's facilities, physically or remotely via electronic means as determined by the Authority to assess the condition of existing equipment and physical site conditions.

(d) *Analysis*. Analyze data presented by Customer and/or collected by or on behalf of the Authority. Outreach to appropriate third parties as necessary to coordinate and/or collect additional data.

(e) *Advice and Guidance*. Deliver oral or written advice, guidance and other recommendations communicated via in person meetings, telephone conversations, or correspondence.

(f) *Deliverables and Reports*. Prepare reports, memorandums, and other documents that memorialize the advice, guidance and recommendations delivered to the Customer and support the Customer's underlying project, where applicable.

The foregoing descriptions are given by way of example and not by way of exclusion. Advisory Services may include services that have not yet been developed or approved by Authority

to date, provided such services are described in a CPC signed by both Parties to this Master Agreement.

4. Further Assistance; Information. In addition to the obligations set forth herein and the respective CPC, Customer shall provide Authority and/or Service Providers with such assistance as may be required to perform the Advisory Services. This may include, but is not limited to, providing access to the Customer's Facility(ies), information such as historical utility data, maintenance logs, existing feasibility studies, reports, equipment drawings or any other information or services reasonably requested by Authority and/or Service Providers.

* * * * * *

Arencibia, Stephanie (Molly)

From:	Richard Sullivan <rsullivan@highlands-ny.gov>
Sent:	Tuesday, April 9, 2019 5:37 AM
To:	Laino, Jeffrey
Cc:	Luteran, Kevin
Subject:	[EXTERNAL]Presentation

CAUTION â€" External Email

Suspicious? Click Report Phishing on Outlook toolbar. For Mobile forward to (abuse@nypa,gov)

Jeff,
Not sure if Kevin is your associate, subordinate, or supervisor, but I wanted to let you know you were concise, germane , well poised and delivered a very well received workup, thank you.
Just a bit on the Village of Highland Falls- in 2016 there was a different team in place, they had an electrician as a trustee who invited NYPA to implement a similar program , but once removed from power, the current team , who I like, ended that effort.
I did speak with the village liaison to streetlights yesterday, and the village has over 250 lights, O and R is changing 7 per year , that would be a lame 30 year effort, and savings would be barely recognized. O and R does have some deal where for an extra $169 per light they will do more per year, and thatâ€™s about all I know about their program, or lack thereof.
So as a good neighbor I kept the village out of it, I tried contacting their Point man since late Feb., no response until yesterday so the citizens you met last night will be charged with the task of inviting/ pressuring the village to participate, either way that is a separate body of government .
I / we look forward to advancing this effort, and with a trustworthy body like NYPA , and the issue of maintenance after ownership being addressed by NYPA and included in your workup, I believe this will be at least plausible, hopefully executable project, and again thank you. When the local paper does an article on this (this Thursday), Iâ€™ll share an online copy if you desire.
Have a great day, Richie

Sent from my iPad

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Sent:	Wednesday, April 10, 2019 8:51 PM
To:	Laino, Jeffrey
Cc:	Luteran, Kevin
Subject:	Re: [EXTERNAL]Presentation

Pleasant Wednesday Jeff,
Sometimes I have days where I have no free time, sorry for delay .
Timeline- next meeting (Earth Day) after community input it is my job to steer public perception so no one kills this effort, I expect that to go well, and last eve I spoke with the supervisor, he really likes the project. The supervisorâ€™s son is on the Village of HF board, and that is who referred a bright LED in his backyard to me, the light was installed by O & R and Iâ€™ve subdued the original concern to both supervisor and his son based on options you presented.
In doing my diligence, Iâ€™ve contacted (long before you) O & R to see what they may offer, so my very best guess is either first meeting in May or possibly the second (near Memorial Day) the decision will be final, I wonâ€™t let it go beyond that timeframe.
Iâ€™ll send tomorrowâ€™s article in the local paper to you, and I may have a question or two over the next few weeks, I hope that timeline is plausible.
Obliged, Richie

Sent from my iPad

> On Apr 9, 2019, at 9:23 AM, Laino, Jeffrey <Jeffrey.Laino@nypa.gov> wrote:
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> Good Morning Richie,
> Thank you for the email, it was my pleasure to present the NYPA street lighting proposal to the Supervisor and Council members last night. I hope all their questions were answered but please reach out to me if any additional questions arise.
> I am attaching the Authorization to Proceed and a sample Master Cost Recovery Agreement(MCRA). These are the 2 documents NYPA will need executed in order to begin the project implementation. I will have the contracting unit at NYPA email you an executable version of the MCRA upon request.
> What do you think the timeline is for the Town to make a decision on moving forward with the project?
> Let me know if there is anything else you need and please send me a link to any news articles regarding the project.
> Thank you and looking forward to working with you.
>
> Jeff Laino
> Customer Business Development Representative New York Power Authority
> 123 Main Street
> White Plains, NY 10601
> (914) 287-3351 (office)
> (914) 312-1260 (cell)
> Jeffrey.Laino@nypa.gov
> www.nypa.gov
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> <Sample 2017 MCRA - Statewide 07242017.pdf>
> <NYPA Street Lighting Authorization to Proceed.pdf>

Arencibia, Stephanie (Molly)

From:	Laino, Jeffrey <Jeffrey.Laino@nypa.gov>
Sent:	Thursday, April 11, 2019 8:22 AM
To:	Richard Sullivan
Subject:	RE: [EXTERNAL]Presentation

No worries, my days get crazy too at times.
Whatever timeline the Town to make a decision is fine.
The Town should be requesting a purchase price from O&R by sending a letter to the Account Manager requesting a purchase price for the street lights. It is non binding but the process of purchasing takes about 6 months and NYPA cannot installing lights until the Town owns the old ones. We can do the design and bidding, but wouldnâ€™t be permitted to start installs.

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> Jeff,
> Not sure if Kevin is your associate, subordinate, or supervisor, but I wanted to let you know you were concise, germane , well poised and delivered a very well received workup, thank you.
> Just a bit on the Village of Highland Falls- in 2016 there was a different team in place, they had an electrician as a trustee who invited NYPA to implement a similar program , but once removed from power, the current team , who I like, ended that effort.
> I did speak with the village liaison to streetlights yesterday, and the village has over 250 lights, O and R is changing 7 per year , that would be a lame 30 year effort, and savings would be barely recognized. O and R does have some deal where for an extra $169 per light they will do more per year, and thatâ€™s about all I know about their program, or lack thereof.
> So as a good neighbor I kept the village out of it, I tried contacting their Point man since late Feb., no response until yesterday so the citizens you met last night will be charged with the task of inviting/ pressuring the village to participate, either way that is a separate body of government .
> I / we look forward to advancing this effort, and with a trustworthy body like NYPA , and the issue of maintenance after ownership being addressed by NYPA and included in your workup, I believe this will be at least plausible, hopefully executable project, and again thank you. When the local paper does an article on this (this Thursday), Iâ€™ll share an online copy if you desire.
> Have a great day, Richie
>
> Sent from my iPad
> <Sample 2017 MCRA - Statewide 07242017.pdf> <NYPA Street Lighting
> Authorization to Proceed.pdf>

Arencibia, Stephanie (Molly)

From:	Laino, Jeffrey <Jeffrey.Laino@nypa.gov>
Sent:	Tuesday, April 16, 2019 12:12 PM
To:	Richard Sullivan
Subject:	RE: [EXTERNAL]Media

Thanks!

From: Richard Sullivan <rsullivan@highlands-ny.gov>
Sent: Tuesday, April 16, 2019 11:49 AM
To: Laino, Jeffrey <Jeffrey.Laino@nypa.gov>
Subject: [EXTERNAL]Media

Jeff, we did not make last weeks paper, this week (Thurs) should have the article. Until then, if you care to see yourself in action, the video of the meeting , I'll be in touch after nexts weeks meeting which I hope the public stays inclined toward this project.
Richie

https://youtu.be/3dKPCJ686Ns
Sent from my iPad

Arencibia, Stephanie (Molly)

From: Richard Sullivan <rsullivan@highlands-ny.gov>
Sent: Monday, April 22, 2019 7:34 AM
To: Laino, Jeffrey
Subject: [EXTERNAL]Last weeks paper
Attachments: IMG_1303.jpg; ATT00001.txt; IMG_1304.jpg; ATT00002.txt

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CAUTION â€" External Email

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Thought youâ€™d enjoy seeing ...
Chat soon
Richie

LED street lights keep coming up

Town heard NYPA presentation on converting

By MARY JANE PITT

The Town Board heard two presentations at its meeting on April 8. While no decisions on either topic were made -- the board went into the evening knowing the presentations were informational only -- the speakers did give board members "plenty of food for thought", Supervisor Bob Livsey said.

The first topic was LED street lights, and the presenter was Jeff Laino from the New York Power Authority.

He'd met Councilman Richard Sullivan at the annual Association of Towns meeting recently, and came to speak to the board about NYPA programs for towns to convert traditional street lights -- which use more energy than LED lights -- to the newer technology lights.

"It's really catching on across the state," Laino said, "and communities are recognizing great savings in both electricity and maintenance costs." He explained that often the lights are more aesthetically pleasing too, "mimicking moonlight as opposed to the more yellow lights you have now".

Fort Montgomery has 167 lights and would be considered a "small project" for NYPA he said as he explained through their 'Smart Street Lighting NY' program the town could finance the purchase and installation of new lights, at about a 2.5 percent interest rate. He said he estimated the cost would be about $164,000, which would include the $58,000 it would cost to purchase the current lights from O&R. He also estimated that with potential savings in electric costs, the town could pay back that loan in about seven years.

He answered many questions about how wattage on LED lights could be different in residential neighborhoods versus business areas ("yes"); the life expectancy of LED fixtures (15-25 years); and if grants to help pay for new lights (typically only available for light packages that include "bells and whistles" like cameras, traffic controllers, etc., "Laino said).

Currently, Sullivan said, the town spends about $45,000 on street lighting.

From the audience, Laino was asked why the lights in Highland Falls weren't included in the presentation -- while that is due to the fact that the town and village pay for their street lights separately, Laino said he'd be happy to talk with village officials.

NYPA's goal, he said, is to convert 500,000 street lights to LED by the year 2025.

Former Town Councilman Bill Edsall lent his support to the project, saying that the research he did showed the town would get "a good return on its investment". He added "the cost of electric keeps rising".

The second topic was cell towers, by James O'Gorman of Communications Engineering.

... might attend; ... invited by public would be advised of the results of the meeting at a later date -- which also means they would not have input.

I submit that many of the 'public'/taxpayers are very knowledgeable of past village goings on -- through time -- and may very well have participated "in some of the 12 previously done studies", be it the Glynwood or Marina studies or others.The out-of-town invitees are a very select group, many of which participated in the earlier marina or other studies, but they do not pay taxes in this community. In my view, keeping all but a few chosen citizens out of a very critical meeting pertaining to the future of the village is not only short-sighted, but insulting to the taxpayers of the village.

Hopefully the mayor will reverse his position and open the meeting to those concerned residents who would like to attend. I submit, they doubtless will contribute toward the end result.

Ray Devereaux

Dear MJ:

According to new research published in the journal Atmospheric Chemistry and Physics: despite significant improvements, 71,000 air pollution-related deaths in 2010 translates to one out of every 35 deaths in the U.S. that year -- as many as from traffic accidents and gun shootings combined.

In Europe, nearly 400,000 people a year die prematurely because of poor air quality according to the European Union.

I don't think a day goes by when there is a weather event on the news that I associate with climate ... about plastics in our oceans are heart breaking.

Monday April 22 is Earth Day: I ask the residents of our Town to take a moment and think about what we can each do to make a better future for our children and our planet.

Bill Edsall

Dear Editor,

Because I have not lived in Highland Falls for decades, I have refrained from responding to any of the letters to the editor, but Deborah Kopald's misrepresentations about LED bulbs need to be addressed.

Although most of her assertions are wrong or flimsy, her claim that the American MEdical Association "came out against them" is dead wrong. It also undercuts all of her other wild claims. The AMA supported LEDs.

Sunlight has its dangers. All or almost all artificial lights have problems. Unshielded red LEDs present unique problems. Almost all museums and galleries use soft, reflected light to minimize UV damage and use 'museum' glass to block UV rays.

I am the president of the 85-year-old Print Club of Albany and its Museum of Prints and Print Making and I know how to avoid UV rays. We have a collection of more than 18,000 prints and take very good care of them.

There is no debate that LEDs are vastly more energy efficient than compact flourescent lights, and LEDs do not contain mercury, like CFLs. Mercury is very harmful.

A GOOGLE search shows lot of articles with positives and negatives about LEDs, but the positives far outweigh the negatives, and the negatives can be mitigated.

Joe Galu

(I am not employed by any part of the LED industry.)

ay at the ...

Arencibia, Stephanie (Molly)

From:	Laino, Jeffrey <Jeffrey.Laino@nypa.gov>
Sent:	Tuesday, July 23, 2019 8:52 AM
To:	Richard Sullivan
Subject:	FW: [EXTERNAL]Town of Highlands_ES_MCRA_2019 between New York Power Authority , mERVIN R. LIVSEY and John Canale is Signed and Filed!
Attachments:	Town of Highlands_ES_MCRA_2019 - signed.pdf; NYPA Street Lighting Authorization to Proceed.pdf

Hi Richie,
See attached signed MCRA. Also attached is the Authorization to Proceed. Once I receive the ATP I can initiate the project and get an engineer assigned to the project so we can schedule a kick off meeting.
Thank you for your help with moving this along!!
Jeff

From: New York Power Authority <echosign@echosign.com>
Sent: Tuesday, July 23, 2019 8:39 AM
To: Canale, John <John.Canale@nypa.gov>; Parille, Lindsay <Lindsay.Parille@nypa.gov>; mERVIN R. LIVSEY <blivsey@highlands-ny.gov>
Cc: Paine, John <John.Paine@nypa.gov>; Laino, Jeffrey <Jeffrey.Laino@nypa.gov>
Subject: [EXTERNAL]Town of Highlands_ES_MCRA_2019 between New York Power Authority , mERVIN R. LIVSEY and John Canale is Signed and Filed!

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Town of Highlands_ES_MCRA_2019 between New York Power Authority , mERVIN R. LIVSEY and John Canale is Signed and Filed!

From: NEW YORK POWER AUTHORITY - Lindsay Parille (New York Power Authority)
To: John Canale, NEW YORK POWER AUTHORITY - Lindsay Parille and mERVIN R. LIVSEY

Cc: New York Power Authority John Paine and jeffrey.laino@nypa.gov

Attached is a final copy of **Town of Highlands_ES_MCRA_2019**.

Copies have been automatically sent to all parties to the agreement.

You can view the document in your Adobe Sign account.

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NEW YORK STATE OF OPPORTUNITY. | NY Power Authority

ANDREW M. CUOMO
Governor

JOHN R. KOELMEL
Chairman

GIL C. QUINIONES
President and Chief Executive Officer

April 5, 2019

Supervisor Bob Livsey
Town of Highlands
254 Main Street
Highland Falls NY 10928

RE: Energy Services Program
Authorization to Proceed with turn-key street light project
Town of Highlands– LED Street Lighting

Dear Supervisor Livsey,

The New York Power Authority (NYPA) is excited to support the Town of Highlands in identifying and implementing a comprehensive street lighting upgrade. Improving the existing street lights is a widely used and effective strategy to achieve the goal of reducing energy consumption, lowering utility costs, and improving light quality throughout the community.

Consistent with the Master Cost Recovery Agreement, NYPA provides a turn-key solution to upgrade the Town of Highlands's existing street lights to energy efficient LED technology. NYPA is pleased to offer these services to replace approximately 167 existing street light fixtures with new high efficient LED technology.

By signing below, the Town of Highlands authorizes NYPA to proceed with the full turn-key solution of the LED street lighting project, which includes the final design report, conducting bids for materials and installation labor, providing construction management, and commissioning the final project. When the design and bidding is completed, you will receive an Initial Customer Installation Commitment (ICIC) for your review and signature. At this point, if you choose to proceed to project implementation all development costs will be rolled into the overall project. Conversely, should you decide not to proceed with the implementation of the project, the Town of Highlands agrees to reimburse NYPA for all costs incurred up to the termination date for the development, design and bidding of the project. The cost of developing the design and for bidding the materials and labor will be determined during the next phase. NYPA will be fully transparent through this process and provide complete documentation as to how it determined all project costs.

By signing below, affirm that you agree to these conditions:

NEW YORK STATE OF OPPORTUNITY. | NY Power Authority

Joseph Rende	
(Name, printed)	(Name, printed)
Senior Director, Customer Business Development	
(Title)	(Title)
(Signature)	(Signature)
(Date)	(Date)

123 Main Street, White Plains, NY 10601 | 914-681-6200 | www.nypa.gov

NEW YORK STATE OF OPPORTUNITY. | NY Power Authority

Master Cost Recovery Agreement No. ____________________
Effective Date: ____________________

ENERGY SERVICES PROGRAM

MASTER COST RECOVERY AGREEMENT

BETWEEN

POWER AUTHORITY OF THE STATE OF NEW YORK

AND

TOWN OF HIGHLANDS

ENERGY SERVICES PROGRAM
MASTER COST RECOVERY AGREEMENT

This Master Cost Recovery Agreement (this "Master Agreement"), dated Jul 23, 2019 ____________________________________, is entered into by and between POWER AUTHORITY OF THE STATE OF NEW YORK, a corporate municipal instrumentality of the State of New York with offices located at 123 Main Street, White Plains, New York 10601 ("Authority") and the Town of Highlands, a municipality with offices located at 254 Main Street, Highland Falls, NY 10928 ("Customer").

WHEREAS, Public Authorities Law §1005(17) permits the Authority, as deemed feasible and advisable by the Trustees, to finance and design, develop, construct, implement, provide and administer energy-related projects, programs and services for any public entity and certain other specified entities; and

WHEREAS, the Trustees have authorized the establishment of the Authority's Energy Services Program ("ESP") to include, among other things, energy efficiency projects and services, clean energy technology projects and services and high-performance and sustainable building projects and services (including technologies that reduce air and other pollution and conserve materials and resources such as water); and the construction, installation and/or operation of facilities or equipment done in connection with any such projects, programs or services; and

WHEREAS, Public Authorities Law §1005(17) permits Customer, a public entity, to enter into an energy services contract with the Authority for such energy-related projects, programs and services as authorized by Public Authorities Law; and

WHEREAS, Authority and Customer desire to work together to develop and implement Projects contemplated under the ESP and to enter into this Master Agreement as more particularly set forth herein.

NOW, THEREFORE, Authority and Customer (sometimes referred to herein collectively as the "Parties" and individually as a "Party"), in consideration of the mutual covenants and conditions contained herein and in these recitals, hereby agree as follows:

DEFINITIONS

The following definitions apply for all purposes of this Master Agreement:

"Advisory Services" means the consulting services provided by Authority or Service Providers to assist Customer in its efforts to reduce energy consumption and associated operations and maintenance costs, to realize environmental benefits, including but not limited to the reduction of air pollution; to conserve natural resources; and/or facilitate the use of clean energy sources at Customer's Facilities.

"Advisory Services Terms and Conditions" means the additional terms and conditions set forth in Exhibit C applicable to Advisory Services Projects provided by Authority or Service Provider to Customer hereunder.

"Ancillary Documents" means documents, other than this Master Agreement and the Customer Project Commitment (and documents that modify them, such as Change Orders and Contingent Work Orders), covering information necessary for the implementation of a specific Project, such as authorizations, Substantial Completion and Operation Transfer Reports, Milestone Completion Reports and Final Inspection Reports, etc.

"Authority's Authorized Representative" means an individual designated by Authority in accordance with Section 10.1(b) to coordinate a Project on behalf of Authority and to communicate with Customer concerning such Project.

"Authority Implemented Work" means Work undertaken by Authority for Customer as more fully set forth in a CPC (subject to the terms and conditions of this Master Agreement and any applicable Transaction Document) through the services of qualified Service Providers or Subproviders engaged by Authority.

"Authority Material Handling Fee" is a fee applied by the Authority to the cost of materials purchased directly by the Authority for a Project, where applicable, to reimburse the Authority for procurement, material handling, storage and/or restocking. The amount of such fee, when applicable to a Project, will be set forth in the CPC, as superseded by the Final CPC.

"Authority Program Fee" mean Authority's fee applicable to each Project. Details of the Authority Program Fee will be set forth in the Compensation Schedule, attached hereto as Exhibit A, and the amount of such fee will be set forth in the CPC, as superseded by the Final CPC.

"Background Intellectual Property Rights" means Intellectual Property Rights of a Party owned, controlled, acquired, developed, invented, generated, authored, conceived or reduced to practice prior to the date of this Master Agreement, or acquired parallel to and independent of this Master Agreement or any Transaction Documents entered into under this Master Agreement.

"Capital Project" is a Project involving the design, construction, installation and/or modification of facilities and/or equipment in Customer's Facility.

"Capital Project Terms and Conditions" means the additional terms and conditions set forth in Exhibit B applicable to Capital Projects provided by Authority or Service Provider to Customer hereunder.

"Change Order" is a Transaction Document that memorializes a modification to the CPC that cannot be made by Contingency Work Order, setting forth agreed-upon additions, deletions or revisions to the Work, and the cost and/or time impact to the Project.

"Compensation Schedule" is a schedule attached hereto as Exhibit A setting forth details about the Authority Program Fee and other relevant Project costs, where applicable, for the different services offered by Authority under this Master Agreement.

"Contingency Work Order" is a Transaction Document that memorializes the Authority's use of the Project Contingency for a Project, such use to be reflected on subsequent CPCs that are executed for the particular Project.

"Customer's Authorized Representative" means an individual designated by Customer in accordance with Section 10.1(a), to coordinate a Project on behalf of Customer and to assist Authority, its Service Providers and Subproviders with the implementation of the Project.

"Customer Project Commitment" or "CPC" is a Transaction Document containing terms and conditions for one or more specific Projects at a Customer's Facility(ies) that includes, at a minimum, the location of Customer's Facility, a detailed scope of Work (including a description of milestones, if any), the projected Project costs and any specific payment terms applicable to the Project.

"Debris" shall mean unregulated materials removed from a Customer Facility and unsuitable for further use.

"Environmental Laws" means all current and future federal, state and local laws (including common law), treaties, regulations, rules, ordinances, codes, decrees, judgments, directives, orders (including consent orders), environmental permits, and obligations and other requirements imposed by any "Governmental Authority" (as defined herein), including New York State Department of Environmental Conservation ("NYS DEC") Technical Administrative Guidance Memoranda and other guidance documents issued or published by any Governmental Authority, in each case, relating to pollution, protection of the environment, natural resources, or protection of human health and safety from conditions in the environment, the presence, "Release" (as defined herein) of, threatened Release of, or exposure to, "Hazardous Substances" (as defined herein), or to the generation, manufacture, processing, distribution, use, treatment, storage, transport, recycling or handling of, or arrangement for such activities with respect to, Hazardous Substances.

"Environmental Liabilities" means all liabilities, obligations, damages, losses, claims, actions, suits, judgments, orders, fines, penalties, fees, expenses, and costs, relating to environmental conditions or activities, including (i) Remediation costs, engineering costs, environmental consultant and expert fees, laboratory fees, permitting fees, investigation costs, defense costs, and reasonable attorneys' fees and expenses; (ii) any claims, demands, and causes of action relating to or resulting from any personal injury (including wrongful death), property damage (real or personal) or natural resource damage; and (iii) any penalties, fines or costs associated with the failure to comply with any Environmental Law.

"Energy Services Program" or "ESP" includes energy efficiency projects and services; clean energy technology projects and services; high-performance and sustainable building programs and services (including technologies that reduce air and other pollution, conserve materials and resources such as water); and the construction, installation and/or operation of facilities or equipment done in connection with any such project, programs and services.

"Facility" means the building, structure or premises owned and/or operated by Customer that may benefit from Customer's participation in Authority's ESP Program.

"Final CPC" means the document that reflects the final reconciliation of Project costs and all amendments to the CPC that is issued by Authority to Customer upon completion of the Work for a Project.

"Final Inspection Report" means the report, if any, to be executed by Authority and Customer after completion of a Project.

"Hazardous Substances" means (i) any petroleum, petroleum products or byproducts, and all other regulated hydrocarbons (including without limitation, petrochemicals and crude oil), or any fraction thereof, coal ash, radon gas, asbestos, asbestos-containing material, urea formaldehyde, polychlorinated biphenyls, chlorofluorocarbons, and other ozone-depleting substances; and (ii) any chemical, material, substance, product or waste (including thermal discharges and hazardous waste) that is prohibited, limited, or regulated by or pursuant to any Environmental Laws.

"Intellectual Property Rights" means any and all intellectual property rights, including, but not limited to rights in any and all of the following: (i) technical information and know-how; (ii) discoveries, improvements, enhancements, upgrades, inventions, (whether or not patentable); (iii) patents, patent applications, patent disclosures, and any other patentable subject matter; (iv) copyrights, applications to register copyrights, works of authorship and any other copyrightable works; (v) trademarks, trade names, trade dresses, brand names, logos and similar marks; (vi) any sketches, drawings, outlines, drafts; (vii) computer software (including source code, executable code, databases, data and related documentation); (viii) trade secrets and know-how; and (ix) all improvements or modifications to any of the foregoing.

"Labor Cost" is that portion of the Total Reimbursement Costs for installation labor performed by Service Provider and Subprovider in connection with the Work performed in connection with a Project pursuant to a CPC based on this Master Agreement. Such costs will be detailed in each CPC.

"Long-Term Repayment Obligation" means the obligation of Customer to repay Authority in accordance with and subject to the terms of a loan agreement after conversion of a Short-Term Repayment Obligation.

"Material Cost" is that portion of the Total Reimbursement Costs related to equipment, materials and supplies in connection with the Work performed in connection with a Project pursuant to a CPC based on this Master Agreement. Such costs will be detailed in each CPC.

"Milestone Completion Report" means a document generated by Authority or Service Provider that identifies a milestone(s) satisfactorily completed during the progress of a Project or phase of a Project (i.e., design, construction, or otherwise), signifies Customer's concurrence with the completion of such milestone and represents Customer's authorization to proceed to the next milestone or phase of the Work, as applicable.

"Other Agreement" means any stand-alone agreements entered into between the Parties at any time, including, without limitation, non-disclosure agreements, privacy agreements, or grant agreements, but shall not include any Master Cost Recovery Agreement, Energy Efficiency Services Agreement or other agreements governing services under the ESP entered into by the Parties prior to the execution of this Master Agreement.

"Project" means any project or service undertaken through Authority's ESP pursuant to a CPC based on this Master Agreement.

"Project Contingency" means a defined budget to be utilized at the Authority's discretion in accordance with Section 2.3 hereof for, among other things, unexpected costs and expenses that may arise during the performance of a Project (usually calculated as a percentage of Material Cost and Labor Cost).

"Release" means any actual or threatened release, spill, emission, emptying, escape, leaking, dumping, injection, pouring, deposit, disposal, discharge, dispersal, leaching, or migration into the environment or within any building, structure, facility, or fixture and/or the exacerbation of any preexisting condition of Hazardous Substances.

"Remediation" means the investigation (including any feasibility studies or reports), cleanup, removal, abatement, transportation, disposal, treatment (including in-situ treatment), management, stabilization, neutralization, collection, or containment of Hazardous Substances and any Release(s), that may be required to satisfy Environmental Laws, in each case, including, without limitation, any closure, restoration or monitoring, operations and maintenance activities, including any engineering or institutional controls, that may be required by any Governmental Authority after the completion of such investigation, study, cleanup, removal, transportation, disposal, treatment, neutralization, collection, or containment activities as well as the performance of any and all obligations imposed by any Governmental Authority in connection with such investigation, cleanup, removal, transportation, disposal, treatment (including in situ treatment), management, stabilization, neutralization, collection, or containment (including any such obligation that may be imposed pursuant to an Environmental permit or a consent order).

"Service Provider(s)" means a third party provider of goods and/or services that Authority, acting as the contracting entity, contracts with through its procurement policies, procedures and guidelines to perform Work in connection with a Project at Customer Facilities.

"Service Provider Fees" means the costs associated with the payment to Service Providers, its Subproviders and other third party professionals for Work performed with respect to a specific Project. Service Provider Fees will be detailed in each CPC.

"Short-Term Interest" is a cost component of the Total Reimbursement Costs of a Project representing the costs incurred by the Authority in connection with financing the delivery of a Project during the time within which such funds remain unpaid by Customer.

"Short-Term Repayment Obligation" refers to Customer's obligation to reimburse Authority for the costs of delivering a Project, as identified in the Final CPC.

"Short-Term Repayment Obligation Maturity Date" means the date set forth in the Final CPC, no later than ninety (90) days following the approval of the Final CPC.

"Specific Subject Matter" shall mean intellectual property rights, Authority's liability and limitation thereof, Project warranties, and amendments to this Master Agreement and/or any Transaction Documents.

"Subprovider(s)" refers to individuals or entities retained by the Service Provider(s) to perform all or part of the Work.

"Substantial Completion and Operation Transfer Report" is a document signed by the Parties signifying that the equipment and/or facilities installed at the Project have been inspected, tested and accepted by Customer.

"Third Party" means any utility company, permit agency, governmental authority having jurisdiction over a Project, any contractor or service provider hired by Customer, or any other third party that is not a Service Provider or Subprovider but is, directly or indirectly, involved in or whose approval is required in connection with, a Project and not under contract, directly or indirectly, with the Authority.

"Total Annual Energy Savings" is the estimated net reduction in Customer's annual usage of (a) energy service, (b) other utilities including, but not limited to, water and sewer, and (c) any related operation or maintenance savings, if applicable, resulting from the installation of one or more energy conservation measures in accordance with this Master Agreement.

"Total Reimbursement Costs" is the sum of all of the costs of a Project as set forth in the CPC and Final CPC, including, but not limited to, to the extent applicable to such Project: (1) Material Cost; (2) Labor Cost; (3) the amount of the Project Contingency applied as a Project cost; (4) Service Provider Fees; (5) Authority Program Fee; (6) Short-Term Interest; and (7) other Project-related costs and expenses.

"Transaction Document(s)" means with respect to a Project, this Master Agreement and any related Customer Project Commitment and any document that modify them, such as Change Orders and Contingency Work Orders.

"Waste" refers to waste PCBs (as defined by the United States Environmental Protection Agency ("USEPA") in 40 CFR Part 761) and hazardous waste (as defined by the USEPA in 40 CFR Part 261 and the NYS DEC in 6 NYCRR Part 371) as well as other material regulated for purposes of release, reuse, disposal, or recycling (e.g. CFCs, ethylene glycol, mercury, oil, asbestos), which form a part of the equipment removed from Customer Facilities due to implementing the Work. Disposal of such Waste shall be conducted in accordance with the provisions set forth in Article IV.

"Work" means the services performed for Customer for a selected Customer Facility pursuant to this Master Agreement and the other Transaction Documents for a Project. The scope of Work shall be described in the CPC, as amended by subsequent Change Orders, Contingency Work Orders, and the Final CPC.

ARTICLE I

SCOPE AND APPLICATION OF AGREEMENT; ORDER OF PRECEDENCE

1.1 Transaction Documents. In connection with each Project, the Parties will, either concurrently with or subsequently to this Master Agreement, enter into one or more Customer Project Commitments, or similar memoranda, that define a specific Project(s) and the costs and fees associated with such Project, and associated Ancillary Documents. Except as otherwise expressly set forth therein, all Transaction Documents, upon execution by the Parties, shall be

governed by the terms and conditions of this Master Agreement. Each Transaction Document shall contain a specific reference to this Master Agreement and CPC, as applicable. This Master Agreement does not obligate Authority to accept requests for Projects issued by Customer or obligate any Party to enter into a CPC.

1.2 Entire Agreement. Subject to the provisions of Section 1.4 below, with respect to a Project, this Master Agreement (including Exhibits A, B, and C and any other exhibits, schedules or appendices hereto) and any Transaction Document which specifically references a Project, constitute the entire agreement between Authority and Customer concerning such Project, and supersedes all prior negotiations, representations, contracts and agreements concerning such Project.

1.3 Conflict and Order of Precedence. In the event of a conflict between the terms of this Master Agreement and the terms and conditions set forth in another Transaction Document, or between the terms of two or more Transaction Documents in effect for a Project, the order of precedence shall be a follows: (i) the terms of the CPC for such Project (as amended by Contingency Work Orders and/or Change Orders and as superseded by the Final CPC) but solely with respect to the price (i.e., the Project's Total Reimbursement Costs), payment terms, and scope of Work (including description of milestones) of the Project; (ii) the terms of this Master Agreement; (iii) the remaining terms of the Project CPC; and (iv) the terms of any Ancillary Document. Notwithstanding the foregoing, the Parties agree that with respect to Specific Subject Matters, if the terms of a Transaction Document concerning a Specific Subject Matter are more favorable to Authority than the respective terms set forth in this Master Agreement, the more favorable terms of the Transaction Document shall prevail with respect to the Project to which it relates. (By way of example, if a Transaction Document includes a term that disclaims any warranties by Authority (or Service Provider) for Work performed, such term would prevail over the warranties set forth in Section 7.1. hereof.)

1.4 Other Agreements. This Master Agreement supersedes all Master Cost Recovery Agreements, Energy Services Agreements or other agreements governing services under the ESP entered into by the Parties prior to the execution of this Master Agreement. Notwithstanding the foregoing, this Master Agreement does not supersede and does not apply to any Other Agreements existing between Customer and Authority. Any projects which Authority has undertaken or undertakes at Customer Facilities pursuant to such Other Agreements, or under prior Energy Services Agreements under which projects remain incomplete as of the date of this Master Agreement, shall be governed by those agreements and related documents, unless otherwise agreed in writing. Termination of this Master Agreement shall have no effect on the Other Agreements which will remain in full force and effect according to their respective terms.

1.5 Amendments. This Master Agreement and any other Transaction Document executed in connection herewith may be amended only in writing signed by an authorized officer or designee of Authority and Customer.

ARTICLE II

GENERAL PROJECT STRUCTURE

2.1 Customer Project Commitment or CPC. For each Project undertaken under this Master Agreement, the parties will enter into one or more CPC(s), each of which will state the specific terms and conditions applicable to such Project, segregating the Project into logical phases to be performed consecutively. Each CPC will include, at a minimum, the phasing plan setting forth how the Project will proceed, the location of Customer's Facility, scope of Work, (including description of milestones, if any), projected Total Reimbursement Costs, and payment terms.

The Authority is not obligated to commence any Work for a particular Project unless or until a CPC is executed by Authority and Customer. Notwithstanding the foregoing, the Parties may agree to expedite the commencement of a portion of the Work associated with a particular Project prior to the execution of a CPC provided that the Parties memorialize such agreement prior to the commencement of such Work in a writing that sets forth the specific items of Work to be commenced and the associated cost of such Work. In such event, Customer agrees to bear the costs of any Work undertaken by Authority or its Service Providers for Customer in preparation for or with respect to such Project or potential Project even if no CPC is ultimately executed.

2.2 Final CPC. As soon as practicable following completion of the Work and receipt of all invoices associated with a Project, Authority will generate a Final CPC which will include all Contingency Work Orders, and all agreed-upon Change Orders, if any. The Final CPC will reconcile the Total Reimbursement Costs set forth in the CPC on the basis of Authority's actual costs and will supersede all prior CPCs. The Final CPC shall also describe the Project-specific terms for the Work completed at the Facility or Facilities, Customer's Short-Term Repayment Obligation, and the final repayment terms. Authority and Customer shall execute such Final CPC, which shall be "deemed executed" unless Customer disputes such Final CPC in writing within forty-five (45) days of the Authority's transmission thereof. If Customer timely disputes the Final CPC, then the Parties shall endeavor to resolve the dispute as expeditiously as possible in accordance with the procedures set forth in Section 11.2; provided, however, that Customer shall pay any undisputed amounts of Customer's Short-Term Repayment Obligations set forth in the Final CPC in accordance with Article V hereof.

2.3 Contingency Work Order. If unexpected costs and expenses arise during the performance of a Project, the Authority may utilize the Project Contingency, provided that (i) the scope modifications, if any, are consistent with the general nature of the Project; (ii) the modifications do not render the Project ineligible under the Authority's Energy Services Program requirements; and (iii) the cumulative increased Project costs do not exceed the Project Contingency. Contingency Work Orders may be utilized to account for, among other things, remedial work required due to design or construction omissions (whether remedial work is caused by omissions of Authority, its Service Providers or Customer) to the extent that the requirements set forth above are met. If the requirements for a Contingency Work Order are not met, Authority and Customer may negotiate a Change Order as described in Section 2.4 below.

As the Project Contingency is utilized, the Authority will issue a Contingency Work Order, which shall be effective upon issuance and automatically update the terms of the respective CPC without the need for express Customer approval. Any objections to the manner in which the Authority is utilizing the Project Contingency must be raised by the Customer in writing to the Authority within seven (7) days of the Authority's issuance of any such Contingency Work Order, or such other period of time identified in the Contingency Work Order. Failure to comply with this notice requirement by the Customer will be deemed a waiver of any claim that (i) the Project Contingency was used improperly; or (ii) that payment on account of such Contingency Work Order is disputed. Upon request, the Authority will provide Customer with periodic reports that establish an accounting of how the Project Contingency is being utilized.

2.4 Change Order. Any party to a CPC may at any time by written notice to the other party request modifications to the Work described in the executed CPC. Authority shall provide Customer with a written analysis of the effects of the requested modification(s) and, provided that the requested modification(s) do not materially alter the general scope of the Project, the Parties will negotiate a Change Order to the CPC. No Change Order shall take effect until it is approved within the time period specified in the Change Order by Authority and by Customer in accordance with Customer's procedures to authorize amendments to the CPC. In the event of a dispute over a request for a Change Order, Authority may elect to proceed with the Work in accordance with the scope of Work as set forth in the CPC (as revised by agreed-upon Change Orders and/or Contingency Work Orders), or the dispute may be treated under the provisions of Section 11.1 hereof.

2.5 Unforeseen Circumstances or Conditions. In the event that circumstances or conditions at Customer's Facility are encountered after a CPC is executed, that may require changes to the Project schedule and/or result in an increase to the Total Reimbursement Costs of the Project, Authority shall as soon as practicable notify Customer. The CPC shall be revised by a Contingency Work Order or a Change Order, as applicable, to incorporate necessary changes to the Project schedule, the scope of Work and/or any increase in the Total Reimbursement Costs, as a result of the existence of the unforeseen circumstance or condition. Customer shall assume any increase in costs as part of its Short-Term Repayment Obligation.

2.6 Third Party Obligations. The Authority shall not be held responsible for any action or failure to act of Customer, its officers, employees, agents, representatives or any Third Party, including, but not limited to, any delay in issuance or any non-issuance of a permit or approval necessary to perform or close out the Work under a Project. Any changes to the Project schedule or scope of Work or any increase in the Total Reimbursement Costs caused by such act or failure to act, shall be Customer's responsibility. If the Third Party conduct necessitates the issuance of a Change Order to compensate the Authority for any changes to the Project schedule, scope of Work or Total Reimbursement Costs resulting from such act or failure to act, Authority may suspend its Work on the Project until Customer approves such Change Order. If Customer fails to approve the Change Order within thirty (30) days of its issuance or the Project is suspended as a result for more than ninety (90) days, Authority, in its sole discretion, may terminate all Project Work and issue a Final CPC as provided in Section 3.4(d) below.

2.7 Execution and Disputes Regarding Reports. The execution of a Milestone Completion, Final Inspection, Substantial Completion and Operation Transfer Report or similar

report(s) shall not be unreasonably withheld by either Party, and the Parties shall endeavor to fully execute such report within thirty (30) days after its submittal to Customer or it shall be deemed executed unless it was disputed by Customer in writing within such thirty (30) day period. In the event of any disputes by Customer with respect to such report(s), the Parties shall endeavor to resolve such dispute as expeditiously as possible in accordance with Sec. 11.1 hereof.

2.8 Limitation on Work in Certain Premises. Absent the express written consent of Authority, no Work of any kind shall be performed in any premises of Customer used for private business use within the meaning of Section 141(b) of the U.S. Internal Revenue Code of 1986, as amended.

2.9 Eligibility Criteria. Projects will be undertaken on an individual basis in Customer's Facilities as deemed feasible and advisable by Authority and mutually agreed to by Authority and Customer. A Project will not proceed unless it satisfies (as determined by Authority in its sole discretion) Authority's requirements related to reduction in overall primary energy costs, energy conservation, results in environmental benefits and/or other requirements of the Authority's Energy Services Program, then in effect.

ARTICLE III

SUSPENSION AND TERMINATION OF PROJECTS

3.1 Suspension of Work.

(a) Suspension by Customer. Customer may direct Authority to suspend Work at any Customer Facility by written notice to Authority. Authority, and the Service Providers and Subproviders, will thereupon cease Work at that Facility as soon as practicable.

(b) Suspension by Authority. In addition to any other right by Authority to suspend Work on a Project set forth herein, Authority may suspend Work at any Customer Facility if any of the following occurs: (i) Customer fails to make payment to Authority when due; and such payment default continues for a period of ten (10) days after written notice thereof by Authority to Customer; (ii) circumstances or conditions at Customer's Facility are discovered after a CPC is executed which require changes to the Project and/or result in an increase to the Project's Total Reimbursement Costs that cannot be covered by the use of any remaining Project Contingency budgeted for the Project; (iii) a Third Party's act or failure to act causes a delay to the critical path of the Project schedule that continues for a period of thirty (30) days after written notice thereof by Authority to Customer; (iv) a delay caused by a Force Majeure event continues for a period of fifteen (15) consecutive days; (v) the existence of a hazard not caused by Authority or its Service Provider(s) that threatens the safety and protection of the site, its inhabitants or the public; or (vi) the existence of an unforeseen circumstance or condition the correction of which could reasonably be expected to (A) create an unreasonable risk for Authority or Service Provider not ordinarily associated with projects of similar size and scope (as determined by Authority); (B) create a threat to life or safety of the inhabitants or the public in general, or (C) violate applicable federal, state or local laws, regulations, codes or standards.

(c) Liability for Cost Increase as Result of Suspension. The suspension of Work by either Party pursuant to the provisions of this Section 3.1 may adversely impact the Project schedule, the scope of Work and/or the Total Reimbursement Costs. The CPC may be revised by a Contingency Work Order or Change Order, as applicable, to incorporate any necessary changes. Customer shall assume any increase in the Total Reimbursement Costs in full as part of its Short-Term Repayment Obligation unless the suspension was caused by the gross negligence or willful misconduct of Authority, its Service Provider or Subprovider, in which case Customer will not be responsible for any increase in the Total Reimbursement Costs to the extent such increase is caused by such gross negligence or willful misconduct.

(d) Resumption of Work After Suspension. In the event Work on a Project was suspended by a Party (whether pursuant to this Section 3.1 or otherwise), Authority and Customer have to agree in writing that Work shall resume before any Work on the Project can continue. In the event Work is suspended for more than ninety (90) days, Authority, in its sole discretion, may terminate Work for that Project and Authority shall issue a Final CPC as provided in Section 3.4(d) below.

3.2 Emergency. If an emergency results in or could reasonably be expected to result in personal injury or loss of life or damage or harm to property or public safety, Customer, acting in good faith in order to prevent, avoid or mitigate personal injury or loss of life or damage or harm to property or public safety may direct a Service Provider to suspend Work. Customer shall provide written notification to Authority of the suspension and events leading up to the suspension within eight (8) hours after the emergency has been stabilized. Sections 3.1(c) and (d) shall also be applicable to a suspension under this Section 3.2.

3.3 Termination of a Project. Authority may terminate a Project (and the related CPC) at any time upon thirty (30) days' prior written notice to Customer. In addition, the following incidents shall be deemed to immediately terminate a Project: (i) closure, abandonment, destruction or material damage to the Facility for which Project Work is being performed; (ii) reduction or elimination of energy savings or other modification to the Project that, in the Authority's opinion, renders the Project ineligible under the Authority's requirements for inclusion in its Energy Services Program , whether due to removal, by-passing or alteration of equipment or due to any unforeseen event; (iii) discovery of asbestos or other hazardous material in Customer's Facility that impedes the execution of the Work; and (iv) failure by Customer to make payment to Authority when due and such payment default continues for a period of thirty (30) days after written notice thereof by Authority to Customer.

3.4 Actions Upon Project Termination or Cancellation. In the event that a Project is canceled or terminated in whole or in part subsequent to execution of a CPC but prior to completion of such Project, Authority shall:

(a) Discontinue or direct Service Provider(s) to discontinue all Work and the placement of all orders for materials, equipment or labor otherwise required for the Project or terminated part of the Project, as applicable;

(b) Cancel or direct Service Provider to cancel all existing orders and subcontracts related to performance of the Project or terminated part of the Project, as applicable;

(c) Take actions reasonably necessary, or as directed by Customer in writing, for the protection and preservation of the Work and all Project-related equipment, materials and property within Authority's or Service Provider's possession and control; and

(d) Issue a Final CPC covering (i) that portion of the Total Reimbursement Cost (excluding the Authority Program Fee) actually incurred by Authority at or prior to such termination/cancellation both for the performed and for the terminated portion(s) of the Work (including, but not limited to, non-cancelable material and equipment not yet incorporated into the Work); (ii) the costs for any additional services performed by Authority or Service Provider pursuant to 3.4(c) hereof; (iii) any wind-down costs incurred by Authority and its Service Providers and Subproviders as a result of the termination/cancellation, along with Service Providers' and Subproviders' reasonable and customary overhead and profit on the Work not executed; and (iv) the Authority Program Fee. The Authority Program Fee for a Project that is terminated or canceled prior to completion shall be as set forth in the Compensation Schedule, unless otherwise agreed upon by the Parties in the CPC.

ARTICLE IV

ENVIRONMENTAL PROVISIONS

4.1 Hazardous Materials and Disposal of Waste and Debris.

(a) General Responsibilities. With respect to Authority Implemented Work, Authority shall require that Service Provider and/or Subprovider (as applicable) be responsible for environmental air monitoring and thoroughly cleaning the job site, including the removal of Waste and Debris generated as a result of a Project. Such removal may involve the management, transportation and disposal of Waste and Debris. If in the course of performing the scope of the Project Work as described in the CPC for any Authority Implemented Work, Authority encounters existing Hazardous Materials, including but not limited to Waste, any such materials shall be handled, transported and disposed of in accordance with applicable local, state and federal laws and regulations, as well as Authority's policies and procedures.

(b) Customer is Generator of Waste. The Customer acknowledges that, in accordance with USEPA and NYS DEC regulations, it is, and remains the Generator of, and holds title to, any Waste encountered during Work performed pursuant to this Master Agreement. If the Customer holds a Hazardous Waste "Generator Identification Number" for the specific site where work is being performed (as defined in Section 3010 of Subtitle C of RCRA), that number will be utilized for any and all hazardous waste disposal. If a Hazardous Waste "Generator Identification Number" does not exist, one may need to be obtained from the USEPA for each site from which Authority removes Waste. The Customer authorizes Authority, where required by USEPA and/or NYS DEC regulations, to apply in the name of the Customer for Hazardous Waste Generator Identification Numbers in order to dispose of Waste pursuant to this Master Agreement and to act as the contact Party for such applications. To the extent that the Customer is the generator of the Waste, a duly authorized representative of the Customer must sign such applications when requested by Authority. The Customer also authorizes Authority, where required by USEPA and/or NYS DEC regulations, to prepare, in the name of the Customer, any manifests or other forms required for the disposal of the Waste generated pursuant to activities under this Master

Agreement. A duly authorized representative of the Customer shall sign any manifests or other shipping records required to ship Waste offsite for disposal.

(c) Notification and Cost of Waste Disposal. With respect to Authority Implemented Work, Authority shall advise Customer (whenever possible, in advance of removal) where material determined to be Waste has been encountered which must be disposed of pursuant to USEPA and NYS DEC regulations. Authority shall keep the Customer fully informed of Authority's activities on its behalf and shall provide the Customer with copies of all applications and other materials provided or received in connection with actions taken pursuant to this authorization. The direct costs of Waste disposal will be included in the Final CPC. Any costs to Authority relating to the Project that may arise subsequent to the time the Final CPC is executed (or deemed executed) under present or future laws or regulations due to pollution, clean-up or otherwise at the site of disposal shall be borne by the Customer. If, however, such costs are due to the negligence or willful acts of Authority's Service Provider or Subprovider or due to the willful acts of Authority, the Customer shall not be responsible. With respect to Authority Implemented Work, Authority shall use reasonable diligence in overseeing the removal and disposal of Waste, shall maintain complete and accurate records thereof, and shall make those records available to the Customer upon request. In addition, any existing equipment determined by the Customer to be useful to the Customer may, at the Customer's request, be retained by the Customer and shall be the sole responsibility of the Customer.

(d) Customer Disposal of Waste. Notwithstanding the foregoing, the Customer shall have the option of disposing of Waste and Debris generated as a result of a Project at its own expense in accordance with all applicable local, state and federal laws and regulations, as well as Authority's policies and procedures.

4.2 Remediation. The Customer shall be responsible for the performance of any Remediation required under applicable local, state and federal Environmental Laws in order to address the existence or suspected existence of Hazardous Substances in, on, or under the job site that are discovered or encountered during Work performed and any Release or threatened Release in, on, under, over or migrating to, from or through the job site. The Customer shall promptly take all actions as are necessary to perform Remediation of any such Release or Discovery, and such other work as may be required by any Governmental Authority to safeguard the health, safety or welfare of any persons, the land and any improvements thereon or there under, from any Release or threatened Release or Discovery. In the case any Remediation is required, the Customer shall be responsible for restoring the affected portion or portions of the job site, together with any and all affected soil and groundwater, to the functional and topographical condition that existed prior to the Release and Remediation, as well as to the condition required by Environmental Laws, and as necessary to satisfy the requirements of any Governmental Authority exercising jurisdiction with respect to the job site for such Release or Discovery.

4.3 Environmental Indemnification. Customer shall be solely responsible for any and all loss, damage or injury to persons or property and for any cleanup costs associated with any site where Waste and Debris are disposed of or comes to be situated including, but not limited to, response and remedial costs. In addition, to the extent permitted by law, the Customer shall, at its sole cost and expense, indemnify, defend and hold harmless Authority and the State of New York against any loss, liability (including, without limitation, judgments, attorney's fees, court costs,

penalties or fines), or expenses of any type (including, but not limited to, required corrective actions) which Authority or the State of New York incurs because of injury to, or death of any person, or on account of damage to property, or any other claim arising out of, in connection with, or as a consequence of (a) the disposition or use of retained equipment by the Customer or anyone for whose acts the Customer may be liable, and (b) any cleanup costs associated with any site where Waste and Debris are disposed of or come to be situated traceable to such Waste and Debris including, but not limited to, response and remedial costs.

ARTICLE V

RECOVERY OF COSTS/REPAYMENT OBLIGATION

5.1 Project Cost. Authority shall initially pay for and/or incur costs for all components of the Total Reimbursement Costs applicable to a Project at the selected Customer Facility. Customer agrees to pay the Authority the Total Reimbursement Costs specified in the respective CPC as reconciled by the Final CPC.

5.2 Total Reimbursement Costs. The following components of the Total Reimbursement Costs may be delineated in a CPC for a particular Project:

(a) Material Cost. The Material Cost represents the cost of materials, equipment, fixtures, tools, construction equipment and machinery, water, heat, utilities, transportation and other facilities necessary for the proper execution and completion of the Work, whether temporary or permanent and whether or not incorporated or to be incorporated into the Work.

(b) Labor Cost. The Labor Cost represents (i) the sum of all wages paid to skilled trade and craft workers, plus employee benefits, payroll taxes, insurance and related costs; or (ii) the fees paid to skilled trade and craft workers that are not employees, in each case as represented on the Service Providers' or Subproviders' invoice.

(c) Project Contingency. The Project Contingency, or a portion thereof, actually applied by the Authority to the Project as set forth in a Contingency Work Order.

(d) Service Provider Fees. The Service Provider Fees represent the costs associated with the payment of Service Providers, Subproviders and other third party professionals based on actual invoices, individual billing rates based on hourly increments, or a percentage fee applied to certain Project costs, plus reimbursable expenses;

(e) Authority Program Fee. The Authority Program Fee reimburses Authority for services provided by Authority during the implementation of a Project. The Authority Program Fee can be based on a percentage fee applied to certain Project costs, a lump sum fee, individual billing rates based on hourly increments and/or other fee arrangements identified in the Compensation Schedule.

(f) Short-Term Interest. Short-Term Interest reimburses the Authority for costs incurred in connection with financing the delivery of a Project. It is based on the underlying source of funds chosen by the Authority, in its sole discretion, to finance a Project during its

implementation and may vary depending upon the actual financing product the Authority selects. In addition to the actual interest expense incurred by the Authority on the short-term debt issued for Project expenses, Short-Term Interest may include additional fees for administering the financing program including but not limited to costs incurred to secure liquidity facilities, remarketing services, purchase of an interest rate cap(s), issuing and payment agents and other financing related costs and credit premiums, if any.

(g) Other Project-Related Costs. Other Project-related costs may include Authority Material Handling Fee, Waste disposal costs, additional Project-specific insurance, surety bond costs, specialty services and other Project-specific costs not otherwise included in any of the above categories.

5.3 Billing. The specific billing method for each Project is set forth in the CPC and/or the long-term financing agreement associated with the particular Project. The final repayment amount due to the Authority will be the Total Reimbursement Costs as reconciled in a Final CPC to reflect adjustments to account for payments made or additional charges incurred by Customer and will constitute the Customer's Short-Term Repayment Obligation. In the event a Project is terminated before completion, Authority shall issue a Final CPC as provided in Section 3.4(d).

5.4 Payment.

(a) Payments. Customer shall pay any invoiced amounts to Authority within thirty (30) days of Customer's receipt of Authority's invoice. Any outstanding amounts not paid within such thirty (30) day period shall accrue additional Short-Term Interest until the date when payment is made in full. Such additional Short-Term Interest will be reflected on subsequent invoices and/or the Final CPC.

(b) Late Payment. Customer's final Short-Term Repayment Obligation shall be fully repaid on or before the Short-Term Repayment Obligation Maturity Date. Any amount due and unpaid on the Short-Term Repayment Obligation Maturity Date shall be subject to a late payment charge determined as the greater of (i) interest in accordance with the late payment rate set forth in State Finance Law §179(g); or (ii) the late charges payable under the terms of Authority's electric service, in accordance with provision 454.6 (b) of Authority's Rules and Regulations for Power Service, as such regulation may be amended from time to time. Authority, in its sole discretion, may waive the application of such late payment charge for a Project upon sufficient justification demonstrated by Customer.

5.5 Grants and Funding. Authority may pursue and apply for grants or other available funding for the respective Project, where applicable, when authorized by Customer. The Customer may assign the right to receive such grants or other available funding to the Authority, and the Authority may, at its sole discretion, accept such assignment. If Authority accepts such assignment, the Authority will apply the funds to reduce the Total Reimbursement Costs, provided the funds are actually received by the Authority by the Short Term Repayment Obligation Maturity Date.

5.6 Long-Term Financing for Capital Projects. Should Customer require financing to satisfy its Short Term Repayment Obligation for a Capital Project, the Customer may apply for permanent long-term financing through any of the financing products offered by the Authority to

convert Customer's Short-Term Repayment Obligation to a Long-Term Repayment Obligation. Authority may agree to such financing, in its sole discretion. Regardless of whether the Customer elects to utilize any of the Authority's available financing products, the Customer is responsible for satisfying its Short Term Repayment Obligation within the time constraints set forth herein.

If the Customer is interested in any of the Authority's long-term financing products, it must indicate its interest by marking the appropriate section of the CPC for the design phase of a Capital Project. To be eligible for the Authority's long-term financing products, Customer must comply with the Authority's policies and procedures for long term repayment. If Customer's long-term financing application is approved by the Authority, the Parties' obligations with respect to long-term financing will be set out in a separate loan agreement with terms and conditions agreed to by the Parties. This long-term financing option will allow the Customer to convert the Short-Term Repayment Obligation to a Long-Term Repayment Obligation.

ARTICLE VI

INSURANCE REQUIREMENTS.

Authority's agreements with the Service Providers shall provide that the Service Provider or Subproviders shall obtain and maintain the policies of insurance with the identified limits set forth in Section 6.1, unless additional policies of insurance and/or higher limits are required under the applicable CPC. The costs of such insurance will be part of the Total Reimbursement Costs.

6.1 Insurance Requirements:

(a) Workers' Compensation (inclusive of New York State disability benefits) and Employer's Liability coverage;

(b) Commercial General Liability insurance policy, including Contractual Liability and Products/Completed Operations Liability coverages, with limits of not less than $2,000,000 per occurrence for bodily injury and not less than $2,000,000 for property damage, such policies naming Authority, Customer and the State of New York as additional insureds under the policy;

(c) Automobile Liability coverage with a minimum limit of $1,000,000 per accident; and

(d) if required under the applicable CPC:

(i) Pollution Liability, including coverage for asbestos abatement, with minimum limits of $1,000,000 per occurrence;

(ii) Professional Liability insurance with a minimum limit of $1,000,000; and

(iii) Builder's risk insurance in the amount of the estimated Total Reimbursement Cost to be issued on a replacement cost basis without optional deductibles and

will include the interests of Customer, Authority, and the Service Providers. Such insurance shall be maintained until final payment has been made by Customer to Authority.

6.2 Adjustments. The types of insurances required and/or policy limits listed in Sections 6.1 above may be adjusted as Customer and Authority deem appropriate in connection with a specific CPC. The form and sufficiency of each insurance policy required to be obtained hereunder by the Service Provider or Subprovider shall be subject to approval by Authority. Authority shall hold all Certificates of Insurance submitted to the Authority by its Service Providers and Subproviders with respect to any Project implemented under this Master Agreement.

6.3 Customer Insurance Requirements. With specific regard to the ESP equipment, for so long as any portion of Customer's Short-Term or Long-Term Repayment Obligation, as applicable, remains unpaid, Customer shall procure an all risk policy of insurance which will insure the equipment for full replacement cost value against loss while the equipment is in Customer's care, custody and control. The insurance policy shall name Authority and the State of New York as additional insured and loss payees, and shall contain a full waiver of subrogation against Authority, its agents, Service Providers, Subproviders and the State of New York. Customer shall also procure a Commercial General Liability insurance policy with minimum limits of $5,000,000 per occurrence for bodily injury and property damage naming Authority and the State of New York as additional insured. In lieu of obtaining all risk and commercial general liability insurance, Customer may request in writing to Authority to self-insure against risk of loss. Authority may approve or deny such request in its sole discretion. Customer agrees to provide any relevant documents or information requested by Authority in order for Authority to make the determination that Customer has sufficient resources to self-insure. The decision to self-insure will not relieve Customer of any of the obligations imposed herein and shall afford Authority the protection against loss and rights it would have received, if Customer had obtained such policies of insurance.

ARTICLE VII

WARRANTIES, DAMAGES, LIABILITY, ETC.

7.1 Service Provider's Warranty Requirements. Authority's agreements with its Service Providers shall provide that all Work performed and any materials provided by the Service Providers under the agreements shall be free from any defects. Such agreements shall further provide that any defective Work or materials identified within one (l) year after (i) execution (or deemed execution) by the Parties of a Substantial Completion and Operation Transfer Report or (ii) if no such report must be signed, completion of the Project, shall be promptly corrected, repaired, replaced, re-performed or otherwise remedied by the Service Provider and/or Subprovider(s) at no additional expense to Customer. Authority's agreements with Service Providers shall also provide that any manufacturers' warranties for equipment installed at Customer's Facilities be assigned to Customer.

Authority shall have no obligation to assist Customer with any warranty claims against a Service Provider or equipment manufacturer. Customer shall coordinate any warranty claims directly with the respective Service Provider or equipment manufacturer.

7.2 Authority Warranty Disclaimer. THE WARRANTY PROVIDED BY SERVICE PROVIDER AND THE ASSIGNED WARRANTIES OF THE EQUIPMENT MANUFACTURERS ARE EXPRESSLY IN LIEU OF ALL OTHER WARRANTIES. AUTHORITY EXPRESSLY EXCLUDES ALL OTHER WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, DESCRIPTION OR QUALITY NOT EXPRESSLY SET FORTH HEREIN, TO THE EXTENT PERMITTED BY LAW. NO AFFIRMATION OF AUTHORITY, BY WORDS OR ACTION, SHALL CONSTITUTE A WARRANTY. DESCRIPTIONS, SPECIFICATIONS, DRAWINGS, AND OTHER PARTICULARS FURNISHED TO CUSTOMER ARE ONLY ESTIMATES AND DO NOT CREATE A WARRANTY.

7.3 Projected Energy Savings. Authority and its Service Providers shall use their best efforts to prepare accurate engineering estimates. After energy efficiency Work is completed in Customer's Facility, it is the intent and expectation of the Parties that Customer's annual energy usage for that Facility shall not increase above the pre-installation level except due to changes in rates or increases in usage not related to the implementation of the ESP Work. Customer is responsible for providing Authority with accurate information concerning the operation of its Facility. Customer understands that the projected energy savings are based upon such Customer input. It is Customer's sole responsibility to ensure that the expected energy savings meet Customer's satisfaction at the time the CPC for a Project is executed.

AUTHORITY HEREBY DISCLAIMS ANY AND ALL LIABILITY FOR ANY ENERGY SAVINGS PROJECTED BY AUTHORITY OR OTHERWISE EXPECTED BY CUSTOMER THAT CANNOT BE ACHIEVED.

7.4 Uncontrollable Forces. Authority shall not be responsible for delays or failures in performance resulting from occurrences beyond its reasonable control including, but not limited to, acts of God, strikes, walkouts, acts of war, or any law, regulation, or action of any court or governmental authority, fire, malfunctions in communication lines or computer hardware, power failures, shipping or delivery delays or other events caused by those not party to this Master Agreement (including, without limitation, any Third Parties, and any Service Providers or Subproviders of Authority). In the event Authority or the Service Providers or Subproviders are unable to fulfill any obligations hereunder by reason of such uncontrollable forces, Customer will be notified in writing and the completion dates described in the CPC will be extended by the amount of additional time reasonably necessary to complete the Work. If necessary, Authority will issue a Contingency Work Order or a Change Order, as applicable.

7.5 Damages, Indemnification by Service Provider.

(a) Damages. Authority's agreements with the Service Providers shall include a provision that all damage of whatever nature resulting from the performance of the Work or resulting to the Work during its progress, from whatever cause shall be borne by the Service Provider, and all Work performed shall be solely at the Service Provider's risk until the Work has been finally inspected and accepted by Authority. The Service Provider, however, shall not be responsible for damages resulting from gross negligence or willful misconduct of officials or employees of Authority or Customer.

(b) Indemnification. Authority's agreements with the Service Providers will include a provision that to the extent permitted by law, the Service Provider shall assume the entire responsibility and liability for and defense of, and pay and indemnify, Authority, Customer, and the State of New York (where a Project undertaken for Customer is located on property of New York State), against any loss, damage, expense or liability and will hold each of them harmless from and pay any loss, damage, cost or expense (including without limitation, judgments, attorney's fees, and court costs) which Authority, Customer or the State of New York incur because of injury to or death of any person or on account of damage to property, or any claim arising out of, in connection with, or as a consequence of, the performance of the Work and/or any act or omission of the Service Provider or any of its Subproviders, employees, agents or anyone directly or indirectly employed by the Service Provider or anyone for whose acts the Service Provider may be liable.

7.6 Limitation of Authority's Liability.

(a) Obligation to Exhaust Remedies against Service Provider. In the event of any alleged Authority liability to Customer, Customer shall first pursue and exhaust all remedies in law against the Service Providers and Subproviders and under the insurance identified in Article VI above and carried by the Service Providers and Subproviders before making any claim or taking any action against Authority.

(b) Exclusion of Indirect, Incidental, Consequential Damages. To the fullest extent permitted by law, Authority shall not be liable to Customer, for any indirect, special, incidental, or consequential damages of any kind (including without limitation, any loss of property or equipment, loss of profits or revenue, loss of use of equipment or power systems, cost of capital, cost of purchased or replacement power or temporary equipment, including additional expenses incurred in using existing facilities) related to or arising in connection with this Master Agreement or any other Transaction Document executed in connection herewith, regardless of the form of action (whether in contract, tort or otherwise), even if Authority has been advised of the possibility of such damages.

(c) Total Liability Cap. The Parties agree that in no event shall Authority's total liability (whether in contract, tort or otherwise) for all claims relating to a Project exceed ten percent (10%) of the Total Reimbursement Costs for such Project set forth in the respective CPC.

(d) No Limitation of Service Provider/Subprovider Liability. Nothing in this Section 7.6 shall be construed as limiting the liability of a Service Provider or Subprovider to Authority or Customer in connection with the performance of such Service Provider's or Subprovider's Work on Customer's premises.

7.7 Customer's Responsibility for Project Equipment and Performed Work. Upon delivery at Customer's Facility, Customer shall be responsible for all damage to all Project materials, supplies and equipment of every description and all Work performed at Customer's site unless such damages are caused by Authority or its Service Providers or Subproviders.

ARTICLE VIII

INTELLECTUAL PROPERTY RIGHTS

8.1 Intellectual Property; Proprietary Information.

(a) Intellectual Property Rights. Neither Party shall acquire, directly or by implication, any ownership of any Background Intellectual Property Rights of the other Party. Each Party shall retain title to any Intellectual Property Rights developed, authored, conceived or reduced to practice independently and solely by that Party during the performance of this Master Agreement without the other Party's Background Intellectual Property Rights. Notwithstanding any of the foregoing, it is agreed by the Parties that Authority shall be the sole owner of all Intellectual Property Rights related to any Project which is jointly developed, invented or otherwise generated during the performance of this Master Agreement or any Transaction Document.

(b) Work Product; Proprietary Information. Unless and until Customer has repaid its Short-Term or Long-Term Repayment Obligation, as applicable, the Facility data, evaluations, design and other information produced by Authority or its Service Providers in connection with a Project shall be the property of Authority. Customer shall have the right to use any such proprietary information for the maintenance of Project installations in its Facilities. Upon payment in full by Customer, such information shall become the property of Customer. Any information identified as confidential which is exchanged by Authority and Customer shall be duly protected by the recipient to the extent permitted by law. It is understood that the Public Officers Law and other statutes and regulations regarding Freedom of Information may require the disclosure of information in certain situations.

ARTICLE IX

TERM AND TERMINATION

9.1 Term. This Master Agreement shall end on the tenth anniversary of the date first shown in the preamble above unless earlier terminated in writing by either Party in accordance with the terms of this Master Agreement.

9.2 Termination of Master Agreement. Unless otherwise provided in this Master Agreement, either Authority or Customer may terminate this Master Agreement at any time upon one hundred twenty (120) days' prior written notice to the other Party.

9.3 Pending Projects. Authority and Customer acknowledge that a Project implemented pursuant to a CPC executed during the Term of this Master Agreement may extend beyond the expiration or early termination of this Master Agreement. Provided that the Project was commenced pursuant to a CPC that was executed during the Term of this Master Agreement, then this Master Agreement will be extended, as it applies to such CPC only and for the sole purpose of completing the Project. The Project implemented pursuant to such CPC may continue until completed or otherwise terminated earlier pursuant to the terms and conditions of this Master Agreement.

9.4 Extension. This Master Agreement may be renewed at the end of the current term for an additional period, such additional period not to exceed a period equal to the original Term, to be mutually determined by the Parties in writing and signed by an authorized officer or designee of Authority and Customer.

ARTICLE X

GENERAL OBLIGATIONS OF THE PARTIES

10.1 Authorized Representatives.

(a) Customer's Authorized Representative. For each Project, Customer shall designate a Customer's Authorized Representative and shall inform Authority in writing accordingly. If Customer desires to change its Customer Authorized Representative, it must notify Authority in writing (in accordance with notice requirements set forth herein) at least five (5) business days prior to such change. Customer's Authorized Representative shall coordinate the Project on behalf of Customer and assist Authority and the Service Providers and Subproviders with the implementation of the Project in the selected Facilities of Customer. Customer's Authorized Representative shall be responsible to obtain all necessary approvals, authorizations, and signatures of Customer with respect to any CPC, Change Order, Final CPC and other Transaction Document.

(b) Authority's Authorized Representative. For each Project, Authority shall designate an Authority's Authorized Representative and shall inform Customer accordingly. Authority's Authorized Representative shall coordinate the Project on behalf of Authority and communicate with Customer. Authority will inform Customer of any changes to its Authorized Representative.

10.2 Authority Obligations. With respect to any Authority Implemented Work, Authority shall comply with the following:

(a) Reporting and Information. Authority shall keep Customer informed as to the progress of the Work and shall provide Customer with periodic reports of all activities by the Service Providers and Subproviders at Customer's Facilities. Authority and its Service Providers shall meet with representatives of Customer upon reasonable notice to discuss any matters concerning the Projects.

(b) Permits, Licenses, Authorizations. Authority shall require that the Service Providers and Subproviders obtain and maintain all permits, licenses and authorizations required to perform the Work in Customer's Facilities and that they will comply with all applicable local, state and federal laws, guidelines and regulations, including applicable local, state and federal building, fire and electrical codes and standards. Any costs associated with permits and licenses that must be obtained by Service Provider or Subprovider for a specific Project will be reflected in the Total Reimbursement Costs. Notwithstanding the foregoing, neither Authority nor Service Provider (or Subprovider) shall be responsible for closing out open permits obtained by Service Provider (or Subprovider) due to existing deficiencies or code violations in Customer's Facility which are outside the Project scope.

(c) Service Provider/Subprovider Performance. Authority shall require its Service Providers and Subproviders to comply with regulations governing access to and performance of the Work in the selected Customer Facilities and to perform such Work in such a manner as not to unreasonably interfere with Customer's business at the Facilities. Authority shall also require its Service Providers and Subproviders to comply with Customer's operational and safety requirements, which in certain instances may require substantial supervision and control over the site by Customer.

(d) Records. Authority's Service Providers shall maintain accurate records of Project Work for a period of six (6) years after completion of a Project.

10.3 Customer Obligations. With respect to any Project entered into in connection with this Master Agreement, Customer shall have the following rights and obligations:

(a) Right to Inspect. Customer and Customer's Authorized Representative may observe and inspect all Work in any of Customer's Facilities and shall have the right to attend all Project job meetings, upon written notice of its intent to attend a particular meeting.

(b) Attendance at Meetings. Upon reasonable request and notice from Authority or Service Provider, Customer shall attend meetings scheduled by Authority or Service Provider to discuss any Project-related matters.

(c) Site Rules and Regulations. Customer must promptly notify Authority of any site specific construction, safety, technical or other requirements and restrictions related to its Facility(ies) prior to the start and during the Project. If Customer becomes aware of any defect in the Work or any failure of Authority or the Service Provider or Subprovider to meet the respective Project requirements, the Customer shall give prompt notice to Authority.

(d) Access. Customer shall provide Authority and its Service Providers safe, proper and timely access to the Facility as necessary to perform the Work. Upon Authority's request, Customer's Authorized Representative will accompany Authority and its Service Providers to Customer Facilities. Customer shall promptly provide verbal and written notice of limitations or changes in site access.

(e) Permits and Licenses.

(i) Customer shall provide Authority or Service Provider with such assistance (including, but not limited to, all necessary information requested by Service Provider) as may be required for Authority or Service Provider to obtain all permits, licenses and authorizations necessary to perform the Work in accordance with all applicable local, state and federal laws, regulations, codes and standards applicable to the Facility.

(ii) Customer shall be responsible and shall hold all licenses, permits, authorizations and regulatory approvals necessary for the lawful conduct of its business as presently conducted, and shall comply with all applicable statutes, laws, ordinances, rules and regulations of all governmental bodies, agencies and subdivisions having, asserting or claiming jurisdiction over it, with respect to any part of the conduct of its business and corporate affairs.

(f) Project Equipment. As long as Customer's Short-Term or Long-Term Repayment Obligation, as applicable, remains outstanding, (i) Customer will keep all Project-related equipment free from any and all liens, claims, encumbrances, and the like; (ii) Customer will not grant a security interest in such equipment to any party without the prior written consent of Authority; (iii) the equipment will remain at the Facility site as designated in a CPC; (iv) Customer will not sell, offer for sale, transfer, or dispose of such equipment without notice to Authority; (v) Customer will not use or permit any person to use the equipment in a manner prohibited by law or in a manner which would void any manufacturer's warranty; (vi) Customer agrees to maintain the equipment in good order and repair at all times, and will not waste or destroy the equipment or any part of it; and (vii) Customer will keep the equipment insured in accordance with the requirements set forth in Section 6.3 hereof.

(g) Coordination. Customer shall be responsible for facilitating coordination with Third Parties as required. Furthermore, Customer shall promptly resolve any disputes or issues that arise with any Third Parties. Customer shall be responsible for any changes to the Project schedule, the scope of Work and/or the Total Reimbursement Costs resulting from any delays due to unresolved disputes or issues with Third Parties pursuant to Section 2.6 hereof.

(h) Review and Approval. Customer will promptly review any documents submitted to it by Authority requiring Customer's decision and shall render any required decision pertaining thereto without undue delay.

(i) Assistance; Timely Performance. Customer shall cooperate with Authority and its Service Providers and Subproviders and provide Authority with such other assistance as necessary to facilitate the performance of the Work. Customer shall perform all obligations set forth in this Master Agreement and any other Transaction Document in a timely manner so as to permit the orderly progress of the Projects. Authority shall not be responsible for any Project delays due to Customer's non-compliance with its obligations set forth herein or in a Transaction Document.

ARTICLE XI

MISCELLANEOUS

11.1 Disputes. In the event of any dispute regarding ESP Work at any Customer Facility, Work there may be suspended by Authority until the matter is resolved to the mutual satisfaction of the Parties in accordance with the procedures set forth in Section 11.2 hereof. In the event the Parties are unable to resolve any such dispute after good faith efforts, the Work at that Facility shall terminate and Authority shall issue a Final CPC as provided in Section 3.4(d) hereof.

11.2 Dispute Resolution. The Parties shall use good faith efforts to settle promptly all disputes arising under this Master Agreement or in connection with any ESP Work. In the event that any dispute, including but not limited to a billing dispute, a dispute regarding the quality of the Work, or a dispute regarding the interpretation of this Master Agreement, arises and cannot be resolved in the normal course of business by operating personnel within twenty (20) days after commencement of a dispute, either Party may give the other Party formal notice of the dispute in accordance with the notice requirements set forth herein. In the event that such notice is given,

the Parties shall attempt to resolve the dispute by negotiation between representatives who have the necessary authority to resolve the dispute in question. Within twenty (20) days after delivery of the notice, the receiving Party shall consider all information relevant to the dispute and shall submit to the other Party (in accordance with the notice requirements set forth herein) a proposal for resolution. Thereafter, the representatives shall confer in person or by telephone, promptly and no later than five (5) days after receipt of the proposal for resolution, to attempt to resolve the dispute. All reasonable requests for information by one Party to another Party will be honored. To the extent that disputes are not resolved pursuant to this process, the Parties reserve all rights under law or equity to seek and pursue remedies through the judicial process.

11.3 Publicity.

(a) Public Announcements. No marketing, publicity, promotion, social media, or advertising regarding this Master Agreement, or any Project undertaken pursuant to this Master Agreement, will be issued by Customer without Authority's prior written approval, which approval will not be unreasonably withheld. Any responses to news media inquiries or social media activities developed by Customer, related to this Master Agreement, or any Project undertaken pursuant to this Master Agreement, must be coordinated with Authority for review and approval prior to their release. Letters, speeches, news and/or press releases, articles for publication, website and social media postings, etc., related to this Master Agreement, or any Project undertaken pursuant to this Master Agreement, must be coordinated with Authority for review and approval prior to their release. Any and all communications, whether verbal, electronic or written, must be submitted to Authority's Corporate Communication Business Unit for prior review and approval. Customer agrees to abide by these terms regarding public announcements during the term of this Master Agreement and for a period of two (2) years following the expiration or termination of this Master Agreement.

(b) Signage. The parties agree that Authority may, at no cost to Customer, install and maintain appropriate publicity signage at or in the vicinity of a Project. Customer will cooperate with Authority, and/or any third-party vendor designated by Authority, by timely responding to any questions regarding the design, manufacture, installation and maintenance of the signage. Customer will provide ordinary maintenance to the signage and promptly notify Authority after Customer becomes aware of any damage that may occur to the signage. The publicity signage may include the identity of the Project, including a brief statement highlighting the Project, any applicable Authority program, New York State program or other initiative under which the Project is implemented and the identity of the parties supporting the Project, including those parties' respective logos. The publicity signage is intended to be placed in an area of Customer's designation with significant public visibility within close proximity to the Project. Authority will be responsible for removing the publicity signage upon the conclusion of a Project, or such earlier time as either Party deems it appropriate.

11.4 Notices. All notices permitted or required hereunder or in connection with any Transaction Document shall be in writing and transmitted either: (i) via certified or registered United States mail, return receipt requested; (ii) by personal delivery; (iii) by expedited delivery service; or (iv) by e-mail, with a copy sent via U.S. Mail.

Such notices shall identify the Master Agreement and the Transaction Document to which it relates, and be addressed as follows or to such different addresses as the Parties may from time-to-time designate in accordance herewith:

To Authority:
NEW YORK POWER AUTHORITY
PROCUREMENT DIVISION
Name: John Canale
Title: Vice President, Strategic Supply Management
Address: 123 Main Street, 5th Floor, White Plains, NY 10601
E-Mail Address: john.canale@nypa.gov

with a copy to:
NEW YORK POWER AUTHORITY
LAW DEPARTMENT
Name: Debra Hopke, Esq.
Title: Principle Attorney
Address: 123 Main Street, 11th Floor, White Plains, NY 10601
E-Mail Address: debra.hopke@nypa.gov

To Customer:
TOWN OF HIGHLANDS
Name: Kelly Pecoraro
Title: Comptroller
Address: 254 Main Street, Highland Falls, NY 10928
E-Mail Address: kpecoraro@highlands-ny.gov

Any such notice shall be deemed to have been given either at the time of personal delivery or, in the case of expedited delivery service or certified or registered United States mail, as of the date of first attempted delivery at the address and in the manner provided herein, or in the case of email, upon receipt. The Parties may, from time to time, specify any new or different address in the United States as their address for purpose of receiving notice under this Master Agreement (and any Transaction Document) by giving fifteen (15) days written notice to the other Party sent in accordance herewith. The Parties agree to mutually designate individuals as their respective representatives for the purposes of receiving notices under this Master Agreement.

11.5 No Waiver. The failure of any Party to insist upon strict adherence to any term of this Master Agreement or any Transaction Document executed in connection herewith on any occasion shall not be considered a waiver nor deprive that Party of the right thereafter to insist upon strict adherence to that term or any other term of this Master Agreement.

11.6 Assignment. This Master Agreement and any Transaction Document executed in connection herewith may not be assigned, transferred nor conveyed by either Party without the prior written consent of the other Party. Any attempted assignment, transfer or conveyance without such consent shall be entirely void ab initio and have no force or effect.

11.7 Governing Law; Venue. This Master Agreement (and any Transaction Document executed in connection herewith) and any and all disputes arising in connection herewith (whether in contract, tort or otherwise) shall be governed by and construed in accordance with the laws of the State of New York without giving effect to any choice or conflict of laws provision or rule that would cause the application of the laws of any jurisdiction other than New York. Any action at law, or in equity, for the enforcement of this Master Agreement (and any Transaction Document executed in connection herewith) or any dispute arising in connection herewith shall be instituted only in a court of competent jurisdiction located in the County of Albany, State of New York.

11.8 No Third Party Beneficiaries. Nothing contained in this Master Agreement shall, directly or indirectly, create a contractual relationship with, or give any claim or right of action in favor of, any third party (including, without limitation, any Service Provider or Subprovider) against Authority.

11.9 Severability. The invalidity or unenforceability of any provisions of this Master Agreement or of any Transaction Document executed in connection herewith shall not affect the validity or enforceability of any other provisions of this Master Agreement or Transaction Document, as applicable, which other provisions shall remain in full force and effect.

11.10 Survival of Provisions. The articles that contain provisions related to the following will survive the expiration, termination or completion of this Master Agreement: Conflict and Order of Precedence; Recovery of Costs and Repayment Obligation, Warranty, Damages, Liability, Ownership of Installed Work and Intellectual Property, Publicity; and Governing Law, Venue.

11.11 Not Construed Against Drafter. Authority and Customer acknowledge that they have read this Master Agreement, have had the opportunity to review it with an attorney of their respective choice, and have agreed to all its terms. Under these circumstances, Authority and Customer agree that the rule of construction that a contract be construed against the drafter shall not be applied in interpreting this Master Agreement and that in the event of any ambiguity in any of the terms or conditions of this Master Agreement, including any exhibits or schedules hereto, such ambiguity shall not be construed for or against any Party hereto on the basis that such Party did or did not author same.

11.12 Headings. The articles and section headings contained in this Master Agreement are for reference purposes only and shall not affect the meaning or interpretation of this Master Agreement.

11.13 Counterparts. This Master Agreement may be executed in counterparts via inked signature or electronic mark, each of which shall be deemed an original, but all of which together shall constitute one and the same instrument. The fully executed Master Agreement may be delivered using pdf or similar file type transmitted via electronic mail, cloud based server, e-signature technology or other similar electronic means.

(SIGNATURE PAGE FOLLOWS)

IN WITNESS WHEREOF, the parties hereto have duly executed this Master Agreement as of the effective date first written above.

POWER AUTHORITY OF THE STATE OF NEW YORK		TOWN OF HIGHLANDS	
By:	John Canale John Canale (Jul 23, 2019)	By:	MERVIN R. LIVSEY mERVIN R. LIVSEY (Jul 23, 2019)
Name:	John Canale	Name:	Mervin Livsey
Title:	Vice President, Strategic Supply Management	Title:	Supervisor
Date:	Jul 23, 2019	Date:	Jul 23, 2019

Signature Page to Master Cost Recovery Agreement No. _______________

NEW YORK STATE OF OPPORTUNITY. | NY Power Authority

EXHIBIT A

STATEWIDE COMPENSATION SCHEDULE

As compensation for services rendered by the Authority under the Master Agreement, the Customer will pay the Authority Program Fee as set forth below.

A. CAPITAL PROJECTS

I. AUTHORITY PROGRAM FEE

For Capital Projects, the Authority Program Fee is calculated as a percentage of the cumulative sum of all costs related to a Project, including, but not limited to all Material Costs; Labor Costs; Service Provider Fees; the amount of the Project Contingency applied as a Project cost; and other Project-related costs and expenses. The Authority Program Fee is in addition to all such costs related to a Project. The Authority Program Fee percentage will be fixed upon execution of the CPC for the installation phase.

1. Authority Program Fee when Service Provider performs Work

The following table sets forth the Authority Program Fee where the Authority delivers a Project using one or more Service Providers to perform audit, design, construction management and/or installation.

Project Size (in millions)	Authority Program Fee
$0 - $3M	12.5%
$3M - $6M	12.0%
$6M - $12.5M	11.5%
$12.5M - $40M	11.0%
$40M - $60M	10.5%
> $60M	10.0%

2. Authority Program Fee when Authority and Service Provider perform Work

The following table sets forth the Authority Program Fee where the Authority will be performing design and construction management with its own forces using one or more Service Providers to perform installation. If the Authority procures material directly in lieu of using one of its Service Providers, there will be an additional Material Handling Fee of 1.5% charged on the Material Cost of the Project.

Project Size (in millions)	Authority Program Fee
$0 - $3M	27.5%
$3M - $6M	27.0%
$6M - $12.5M	26.5%
$12.5M - $40M	26.0%

$40M - $60M	25.5%
> $60M	25.0%

3. Authority Program Fee when Authority provides Audit Services Only

The Authority Program fee for providing Audit services not contemplated as part of a full project (i.e. design, construction management and/or installation) is calculated as twenty-five percent (25%) of the costs related to the Audit.

II. MILESTONE PAYMENTS

To the extent applicable, the Authority Program Fee will be paid on milestones as detailed in the CPC or as otherwise mutually agreed upon.

III. AUTHORITY FEE IN THE EVENT OF PROJECT TERMINATION

1. Termination at or after Audit Phase

If a Project is terminated at or after the audit phase, but prior to moving forward with any design or implementation, the Authority's Program Fee is calculated as twenty-five percent (25%) of the actual costs associated with such audit.

2. Termination during Design, Procurement or Installation Phase

If a Project is terminated in whole or part during the design, procurement or installation phase, the Authority's Program Fee for the Project will be the cumulative percentage value at the current milestone (as if it had been achieved) and calculated based on the estimated Project costs, including, but not limited to all Material Costs; Labor Costs; Service Provider Fees; the amount of the Project Contingency applied as a Project cost; and other Project-related costs and expenses up through the current milestone (as if it had been achieved). For the purposes of calculating the Authority's Program Fee, the then current milestone is assumed complete once the Project is canceled.

The following table sets forth the Authority Program Fee percentage segmented by milestone.

Milestone	% of Authority's Program Fee	Cumulative Authority Program Fee Percentage
30% Design	10%	10% + (audit cost)
90% Design	15%	25% + (audit cost)
100% Design & Bidding	15%	40% + (audit cost)
Construction CPC Preparation	10%	50% + (audit cost)
Construction (25% completion)	10%	60% + (audit cost)
Construction (50% completion)	15%	75% + (audit cost)

Construction (75% completion)	15%	90% + (audit cost)
Construction (100% completion)	10%	100% + (audit cost)

B. ADVISORY SERVICES PROJECTS

I. AUTHORITY PROGRAM FEE

The Authority Program Fee for the Advisory Services will be calculated according to one of the following methods as set forth in the CPC for the Project:

Time and Materials: The Authority's Program Fee maybe based on actual time and cost of material incurred by Authority or its Service Providers in connection with a Project based on rates defined in the Project CPC.

Lump Sum: The Authority's Program Fee may be based on the percentage complete of a lump sum or milestones defined in the Project CPC.

Unit Price: The Authority's Program Fee maybe based on the unit prices defined in the Project CPC.

Percent of Materials and Labor: The Authority's Program Fee maybe based on a percentage of Service Provider Material Costs and Labor Costs as defined in the Project CPC.

Other Mechanisms: The Authority's Program Fee may be based on an evolving cost recovery mechanisms not defined in this Master Agreement. If other mechanisms are selected, the Authority's Program Fee will be based on mutual Authority and Customer agreement and will be defined in the Project CPC.

II. PROJECT TERMINATION

If a Project is terminated in whole or part prior to completion of a Project, the Authority's Program Fee will be based on the Project costs incurred by Authority up until the date of termination. For the purposes of calculating the Authority's Program Fee, as applicable, the then current milestone is assumed complete once the Project is canceled.

NEW YORK STATE OF OPPORTUNITY. | NY Power Authority

EXHIBIT B

CAPITAL PROJECT TERMS AND CONDITIONS

1. Application. In addition to the terms and conditions set forth in the main body of this Master Agreement, these Capital Project Terms and Conditions shall apply to all Capital Projects provided by Authority or Service Provider to Customer under the Master Agreement.

2. Capital Project Services. Capital Projects are generally delivered through the services of qualified installation Service Providers or Subproviders under contract with the Authority. Capital Project services may include any or all of the following services (as more fully described below): audit, design, construction management, equipment procurement, installation, commissioning, disposal of Waste, financing and other Project related services required to install a Project.

3. Audit.

(a) Scope. After Customer has identified potential Projects for Authority's and Customer's consideration, Customer may request that Authority perform an audit of the Facility. The audit will help identify opportunities for implementing ESP measures and will be scheduled by Customer's Authorized Representative and/or the appropriate Facility manager. The scope of the audit will be set forth in a CPC which shall be executed by an authorized officer or designee of Authority and Customer prior to commencement of any audit Work. In some instances, the audit will involve a complete inventory of the systems which are currently used in normal operation, while in others a more targeted approach will be taken. The audit may also include an analysis of whether hazardous materials and Waste related to those systems are likely to be present or generated as a result of installing a Project.

(b) Audit Report. Based upon the results of the audit, a written report will be furnished to Customer. The report will include an estimate of the Total Reimbursement Costs as well as estimates of the potential Total Annual Energy Savings and environmental or sustainability benefits, as applicable, that Customer can reasonably expect through implementation of the recommendations made in the report. If, after analysis of the report by Authority and Customer, Authority, in its sole discretion, determines that the Project either (1) does not meet Authority's eligibility criteria, or (2) is not appropriate at such Facility, activity there will cease.

(c) Deferment of Total Reimbursement Costs for Audit Work. Upon completion of the audit Work, if Customer and Authority decide to proceed to the next phase, Customer and Authority will execute a CPC reflecting the scope of such next Project phase. By executing the CPC, Customer acknowledges its concurrence with the audit results. Subject to Authority's approval, Customer may request that payment of the Total Reimbursement Costs for the audit Work, be deferred and included in the Total Reimbursement Costs of the CPC for the next Project phase.

4. Project Design.

(a) General. If agreed upon by the Parties in a CPC, Authority shall prepare a Project design. Customer will be asked to review all aspects of the design and specifications. Where deemed appropriate by Authority and Customer, the Service Provider will arrange for geotechnical surveys (i.e., soil tests, borings, and related evaluations), surveys of the site (i.e., to determine physical characteristics of the site, such as utility locations), and/or demonstration installations (i.e., the installation of sample lighting fixtures or other equipment) of selected measures in Customer's Facility, all at Customer's sole risk.

(b) Milestones and Milestone Completion Reports. Authority will submit the Project design documents to the Customer at 30%, 60%, 90% and "final" design milestones, or according to the milestone schedule set forth in the respective CPC. Upon completion of each design milestone, Customer and Authority (or their duly authorized representatives) shall promptly review the design Work, or applicable portions thereof and Customer and Authority shall jointly sign a Milestone Completion Report. It shall be Customer's responsibility to determine that the proposed design meets Customer's needs.

(c) Deferment of Total Reimbursement Costs for Design Work. Unless otherwise set forth in the CPC for a Project, Authority may invoice the Customer for the Total Reimbursement Costs for the performed design Work through the milestone(s), if any, set forth in the CPC (plus any Total Reimbursement Costs incurred during the audit, if such costs were deferred and rolled over). Customer may request payment deferral if Customer approves Authority to proceed to the next milestone or the next Project phase. With Authority's approval, Customer's Short-Term Repayment Obligation will be deferred and rolled into the next milestone invoice, or at design completion, become part of the Total Reimbursement Costs of the CPC for the next Project phase.

(d) Ownership of Design Work Upon Early Termination. If Customer terminates the design Project prior to its completion, upon receipt of Customer's final payment, Authority will deliver to Customer all design plans and documents completed through the date of termination. Customer's use of such design plans and documents will be subject to any copyrights of the Authority and/or the designer. By using any incomplete or unfinished design plans and/or documents that have not been sealed with the licensed design professional's stamp upon delivery to Customer, Customer accepts full and complete responsibility for such design and further agrees to hold Authority harmless from its use of such incomplete or unfinished design plans and/or documents.

5. Procurement. After Authority and Customer agree on the Project's design and technical specifications, Authority or the Service Provider will competitively solicit, using the Authority's procurement guidelines, bids for the Work as set forth in the design documents. The resulting final design, specifications and bid price shall be incorporated into a CPC for the Project. Authority's contracts with its Service Providers will require compliance with the Authority's guidelines regarding the competitive solicitation of the services of Subproviders for Customer's Facilities, including the selection of minority and women-owned business enterprises. The services of Subproviders and equipment procurement will be obtained through a competitive bid process conducted by the Service Provider with Authority oversight. In the event Customer

decides not to proceed with the installation Project, Customer shall reimburse Authority for the costs of any Work undertaken by Authority and/or its Service Provider in connection with the procurement process and the associated cost and expense of same.

6. Installation.

(a) General. After Authority and Customer have entered into a CPC for installation Work, the Service Provider and/or its Subproviders will perform the Work pursuant to the design and technical specifications set forth in such CPC.

(b) Substantial Completion and Operation Transfer Report. After Customer has inspected, tested and accepted the Project equipment, or portion thereof, installed by the Service Provider, the Parties will execute a Substantial Completion and Operation Transfer Report for the completed portion of the Work signifying (i) that Customer accepts responsibility for operation and maintenance of the installed equipment, (ii) that the Project, or specified portion thereof, is substantially complete, and (iii) the commencement of any warranty period.

(c) Final Inspection Report. Upon completion of the Work, Customer and Authority (or their duly authorized representatives) shall promptly inspect the entire Facility, or applicable portions thereof. Authority or its Service Providers will confirm that the Work has been satisfactorily completed according to the provisions of this Master Agreement and the applicable CPC. Authority and Customer shall jointly sign a Final Inspection Report.

7. Maintenance and Post-Installation Audit. Authority will provide Customer with information regarding the maintenance of Project installations and recommendations for appropriate replacement equipment to be used in those installations to facilitate proper usage and, if applicable, energy savings at Customer's Facilities. After the Project installations are completed, Customer shall use reasonable efforts to see that such maintenance and materials instructions are followed at its Facilities. While any portion of the Customer's Short-Term Repayment Obligation remains outstanding, Authority may, upon reasonable notice to Customer, audit installations in Customer's Facilities to evaluate compliance with such maintenance and materials instructions.

8. Project Closeout for Capital Projects. Notwithstanding the terms set forth in the CPC or Final CPC, the Customer shall, within the time specified in the Final CPC, (a) repay the Short-Term Repayment Obligation or (b) convert the Short-Term Repayment Obligation to a Long-Term Repayment Obligation and enter long term repayment consistent with the Authority's policies and procedures. The Customer shall make payment of that portion of the Short-Term Repayment Obligation that is not converted to the Long-Term Repayment Obligation upon receipt of the Authority's invoice and in accordance with the terms of this Master Agreement. The Short Term Repayment Obligation, as set forth in the Final CPC, shall include the Authority's estimate of Short-Term Interest to be accrued between the issuance of the Final CPC and conversion to long term repayment.

9. Authority Obligations. In addition to the obligations otherwise set forth herein and the respective CPC, Authority shall require the Service Provider to adhere to the Project's design

and technical specifications as set forth in the CPC and minimize any interference with the normal operations at Customer's Facility.

10. Customer Obligations. In addition to the obligations otherwise set forth herein and the respective CPC, Customer shall promptly review all completed installations. Customer shall review and approve, as may be required, any corrective or restoration Work resulting from improper work by the Service Provider.

11. Customer-Supplied Equipment and/or Work. Customer and Authority may agree in the CPC for the provision of Customer materials and/or completion of Customer work in connection with a Project, independent of Authority. If so, then Customer shall be responsible for any changes to the Project schedule, scope of Work or any increase in the Total Reimbursement Costs caused by Customer due to non-delivery of Customer materials or non- or late performance of Customer work and Authority shall issue any necessary Contingency Work Order or Change Order, as applicable. Authority may suspend its Work on the Project until Customer approves such Change Order. Furthermore, if the Customer does not meet the Project schedule with respect to Customer materials and/or Customer work, Authority has the right to terminate the Project if the delay is not cured within fifteen (15) days of written notice thereof by Authority to Customer and turn it over to Customer for completion without any liability on the part of Authority.

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NEW YORK STATE OF OPPORTUNITY. | NY Power Authority

EXHIBIT C

ADVISORY SERVICES TERMS AND CONDITIONS

1. Application. In addition to the terms and conditions set forth in the main body of this Master Agreement, these Advisory Services Terms and Conditions shall apply to all Advisory Services Projects provided by Authority or Service Provider to Customer pursuant to the Master Agreement.

2. Advisory Services. Upon Customer's request, Authority may provide any or all of the Advisory Services described below. Advisory Services may be provided by Authority employees and/or Service Providers with expertise in the area as determined by Authority. Authority and Customer will cooperate in good faith during the performance of such Advisory Services.

3. Description of Services

(a) *Review*. Review of information provided by the Customer regarding, among other things, Customer's site conditions, future plans for modifications to facilities, operations and/or usage, historical utility data, any relevant strategic plans or initiatives, and other relevant requirements that are specific to Customer.

(b) *Meetings*. Participate in meetings and conference calls as mutually agreed upon by the parties as being in the best interests of the Project or as otherwise detailed in the Customer Project Commitment.

(c) *Site Observations*. Observe Customer's facilities, physically or remotely via electronic means as determined by the Authority to assess the condition of existing equipment and physical site conditions.

(d) *Analysis*. Analyze data presented by Customer and/or collected by or on behalf of the Authority. Outreach to appropriate third parties as necessary to coordinate and/or collect additional data.

(e) *Advice and Guidance*. Deliver oral or written advice, guidance and other recommendations communicated via in person meetings, telephone conversations, or correspondence.

(f) *Deliverables and Reports*. Prepare reports, memorandums, and other documents that memorialize the advice, guidance and recommendations delivered to the Customer and support the Customer's underlying project, where applicable.

The foregoing descriptions are given by way of example and not by way of exclusion. Advisory Services may include services that have not yet been developed or approved by Authority

to date, provided such services are described in a CPC signed by both Parties to this Master Agreement.

4. Further Assistance; Information. In addition to the obligations set forth herein and the respective CPC, Customer shall provide Authority and/or Service Providers with such assistance as may be required to perform the Advisory Services. This may include, but is not limited to, providing access to the Customer's Facility(ies), information such as historical utility data, maintenance logs, existing feasibility studies, reports, equipment drawings or any other information or services reasonably requested by Authority and/or Service Providers.

* * * * * *

Signature: mERVIN R. LIVSEY
mERVIN R. LIVSEY (Jul 23, 2019)

Email: blivsey@highlands-ny.gov

Title: Town of Highlands Supervisor

Company: Town of Highlands

Signature: John Canale
John Canale (Jul 23, 2019)

Email: john.canale@nypa.gov

Title: VP Strategic Supply Management

Company: New York Power Authority

Arencibia, Stephanie (Molly)

From:	Matthew Christian <mchristian@guthdeconzo.com>
Sent:	Tuesday, December 10, 2019 2:01 PM
To:	blivsey@highlands-ny.gov; rsullivan@highlands-ny.gov
Cc:	Laino, Jeffrey; Hermann, Charles; Bou Reed
Subject:	[EXTERNAL]Highlands Kick Off Meeting Minutes
Attachments:	Highlands Kick Off Meeting Minutes 12102019 w attachments.pdf

All,

It was great meeting everyone yesterday and we are excited to get this project started.

Please see attached for the minutes from yesterday's kickoff meeting. Please review and let me know if there are any additional comments or questions. I received the registry copy from Rich.

Thanks,

Matt Christian
Construction Manager

Guth DeConzo Construction Management, Inc.
T: 518-266-9600 X 117
M: 518-596-5996
GuthDeConzo.com
433 River Street, Suite 6004 | Troy NY 12180

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CONSTRUCTION MANAGEMENT, INC.

Highlands LED Street Lighting Kick Off Meeting

December 9, 2019

Minutes

LED Street Lighting Project

1) **Define Role, Responsibilities and Primary Contact for Each Party**
   a. Guth DeConzo: Matt Christian – Construction Manager, Bou Reed – Director Electrical Engineering (absent)
   b. NYPA: Jeff Laino – Business Development Representative, Charles Hermann – Project Manager
   c. Town of Highlands: Bob Livsey – Supervisor, Richard Sullivan – Councilman
2) **Establish Scope of Work for Project**
   a. 1 for 1 LED Street Lighting Conversion: The existing town registry based on O&R billing indicates approximately 168 cobra head fixtures, with 1 existing LED fixture. The basis of design will be a one for one conversion of each existing fixture to LED. Guth DeConzo will design to IES and RP8 standards. Town to provide existing registry documents.
   b. Decorative Light Fixture LED Conversion: There are no decorative street lights within the town's limits.
   c. Miscellaneous Scope - Underground Infrastructure, Parks, Parking Lots, Underpasses, Etc..: The town would like their DPW, Fort Montgomery residential parking lot (by intersection of 9W and Firefighters Memorial Drive), Mine Dock Park, Brooks Lake Parking and the Town Hall building included as additional exterior scope. The Town Hall building also has interior fixtures to be included as additional scope.
   d. Lighting Control Technology & Smart City: The town would like to see options for both a standard dusk to dawn photocell as well as a lighting control nodes.
3) **Open Discussion regarding Design Requirements/Information**
   a. Discuss existing lighting system including:

242 West 30th Street ♦ New York, NY 10001 ♦ Phone: 212.967.4306 ♦ Fax: 212.967.4309
433 River Street Suite 6004♦ Troy, NY 12180 ♦ Phone: 518.266.9600 ♦ Fax: 518.266.8938
www.guthdeconzo.com

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i. Fuseholder/Fuse Type & System: Guth DeConzo requires installation contractor to install/replace fuses and fuseholders on all cobra head fixtures.
ii. Photocell (basic or smart): Guth DeConzo will provide pricing for both options. The town currently has dusk to dawn photocells.
iii. Condition of existing wiring, poles, bases, arms, etc…: Existing infrastructure is in B grade status. There are no known existing conditions that would require allowances carried for infrastructure above and beyond standard practice.
iv. Percentage of poles that are wood versus steel/aluminum: It is believed that the overwhelming majority of poles are wood. No known steel/aluminum poles with cobra heads on them.
v. Maintenance (Current, Ongoing, future): O&R currently maintains the existing system. The town understands they will be responsible for system once bought out from O&R/after project completion. In order to be eligible for NYPA's ongoing maintenance agreement the municipality must have lighting control nodes, not dusk to dawn photocells.

b. Define areas where increased light levels are requested, if applicable: Town requests insight into Mine Rd. as an area to potentially add lighting. There are no other areas that will require additional design for increased lighting. There may be some areas identified during the construction process to add a few lights on existing poles.
c. Discuss smart technology deployment, if applicable: The town will be eligible for NYPA's Smart City Grant. NYPA will send follow up documentation that explains the details and qualifications of the grant. Guth DeConzo will be able to guide the discussion and design process for the grant if the town wishes to pursue.
d. Discuss additional options Village/Town would like to consider: No additional scope items at this time.
e. Discuss accuracy of Utility Registry and steps taken during design to establish accuracy: The town acknowledged that is common for there to be a slight discrepancy between the existing O&R registry and what infrastructure is actually installed. Guth DeConzo will cross reference O&R data with in-person site visits and use online

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audit services akin to Google Maps. Guth DeConzo will identify any outstanding items in the design report.

f. Discuss color temperature (3000K vs. 4000K): Guth DeConzo explained the differences of color temperatures and the village was satisfied with 3000K for all fixtures.

g. High resolution street map for each Village/Town: The town is going to provide a digital version of the town's boundaries and there are also streetlights overlaid on top.

h. Existing utility bills: Town to provide minimum of 1 year's previous utility bills, but if 2 or more years are available that would be beneficial. Please also provide utility bills for all areas identified under miscellaneous scope.

4) Construction Related Items

a. Staging location for Fixtures, disposal items, contractor work vehicles: The Fort Montgomery residential parking lot was discussed and visited post meeting. The area can provide adequate space, but is not fenced in. This is an open item and will be discussed in the future.

b. Will police escorts be required for any work areas? No police escorts will be required for this work, but Canterbury Rd must utilize flagmen and signage at all times. This is a narrow road that has a lot of turns etc. with steady residential traffic. This is a high priority safety area.

c. Are there any restrictions in construction hours, days or locations? Permitted work times are 7am-9am, no work will commence before 7am.

d. List of Projected Bidders. Requests by Village/Town: Town has no specific requests.

e. Discuss complaint protocol.: Current complaint protocol involves standard phone call procedure when a light is out etc. Reports are then made directly to O&R. Protocol during construction can be modified depending if the lighting control technology is being utilized.

f. Discuss verification process of installation and acceptance sign-offs: At the end of construction completion the town will sign off on substantial completion of a fully operating lighting system. If the lighting control nodes are used there will be a separate acceptance sign off and commissioning phase with training.

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5) **General Overview - Design / Bidding / Construction Timeline**

a. Design Development: Guth DeConzo will begin their design once they have all proper documentation (registry, bills etc.). This process takes approximately 9 months, but is subject to extend if the scope is expanded. The town simultaneously needs to begin the purchase of their assets from O&R. NYPA is going to send documentation that explains the buyout process and what steps need to be take in order to ensure this is properly complete. Please note construction cannot take place until the town owns their assets.

A 90% design meeting review will be conducted between the town, NYPA and Guth DeConzo to review and confirm final scope and projected economics. Estimated cost will be updated during the design phase based on actual fixture quantities, addition/removal of project scope by customer, conditions of existing infrastructure, photometrics, etc. A 100% Design will be submitted to the town and NYPA for approval.

b. Bidding (ICIC): Once the 100% design is approved, Guth DeConzo will bid out the labor portion of the work to vetted contractors. The fixture material will be procured through NYPA's direct purchase agreements. This process takes about a month. It will take another month to develop the ICIC documentation, which becomes the contract between the town and NYPA.

c. Contract Awards: This process takes a few weeks to confirm sign off of all parties in preparation for construction.

d. Start Construction: Once all documentation is signed, NYPA will give Guth DeConzo authorization to begin construction. At this time Guth DeConzo will place purchase order for material. When all material is on site installation will begin. Installation time will vary depending on size of scope additional to one for one replacement.

e. Complete Construction

6) **NYPA Discussion Topics**

a. Discuss Pending MCRA's and NTP's: NYPA confirmed that all of these forms have been completed.

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b. Discuss Public/Private Use Questionnaires: NYPA will provide any follow up information and documentation if necessary.
c. Discuss Publicity/Project Announcements: NYPA will provide any follow up information and documentation if necessary.

7) **Open Discussion**
   a. The town would like to install a mock up of few fixtures in a selected area, potentially along Firefighters Memorial Drive. Without the town owning their system yet, this item could be delayed until the town owns their system from O&R. Guth DeConzo will follow up with NYPA and O&R to see if this is possible and what the interim steps could be.

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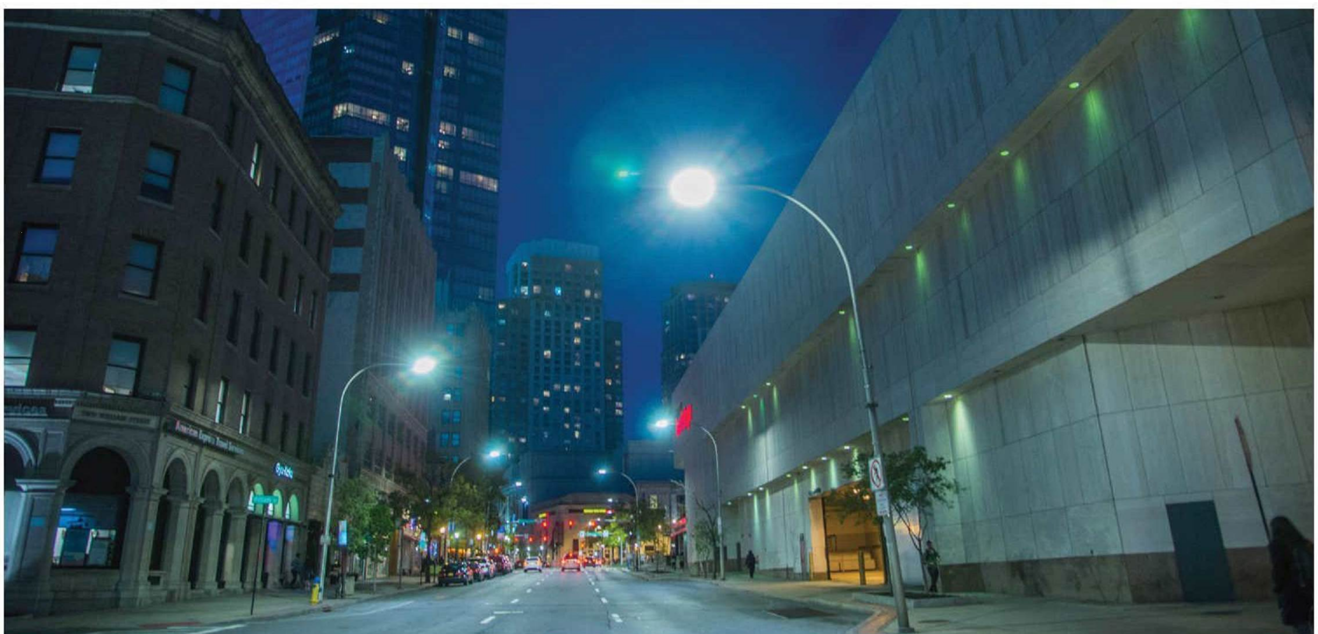
MEETING SIGN-IN SHEET

Project: Town of Highland LED Streetlight Conversion	**Meeting Date:** December 9, 2019
Facilitator: Guth DeConzo	**Place/Room:** Town of Highland Hall

Name	Title	Company	Phone	E-Mail
Matt Christian	CM	Guth DeConzo	518-596-5996	mchristian@guthdeconzo.com
Charles Herman	PM, Lead Engineer	NYPA	914 390 8208	charles.herman@nypa.gov
Jeff Laino	Key Acct Mgr	NYPA	914-312-1260	Jeffrey.Laino@nypa.gov
Bob Livsey	Supervisor	Highlands	845 446 4280 x 312	blivsey@highlands-ny.gov
Richard Sullivan	Councilman	Highlands	845 642 5587	rsullivan@highlands-ny.gov

Smart Street Lighting NY Grant Program Guidelines

Customer Energy Solutions



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Program Overview

As an enhancement to the Smart Street Lighting NY Program, the New York Power Authority (NYPA) is pleased to announce the Smart City Technology Grant Program ("Smart City Grant"). The Smart City Grant, scheduled to go through December 31, 2025, will support the planning and installation of Smart City sensor hardware and software technology as part of LED street lighting conversions.

Applicants that meet all the requirements will be eligible to receive a range of grant funding outlined in the grant allocation table. Grant amounts will depend on the quantity of street lights, as well as, the amount of matching funds the community may contribute. If no matching funds are contributed then the community is eligible to receive the base grant amount. The community may contribute as much as they like but will only receive matching funds from NYPA up to the max amount in their tier plus the base grant amount as outline in the equation below.

(Base Grant) + (Community Contribution) + (NYPA Match of Contribution) = Total Smart City Cost

As technology continues to evolve, municipalities are able to make data driven decisions to enhance the operation of their assets and improve public services to their residents. Street lighting systems are no longer used solely to illuminate roadways, but are now considered vertical assets that can be used for a variety of new and innovative functions. NYPA will work with program participants statewide to enhance LED street lighting conversions by integrating one or more of the following technology categories:

- **Public safety:** video analytics, noise and motion monitoring, gunshot detection
- **Environmental:** air quality, ice and snow detection, sewer and storm water monitoring, weather detection
- **Transportation:** traffic optimization, traffic monitoring, parking management
- **Connectivity:** digital kiosks, connected vehicles, smart phone applications

As new technologies are developed, NYPA will expand the offerings mentioned above. NYPA will also provide municipalities with information on the potential roll out of 5G broadband small cell technology and public Wi-Fi. Adequate connectivity will be the backbone of how Smart City and Internet of Things (IoT) sensors communicate while also enhancing cellular density.

Application Requirements

The online application must be submitted for participation. In order for applications to be considered for award by NYPA, the applicant must satisfy the following requirements:

- Applications must be submitted by an authorized employee of the municipality implementing the project. While consultants or third parties may assist in creating project applications, applications submitted by third parties on behalf of the municipality will not be entertained.

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- Each Applicant will be limited to submitting one application. Each application must include only one project, but the project can include installations at multiple locations. If the street lighting conversion is completed in multiple phases additional applications will not be accepted.
- Smart City sensors, hardware, and software must be preapproved by NYPA before an application is submitted. Please see the attached list of prequalified Smart City solutions. If there is a system that is not listed that an Applicant would like to implement, please send a comprehensive Scope of Work, respective cut sheets, and a project budget to the Program Manager Kevin Luteran (contact information below).

Project Parameters

If an application is deemed incomplete, the applicant will be notified within 30 days of receipt of the application. The applicant must then resubmit the appropriate documentation to be considered for funding. Failure to resubmit revised application may result to declination of an application. If approved, Applicants will be notified of award decisions with a grant award notification within 30 days of applying.

Projects submitted for consideration <u>must</u> satisfy the following requirements:

- The installation of all Smart City devices are to be installed at the time of the installation of the LED street lights by NYPA. NYPA will also accept applications from municipalities who converted their street lights through NYPA after July 2017.
- Eligible Applicants can choose to supplement NYPA's contributions with 50% matching funds of the total project cost in order to acquire additional grant funds. Matching funds can come from any combination of capital from the municipality's budget or NYPA financing, if eligible. Matching funds are to be paid directly to NYPA as defined in the Customer Project Commitment (CPC). Customers must decide whether they will contribute matching funds at the time that the Authorization to Proceed (ATP) for the street lighting conversion is executed.
- Once a project has been officially awarded, the municipality will not be able to modify the project scope without approval from NYPA. If the matching funding option is chosen and upon completion of the work, the total project cost is below what was originally projected and approved, the municipality must still meet the 50% match requirement of the total project cost and NYPA will retain any unused grant funds. Any excess funds not used will not be paid to the Applicant. If upon completion of the work the cost of the Smart City technology is above what was originally projected and approved, the municipality will be responsible for the difference between what was awarded and the final cost of the project. NYPA will not accrue any project costs in excess of the originally agreed upon total allocation amount without consent.
- The municipality will own all hardware and software associated with the grant program. The municipality is also responsible for operation and maintenance of the system after the respective program warranty expires.
- The municipality will allow NYPA to access non-sensitive data generated by Smart City systems in order to test, learn, and enhance the program as long as the data is anonymous, non-identifiable, and co-mingled with other data. Municipalities may be required to enter into a third party service agreement with a Smart City technology provider.

- The program will be offered up to year 2025 or until the capped program funding is depleted. NYPA does not guarantee this grant amount if the program funds are fully committed at the time you submit your application. Awards will be made on a first come first serve basis.
- Grant funds will not be dispersed to the municipality directly, they will be used as credit to the project to offset total project costs.
- As with all aspects of the Smart Street Lighting NY, all costs incurred to develop Smart City projects are subject to cost recovery fees.
- NYPA reserves the right to modify the parameters of the program at any time.
- Awards from NYPA shall follow the chart below in total grant allocation amount, per individual project:

Grant Allocation

Number of Street Lights	**Base Grant Amount** (No customer match)	**Matching Amount** (up to 50% match)	**Total Amount** (Base + Matching)
0 to 500	Up to $20,000	Up to $40,000	Up to $60,000
501 to 1,000	Up to $40,000	Up to $80,000	Up to $120,000
1,001 to 5,000	Up to $75,000	Up to $150,000	Up to $225,000
>5,000	Up to $100,000	Up to $200,000	Up to $300,000

Example Project

Number of Street Lights	3,500
Base project cost for LED conversion	$5,000,000
NYPA Base Grant Amount	$75,000
NYPA Matching Funds	$100,000
City's Contribution	$100,000
Total Grant Amount	$175,000
Net Project Cost	$5,000,000
Gross Project Cost (LED + Smart City)	$5,275,000

For any questions please contact:

Kevin Luteran
Smart Street Lighting NY Program Manager
SmartStreetLightingNY@NYPA.gov
(518) 433-6742

Applications can be submitted here:

https://www.nypa.gov/services/customer-energy-solutions/smart-street-lighting-ny

Appendix B: Purchasing Street Lights Procedural Framework

Municipality may submit to utility a formal request to purchase a portion of or entire streetlight system. Please note, a municipality may request a purchase price proposal from the utility only once every 12-month period.[2]

Municipality's formal request may be in the form of a letter or email, including the date when the request is made. Municipality should state desire to receive a proposal for the entire street light system or include a description of the portion of the system the municipality is interested in purchasing, such as number of streetlights, geographic region, etc.

Utility company has up to 90 days to provide proposed purchase price to municipality.[2]

Utility Purchase proposals must:

- "Separately itemize each cost element of the proposed purchase price including the book value, original cost, depreciation, etcetera."[2]
- Include "an explanation of how each cost is developed"*
- "Resolve any confidentiality concerns, the utilities may require execution of a non-disclosure agreement, as deemed necessary"[2]
- Municipality has up to 180 days from the receipt of the purchase price proposal to review and respond to utility their intent to move forward with the purchase.[2]
- Within the 180 days, or after, if communication was sent to utility about intent to move forward, municipality and utility may negotiate and establish purchase price for the streetlight system.[3]

Utility Contact for Streetlight Requests

Orange and Rockland
Theresa Johnson
JohnsonThe@oru.com
(845) 577-3193

National Grid/Niagara Mohawk
John Walter
John.walter@nationalgrid.com
(716) 831-7739

Rochester Gas & Electric/ New York State Electric and Gas
Kelly Dietrick
(585) 724-8135

Central Hudson
Jessica Caserto
Jcaserto@cenhud.com
(845) 486-5485

- Once a purchase price is agreed to, the utility has up to 60 days to file the final sale price for the Public Service Commission approval.
- Upon the Public Service Commission's approval, the municipality and utility may move forward with the streetlight sale.[4]

[2] Case 15-E-0745, 0746, 0747, 0748, 0749, Order Approving Tariff Amendments with Modifications, New York State Public Service Commission (issued October 14, 2016).

[3] Purchase price per streetlight may range from $150 – to upwards of $400. The price variance is primarily due to the depreciation of installed equipment.

[4] If financing the purchase of the streetlights through NYPA, NYPA would issue a check to the municipality and they would then pay the utility.

Arencibia, Stephanie (Molly)

From:	Laino, Jeffrey
Sent:	Tuesday, December 10, 2019 2:37 PM
To:	Richard Sullivan
Subject:	RE: [EXTERNAL]Highlands Kick Off Meeting Minutes
Attachments:	existing lights purchase process.pdf; Smart City Grant Guideline.pdf

The smart city technology grant guidelines and fixture purchase process documents.

From: Matthew Christian <mchristian@guthdeconzo.com>
Sent: Tuesday, December 10, 2019 2:01 PM
To: blivsey@highlands-ny.gov; rsullivan@highlands-ny.gov
Cc: Laino, Jeffrey <Jeffrey.Laino@nypa.gov>; Hermann, Charles <Charles.Hermann@nypa.gov>; Bou Reed <breed@guthdeconzo.com>
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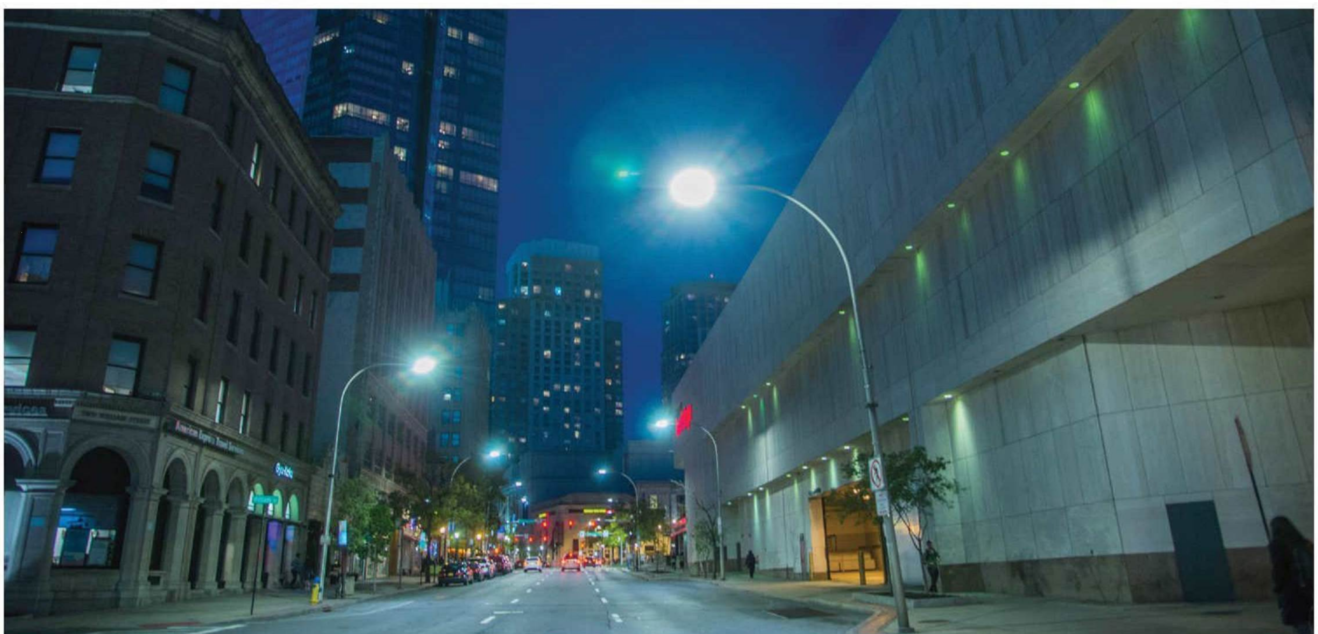
Smart Street Lighting NY Grant Program Guidelines

Customer Energy Solutions



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Applications can be submitted here:

https://www.nypa.gov/services/customer-energy-solutions/smart-street-lighting-ny

Appendix B: Purchasing Street Lights Procedural Framework

Municipality may submit to utility a formal request to purchase a portion of or entire streetlight system. Please note, a municipality may request a purchase price proposal from the utility only once every 12-month period.[2]

Municipality's formal request may be in the form of a letter or email, including the date when the request is made. Municipality should state desire to receive a proposal for the entire street light system or include a description of the portion of the system the municipality is interested in purchasing, such as number of streetlights, geographic region, etc.

Utility company has up to 90 days to provide proposed purchase price to municipality.[2]

Utility Purchase proposals must:

- "Separately itemize each cost element of the proposed purchase price including the book value, original cost, depreciation, etcetera."[2]
- Include "an explanation of how each cost is developed"*
- "Resolve any confidentiality concerns, the utilities may require execution of a non-disclosure agreement, as deemed necessary"[2]
- Municipality has up to 180 days from the receipt of the purchase price proposal to review and respond to utility their intent to move forward with the purchase.[2]
- Within the 180 days, or after, if communication was sent to utility about intent to move forward, municipality and utility may negotiate and establish purchase price for the streetlight system.[3]

Utility Contact for Streetlight Requests

Orange and Rockland
Theresa Johnson
JohnsonThe@oru.com
(845) 577-3193

National Grid/Niagara Mohawk
John Walter
John.walter@nationalgrid.com
(716) 831-7739

Rochester Gas & Electric/ New York State Electric and Gas
Kelly Dietrick
(585) 724-8135

Central Hudson
Jessica Caserto
Jcaserto@cenhud.com
(845) 486-5485

- Once a purchase price is agreed to, the utility has up to 60 days to file the final sale price for the Public Service Commission approval.
- Upon the Public Service Commission's approval, the municipality and utility may move forward with the streetlight sale.[4]

[2] Case 15-E-0745, 0746, 0747, 0748, 0749, Order Approving Tariff Amendments with Modifications, New York State Public Service Commission (issued October 14, 2016).

[3] Purchase price per streetlight may range from $150 – to upwards of $400. The price variance is primarily due to the depreciation of installed equipment.

[4] If financing the purchase of the streetlights through NYPA, NYPA would issue a check to the municipality and they would then pay the utility.

Arencibia, Stephanie (Molly)

From:	Kelly Pecoraro <kpecoraro@highlands-ny.gov>
Sent:	Wednesday, December 11, 2019 11:06 AM
To:	Richard Sullivan; Bob Livsey
Cc:	Laino, Jeffrey; Hermann, Charles; Bou Reed; Matthew Christian
Subject:	RE: Highlands Kick Off Meeting Minutes
Attachments:	June 2018 through November 2019.pdf

Attached please find Orange & Rockland street light bills from June 2018 through November 2019. Please let me know if you need anything else.

Regards,
Kelly

Kelly Pecoraro
Comptroller
Town of Highlands
254 Main Street
Highland Falls, NY 10928
845-446-4280 ext 325|f 845-446-6507

From: Richard Sullivan
Sent: Wednesday, December 11, 2019 7:05 AM
To: Bob Livsey <blivsey@highlands-ny.gov>
Cc: Laino, Jeffrey <Jeffrey.Laino@nypa.gov>; Hermann, Charles <Charles.Hermann@nypa.gov>; Bou Reed <breed@guthdeconzo.com>; Matthew Christian <mchristian@guthdeconzo.com>
Subject: Re: Highlands Kick Off Meeting Minutes

I haven't reviewed minutes yet, just wanted to let all know I had 3 assignments :
- inventory- done, emailed
- 12 months or more of billing - to be done by next Monday
- get O & R buyout price for 167 lights ....
On the last one, Teresa Johnson called me yesterday and acknowledged that on July 10th the town did indeed pursue this task, she is expediting O & R legal Dept to get this done, I will keep pressure on her/them .

Great meeting, my gut trusts what we are doing, expect digital copies of bills soon, and I will send self cartographied maps soon as well.
Obliged, Richie

Sent from my iPad

On Dec 10, 2019, at 2:01 PM, Matthew Christian <mchristian@guthdeconzo.com> wrote:

All,

It was great meeting everyone yesterday and we are excited to get this project started.

Please see attached for the minutes from yesterday's kickoff meeting. Please review and let me know if there are any additional comments or questions. I received the registry copy from Rich.

Thanks,

Matt Christian
Construction Manager

<image001.png> **Guth DeConzo Construction Management, Inc.**
T: 518-266-9600 X 117
M: 518-596-5996
GuthDeConzo.com
433 River Street, Suite 6004 | Troy NY 12180

<Highlands Kick Off Meeting Minutes 12102019 w attachments.pdf>

Orange & Rockland
Rockland Electric Company

1-877-434-4100 www.oru.com

TOWN OF HIGHLANDS
TOWN RD LITE 2
HIGHLAND FALLS, NY 10928
STREET LIGHTING

Your next Meter Reading will be:

If you have questions about this bill, call toll-free 1-877-434-4100 or go to www.oru.com

ELEC MUNICIPAL STREET LIGHTING-DELIVERY
Jul 1
Jun 1
Total Usage (KWH) 30 Days [redacted]

Delivery Charges

Delivery Chg				[redacted]
Energy Cst Adj	[redacted]	KWH @	¢ 0.28000¢	
SBC Chg		KWH @	0.58700¢	
Transition Adj Chg		KWH @	-0.00500¢	
NY Assessment		KWH @	0.00000¢	
Government surcharges - Delivery				
Total Delivery Charges				
Total Supplier Charge				
CURRENT LIGHTING CHARGES				

BILLING DATE 06/20/18

BILLING SUMMARY

ACCOUNT NUMBER [redacted]

Last Bill	[redacted]
Payments: 06/11/18	[redacted]
Service Charges Lighting	[redacted]
TOTAL AMOUNT DUE	[redacted]

O&R certifies that the amount of $3,398.11 is correct, that items, services & disbursements charged were rendered as stated and no part has been paid or satisfied. Exempt taxes are excluded and the amount claimed is due on 07/16/2018.

MANAGER CUSTOMER ACCOUNTING
MARIE QUIGLEY

To avoid a 1.5% late charge, please pay by 07/13/2018.

Your lighting service energy supplier is Constellation New Energy C&I. They can be contacted at 1-844-636-3749.

We offer convenient payment options such as pay by phone, pay online or in person at Village of Kiryas Joel, 51 Forest Rd, Suite 340, Monroe.

Have your payments electronically deducted from your bank account by enrolling in Automatic Bill Payment. Place an X in the box on your bill stub. Details at www.oru.com/ABP

TOWN OF HIGHLANDS
TOWN RD LITE 2
HIGHLAND FALLS, NY10928

Account Number: [redacted]

Billing Date: 06/20/18

ELEC MUNICIPAL STREET LIGHTING-DELIVERY

From: 06/01/2018 To: 07/01/2018

	1	27500 LUM 8FT 141 S	[redacted]	[redacted]	[redacted]
	3	46000 LUM 8FT 144 S			
	26	22500 LUM 8FT 121 M			
	19	5800 LUM 8FT 131 S			
	7	9500 LUM 8FT 134 S			
	92	7900 LUM 8FT 114 M			
	19	4000 LUM 8FT 111 M			
Total	167				

Orange & Rockland
Rockland Electric Company

Spring Valley NY 10977-5300
1-877-434-4100 www.oru.com

Constellation New Energy C&I
PO Box 4911
Houston TX 77210-4911

See page 1 for Total
Amount Due

Supplemental Statement

FOR INFORMATIONAL PURPOSES ONLY

TOWN OF HIGHLANDS
TOWN RD LITE 2
HIGHLAND FALLS, NY 10928

Your next Meter Reading will be:

For Energy Supplier service information call 1-844-636-3749
www.newenergy.com

Supplier LIGHTING CHARGES
Jun 01-Jul 01 [redacted] KWH @ 6.3470¢
TOTAL SUPPLIER UNMETERED CHARGE [redacted]

BILLING DATE 06/20/18

Constellation New Energy C&I

CUSTOMER'S ACCOUNT NUMBER
[redacted]

Current Supplier Charges
Unmetered [redacted]

E

002283 ORODNS12 004331 0100000000

TOTAL SUPPLIER CHARGES [redacted]

DO NOT PAY THESE SUPPLIER CHARGES SEPARATELY.

They are included in the Total Amount Due on Page 1 of your O&R bill.

0000513

Orange & Rockland
Rockland Electric Company

390 West Route 59
Spring Valley NY 10977-5320
1-877-434-4100 www.oru.com

TOWN OF HIGHLANDS
TOWN RD LITE 2
HIGHLAND FALLS, NY 10928
STREET LIGHTING

Your next Meter Reading will be:

If you have questions about this bill, call toll-free 1-877-434-4100 or go to www.oru.com

ELEC MUNICIPAL STREET LIGHTING-DELIVERY
Aug 1
Jul 1
Total Usage (KWH) 31 Days [redacted]

Delivery Charges

Delivery Chg			[redacted]
Energy Cst Adj	[redacted] KWH @	¢ 0.18800¢	
SBC Chg	KWH @	0.58700¢	
Transition Adj Chg	KWH @	-0.00500¢	
NY Assessment	KWH @	0.00000¢	
Government surcharges - Delivery			
Total Delivery Charges			
Total Supplier Charge			
CURRENT LIGHTING CHARGES			

BILLING DATE 07/23/18

BILLING SUMMARY

ACCOUNT NUMBER
[redacted]

Last Bill	[redacted]
Payments: 07/09/18	
Adjustments: Outage Credit	
Service Charges: Lighting	
TOTAL AMOUNT DUE	

O&R certifies that the amount of $3,438.51 is correct, that items, services & disbursements charged were rendered as stated and no part has been paid or satisfied. Exempt taxes are excluded and the amount claimed is due on 08/17/2018.

MANAGER CUSTOMER ACCOUNTING
MARIE QUIGLEY

To avoid a 1.5% late charge, please pay by 08/15/2018.

Your lighting service energy supplier is Constellation New Energy C&I. They can be contacted at 1-844-636-3749.

*We offer convenient payment options such as pay by phone, pay online or in person at **Village of Kiryas Joel, 51 Forest Rd, Suite 340, Monroe.***

Have your payments electronically deducted from your bank account by enrolling in Automatic Bill Payment. Place an X in the box on your bill stub. Details at www.oru.com/ABP

RECEIVED
JUL 27 2018
COMPTROLLER'S OFFICE

S 000497 OROLNS12 000900 0100000000

Orange & Rockland

TOTAL AMOUNT DUE [redacted]

V00218 [redacted]

Amount enclosed:

0000497 01 AB 0.405 01 TR 00004 OROLNS12 0100000000
TOWN OF HIGHLANDS
254 MAIN ST
HIGHLAND FALLS, NY 10928-1804

To avoid a late charge pay by 08/15/2018

'X' to enroll in ABP

PO Box 1005
Spring Valley NY 10977

0009 9991596009 0000000000 00000339670

0000338

This bill is due on receipt. Detach and mail this portion with payment.

TOWN OF HIGHLANDS
TOWN RD LITE 2
HIGHLAND FALLS, NY10928

Account Number: [redacted]

Billing Date: 07/23/18

ELEC MUNICIPAL STREET LIGHTING-DELIVERY

From: 07/01/2018 To: 08/01/2018

3	46000 LUM 8FT 144 S	[redacted]	[redacted]	[redacted]
1	27500 LUM 8FT 141 S			
26	22500 LUM 8FT 121 M			
92	7900 LUM 8FT 114 M			
19	4000 LUM 8FT 111 M			
7	9500 LUM 8FT 134 S			
19	5800 LUM 8FT 131 S			
Total 167				

Orange & Rockland
Rockland Electric Company

390 West Route 59
Spring Valley NY 10977-5320
1-877-434-4100 www.oru.com

Constellation New Energy C&I
PO Box 4911
Houston TX 77210-4911

See page 1 for Total Amount Due

Supplemental Statement

FOR INFORMATIONAL PURPOSES ONLY

TOWN OF HIGHLANDS
TOWN RD LITE 2
HIGHLAND FALLS, NY 10928

Your next Meter Reading will be:

For Energy Supplier service information call 1-844-636-3749
www.newenergy.com

Supplier LIGHTING CHARGES
Jul 01-Aug 01 [redacted] KWH @ 6.3470¢
TOTAL SUPPLIER UNMETERED CHARGE [redacted]

BILLING DATE 07/23/18

Constellation New Energy C&I

CUSTOMER'S ACCOUNT NUMBER
[redacted]

Current Supplier Charges
Unmetered [redacted]

000497 OROLNS12 000901 0100000000 E

TOTAL SUPPLIER CHARGES [redacted]

DO NOT PAY THESE SUPPLIER CHARGES SEPARATELY.

They are included in the Total Amount Due on Page 1 of your O&R bill.

0000339

Orange & Rockland
Rockland Electric Company

390 West Route 59
Spring Valley NY 10977-5320
1-877-434-4100 www.oru.com

TOWN OF HIGHLANDS
TOWN RD LITE 2
HIGHLAND FALLS, NY 10928
STREET LIGHTING

Your next Meter Reading will be:

If you have questions about this bill, call toll-free 1-877-434-4100 or go to www.oru.com

ELEC MUNICIPAL STREET LIGHTING-DELIVERY
Sep 1
Aug 1
Total Usage (KWH) 31 Days [redacted]

Delivery Charges

Delivery Chg			¢ 0.24600¢	[redacted]
Energy Cst Adj	[redacted]	KWH @		
SBC Chg		KWH @	0.58700¢	
Transition Adj Chg		KWH @	-0.00500¢	
NY Assessment		KWH @	0.00000¢	
Government surcharges - Delivery				
Total Delivery Charges				
Total Supplier Charge				
CURRENT LIGHTING CHARGES				

BILLING DATE 08/22/18

BILLING SUMMARY

ACCOUNT NUMBER [redacted]

Last Bill [redacted]
Payments:
08/08/18
Adjustments
Outage Credit
Service Charges
Lighting
TOTAL AMOUNT DUE

O&R certifies that the amount of $3,434.20 is correct, that items, services & disbursements charged were rendered as stated and no part has been paid or satisfied. Exempt taxes are excluded and the amount claimed is due on 09/17/2018.

MANAGER CUSTOMER ACCOUNTING
MARIE QUIGLEY

To avoid a 1.5% late charge, please pay by 09/14/2018.

Your lighting service energy supplier is Constellation New Energy C&I. They can be contacted at 1-844-636-3749.

We offer convenient payment options such as pay by phone, pay online or in person at Village of Kiryas Joel, 51 Forest Rd, Suite 340, Monroe.

Have your payments electronically deducted from your bank account by enrolling in Automatic Bill Payment. Place an X in the box on your bill stub. Details at www.oru.com/ABP

RECEIVED
AUG 27 2018
COMPTROLLER'S OFFICE

S 006004 OROTNS12 011725 0100000000

Orange & Rockland

TOTAL AMOUNT DUE [redacted]

V00216 [redacted]

Amount enclosed:

To avoid a late charge pay by 09/14/2018

'X' to enroll in ABP

0006004 01 AB 0.405 01 TR 00017 OROTNS12 0100000000
TOWN OF HIGHLANDS
254 MAIN ST
HIGHLAND FALLS, NY 10928-1804

PO Box 1005
Spring Valley NY 10977

0009 9991596009 0000000000 00000327893

0001075

This bill is due on receipt. Detach and mail this portion with payment.

TOWN OF HIGHLANDS
TOWN RD LITE 2
HIGHLAND FALLS, NY10928

Account Number: 99915-96009

Billing Date: 08/22/18

ELEC MUNICIPAL STREET LIGHTING-DELIVERY

From: 08/01/2018 To: 09/01/2018

17	22500 LUM 8FT 121 M	[redacted]	[redacted]	[redacted]
4	46000 LUM 8FT 144 S	[redacted]	[redacted]	[redacted]
6	27500 LUM 8FT 141 S	[redacted]	[redacted]	[redacted]
2	16000 LUM 8FT 138 S	[redacted]	[redacted]	[redacted]
28	9500 LUM 8FT 134 S	[redacted]	[redacted]	[redacted]
22	5800 LUM 8FT 131 S	[redacted]	[redacted]	[redacted]
2	5800 LUM 130 S	[redacted]	[redacted]	[redacted]
68	7900 LUM 8FT 114 M	[redacted]	[redacted]	[redacted]
18	4000 LUM 8FT 111 M	[redacted]	[redacted]	[redacted]
Total 167		[redacted]	[redacted]	[redacted]

Orange & Rockland
Rockland Electric Company

390 West Route 59
Spring Valley NY 10977-5320
1-877-434-4100 www.oru.com

Constellation New Energy C&I
PO Box 4911
Houston TX 77210-4911

See page 1 for Total Amount Due

Supplemental Statement

FOR INFORMATIONAL PURPOSES ONLY

TOWN OF HIGHLANDS
TOWN RD LITE 2
HIGHLAND FALLS, NY 10928

Your next Meter Reading will be:

For Energy Supplier service information call 1-844-636-3749
www.newenergy.com

Supplier LIGHTING CHARGES
Aug 01-Sep 01 [redacted] KWH @ 6.3470¢
TOTAL SUPPLIER UNMETERED CHARGE [redacted]

BILLING DATE 08/22/18

Constellation New Energy C&I

CUSTOMER'S ACCOUNT NUMBER
[redacted]

Current Supplier Charges
Unmetered [redacted]

006004 ORGTNS12 011726 0100000000 E

TOTAL SUPPLIER CHARGES [redacted]

DO NOT PAY THESE SUPPLIER CHARGES SEPARATELY.

They are included in the Total Amount Due on Page 1 of your O&R bill.

0001076

Orange and Rockland Electric Company
Spring Valley NY 10977-5320
1-877-434-4100 www.oru.com

TOWN OF HIGHLANDS
TOWN RD LITE 2
HIGHLAND FALLS, NY 10928
STREET LIGHTING

Your next Meter Reading will be:

If you have questions about this bill, call toll-free 1-877-434-4100 or go to www.oru.com

ELEC MUNICIPAL STREET LIGHTING-DELIVERY
Oct 1
Sep 1
Total Usage (KWH) 30 Days [redacted]

BILLING DATE 09/20/18

BILLING SUMMARY

ACCOUNT NUMBER
[redacted]

Delivery Charges

Delivery Chg				[redacted]
Energy Cst Adj	[redacted]	KWH @	¢ 0.23600¢	
SBC Chg		KWH @	0.58700¢	
Transition Adj Chg		KWH @	-0.00500¢	
NY Assessment		KWH @	0.00000¢	
Government surcharges - Delivery				
Total Delivery Charges				
Total Supplier Charge				
CURRENT LIGHTING CHARGES				

Last Bill	[redacted]
Payments:	
09/04/18	
Service Charges	
Lighting	
TOTAL AMOUNT DUE	

O&R certifies that the amount of $3,508.83 is correct, that items, services & disbursements charged were rendered as stated and no part has been paid or satisfied. Exempt taxes are excluded and the amount claimed is due on 10/15/2018.

MANAGER CUSTOMER ACCOUNTING
MARIE QUIGLEY

To avoid a 1.5% late charge, please pay by 10/13/2018.

Your lighting service energy supplier is Constellation New Energy C&I. They can be contacted at 1-844-636-3749.

We offer convenient payment options such as pay by phone, pay online or in person at Village of Kiryas Joel, 51 Forest Rd, Suite 340, Monroe.

Have your payments electronically deducted from your bank account by enrolling in Automatic Bill Payment. Place an X in the box on your bill stub. Details at www.oru.com/ABP

TOWN OF HIGHLANDS
TOWN RD LITE 2
HIGHLAND FALLS, NY10928

Account Number: [redacted]

Billing Date: 09/20/18

ELEC MUNICIPAL STREET LIGHTING-DELIVERY

From: 09/01/2018 To: 10/01/2018

4	46000 LUM 8FT 144 S	[redacted]	[redacted]	[redacted]
6	27500 LUM 8FT 141 S	[redacted]	[redacted]	[redacted]
2	16000 LUM 8FT 138 S	[redacted]	[redacted]	[redacted]
17	22500 LUM 8FT 121 M	[redacted]	[redacted]	[redacted]
68	7900 LUM 8FT 114 M	[redacted]	[redacted]	[redacted]
18	4000 LUM 8FT 111 M	[redacted]	[redacted]	[redacted]
28	9500 LUM 8FT 134 S	[redacted]	[redacted]	[redacted]
22	5800 LUM 8FT 131 S	[redacted]	[redacted]	[redacted]
2	5800 LUM 130 S	[redacted]	[redacted]	[redacted]
Total 167		[redacted]	[redacted]	[redacted]

Rockland Electric Company

Spring Valley NY 10977-5320
1-877-434-4100 www.oru.com

Constellation New Energy C&I
PO Box 4911
Houston TX 77210-4911

See page 1 for Total Amount Due

Supplemental Statement

FOR INFORMATIONAL PURPOSES ONLY

TOWN OF HIGHLANDS
TOWN RD LITE 2
HIGHLAND FALLS, NY 10928

Your next Meter Reading will be:

For Energy Supplier service information call 1-844-636-3749
www.newenergy.com

Supplier LIGHTING CHARGES
Sep 01-Oct 01 [redacted] @. 6.3470¢
TOTAL SUPPLIER UNMETERED CHARGE [redacted]

BILLING DATE 09/20/18

Constellation New Energy C&I

CUSTOMER'S ACCOUNT NUMBER
[redacted]

Current Supplier Charges
Unmetered [redacted]

005774 OROXNS12 011291 0100000000 E

TOTAL SUPPLIER CHARGES [redacted]

DO NOT PAY THESE SUPPLIER CHARGES SEPARATELY.

They are included in the Total Amount Due on Page 1 of your O&R bill.

0000960

Orange and Rockland Electric Company
Spring Valley NY 10977-5320
1-877-434-4100 www.oru.com

TOWN OF HIGHLANDS
TOWN RD LITE 2
HIGHLAND FALLS, NY 10928
STREET LIGHTING

Your next Meter Reading will be:

If you have questions about this bill, call toll-free 1-877-434-4100 or go to www.oru.com

ELEC MUNICIPAL STREET LIGHTING-DELIVERY
Nov 1
Oct 1
Total Usage (KWH) 31 Days [redacted]

Delivery Charges

Delivery Chg				[redacted]
Energy Cst Adj	[redacted]	KWH @	¢ 0.23500¢	
SBC Chg		KWH @	0.58700¢	
Transition Adj Chg		KWH @	-0.00500¢	
NY Assessment		KWH @	0.00000¢	
Government surcharges - Delivery				
Total Delivery Charges				
Total Supplier Charge				
CURRENT LIGHTING CHARGES				

BILLING DATE 10/19/18

BILLING SUMMARY

ACCOUNT NUMBER [redacted]

Last Bill	[redacted]
Payments: 10/04/18	[redacted]
Service Charges Lighting	[redacted]
TOTAL AMOUNT DUE	[redacted]

O&R certifies that the amount of $3,647.65 is correct, that items, services & disbursements charged were rendered as stated and no part has been paid or satisfied. Exempt taxes are excluded and the amount claimed is due on 11/13/2018.

MANAGER CUSTOMER ACCOUNTING
MARIE QUIGLEY

To avoid a 1.5% late charge, please pay by 11/11/2018.

Your lighting service energy supplier is Constellation New Energy C&I. They can be contacted at 1-844-636-3749.

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RECEIVED
OCT 24 2018
COMPTROLLER'S OFFICE

TOWN OF HIGHLANDS
TOWN RD LITE 2
HIGHLAND FALLS, NY10928

Account Number: [redacted]

Billing Date: 10/19/18

ELEC MUNICIPAL STREET LIGHTING-DELIVERY

From: 10/01/2018 To: 11/01/2018

4	46000 LUM 8FT 144 S	[redacted]	[redacted]	[redacted]
6	27500 LUM 8FT 141 S			
2	16000 LUM 8FT 138 S			
17	22500 LUM 8FT 121 M			
68	7900 LUM 8FT 114 M			
18	4000 LUM 8FT 111 M			
28	9500 LUM 8FT 134 S			
22	5800 LUM 8FT 131 S			
2	5800 LUM 130 S			
Total 167				

Rockland Electric Company
Spring Valley NY 10977-5320
1-877-434-4100 www.oru.com

Constellation New Energy C&I
PO Box 4911
Houston TX 77210-4911

See page 1 for Total Amount Due

Supplemental Statement

FOR INFORMATIONAL PURPOSES ONLY

TOWN OF HIGHLANDS
TOWN RD LITE 2
HIGHLAND FALLS, NY 10928

Your next Meter Reading will be:

For Energy Supplier service Information call 1-844-636-3749
www.newenergy.com

Supplier LIGHTING CHARGES
Oct 01-Nov 01 [redacted] KWH @ 6.3470¢
TOTAL SUPPLIER UNMETERED CHARGE [redacted]

BILLING DATE 10/19/18

Constellation New Energy C&I

CUSTOMER'S ACCOUNT NUMBER
[redacted]

Current Supplier Charges
Unmetered [redacted]

TOTAL SUPPLIER CHARGES [redacted]

DO NOT PAY THESE SUPPLIER CHARGES SEPARATELY.

They are included in the Total Amount Due on Page 1 of your O&R bill.

0001022

Orange & Rockland
Rockland Electric Company

390 West Route 59
Spring Valley NY 10977-5320
1-877-434-4100 www.oru.com

TOWN OF HIGHLANDS
TOWN RD LITE 2
HIGHLAND FALLS, NY 10928
STREET LIGHTING

Your next Meter Reading will be:

If you have questions about this bill, call toll-free 1-877-434-4100 or go to www.oru.com

ELEC MUNICIPAL STREET LIGHTING-DELIVERY
Dec 1
Nov 1
Total Usage (KWH) 30 Days [redacted]

Delivery Charges

Delivery Chg			¢ 0.24000¢	[redacted]
Energy Cst Adj	[redacted]	KWH @		
SBC Chg		KWH @	0.58700¢	
Transition Adj Chg		KWH @	-0.01500¢	
NY Assessment		KWH @	0.00000¢	
Government surcharges - Delivery				
Total Delivery Charges				
Total Supplier Charge				
CURRENT LIGHTING CHARGES				

BILLING DATE 11/20/18

BILLING SUMMARY

ACCOUNT NUMBER
[redacted]

Last Bill	[redacted]
Payments: 10/30/18	[redacted]
Service Charges Lighting	[redacted]
TOTAL AMOUNT DUE	[redacted]

O&R certifies that the amount of $3,707.34 is correct, that items, services & disbursements charged were rendered as stated and no part has been paid or satisfied. Exempt taxes are excluded and the amount claimed is due on 12/17/2018.

MANAGER CUSTOMER ACCOUNTING
MARIE QUIGLEY

To avoid a 1.5% late charge, please pay by 12/13/2018.

Your lighting service energy supplier is Constellation New Energy C&I. They can be contacted at 1-844-636-3749.

We offer convenient payment options such as pay by phone, pay online or in person at Village of Kiryas Joel, 51 Forest Rd, Suite 340, Monroe.

Have your payments electronically deducted from your bank account by enrolling in Automatic Bill Payment. Place an X in the box on your bill stub. Details at www.oru.com/ABP

RECEIVED
NOV 26 2018
COMPTROLLER'S OFFICE

S 001331 ORO6NS12 002326 0100000000

Orange & Rockland [redacted]

TOTAL AMOUNT DUE [redacted]

V00216

Amount enclosed:

0001331 01 AB 0.405 01 TR 00006 ORO6NS12 0100000000
TOWN OF HIGHLANDS
254 MAIN ST
HIGHLAND FALLS, NY 10928-1804

To avoid a late charge pay by 12/13/2018

'X' to enroll in ABP

PO Box 1005
Spring Valley NY 10977

0009 9991596009 0000000000 00003707347

0000961

This bill is due on receipt. Detach and mail this portion with payment.

TOWN OF HIGHLANDS
TOWN RD LITE 2
HIGHLAND FALLS, NY10928

Account Number: [redacted]

Billing Date: 11/20/18

ELEC MUNICIPAL STREET LIGHTING-DELIVERY

From: 11/01/2018 To: 12/01/2018

17	22500 LUM 8FT 121 M	[redacted]	[redacted]	[redacted]
4	46000 LUM 8FT 144 S			
6	27500 LUM 8FT 141 S			
2	16000 LUM 8FT 138 S			
28	9500 LUM 8FT 134 S			
22	5800 LUM 8FT 131 S			
2	5800 LUM 130 S			
68	7900 LUM 8FT 114 M			
18	4000 LUM 8FT 111 M			
Total	167			

Orange & Rockland
Rockland Electric Company

390 West Route 59
Spring Valley NY 10977-5320
1-877-434-4100 www.oru.com

TOWN OF HIGHLANDS
TOWN RD LITE 2
HIGHLAND FALLS, NY 10928
STREET LIGHTING

Your next Meter Reading will be:

If you have questions about this bill, call toll-free 1-877-434-4100 or go to www.oru.com

ELEC MUNICIPAL STREET LIGHTING-DELIVERY
Jan 1
Dec 1
Total Usage (KWH) 31 Days [redacted]

Delivery Charges

Delivery Chg	[redacted]			[redacted]
Energy Cst Adj		KWH @	¢ 0.23700¢	
SBC Chg		KWH @	0.58700¢	
Transition Adj Chg		KWH @	-0.01500¢	
NY Assessment		KWH @	0.00000¢	
Government surcharges - Delivery				
Total Delivery Charges				
Total Supplier Charge				
CURRENT LIGHTING CHARGES				

BILLING DATE 12/20/18

BILLING SUMMARY

ACCOUNT NUMBER [redacted]

Last Bill	[redacted]
Payments: 12/10/18	
Service Charges Lighting	
TOTAL AMOUNT DUE	

O&R certifies that the amount of $3,807.04 is correct, that items, services & disbursements charged were rendered as stated and no part has been paid or satisfied. Exempt taxes are excluded and the amount claimed is due on 01/14/2019.

MANAGER CUSTOMER ACCOUNTING
MARIE QUIGLEY

To avoid a 1.5% late charge, please pay by 01/12/2019.

Your lighting service energy supplier is Constellation New Energy C&I. They can be contacted at 1-844-636-3749.

We offer convenient payment options such as pay by phone, pay online or in person at Village of Kiryas Joel, 51 Forest Rd, Suite 340, Monroe.

Have your payments electronically deducted from your bank account by enrolling in Automatic Bill Payment. Place an X in the box on your bill stub. Details at www.oru.com/ABP

RECEIVED
DEC 26 2018
COMPTROLLER'S OFFICE

S 005376 OROBNS12 010252 0100000000

Orange & Rockland

V00216 [redacted]

0005376 01 AB 0.405 01 TR 00018 OROBNS12 0100000000
TOWN OF HIGHLANDS
254 MAIN ST
HIGHLAND FALLS, NY 10928-1804

TOTAL AMOUNT DUE [redacted]

Amount enclosed:

To avoid a late charge pay by 01/12/2019

'X' to enroll in ABP

PO Box 1005
Spring Valley NY 10977

0009 9991596009 0000000000 00000380704

0000931

This bill is due on receipt. Detach and mail this portion with payment.

TOWN OF HIGHLANDS
TOWN RD LITE 2
HIGHLAND FALLS, NY10928

Account Number: [redacted]

Billing Date: 12/20/18

ELEC MUNICIPAL STREET LIGHTING-DELIVERY
From: 12/01/2018 To: 01/01/2019

17	22500 LUM 8FT 121 M	[redacted]	[redacted]	[redacted]
6	27500 LUM 8FT 141 S			
2	16000 LUM 8FT 138 S			
4	46000 LUM 8FT 144 S			
28	9500 LUM 8FT 134 S			
23	5800 LUM 8FT 131 S			
2	5800 LUM 130 S			
68	7900 LUM 8FT 114 M			
18	4000 LUM 8FT 111 M			
Total 168				

Orange & Rockland
Rockland Electric Company

Spring Valley NY
1-877-434-4100 www.oru.com

GHLANDS
LITE 2
HLAND FALLS, NY 10928
STREET LIGHTING

Your next Meter Reading will be:

If you have questions about this bill, call toll-free 1-877-434-4100 or go to www.oru.com

ELEC MUNICIPAL STREET LIGHTING-DELIVERY
Feb 1
Jan 1
Total Usage (KWH) 31 Days [redacted]

Delivery Charges

Delivery Chg				[redacted]
Energy Cst Adj	[redacted]	KWH @	¢ 0.01200¢	
SBC Chg		KWH @	0.56200¢	
Transition Adj Chg		KWH @	-0.01500¢	
NY Assessment		KWH @	0.00000¢	
Government surcharges - Delivery				
Total Delivery Charges				
CURRENT UNMETERED CHARGE				

O&R certifies that the amount of $2,775.87 is correct, that items, services & disbursements charged were rendered as stated and no part has been paid or satisfied. Exempt taxes are excluded and the amount claimed is due on 02/19/2019.

MANAGER CUSTOMER ACCOUNTING
MARIE QUIGLEY

To avoid a 1.5% late charge, please pay by 02/15/2019.

Your lighting service energy supplier is Constellation New Energy C&I. They can be contacted at 1-844-636-3749.

We offer convenient payment options such as pay by phone, pay online or in person at Village of Kiryas Joel, 51 Forest Rd, Suite 340, Monroe.

Have your payments electronically deducted from your bank account by enrolling in Automatic Bill Payment. Place an X in the box on your bill stub. Details at www.oru.com/ABP

BILLING DATE 01/23/19

BILLING SUMMARY

ACCOUNT NUMBER
[redacted]

Last Bill
Payments:
01/09/19
Adjustments
Billing Charge
Outage Credit
Service Charges
Lighting
TOTAL
AMOUNT DUE
[redacted]

RECEIVED
JAN 28 2019
COMPTROLLER'S OFFICE

N OF HIGHLANDS
N RD LITE 2
HIGHLAND FALLS, NY10928

Account Number: [redacted]

Billing Date: 01/23/19

ELEC MUNICIPAL STREET LIGHTING-DELIVERY

From: 01/01/2019 To: 02/01/2019

4	46000 LUM 8FT 144 S	[redacted]	[redacted]	[redacted]
1	27500 LUM 15FT 142 S			
6	27500 LUM 8FT 141 S			
2	16000 LUM 8FT 138 S			
16	22500 LUM 8FT 121 M			
68	7900 LUM 8FT 114 M			
18	4000 LUM 8FT 111 M			
28	9500 LUM 8FT 134 S			
22	5800 LUM 8FT 131 S			
2	5800 LUM 130 S			
1	3900 LUM 8FT 194 L			
Total 168				

Rockland Electric Company Spring Valley NY 10977-5320 1-877-434-4100 www.oru.com

TOWN OF HIGHLANDS
TOWN RD LITE 2
HIGHLAND FALLS, NY 10928
STREET LIGHTING

Your next Meter Reading will be:

If you have questions about this bill, call toll-free 1-877-434-4100 or go to www.oru.com

ELEC MUNICIPAL STREET LIGHTING-DELIVERY

Mar 1
Feb 1
Total Usage (KWH) 28 Days [redacted]

Delivery Charges

Delivery Chg			[redacted]
Energy Cst Adj	[redacted] KWH @	0.24200¢	
SBC Chg	KWH @	0.56200¢	
Transition Adj Chg	KWH @	-0.01500¢	
NY Assessment	KWH @	0.00000¢	
Government surcharges - Delivery			
Total Delivery Charges			
CURRENT UNMETERED CHARGE			

BILLING DATE 02/21/19

BILLING SUMMARY

ACCOUNT NUMBER [redacted]

Last Bill	[redacted]
Payments: 02/04/19	[redacted]
Adjustments Billing Charge	[redacted]
Service Charges Lighting	[redacted]
TOTAL AMOUNT DUE	[redacted]

O&R certifies that the amount of $2,789.83 is correct, that items, services & disbursements charged were rendered as stated and no part has been paid or satisfied. Exempt taxes are excluded and the amount claimed is due on 03/18/2019.

MANAGER CUSTOMER ACCOUNTING
MARIE QUIGLEY

To avoid a 1.5% late charge, please pay by 03/16/2019.

Your lighting service energy supplier is Constellation New Energy C&I. They can be contacted at 1-844-636-3749.

We offer convenient payment options such as pay by phone, pay online or in person at Village of Kiryas Joel, 51 Forest Rd, Suite 340, Monroe.

Have your payments electronically deducted from your bank account by enrolling in Automatic Bill Payment. Place an X in the box on your bill stub. Details at www.oru.com/ABP

RECEIVED
FEB 25 2019
COMPTROLLER'S OFFICE

0004980 OROMNS12 009454 0100000000

TOWN OF HIGHLANDS
TOWN RD LITE 2
HIGHLAND FALLS, NY10928

Account Number: [redacted]

Billing Date: 02/21/19

ELEC MUNICIPAL STREET LIGHTING-DELIVERY
From: 02/01/2019 To: 03/01/2019

16	22500 LUM 8FT 121 M	[redacted]	[redacted]	[redacted]
4	46000 LUM 8FT 144 S			
1	27500 LUM 15FT 142 S			
6	27500 LUM 8FT 141 S			
2	16000 LUM 8FT 138 S			
28	9500 LUM 8FT 134 S			
22	5800 LUM 8FT 131 S			
2	5800 LUM 130 S			
1	3900 LUM 8FT 194 L			
68	7900 LUM 8FT 114 M			
18	4000 LUM 8FT 111 M			
Total 168				

Orange & Rockland
Rockland Electric Company

1-877-434-4100 www.oru.com

)WN OF HIGHLANDS
)WN RD LITE 2
GHLAND FALLS, NY 10928
'REET LIGHTING

Your next Meter Reading will be:

If you have questions about this bill, call toll-free 1-877-434-4100 or go to www.oru.com

LEC MUNICIPAL STREET LIGHTING-DELIVERY
or 1
ar 1
otal Usage (KWH) 31 Days [redacted]

BILLING DATE 03/21/19

BILLING SUMMARY

ACCOUNT NUMBER [redacted]

Delivery Charges

Delivery Chg	[redacted]			[redacted]
Energy Cst Adj		KWH @	¢ 0.01200¢	
SBC Chg		KWH @	0.56200¢	
Transition Adj Chg		KWH @	-0.01500¢	
NY Assessment		KWH @	0.00000¢	
Government surcharges - Delivery				
Total Delivery Charges				
CURRENT UNMETERED CHARGE				

Last Bill
Payments:
03/04/19
Adjustments
Billing Charge
Service Charges
Lighting
TOTAL
AMOUNT DUE [redacted]

O&R certifies that the amount of $2,760.03 is correct, that items, services & disbursements charged were rendered as stated and no part has been paid or satisfied. Exempt taxes are excluded and the amount claimed is due on 04/15/2019.

MANAGER CUSTOMER ACCOUNTING
MARIE QUIGLEY

To avoid a 1.5% late charge, please pay by 04/13/2019.

Your lighting service energy supplier is Constellation New Energy C&I. They can be contacted at 1-844-536-3749.

We offer convenient payment options such as pay by phone, pay online or in person at Village of Kiryas Joel, 51 Forest Rd, Suite 340, Monroe.

Coming Soon - we're making it easier to see your amount due and pay by date.

Have your payments electronically deducted from your bank account by enrolling in Automatic Bill Payment. Place an X in the box on your bill stub. Details at www.oru.com/ABP

TOWN OF HIGHLANDS
TOWN RD LITE 2
HIGHLAND FALLS, NY10928

Account Number [redacted]

Billing Date: 03/21/19

ELEC MUNICIPAL STREET LIGHTING-DELIVERY

From: 03/01/2019 To: 04/01/2019

16	22500 LUM 8FT 121 M	[redacted]	[redacted]	[redacted]
4	46000 LUM 8FT 144 S			
1	27500 LUM 15FT 142 S			
6	27500 LUM 8FT 141 S			
2	16000 LUM 8FT 138 S			
28	9500 LUM 8FT 134 S			
22	5800 LUM 8FT 131 S			
2	5800 LUM 130 S			
1	3900 LUM 8FT 194 L			
68	7900 LUM 8FT 114 M			
18	4000 LUM 8FT 111 M			
Total 168				

Rockland Electric Company
Spring Valley NY 10977-5320
1-877-434-4100 www.oru.com

TOWN OF HIGHLANDS
TOWN RD LITE 2
HIGHLAND FALLS, NY 10928
STREET LIGHTING

Your next Meter Reading will be:

If you have questions about this bill, call toll-free 1-877-434-4100 or go to www.oru.com

ELEC MUNICIPAL STREET LIGHTING-DELIVERY
May 1
Apr 1
Total Usage (KWH) 30 Days [redacted]

BILLING DATE 04/19/19

BILLING SUMMARY

ACCOUNT NUMBER [redacted]

Delivery Charges

Delivery Chg			[redacted]
Energy Cst Adj	[redacted] KWH @	¢ 0.05300¢	
SBC Chg	KWH @	0.56200¢	
DRS RA	KWH @	-0.96100¢	
Transition Adj Chg	KWH @	-0.02100¢	
NY Assessment	KWH @	0.00000¢	
Government surcharges - Delivery			
Total Delivery Charges			
CURRENT UNMETERED CHARGE			

Last Bill	[redacted]
Payments:	
04/01/19	
Adjustments	
Billing Charge	
Service Charges	
Lighting	
TOTAL AMOUNT DUE	

O&R certifies that the amount of $2,401.71 is correct, that items, services & disbursements charged were rendered as stated and no part has been paid or satisfied. Exempt taxes are excluded and the amount claimed is due on 05/14/2019.

MANAGER CUSTOMER ACCOUNTING
MARIE QUIGLEY

To avoid a 1.5% late charge, please pay by 05/12/2019.

Your lighting service energy supplier is Direct Energy Business. They can be contacted at 1-888-925-9115.

We offer convenient payment options such as pay by phone, pay online or in person at Village of Kiryas Joel, 51 Forest Rd, Suite 340, Monroe.

Have your payments electronically deducted from your bank account by enrolling in Automatic Bill Payment. Place an X in the box on your bill stub. Details at www.oru.com/ABP

S 005244 OROONS12 010706 0100000000

TOWN OF HIGHLANDS
TOWN RD LITE 2
HIGHLAND FALLS, NY10928

Account Number: [redacted]

Billing Date: 04/19/19

ELEC MUNICIPAL STREET LIGHTING-DELIVERY

From: 04/01/2019 To: 05/01/2019

	4	46000 LUM 8FT 144 S	[redacted]	[redacted]	[redacted]
	1	27500 LUM 15FT 142 S			
	6	27500 LUM 8FT 141 S			
	2	16000 LUM 8FT 138 S			
	16	22500 LUM 8FT 121 M			
	68	7900 LUM 8FT 114 M			
	18	4000 LUM 8FT 111 M			
	28	9500 LUM 8FT 134 S			
	22	5800 LUM 8FT 131 S			
	2	5800 LUM 130 S			
	1	3900 LUM 8FT 194 L			
Total	168				

Orange & Rockland
Rockland Electric Company

Your next Meter Reading will be:

If you have questions about this bill, call toll-free 1-877-434-4100 or go to www.oru.com

. OF HIGHLANDS
WN RD LITE 2
IGHLAND FALLS, NY 10928
TREET LIGHTING

BILLING DATE 05/21/19

ELEC MUNICIPAL STREET LIGHTING-DELIVERY
Jun 1
May 1
Total Usage (KWH) 31 Days [redacted]

Delivery Charges

Delivery Chg	[redacted] KWH @	-0.05800¢	[redacted]
Energy Cst Adj	KWH @	0.56200¢	
SBC Chg	KWH @	-0.96100¢	
DRS RA	KWH @	-0.02100¢	
Transition Adj Chg	KWH @	0.00000¢	
NY Assessment			
Government surcharges - Delivery			
Total Delivery Charges			
CURRENT UNMETERED CHARGE			

BILLING SUMMARY

ACCOUNT NUMBER [redacted]

Last Bill
Payments: [redacted]
05/13/19

Adjustments [redacted]
Billing Charge
Service Charges [redacted]
Lighting
TOTAL
AMOUNT DUE

O&R certifies that the amount of $2,394.15 is correct, that items, services & disbursements charged were rendered as stated and no part has been paid or satisfied. Exempt taxes are excluded and the amount claimed is due on 06/17/2019.

MANAGER CUSTOMER ACCOUNTING
MARIE QUIGLEY

To avoid a 1.5% late charge, please pay by 06/13/2019.

Your lighting service energy supplier is Direct Energy Business. They can be contacted at 1-888-925-9115.

We offer convenient payment options such as pay by phone, pay online or in person at ***Village of Kiryas Joel, 51 Forest Rd, Suite 340, Monroe.***

Beginning with your next meter reading, your electric usage will be billed at the summer rate applicable from June 1 - Sept. 30.

Have your payments electronically deducted from your bank account by enrolling in Automatic Bill Payment. Place an X in the box on your bill stub. Details at www.oru.com/ABP

RECEIVED
MAY 24 2019
COMPTROLLER'S OFFICE

TOWN OF HIGHLANDS
TOWN RD LITE 2
HIGHLAND FALLS, NY10928

Account Number: [redacted]

Billing Date: 05/21/19

ELEC MUNICIPAL STREET LIGHTING-DELIVERY

From: 05/01/2019 To: 06/01/2019

16	22500 LUM 8FT 121 M	[redacted]	[redacted]	[redacted]
4	46000 LUM 8FT 144 S			
1	27500 LUM 15FT 142 S			
6	27500 LUM 8FT 141 S			
2	16000 LUM 8FT 138 S			
28	9500 LUM 8FT 134 S			
22	5800 LUM 8FT 131 S			
2	5800 LUM 130 S			
1	3900 LUM 8FT 194 L			
68	7900 LUM 8FT 114 M			
18	4000 LUM 8FT 111 M			
Total	168			

Orange & Rockland

TOWN OF HIGHLANDS
TOWN RD LITE 2
HIGHLAND FALLS, NY 10928
STREET LIGHTING

Your next Meter Reading will be:

Amount Due $2403.67
Pay By 07/12/19

BILLING DATE 06/19/19

BILLING SUMMARY

ACCOUNT NUMBER
[redacted]

Last Bill	[redacted]
Payments:	
06/10/19	
Adjustments	
Billing Charge	
Service Charges	
Lighting	
TOTAL AMOUNT DUE	

ELEC MUNICIPAL STREET LIGHTING-DELIVERY
Jul 1
Jun 1
Total Usage (KWH) 30 Days [redacted]

Delivery Charges

Delivery Chg				[redacted]
Energy Cst Adj	[redacted]	KWH @	¢ -0.00300¢	
SBC Chg		KWH @	0.56200¢	
DRS RA		KWH @	-0.96100¢	
Transition Adj Chg		KWH @	-0.02100¢	
NY Assessment		KWH @	0.00000¢	
Government surcharges - Delivery				
Total Delivery Charges				
CURRENT UNMETERED CHARGE				

O&R certifies that the amount of $2,403.67 is correct, that items, services & disbursements charged were rendered as stated and no part has been paid or satisfied. Exempt taxes are excluded and the amount claimed is due on 07/15/2019.

MANAGER CUSTOMER ACCOUNTING
MARIE QUIGLEY

To avoid a 1.5% late charge, please pay by 07/12/2019.

Your lighting service energy supplier is Direct Energy Business. They can be contacted at 1-888-925-9115.

*We offer convenient payment options such as pay by phone, pay online or in person at **Village of Kiryas Joel, 51 Forest Rd, Suite 340, Monroe.***

It's here - The first step to improving your bill. We've highlighted the Amount Due and Pay By Date, and added color to your energy usage graph.

Have your payments electronically deducted from your bank account by enrolling in Automatic Bill Payment. Place an X in the box on your bill stub. Details at www.oru.com/ABP

S 005423 ORODNS12 010519 0100000000

TOWN OF HIGHLANDS
TOWN RD LITE 2
HIGHLAND FALLS, NY10928

Account Number: [redacted]

Billing Date: 06/19/19

ELEC MUNICIPAL STREET LIGHTING-DELIVERY

From: 06/01/2019 To: 07/01/2019

4	46000 LUM 8FT 144 S	[redacted]	[redacted]	[redacted]
1	27500 LUM 15FT 142 S			
6	27500 LUM 8FT 141 S			
2	16000 LUM 8FT 138 S			
16	22500 LUM 8FT 121 M			
68	7900 LUM 8FT 114 M			
18	4000 LUM 8FT 111 M			
28	9500 LUM 8FT 134 S			
22	5800 LUM 8FT 131 S			
2	5800 LUM 130 S			
1	3900 LUM 8FT 194 L			
Total	168			

Orange & Rockland

TOWN OF HIGHLANDS
TOWN RD LITE 2
HIGHLAND FALLS, NY 10928
STREET LIGHTING

Your next Meter Reading will be:

ELEC MUNICIPAL STREET LIGHTING-DELIVERY

Aug 1
Jul 1
Total Usage (KWH) 31 Days [redacted]

Delivery Charges

Delivery Chg			[redacted]
Energy Cst Adj	[redacted] KWH @	¢ -0.03600¢	
SBC Chg	KWH @	0.56200¢	
DRS RA	KWH @	-0.96100¢	
Transition Adj Chg	KWH @	-0.02100¢	
NY Assessment	KWH @	0.00000¢	
Government surcharges - Delivery			
Total Delivery Charges			
CURRENT UNMETERED CHARGE			

BILLING DATE 07/22/19

BILLING SUMMARY

ACCOUNT NUMBER
[redacted]

Last Bill	[redacted]
Payments: 07/15/19	
Adjustments	
Manual Adj	
Credit	
Credit	
Billing Charge	
Service Charges	
Lighting	
CREDIT BALANCE DO NOT PAY	

O&R certifies that the amount of $2,391.66 is correct, that items, services & disbursements charged were rendered as stated and no part has been paid or satisfied. Exempt taxes are excluded and the amount claimed is due on 08/16/2019.

MANAGER CUSTOMER ACCOUNTING
THERESA MANERA

To avoid a 1.5% late charge, please pay by 08/14/2019.

Your lighting service energy supplier is Direct Energy Business. They can be contacted at 1-888-925-9115.

CREDIT BALANCE - Do Not Pay 10.71.

*We offer convenient payment options such as pay by phone, pay online or in person at **Village of Kiryas Joel, 51 Forest Rd, Suite 340, Monroe.***

Have your payments electronically deducted from your bank account by enrolling in Automatic Bill Payment. Place an X in the box on your bill stub. Details at www.oru.com/ABP

RECEIVED
JUL 26 2019
COMPTROLLER'S OFFICE

S 000519 OROLNS12 000983 0000000000

TOWN OF HIGHLANDS
TOWN RD LITE 2
HIGHLAND FALLS, NY10928

Account Number [redacted]

Billing Date: 07/22/19

ELEC MUNICIPAL STREET LIGHTING-DELIVERY

From: 07/01/2019 To: 08/01/2019

16	22500 LUM 8FT 121 M	[redacted]	[redacted]	[redacted]
4	46000 LUM 8FT 144 S	[redacted]	[redacted]	[redacted]
1	27500 LUM 15FT 142 S	[redacted]	[redacted]	[redacted]
6	27500 LUM 8FT 141 S	[redacted]	[redacted]	[redacted]
2	16000 LUM 8FT 138 S	[redacted]	[redacted]	[redacted]
28	9500 LUM 8FT 134 S	[redacted]	[redacted]	[redacted]
21	5800 LUM 8FT 131 S	[redacted]	[redacted]	[redacted]
2	5800 LUM 130 S	[redacted]	[redacted]	[redacted]
2	5000 LUM 8FT 196 L	[redacted]	[redacted]	[redacted]
1	3900 LUM 8FT 194 L	[redacted]	[redacted]	[redacted]
67	7900 LUM 8FT 114 M	[redacted]	[redacted]	[redacted]
18	4000 LUM 8FT 111 M	[redacted]	[redacted]	[redacted]
Total	168	[redacted]	[redacted]	[redacted]

Orange & Rockland

Amount Due $2,380.77
Pay By 09/12/19

TOWN OF HIGHLANDS
TOWN RD LITE 2
HIGHLAND FALLS, NY 10928
STREET LIGHTING

Your next Meter Reading will be:

ELEC MUNICIPAL STREET LIGHTING-DELIVERY

Sep 1
Aug 1
Total Usage (KWH) 31 Days [redacted]

Delivery Charges

Delivery Chg				[redacted]
Energy Cst Adj	[redacted]	KWH @	¢ -0.00300¢	
SBC Chg		KWH @	0.56200¢	
DRS RA		KWH @	-0.96100¢	
Transition Adj Chg		KWH @	-0.02100¢	
NY Assessment		KWH @	0.00000¢	
Government surcharges - Delivery				
Total Delivery Charges				
CURRENT UNMETERED CHARGE				

BILLING DATE 08/20/19

BILLING SUMMARY

ACCOUNT NUMBER [redacted]

Last Bill	[redacted]
Payments as of 08/20/19	
Adjustments	
Billing Charge	
Service Charges	
Lighting	
TOTAL AMOUNT DUE	

O&R certifies that the amount of $2,390.18 is correct, that items, services & disbursements charged were rendered as stated and no part has been paid or satisfied. Exempt taxes are excluded and the amount claimed is due on 09/16/2019.

MANAGER CUSTOMER ACCOUNTING
THERESA MANERA

To avoid a 1.5% late charge, please pay by 09/12/2019.

Your lighting service energy supplier is Direct Energy Business. They can be contacted at 1-888-925-9115.

*We offer convenient payment options such as pay by phone, pay online or in person at **Village of Kiryas Joel, 51 Forest Rd, Suite 340, Monroe.***

Have your payments electronically deducted from your bank account by enrolling in Automatic Bill Payment. Place an X in the box on your bill stub. Details at www.oru.com/ABP

RECEIVED
AUG 23 2019
COMPTROLLER'S OFFICE

TOWN OF HIGHLANDS
TOWN RD LITE 2
HIGHLAND FALLS, NY10928

Account Number [redacted]

Billing Date: 08/20/19

ELEC MUNICIPAL STREET LIGHTING-DELIVERY.

From: 08/01/2019 To: 09/01/2019

4	46000 LUM 8FT 144 S	[redacted]
1	27500 LUM 15FT 142 S	
6	27500 LUM 8FT 141 S	
2	16000 LUM 8FT 138 S	
16	22500 LUM 8FT 121 M	
67	7900 LUM 8FT 114 M	
18	4000 LUM 8FT 111 M	
28	9500 LUM 8FT 134 S	
21	5800 LUM 8FT 131 S	
2	5800 LUM 130 S	
2	5000 LUM 8FT 196 L	
1	3900 LUM 8FT 194 L	
Total	168	

Orange & Rockland

TOWN OF HIGHLANDS
TOWN RD LITE 2
HIGHLAND FALLS, NY 10928
STREET LIGHTING

Your next Meter Reading will be:

Amount Due $2,389.44
Pay By 10/12/19

BILLING DATE 09/19/19

BILLING SUMMARY

ACCOUNT NUMBER [redacted]

Last Bill	[redacted]
Payments:	
09/03/19	
Adjustments	
Billing Charge	
Service Charges	
Lighting	
TOTAL AMOUNT DUE	

ELEC MUNICIPAL STREET LIGHTING-DELIVERY
Oct 1
Sep 1
Total Usage (KWH) 30 Days [redacted]

Delivery Charges

Delivery Chg				[redacted]
Energy Cst Adj	[redacted]	KWH @	¢ 0.01800¢	
SBC Chg		KWH @	0.56200¢	
DRS RA		KWH @	-0.96100¢	
Transition Adj Chg		KWH @	-0.02100¢	
NY Assessment		KWH @	0.00000¢	
Government surcharges - Delivery				
Total Delivery Charges				
CURRENT UNMETERED CHARGE				

O&R certifies that the amount of $2,389.44 is correct, that items, services & disbursements charged were rendered as stated and no part has been paid or satisfied. Exempt taxes are excluded and the amount claimed is due on 10/15/2019.

MANAGER CUSTOMER ACCOUNTING
THERESA MANERA

To avoid a 1.5% late charge, please pay by 10/12/2019.

Your lighting service energy supplier is Direct Energy Business. They can be contacted at 1-888-925-9115.

*We offer convenient payment options such as pay by phone, pay online or in person at **Village of Kiryas Joel, 51 Forest Rd, Suite 340, Monroe.***

Have your payments electronically deducted from your bank account by enrolling in Automatic Bill Payment. Place an X in the box on your bill stub. Details at www.oru.com/ABP

TOWN OF HIGHLANDS
TOWN RD LITE 2
HIGHLAND FALLS, NY10928

Account Number [redacted]

Billing Date: 09/19/19

ELEC MUNICIPAL STREET LIGHTING-DELIVERY

From: 09/01/2019 To: 10/01/2019

16	22500 LUM 8FT 121 M	[redacted]	[redacted]	[redacted]
4	46000 LUM 8FT 144 S			
1	27500 LUM 15FT 142 S			
6	27500 LUM 8FT 141 S			
2	16000 LUM 8FT 138 S			
28	9500 LUM 8FT 134 S			
21	5800 LUM 8FT 131 S			
2	5800 LUM 130 S			
2	5000 LUM 8FT 196 L			
1	3900 LUM 8FT 194 L			
67	7900 LUM 8FT 114 M			
18	4000 LUM 8FT 111 M			
Total	168			

Orange & Rockland

TOWN OF HIGHLANDS
TOWN RD LITE 2
HIGHLAND FALLS, NY 10928
STREET LIGHTING

Your next Meter Reading will be:

Amount Due $2,379.04
Pay By 11/10/19

ELEC MUNICIPAL STREET LIGHTING-DELIVERY
Nov 1
Oct 1
Total Usage (KWH) 31 Days [redacted]

Delivery Charges

Delivery Chg				[redacted]
Energy Cst Adj	[redacted]	KWH @	¢ -0.00200¢	
SBC Chg		KWH @	0.56200¢	
DRS RA		KWH @	-0.96100¢	
Transition Adj Chg		KWH @	-0.02100¢	
NY Assessment		KWH @	0.00000¢	
Government surcharges - Delivery				
Total Delivery Charges				
CURRENT UNMETERED CHARGE				

BILLING DATE 10/18/19

BILLING SUMMARY

ACCOUNT NUMBER
[redacted]

Last Bill	[redacted]
Payments:	
09/30/19	
Adjustments	
Billing Charge	
Service Charges	
Lighting	
TOTAL AMOUNT DUE	

O&R certifies that the amount of $2,379.04 is correct, that items, services & disbursements charged were rendered as stated and no part has been paid or satisfied. Exempt taxes are excluded and the amount claimed is due on 11/12/2019.

MANAGER CUSTOMER ACCOUNTING
THERESA MANERA

To avoid a 1.5% late charge, please pay by 11/10/2019.

Your lighting service energy supplier is Direct Energy Business. They can be contacted at 1-888-925-9115.

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RECEIVED
OCT 23 2019
COMPTROLLER'S OFFICE

S 006384 ORC2NS12 013013 0100000000

TOWN OF HIGHLANDS
TOWN RD LITE 2
HIGHLAND FALLS, NY10928

Account Number: [redacted]

Billing Date: 10/18/19

ELEC MUNICIPAL STREET LIGHTING-DELIVERY

From: 10/01/2019 To: 11/01/2019

4	46000 LUM 8FT 144 S	[redacted]	[redacted]	[redacted]
1	27500 LUM 15FT 142 S			
6	27500 LUM 8FT 141 S			
2	16000 LUM 8FT 138 S			
16	22500 LUM 8FT 121 M			
67	7900 LUM 8FT 114 M			
18	4000 LUM 8FT 111 M			
28	9500 LUM 8FT 134 S			
21	5800 LUM 8FT 131 S			
2	5800 LUM 130 S			
2	5000 LUM 8FT 196 L			
1	3900 LUM 8FT 194 L			
Total	168			

Orange & Rockland

Amount Due $2,373.11
Pay By 12/12/19

TOWN OF HIGHLANDS
TOWN RD LITE 2
HIGHLAND FALLS, NY 10928
STREET LIGHTING

Your next Meter Reading will be:

ELEC MUNICIPAL STREET LIGHTING-DELIVERY
Dec 1
Nov 1
Total Usage (KWH) 30 Days [redacted]

Delivery Charges

Delivery Chg	[redacted]			[redacted]
Energy Cst Adj		KWH @	¢ 0.00300¢	
SBC Chg		KWH @	0.56200¢	
DRS RA		KWH @	-0.96100¢	
Transition Adj Chg		KWH @	-0.02100¢	
NY Assessment		KWH @	0.00000¢	
Government surcharges - Delivery				
Total Delivery Charges				
CURRENT UNMETERED CHARGE				

BILLING DATE 11/19/19

BILLING SUMMARY

ACCOUNT NUMBER
[redacted]

Last Bill	[redacted]
Payments:	
10/28/19	
Adjustments	
Billing Charge	
Service Charges	
Lighting	
TOTAL AMOUNT DUE	

O&R certifies that the amount of $2,373.11 is correct, that items, services & disbursements charged were rendered as stated and no part has been paid or satisfied. Exempt taxes are excluded and the amount claimed is due on 12/16/2019.

MANAGER CUSTOMER ACCOUNTING
THERESA MANERA

To avoid a 1.5% late charge, please pay by 12/12/2019.

Your lighting service energy supplier is Direct Energy Business. They can be contacted at 1-888-925-9115.

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Have your payments electronically deducted from your bank account by enrolling in Automatic Bill Payment. Place an X in the box on your bill stub. Details at www.oru.com/ABP

RECEIVED
NOV 25 2019
COMPTROLLER'S OFFICE

S 005155 ORO8NS12 010074 0100000000

TOWN OF HIGHLANDS
TOWN RD LITE 2
HIGHLAND FALLS, NY10928

Account Numbe[redacted]

Billing Date: 11/19/19

ELEC MUNICIPAL STREET LIGHTING-DELIVERY

From: 11/01/2019 To: 12/01/2019

	4	46000 LUM 8FT 144 S	[redacted]	[redacted]	[redacted]
	1	27500 LUM 15FT 142 S	[redacted]	[redacted]	[redacted]
	6	27500 LUM 8FT 141 S	[redacted]	[redacted]	[redacted]
	2	16000 LUM 8FT 138 S	[redacted]	[redacted]	[redacted]
	16	22500 LUM 8FT 121 M	[redacted]	[redacted]	[redacted]
	67	7900 LUM 8FT 114 M	[redacted]	[redacted]	[redacted]
	18	4000 LUM 8FT 111 M	[redacted]	[redacted]	[redacted]
	27	9500 LUM 8FT 134 S	[redacted]	[redacted]	[redacted]
	21	5800 LUM 8FT 131 S	[redacted]	[redacted]	[redacted]
	2	5800 LUM 130 S	[redacted]	[redacted]	[redacted]
	2	5000 LUM 8FT 196 L	[redacted]	[redacted]	[redacted]
	2	3900 LUM 8FT 194 L	[redacted]	[redacted]	[redacted]
Total	168		[redacted]	[redacted]	[redacted]

Arencibia, Stephanie (Molly)

From:	Kelly Pecoraro <kpecoraro@highlands-ny.gov>
Sent:	Wednesday, December 11, 2019 4:21 PM
To:	Matthew Christian; Richard Sullivan; Bob Livsey
Cc:	Laino, Jeffrey; Hermann, Charles; Bou Reed
Subject:	RE: Highlands Kick Off Meeting Minutes

Hi Matt.

We have about 14 O&R accounts. Do you want to see one of each to determine which ones you need?

Kelly

Kelly Pecoraro
Comptroller
Town of Highlands
254 Main Street
Highland Falls, NY 10928
845-446-4280 ext 325|f 845-446-6507

From: Matthew Christian [mailto:mchristian@guthdeconzo.com]
Sent: Wednesday, December 11, 2019 12:13 PM
To: Kelly Pecoraro <kpecoraro@highlands-ny.gov>; Richard Sullivan <rsullivan@highlands-ny.gov>; Bob Livsey <blivsey@highlands-ny.gov>
Cc: Laino, Jeffrey <Jeffrey.Laino@nypa.gov>; Hermann, Charles <Charles.Hermann@nypa.gov>; Bou Reed <breed@guthdeconzo.com>
Subject: RE: Highlands Kick Off Meeting Minutes

Thank you for sending that over Kelly. We will review this, but at a quick glance this should suffice for the streetlighting portion. If the park locations are on metered accounts we will need copies of those bills as well and anything else included in the additional scope like town hall.

Regards,

Matt

From: Kelly Pecoraro <kpecoraro@highlands-ny.gov>
Sent: Wednesday, December 11, 2019 11:06 AM
To: Richard Sullivan <rsullivan@highlands-ny.gov>; Bob Livsey <blivsey@highlands-ny.gov>
Cc: Laino, Jeffrey <Jeffrey.Laino@nypa.gov>; Hermann, Charles <Charles.Hermann@nypa.gov>; Bou Reed <breed@guthdeconzo.com>; Matthew Christian <mchristian@guthdeconzo.com>
Subject: RE: Highlands Kick Off Meeting Minutes

Attached please find Orange & Rockland street light bills from June 2018 through November 2019. Please let me know if you need anything else.

Regards,
Kelly

Kelly Pecoraro
Comptroller
Town of Highlands
254 Main Street
Highland Falls, NY 10928
845-446-4280 ext 325|f 845-446-6507

From: Richard Sullivan
Sent: Wednesday, December 11, 2019 7:05 AM
To: Bob Livsey <blivsey@highlands-ny.gov>
Cc: Laino, Jeffrey <Jeffrey.Laino@nypa.gov>; Hermann, Charles <Charles.Hermann@nypa.gov>; Bou Reed <breed@guthdeconzo.com>; Matthew Christian <mchristian@guthdeconzo.com>
Subject: Re: Highlands Kick Off Meeting Minutes

I haven't reviewed minutes yet, just wanted to let all know I had 3 assignments :
- inventory- done, emailed
- 12 months or more of billing - to be done by next Monday
- get O & R buyout price for 167 lights ....

On the last one, Teresa Johnson called me yesterday and acknowledged that on July 10th the town did indeed pursue this task, she is expediting O & R legal Dept to get this done, I will keep pressure on her/them .

Great meeting, my gut trusts what we are doing, expect digital copies of bills soon, and I will send self cartographied maps soon as well.
Obliged, Richie

Sent from my iPad

On Dec 10, 2019, at 2:01 PM, Matthew Christian <mchristian@guthdeconzo.com> wrote:

All,

It was great meeting everyone yesterday and we are excited to get this project started.

Please see attached for the minutes from yesterday's kickoff meeting. Please review and let me know if there are any additional comments or questions. I received the registry copy from Rich.

Thanks,

Matt Christian
Construction Manager

<image001.png> **Guth DeConzo Construction Management, Inc.**
T: 518-266-9600 X 117
M: 518-596-5996
GuthDeConzo.com
433 River Street, Suite 6004 | Troy NY 12180

recipient, or the employee or agent responsible for delivering this message to the intended recipient, you are hereby notified that any review, dissemination, distribution, printing, or copying of this e-mail message and/or any attachments is strictly prohibited. If you have received this transmission in error, please notify the sender immediately and permanently delete this e-mail [shred the document] and any attachments.

<Highlands Kick Off Meeting Minutes 12102019 w attachments.pdf>

Arencibia, Stephanie (Molly)

From:	Laino, Jeffrey <Jeffrey.Laino@nypa.gov>
Sent:	Tuesday, February 26, 2019 11:38 AM
To:	Luteran, Kevin; Richard Sullivan
Cc:	Bob Livsey
Subject:	RE: [EXTERNAL]Street lights

Thanks for making the introduction, happy to develop an initial estimate of project costs and savings. Please send the items Kevin listed, this will allow me to prepare the estimate.
Looking forward to working with you.
Regards,

Jeff Laino
Customer Business Development Representative New York Power Authority
123 Main Street
White Plains, NY 10601
(914) 287-3351 (office)
(914) 312-1260 (cell)
Jeffrey.Laino@nypa.gov
www.nypa.gov

-----Original Message-----
From: Luteran, Kevin
Sent: Tuesday, February 26, 2019 8:48 AM
To: Richard Sullivan <rsullivan@highlands-ny.gov>; Laino, Jeffrey <Jeffrey.Laino@nypa.gov>
Cc: Bob Livsey <blivsey@highlands-ny.gov>
Subject: RE: [EXTERNAL]Street lights

Good Morning Richie,

Thank you for reaching out, I would like to introduce you to Jeff Laino, you may have met Jeff at the Association of Towns conference but he will be able to help put together a proposal for you. To get started we will need a 1-2 copies of your street light utility bill, as well as any information on any customer-owned lights. Also, please share the purchase price from the utility, if you havenâ€™t requested this information it is not a big deal, we have a pretty good sense of what the cost will be but I would encourage you to submit your request as soon as possible since it could take up to 90 days to receive. As a reminder there is no commitment to request you purchase price from your utility. For your convenience I have attached Jeff's contact information below,

Jeff Laino
Customer Business Development Representative New York Power Authority
123 Main Street
White Plains, NY 10601
(914) 287-3351 (office)
(914) 312-1260 (cell)
Jeffrey.Laino@nypa.gov
www.nypa.gov

Feel free to reach out with any other questions,

Kevin

-----Original Message-----
From: Richard Sullivan <rsullivan@highlands-ny.gov>
Sent: Tuesday, February 26, 2019 7:51 AM
To: Luteran, Kevin <Kevin.Luteran@nypa.gov>
Cc: Bob Livsey <blivsey@highlands-ny.gov>
Subject: [EXTERNAL]Street lights

____

CAUTION â€" External Email

Suspicious? Click Report Phishing on Outlook toolbar. For Mobile forward to (abuse@nypa,gov)

____
____

Greetings,
I attended your presentation at the annual Association of Towns, and asked a few questions, one being the cost of a proposal ; it was indicated they are free of charge .

I am a town councilman, Town of Highlands, I have more than enough data as per your comments at the presentation to initiate a proposal, and I participated in a webinar last summer given by CT Male. I have a fairly good grasp on places like Kingston and Rhinebeck with thousands of street lights, Town of Highlands has 167 and a very small DPW, there is public interest in new ways of going Green, Iâ€™m concerned about pole rental costs and the burden of ownership , I look forward to discussion with no commitment .
Obliged, Richie Sullivan, Town of Highlands Councilman

8456425587
254 Main Street
Highland Falls, NY 10928
Town Supervisor Bob Livsey (Ccd)
Sent from my iPad

Arencibia, Stephanie (Molly)

From:	Richard Sullivan <rsullivan@highlands-ny.gov>
Sent:	Wednesday, July 10, 2019 12:00 PM
To:	Kelly Pecoraro; Bob Livsey
Cc:	Laino, Jeffrey
Subject:	[EXTERNAL]LED process

Good Morning Kelly ,
The process is something like this, and I've included a few contacts to help lessen the communication wonderment :
We must communicate, officially, our intent to acquire the streetlights from O & R, they have 60 days to respond with a number; Jeff gave an estimate in the proposal from April based on the 167 inventory I downloaded from O & R's portal
.
Jeff/NYPA will send an executable document this week, so NYPA administrative work and O & R acquisition happen in parallel, NYPA will include acquisition costs in our package if we chose, which I believe we will go for that option.
At O & R I have spoken a few times with Teresa Johnson, 8457835573 , JohnsonThe@oru.com is her email , she's on vacation this week, if desired I'll call her next week to initiate acquisition. I have again included NYPA workup in case you did not see it , and subsequent to events mentioned NYPA and the town will have a kickoff meeting.
Assuming all goes well, such things as increasing or decreasing # of lights will surface, Jeff mentioned different options for dimmers, and a pilot area for observance before buildout , but ultimately this is 2-3 weeks work for the contractor that NYPA assigns to this job, and I fully expect my name to be regularly singled out by opposition, I believe in what we are doing and hope anyone with concern drives down Strawtown Road in Clarkstown at night to get a true taste of what will manifest.
Jeff's office is

Customer Business Development Representative
New York Power Authority
123 Main Street
White Plains, NY 10601
(914) 287-3351 (office)
(914) 312-1260 (cell)
Jeffrey.Laino@nypa.gov
www.nypa.gov

Kelly and Bob :
Kelly Pecoraro
Comptroller
Town of Highlands
254 Main Street
Highland Falls, NY 10928
845-446-4280 ext 325|f 845-446-6507
Bob x 312 at same address.

Obliged, Richie

Arencibia, Stephanie (Molly)

From: Laino, Jeffrey <Jeffrey.Laino@nypa.gov>
Sent: Wednesday, July 10, 2019 1:22 PM
To: Richard Sullivan; Kelly Pecoraro; Bob Livsey
Subject: RE: [EXTERNAL]LED process

Thanks Rich. I put in the contract request and you should receive the contract via email in a few days.
Just a note on the project time line. The physical installs of the new fixtures should indeed take about 3 weeks. The engineering design work actually takes a bit longer than that, but we can get the project all ready for actual installs while the purchase details are settled with your utility. NYPA can finance the purchase of the fixtures. That process will be articulated when we kick off the project but we cannot start installs until the town takes ownership.
Looking forward to the kick off meeting!!
Regards,

Jeff Laino
Customer Business Development Representative
New York Power Authority
123 Main Street
White Plains, NY 10601
(914) 287-3351 (office)
(914) 312-1260 (cell)
Jeffrey.Laino@nypa.gov
www.nypa.gov

From: Richard Sullivan <rsullivan@highlands-ny.gov>
Sent: Wednesday, July 10, 2019 12:00 PM
To: Kelly Pecoraro <kpecoraro@highlands-ny.gov>; Bob Livsey <blivsey@highlands-ny.gov>
Cc: Laino, Jeffrey <Jeffrey.Laino@nypa.gov>
Subject: [EXTERNAL]LED process

Good Morning Kelly ,
The process is something like this, and I've included a few contacts to help lessen the communication wonderment :
We must communicate, officially, our intent to acquire the streetlights from O & R, they have 60 days to respond with a number; Jeff gave an estimate in the proposal from April based on the 167 inventory I downloaded from O & R's portal .
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NYPA workup in case you did not see it , and subsequent to events mentioned NYPA and the town will have a kickoff meeting.
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Jeff's office is

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www.nypa.gov

Kelly and Bob :
Kelly Pecoraro
Comptroller
Town of Highlands
254 Main Street
Highland Falls, NY 10928
845-446-4280 ext 325|f 845-446-6507
Bob x 312 at same address.

Obliged, Richie

Arencibia, Stephanie (Molly)

From:	Parille, Lindsay <Lindsay.Parille@nypa.gov>
Sent:	Tuesday, July 16, 2019 9:55 AM
To:	Bob Livsey
Cc:	Paine, John; Laino, Jeffrey
Subject:	RE: Please sign Town of Highlands_ES_MCRA_2019

Good morning,
I have canceled the agreement and reissued with the appropriate name. You should have received a new email from Adobe Sign.

Thank you,

Lindsay Parille
Power Contracts & Tariff Analyst

New York Power Authority
123 Main St.
White Plains, NY 10601
914.681.6256 I Lindsay.Parille@nypa.gov
www.nypa.gov

From: Bob Livsey <blivsey@highlands-ny.gov>
Sent: Tuesday, July 16, 2019 8:41 AM
To: Parille, Lindsay <Lindsay.Parille@nypa.gov>
Subject: RE: Please sign Town of Highlands_ES_MCRA_2019

On a "legal" document I should have my name as printed below, not Bob Livsey. I will cross out Bob Livsey and enter my proper name.

MERVIN R. LIVSEY
Supervisor, Town of Highlands
254 Main Street
Highland Falls, NY 10928
845 446-4280 x 312
Fax 845 446 4298
Cell 845 238 8074
blivsey@highlands-ny.gov

From: NEW YORK POWER AUTHORITY - Lindsay Parille [mailto:echosign@echosign.com]
Sent: Friday, July 12, 2019 4:48 PM
To: Bob Livsey <blivsey@highlands-ny.gov>
Subject: Please sign Town of Highlands_ES_MCRA_2019

[redacted]

NEW YORK POWER AUTHORITY - Lindsay Parille Has Sent You **Town of Highlands_ES_MCRA_2019** to Sign

NEW YORK POWER AUTHORITY - Lindsay Parille (New York Power Authority) says:
"Please review and complete Town of Highlands_ES_MCRA_2019."

Click here to review and sign **Town of Highlands_ES_MCRA_2019**.

After you sign **Town of Highlands_ES_MCRA_2019**, the agreement will be sent to **John Canale.** Then, all parties will receive a final PDF copy by email.

If you need to delegate this document to an authorized party for signature, **please do not forward this email.** Instead, click here to delegate.

Arencibia, Stephanie (Molly)

From:	Laino, Jeffrey <Jeffrey.Laino@nypa.gov>
Sent:	Tuesday, July 16, 2019 10:02 AM
To:	Richard Sullivan
Subject:	FW: Please sign Town of Highlands_ES_MCRA_2019
Attachments:	NYPA Street Lighting Authorization to Proceed.pdf

Hi Richie,
Just letting you know that the Town Supervisor has the MCRA. We will need the MCRA and the attached Authorization to Proceed in order to begin the design and procurement stages of the project, which can happen while the fixture purchase process with O&R gets completed.
Thank you,
Jeff

From: Parille, Lindsay
Sent: Tuesday, July 16, 2019 9:55 AM
To: Bob Livsey <blivsey@highlands-ny.gov>
Cc: Paine, John <John.Paine@nypa.gov>; Laino, Jeffrey <Jeffrey.Laino@nypa.gov>
Subject: RE: Please sign Town of Highlands_ES_MCRA_2019

Good morning,
I have canceled the agreement and reissued with the appropriate name. You should have received a new email from Adobe Sign.

Thank you,

Lindsay Parille
Power Contracts & Tariff Analyst

New York Power Authority
123 Main St.
White Plains, NY 10601
914.681.6256 I Lindsay.Parille@nypa.gov
www.nypa.gov

From: Bob Livsey <blivsey@highlands-ny.gov>
Sent: Tuesday, July 16, 2019 8:41 AM
To: Parille, Lindsay <Lindsay.Parille@nypa.gov>
Subject: RE: Please sign Town of Highlands_ES_MCRA_2019

On a "legal" document I should have my name as printed below, not Bob Livsey. I will cross out Bob Livsey and enter my proper name.

MERVIN R. LIVSEY
Supervisor, Town of Highlands
254 Main Street
Highland Falls, NY 10928

845 446-4280 x 312
Fax 845 446 4298
Cell 845 238 8074
blivsey@highlands-ny.gov

From: NEW YORK POWER AUTHORITY - Lindsay Parille [mailto:echosign@echosign.com]
Sent: Friday, July 12, 2019 4:48 PM
To: Bob Livsey <blivsey@highlands-ny.gov>
Subject: Please sign Town of Highlands_ES_MCRA_2019

NEW YORK POWER AUTHORITY - Lindsay Parille Has Sent You **Town of Highlands_ES_MCRA_2019** to Sign

NEW YORK POWER AUTHORITY - Lindsay Parille (New York Power Authority) says:
"Please review and complete Town of Highlands_ES_MCRA_2019."

Click here to review and sign **Town of Highlands_ES_MCRA_2019.**

After you sign **Town of Highlands_ES_MCRA_2019**, the agreement will be sent to **John Canale.** Then, all parties will receive a final PDF copy by email.

If you need to delegate this document to an authorized party for signature, **please do not forward this email**. Instead, click here to delegate.

NEW YORK STATE OF OPPORTUNITY. | NY Power Authority

ANDREW M. CUOMO
Governor

JOHN R. KOELMEL
Chairman

GIL C. QUINIONES
President and Chief Executive Officer

April 5, 2019

Supervisor Bob Livsey
Town of Highlands
254 Main Street
Highland Falls NY 10928

RE: Energy Services Program
Authorization to Proceed with turn-key street light project
Town of Highlands– LED Street Lighting

Dear Supervisor Livsey,

The New York Power Authority (NYPA) is excited to support the Town of Highlands in identifying and implementing a comprehensive street lighting upgrade. Improving the existing street lights is a widely used and effective strategy to achieve the goal of reducing energy consumption, lowering utility costs, and improving light quality throughout the community.

Consistent with the Master Cost Recovery Agreement, NYPA provides a turn-key solution to upgrade the Town of Highlands's existing street lights to energy efficient LED technology. NYPA is pleased to offer these services to replace approximately 167 existing street light fixtures with new high efficient LED technology.

By signing below, the Town of Highlands authorizes NYPA to proceed with the full turn-key solution of the LED street lighting project, which includes the final design report, conducting bids for materials and installation labor, providing construction management, and commissioning the final project. When the design and bidding is completed, you will receive an Initial Customer Installation Commitment (ICIC) for your review and signature. At this point, if you choose to proceed to project implementation all development costs will be rolled into the overall project. Conversely, should you decide not to proceed with the implementation of the project, the Town of Highlands agrees to reimburse NYPA for all costs incurred up to the termination date for the development, design and bidding of the project. The cost of developing the design and for bidding the materials and labor will be determined during the next phase. NYPA will be fully transparent through this process and provide complete documentation as to how it determined all project costs.

By signing below, affirm that you agree to these conditions:

NEW YORK STATE OF OPPORTUNITY. | NY Power Authority

Joseph Rende	
(Name, printed)	(Name, printed)
Senior Director, Customer Business Development	
(Title)	(Title)
(Signature)	(Signature)
(Date)	(Date)

Arencibia, Stephanie (Molly)

From: Bob Livsey <blivsey@highlands-ny.gov>
Sent: Tuesday, July 16, 2019 8:41 AM
To: Parille, Lindsay
Subject: RE: Please sign Town of Highlands_ES_MCRA_2019

On a “legal” document I should have my name as printed below, not Bob Livsey. I will cross out Bob Livsey and enter my proper name.

MERVIN R. LIVSEY
Supervisor, Town of Highlands
254 Main Street
Highland Falls, NY 10928
845 446-4280 x 312
Fax 845 446 4298
Cell 845 238 8074
blivsey@highlands-ny.gov

From: NEW YORK POWER AUTHORITY - Lindsay Parille [mailto:echosign@echosign.com]
Sent: Friday, July 12, 2019 4:48 PM
To: Bob Livsey <blivsey@highlands-ny.gov>
Subject: Please sign Town of Highlands_ES_MCRA_2019

[redacted]

[redacted]

NEW YORK POWER AUTHORITY - Lindsay Parille Has Sent You **Town of Highlands_ES_MCRA_2019** to Sign

NEW YORK POWER AUTHORITY - Lindsay Parille (New York Power Authority) says:
"Please review and complete Town of Highlands_ES_MCRA_2019."

Click here to review and sign **Town of Highlands_ES_MCRA_2019.**

After you sign **Town of Highlands_ES_MCRA_2019**, the agreement will be sent to **John Canale**. Then, all parties will receive a final PDF copy by email.

If you need to delegate this document to an authorized party for signature, **please do not forward this email**. Instead, click here to delegate.

Arencibia, Stephanie (Molly)

From:	New York Power Authority <echosign@echosign.com>
Sent:	Tuesday, July 23, 2019 8:39 AM
To:	Canale, John; Parille, Lindsay; mERVIN R. LIVSEY
Cc:	Paine, John; Laino, Jeffrey
Subject:	[EXTERNAL]Town of Highlands_ES_MCRA_2019 between New York Power Authority , mERVIN R. LIVSEY and John Canale is Signed and Filed!
Attachments:	Town of Highlands_ES_MCRA_2019 - signed.pdf

CAUTION — External Email
Suspicious? Click Report Phishing on Outlook toolbar. For **Mobile** forward to (abuse@nypa.gov)

Town of Highlands_ES_MCRA_2019 between New York Power Authority , mERVIN R. LIVSEY and John Canale is Signed and Filed!

From: NEW YORK POWER AUTHORITY - Lindsay Parille (New York Power Authority)
To: John Canale, NEW YORK POWER AUTHORITY - Lindsay Parille and mERVIN R. LIVSEY

Cc: New York Power Authority John Paine and jeffrey.laino@nypa.gov

Attached is a final copy of **Town of Highlands_ES_MCRA_2019**.

Copies have been automatically sent to all parties to the agreement.

You can view the document in your Adobe Sign account.

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- Exchange, Sign, and File Any Document. In Seconds!
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Master Cost Recovery Agreement No. ____________________
Effective Date: ____________________

ENERGY SERVICES PROGRAM

MASTER COST RECOVERY AGREEMENT

BETWEEN

POWER AUTHORITY OF THE STATE OF NEW YORK

AND

TOWN OF HIGHLANDS

ENERGY SERVICES PROGRAM
MASTER COST RECOVERY AGREEMENT

This Master Cost Recovery Agreement (this "Master Agreement"), dated Jul 23, 2019 ____________________________________, is entered into by and between POWER AUTHORITY OF THE STATE OF NEW YORK, a corporate municipal instrumentality of the State of New York with offices located at 123 Main Street, White Plains, New York 10601 ("Authority") and the Town of Highlands, a municipality with offices located at 254 Main Street, Highland Falls, NY 10928 ("Customer").

WHEREAS, Public Authorities Law §1005(17) permits the Authority, as deemed feasible and advisable by the Trustees, to finance and design, develop, construct, implement, provide and administer energy-related projects, programs and services for any public entity and certain other specified entities; and

WHEREAS, the Trustees have authorized the establishment of the Authority's Energy Services Program ("ESP") to include, among other things, energy efficiency projects and services, clean energy technology projects and services and high-performance and sustainable building projects and services (including technologies that reduce air and other pollution and conserve materials and resources such as water); and the construction, installation and/or operation of facilities or equipment done in connection with any such projects, programs or services; and

WHEREAS, Public Authorities Law §1005(17) permits Customer, a public entity, to enter into an energy services contract with the Authority for such energy-related projects, programs and services as authorized by Public Authorities Law; and

WHEREAS, Authority and Customer desire to work together to develop and implement Projects contemplated under the ESP and to enter into this Master Agreement as more particularly set forth herein.

NOW, THEREFORE, Authority and Customer (sometimes referred to herein collectively as the "Parties" and individually as a "Party"), in consideration of the mutual covenants and conditions contained herein and in these recitals, hereby agree as follows:

DEFINITIONS

The following definitions apply for all purposes of this Master Agreement:

"Advisory Services" means the consulting services provided by Authority or Service Providers to assist Customer in its efforts to reduce energy consumption and associated operations and maintenance costs, to realize environmental benefits, including but not limited to the reduction of air pollution; to conserve natural resources; and/or facilitate the use of clean energy sources at Customer's Facilities.

"Advisory Services Terms and Conditions" means the additional terms and conditions set forth in Exhibit C applicable to Advisory Services Projects provided by Authority or Service Provider to Customer hereunder.

"Ancillary Documents" means documents, other than this Master Agreement and the Customer Project Commitment (and documents that modify them, such as Change Orders and Contingent Work Orders), covering information necessary for the implementation of a specific Project, such as authorizations, Substantial Completion and Operation Transfer Reports, Milestone Completion Reports and Final Inspection Reports, etc.

"Authority's Authorized Representative" means an individual designated by Authority in accordance with Section 10.1(b) to coordinate a Project on behalf of Authority and to communicate with Customer concerning such Project.

"Authority Implemented Work" means Work undertaken by Authority for Customer as more fully set forth in a CPC (subject to the terms and conditions of this Master Agreement and any applicable Transaction Document) through the services of qualified Service Providers or Subproviders engaged by Authority.

"Authority Material Handling Fee" is a fee applied by the Authority to the cost of materials purchased directly by the Authority for a Project, where applicable, to reimburse the Authority for procurement, material handling, storage and/or restocking. The amount of such fee, when applicable to a Project, will be set forth in the CPC, as superseded by the Final CPC.

"Authority Program Fee" mean Authority's fee applicable to each Project. Details of the Authority Program Fee will be set forth in the Compensation Schedule, attached hereto as Exhibit A, and the amount of such fee will be set forth in the CPC, as superseded by the Final CPC.

"Background Intellectual Property Rights" means Intellectual Property Rights of a Party owned, controlled, acquired, developed, invented, generated, authored, conceived or reduced to practice prior to the date of this Master Agreement, or acquired parallel to and independent of this Master Agreement or any Transaction Documents entered into under this Master Agreement.

"Capital Project" is a Project involving the design, construction, installation and/or modification of facilities and/or equipment in Customer's Facility.

"Capital Project Terms and Conditions" means the additional terms and conditions set forth in Exhibit B applicable to Capital Projects provided by Authority or Service Provider to Customer hereunder.

"Change Order" is a Transaction Document that memorializes a modification to the CPC that cannot be made by Contingency Work Order, setting forth agreed-upon additions, deletions or revisions to the Work, and the cost and/or time impact to the Project.

"Compensation Schedule" is a schedule attached hereto as Exhibit A setting forth details about the Authority Program Fee and other relevant Project costs, where applicable, for the different services offered by Authority under this Master Agreement.

"Contingency Work Order" is a Transaction Document that memorializes the Authority's use of the Project Contingency for a Project, such use to be reflected on subsequent CPCs that are executed for the particular Project.

"Customer's Authorized Representative" means an individual designated by Customer in accordance with Section 10.1(a), to coordinate a Project on behalf of Customer and to assist Authority, its Service Providers and Subproviders with the implementation of the Project.

"Customer Project Commitment" or "CPC" is a Transaction Document containing terms and conditions for one or more specific Projects at a Customer's Facility(ies) that includes, at a minimum, the location of Customer's Facility, a detailed scope of Work (including a description of milestones, if any), the projected Project costs and any specific payment terms applicable to the Project.

"Debris" shall mean unregulated materials removed from a Customer Facility and unsuitable for further use.

"Environmental Laws" means all current and future federal, state and local laws (including common law), treaties, regulations, rules, ordinances, codes, decrees, judgments, directives, orders (including consent orders), environmental permits, and obligations and other requirements imposed by any "Governmental Authority" (as defined herein), including New York State Department of Environmental Conservation ("NYS DEC") Technical Administrative Guidance Memoranda and other guidance documents issued or published by any Governmental Authority, in each case, relating to pollution, protection of the environment, natural resources, or protection of human health and safety from conditions in the environment, the presence, "Release" (as defined herein) of, threatened Release of, or exposure to, "Hazardous Substances" (as defined herein), or to the generation, manufacture, processing, distribution, use, treatment, storage, transport, recycling or handling of, or arrangement for such activities with respect to, Hazardous Substances.

"Environmental Liabilities" means all liabilities, obligations, damages, losses, claims, actions, suits, judgments, orders, fines, penalties, fees, expenses, and costs, relating to environmental conditions or activities, including (i) Remediation costs, engineering costs, environmental consultant and expert fees, laboratory fees, permitting fees, investigation costs, defense costs, and reasonable attorneys' fees and expenses; (ii) any claims, demands, and causes of action relating to or resulting from any personal injury (including wrongful death), property damage (real or personal) or natural resource damage; and (iii) any penalties, fines or costs associated with the failure to comply with any Environmental Law.

"Energy Services Program" or "ESP" includes energy efficiency projects and services; clean energy technology projects and services; high-performance and sustainable building programs and services (including technologies that reduce air and other pollution, conserve materials and resources such as water); and the construction, installation and/or operation of facilities or equipment done in connection with any such project, programs and services.

"Facility" means the building, structure or premises owned and/or operated by Customer that may benefit from Customer's participation in Authority's ESP Program.

"Final CPC" means the document that reflects the final reconciliation of Project costs and all amendments to the CPC that is issued by Authority to Customer upon completion of the Work for a Project.

"Final Inspection Report" means the report, if any, to be executed by Authority and Customer after completion of a Project.

"Hazardous Substances" means (i) any petroleum, petroleum products or byproducts, and all other regulated hydrocarbons (including without limitation, petrochemicals and crude oil), or any fraction thereof, coal ash, radon gas, asbestos, asbestos-containing material, urea formaldehyde, polychlorinated biphenyls, chlorofluorocarbons, and other ozone-depleting substances; and (ii) any chemical, material, substance, product or waste (including thermal discharges and hazardous waste) that is prohibited, limited, or regulated by or pursuant to any Environmental Laws.

"Intellectual Property Rights" means any and all intellectual property rights, including, but not limited to rights in any and all of the following: (i) technical information and know-how; (ii) discoveries, improvements, enhancements, upgrades, inventions, (whether or not patentable); (iii) patents, patent applications, patent disclosures, and any other patentable subject matter; (iv) copyrights, applications to register copyrights, works of authorship and any other copyrightable works; (v) trademarks, trade names, trade dresses, brand names, logos and similar marks; (vi) any sketches, drawings, outlines, drafts; (vii) computer software (including source code, executable code, databases, data and related documentation); (viii) trade secrets and know-how; and (ix) all improvements or modifications to any of the foregoing.

"Labor Cost" is that portion of the Total Reimbursement Costs for installation labor performed by Service Provider and Subprovider in connection with the Work performed in connection with a Project pursuant to a CPC based on this Master Agreement. Such costs will be detailed in each CPC.

"Long-Term Repayment Obligation" means the obligation of Customer to repay Authority in accordance with and subject to the terms of a loan agreement after conversion of a Short-Term Repayment Obligation.

"Material Cost" is that portion of the Total Reimbursement Costs related to equipment, materials and supplies in connection with the Work performed in connection with a Project pursuant to a CPC based on this Master Agreement. Such costs will be detailed in each CPC.

"Milestone Completion Report" means a document generated by Authority or Service Provider that identifies a milestone(s) satisfactorily completed during the progress of a Project or phase of a Project (i.e., design, construction, or otherwise), signifies Customer's concurrence with the completion of such milestone and represents Customer's authorization to proceed to the next milestone or phase of the Work, as applicable.

"Other Agreement" means any stand-alone agreements entered into between the Parties at any time, including, without limitation, non-disclosure agreements, privacy agreements, or grant agreements, but shall not include any Master Cost Recovery Agreement, Energy Efficiency Services Agreement or other agreements governing services under the ESP entered into by the Parties prior to the execution of this Master Agreement.

"Project" means any project or service undertaken through Authority's ESP pursuant to a CPC based on this Master Agreement.

"Project Contingency" means a defined budget to be utilized at the Authority's discretion in accordance with Section 2.3 hereof for, among other things, unexpected costs and expenses that may arise during the performance of a Project (usually calculated as a percentage of Material Cost and Labor Cost).

"Release" means any actual or threatened release, spill, emission, emptying, escape, leaking, dumping, injection, pouring, deposit, disposal, discharge, dispersal, leaching, or migration into the environment or within any building, structure, facility, or fixture and/or the exacerbation of any preexisting condition of Hazardous Substances.

"Remediation" means the investigation (including any feasibility studies or reports), cleanup, removal, abatement, transportation, disposal, treatment (including in-situ treatment), management, stabilization, neutralization, collection, or containment of Hazardous Substances and any Release(s), that may be required to satisfy Environmental Laws, in each case, including, without limitation, any closure, restoration or monitoring, operations and maintenance activities, including any engineering or institutional controls, that may be required by any Governmental Authority after the completion of such investigation, study, cleanup, removal, transportation, disposal, treatment, neutralization, collection, or containment activities as well as the performance of any and all obligations imposed by any Governmental Authority in connection with such investigation, cleanup, removal, transportation, disposal, treatment (including in situ treatment), management, stabilization, neutralization, collection, or containment (including any such obligation that may be imposed pursuant to an Environmental permit or a consent order).

"Service Provider(s)" means a third party provider of goods and/or services that Authority, acting as the contracting entity, contracts with through its procurement policies, procedures and guidelines to perform Work in connection with a Project at Customer Facilities.

"Service Provider Fees" means the costs associated with the payment to Service Providers, its Subproviders and other third party professionals for Work performed with respect to a specific Project. Service Provider Fees will be detailed in each CPC.

"Short-Term Interest" is a cost component of the Total Reimbursement Costs of a Project representing the costs incurred by the Authority in connection with financing the delivery of a Project during the time within which such funds remain unpaid by Customer.

"Short-Term Repayment Obligation" refers to Customer's obligation to reimburse Authority for the costs of delivering a Project, as identified in the Final CPC.

"Short-Term Repayment Obligation Maturity Date" means the date set forth in the Final CPC, no later than ninety (90) days following the approval of the Final CPC.

"Specific Subject Matter" shall mean intellectual property rights, Authority's liability and limitation thereof, Project warranties, and amendments to this Master Agreement and/or any Transaction Documents.

"Subprovider(s)" refers to individuals or entities retained by the Service Provider(s) to perform all or part of the Work.

"Substantial Completion and Operation Transfer Report" is a document signed by the Parties signifying that the equipment and/or facilities installed at the Project have been inspected, tested and accepted by Customer.

"Third Party" means any utility company, permit agency, governmental authority having jurisdiction over a Project, any contractor or service provider hired by Customer, or any other third party that is not a Service Provider or Subprovider but is, directly or indirectly, involved in or whose approval is required in connection with, a Project and not under contract, directly or indirectly, with the Authority.

"Total Annual Energy Savings" is the estimated net reduction in Customer's annual usage of (a) energy service, (b) other utilities including, but not limited to, water and sewer, and (c) any related operation or maintenance savings, if applicable, resulting from the installation of one or more energy conservation measures in accordance with this Master Agreement.

"Total Reimbursement Costs" is the sum of all of the costs of a Project as set forth in the CPC and Final CPC, including, but not limited to, to the extent applicable to such Project: (1) Material Cost; (2) Labor Cost; (3) the amount of the Project Contingency applied as a Project cost; (4) Service Provider Fees; (5) Authority Program Fee; (6) Short-Term Interest; and (7) other Project-related costs and expenses.

"Transaction Document(s)" means with respect to a Project, this Master Agreement and any related Customer Project Commitment and any document that modify them, such as Change Orders and Contingency Work Orders.

"Waste" refers to waste PCBs (as defined by the United States Environmental Protection Agency ("USEPA") in 40 CFR Part 761) and hazardous waste (as defined by the USEPA in 40 CFR Part 261 and the NYS DEC in 6 NYCRR Part 371) as well as other material regulated for purposes of release, reuse, disposal, or recycling (e.g. CFCs, ethylene glycol, mercury, oil, asbestos), which form a part of the equipment removed from Customer Facilities due to implementing the Work. Disposal of such Waste shall be conducted in accordance with the provisions set forth in Article IV.

"Work" means the services performed for Customer for a selected Customer Facility pursuant to this Master Agreement and the other Transaction Documents for a Project. The scope of Work shall be described in the CPC, as amended by subsequent Change Orders, Contingency Work Orders, and the Final CPC.

ARTICLE I

SCOPE AND APPLICATION OF AGREEMENT; ORDER OF PRECEDENCE

1.1 Transaction Documents. In connection with each Project, the Parties will, either concurrently with or subsequently to this Master Agreement, enter into one or more Customer Project Commitments, or similar memoranda, that define a specific Project(s) and the costs and fees associated with such Project, and associated Ancillary Documents. Except as otherwise expressly set forth therein, all Transaction Documents, upon execution by the Parties, shall be

governed by the terms and conditions of this Master Agreement. Each Transaction Document shall contain a specific reference to this Master Agreement and CPC, as applicable. This Master Agreement does not obligate Authority to accept requests for Projects issued by Customer or obligate any Party to enter into a CPC.

1.2 Entire Agreement. Subject to the provisions of Section 1.4 below, with respect to a Project, this Master Agreement (including Exhibits A, B, and C and any other exhibits, schedules or appendices hereto) and any Transaction Document which specifically references a Project, constitute the entire agreement between Authority and Customer concerning such Project, and supersedes all prior negotiations, representations, contracts and agreements concerning such Project.

1.3 Conflict and Order of Precedence. In the event of a conflict between the terms of this Master Agreement and the terms and conditions set forth in another Transaction Document, or between the terms of two or more Transaction Documents in effect for a Project, the order of precedence shall be a follows: (i) the terms of the CPC for such Project (as amended by Contingency Work Orders and/or Change Orders and as superseded by the Final CPC) but solely with respect to the price (i.e., the Project's Total Reimbursement Costs), payment terms, and scope of Work (including description of milestones) of the Project; (ii) the terms of this Master Agreement; (iii) the remaining terms of the Project CPC; and (iv) the terms of any Ancillary Document. Notwithstanding the foregoing, the Parties agree that with respect to Specific Subject Matters, if the terms of a Transaction Document concerning a Specific Subject Matter are more favorable to Authority than the respective terms set forth in this Master Agreement, the more favorable terms of the Transaction Document shall prevail with respect to the Project to which it relates. (By way of example, if a Transaction Document includes a term that disclaims any warranties by Authority (or Service Provider) for Work performed, such term would prevail over the warranties set forth in Section 7.1. hereof.)

1.4 Other Agreements. This Master Agreement supersedes all Master Cost Recovery Agreements, Energy Services Agreements or other agreements governing services under the ESP entered into by the Parties prior to the execution of this Master Agreement. Notwithstanding the foregoing, this Master Agreement does not supersede and does not apply to any Other Agreements existing between Customer and Authority. Any projects which Authority has undertaken or undertakes at Customer Facilities pursuant to such Other Agreements, or under prior Energy Services Agreements under which projects remain incomplete as of the date of this Master Agreement, shall be governed by those agreements and related documents, unless otherwise agreed in writing. Termination of this Master Agreement shall have no effect on the Other Agreements which will remain in full force and effect according to their respective terms.

1.5 Amendments. This Master Agreement and any other Transaction Document executed in connection herewith may be amended only in writing signed by an authorized officer or designee of Authority and Customer.

ARTICLE II

GENERAL PROJECT STRUCTURE

2.1 Customer Project Commitment or CPC. For each Project undertaken under this Master Agreement, the parties will enter into one or more CPC(s), each of which will state the specific terms and conditions applicable to such Project, segregating the Project into logical phases to be performed consecutively. Each CPC will include, at a minimum, the phasing plan setting forth how the Project will proceed, the location of Customer's Facility, scope of Work, (including description of milestones, if any), projected Total Reimbursement Costs, and payment terms.

The Authority is not obligated to commence any Work for a particular Project unless or until a CPC is executed by Authority and Customer. Notwithstanding the foregoing, the Parties may agree to expedite the commencement of a portion of the Work associated with a particular Project prior to the execution of a CPC provided that the Parties memorialize such agreement prior to the commencement of such Work in a writing that sets forth the specific items of Work to be commenced and the associated cost of such Work. In such event, Customer agrees to bear the costs of any Work undertaken by Authority or its Service Providers for Customer in preparation for or with respect to such Project or potential Project even if no CPC is ultimately executed.

2.2 Final CPC. As soon as practicable following completion of the Work and receipt of all invoices associated with a Project, Authority will generate a Final CPC which will include all Contingency Work Orders, and all agreed-upon Change Orders, if any. The Final CPC will reconcile the Total Reimbursement Costs set forth in the CPC on the basis of Authority's actual costs and will supersede all prior CPCs. The Final CPC shall also describe the Project-specific terms for the Work completed at the Facility or Facilities, Customer's Short-Term Repayment Obligation, and the final repayment terms. Authority and Customer shall execute such Final CPC, which shall be "deemed executed" unless Customer disputes such Final CPC in writing within forty-five (45) days of the Authority's transmission thereof. If Customer timely disputes the Final CPC, then the Parties shall endeavor to resolve the dispute as expeditiously as possible in accordance with the procedures set forth in Section 11.2; provided, however, that Customer shall pay any undisputed amounts of Customer's Short-Term Repayment Obligations set forth in the Final CPC in accordance with Article V hereof.

2.3 Contingency Work Order. If unexpected costs and expenses arise during the performance of a Project, the Authority may utilize the Project Contingency, provided that (i) the scope modifications, if any, are consistent with the general nature of the Project; (ii) the modifications do not render the Project ineligible under the Authority's Energy Services Program requirements; and (iii) the cumulative increased Project costs do not exceed the Project Contingency. Contingency Work Orders may be utilized to account for, among other things, remedial work required due to design or construction omissions (whether remedial work is caused by omissions of Authority, its Service Providers or Customer) to the extent that the requirements set forth above are met. If the requirements for a Contingency Work Order are not met, Authority and Customer may negotiate a Change Order as described in Section 2.4 below.

As the Project Contingency is utilized, the Authority will issue a Contingency Work Order, which shall be effective upon issuance and automatically update the terms of the respective CPC without the need for express Customer approval. Any objections to the manner in which the Authority is utilizing the Project Contingency must be raised by the Customer in writing to the Authority within seven (7) days of the Authority's issuance of any such Contingency Work Order, or such other period of time identified in the Contingency Work Order. Failure to comply with this notice requirement by the Customer will be deemed a waiver of any claim that (i) the Project Contingency was used improperly; or (ii) that payment on account of such Contingency Work Order is disputed. Upon request, the Authority will provide Customer with periodic reports that establish an accounting of how the Project Contingency is being utilized.

2.4 Change Order. Any party to a CPC may at any time by written notice to the other party request modifications to the Work described in the executed CPC. Authority shall provide Customer with a written analysis of the effects of the requested modification(s) and, provided that the requested modification(s) do not materially alter the general scope of the Project, the Parties will negotiate a Change Order to the CPC. No Change Order shall take effect until it is approved within the time period specified in the Change Order by Authority and by Customer in accordance with Customer's procedures to authorize amendments to the CPC. In the event of a dispute over a request for a Change Order, Authority may elect to proceed with the Work in accordance with the scope of Work as set forth in the CPC (as revised by agreed-upon Change Orders and/or Contingency Work Orders), or the dispute may be treated under the provisions of Section 11.1 hereof.

2.5 Unforeseen Circumstances or Conditions. In the event that circumstances or conditions at Customer's Facility are encountered after a CPC is executed, that may require changes to the Project schedule and/or result in an increase to the Total Reimbursement Costs of the Project, Authority shall as soon as practicable notify Customer. The CPC shall be revised by a Contingency Work Order or a Change Order, as applicable, to incorporate necessary changes to the Project schedule, the scope of Work and/or any increase in the Total Reimbursement Costs, as a result of the existence of the unforeseen circumstance or condition. Customer shall assume any increase in costs as part of its Short-Term Repayment Obligation.

2.6 Third Party Obligations. The Authority shall not be held responsible for any action or failure to act of Customer, its officers, employees, agents, representatives or any Third Party, including, but not limited to, any delay in issuance or any non-issuance of a permit or approval necessary to perform or close out the Work under a Project. Any changes to the Project schedule or scope of Work or any increase in the Total Reimbursement Costs caused by such act or failure to act, shall be Customer's responsibility. If the Third Party conduct necessitates the issuance of a Change Order to compensate the Authority for any changes to the Project schedule, scope of Work or Total Reimbursement Costs resulting from such act or failure to act, Authority may suspend its Work on the Project until Customer approves such Change Order. If Customer fails to approve the Change Order within thirty (30) days of its issuance or the Project is suspended as a result for more than ninety (90) days, Authority, in its sole discretion, may terminate all Project Work and issue a Final CPC as provided in Section 3.4(d) below.

2.7 Execution and Disputes Regarding Reports. The execution of a Milestone Completion, Final Inspection, Substantial Completion and Operation Transfer Report or similar

report(s) shall not be unreasonably withheld by either Party, and the Parties shall endeavor to fully execute such report within thirty (30) days after its submittal to Customer or it shall be deemed executed unless it was disputed by Customer in writing within such thirty (30) day period. In the event of any disputes by Customer with respect to such report(s), the Parties shall endeavor to resolve such dispute as expeditiously as possible in accordance with Sec. 11.1 hereof.

2.8 Limitation on Work in Certain Premises. Absent the express written consent of Authority, no Work of any kind shall be performed in any premises of Customer used for private business use within the meaning of Section 141(b) of the U.S. Internal Revenue Code of 1986, as amended.

2.9 Eligibility Criteria. Projects will be undertaken on an individual basis in Customer's Facilities as deemed feasible and advisable by Authority and mutually agreed to by Authority and Customer. A Project will not proceed unless it satisfies (as determined by Authority in its sole discretion) Authority's requirements related to reduction in overall primary energy costs, energy conservation, results in environmental benefits and/or other requirements of the Authority's Energy Services Program, then in effect.

ARTICLE III

SUSPENSION AND TERMINATION OF PROJECTS

3.1 Suspension of Work.

(a) Suspension by Customer. Customer may direct Authority to suspend Work at any Customer Facility by written notice to Authority. Authority, and the Service Providers and Subproviders, will thereupon cease Work at that Facility as soon as practicable.

(b) Suspension by Authority. In addition to any other right by Authority to suspend Work on a Project set forth herein, Authority may suspend Work at any Customer Facility if any of the following occurs: (i) Customer fails to make payment to Authority when due; and such payment default continues for a period of ten (10) days after written notice thereof by Authority to Customer; (ii) circumstances or conditions at Customer's Facility are discovered after a CPC is executed which require changes to the Project and/or result in an increase to the Project's Total Reimbursement Costs that cannot be covered by the use of any remaining Project Contingency budgeted for the Project; (iii) a Third Party's act or failure to act causes a delay to the critical path of the Project schedule that continues for a period of thirty (30) days after written notice thereof by Authority to Customer; (iv) a delay caused by a Force Majeure event continues for a period of fifteen (15) consecutive days; (v) the existence of a hazard not caused by Authority or its Service Provider(s) that threatens the safety and protection of the site, its inhabitants or the public; or (vi) the existence of an unforeseen circumstance or condition the correction of which could reasonably be expected to (A) create an unreasonable risk for Authority or Service Provider not ordinarily associated with projects of similar size and scope (as determined by Authority); (B) create a threat to life or safety of the inhabitants or the public in general, or (C) violate applicable federal, state or local laws, regulations, codes or standards.

(c) Liability for Cost Increase as Result of Suspension. The suspension of Work by either Party pursuant to the provisions of this Section 3.1 may adversely impact the Project schedule, the scope of Work and/or the Total Reimbursement Costs. The CPC may be revised by a Contingency Work Order or Change Order, as applicable, to incorporate any necessary changes. Customer shall assume any increase in the Total Reimbursement Costs in full as part of its Short-Term Repayment Obligation unless the suspension was caused by the gross negligence or willful misconduct of Authority, its Service Provider or Subprovider, in which case Customer will not be responsible for any increase in the Total Reimbursement Costs to the extent such increase is caused by such gross negligence or willful misconduct.

(d) Resumption of Work After Suspension. In the event Work on a Project was suspended by a Party (whether pursuant to this Section 3.1 or otherwise), Authority and Customer have to agree in writing that Work shall resume before any Work on the Project can continue. In the event Work is suspended for more than ninety (90) days, Authority, in its sole discretion, may terminate Work for that Project and Authority shall issue a Final CPC as provided in Section 3.4(d) below.

3.2 Emergency. If an emergency results in or could reasonably be expected to result in personal injury or loss of life or damage or harm to property or public safety, Customer, acting in good faith in order to prevent, avoid or mitigate personal injury or loss of life or damage or harm to property or public safety may direct a Service Provider to suspend Work. Customer shall provide written notification to Authority of the suspension and events leading up to the suspension within eight (8) hours after the emergency has been stabilized. Sections 3.1(c) and (d) shall also be applicable to a suspension under this Section 3.2.

3.3 Termination of a Project. Authority may terminate a Project (and the related CPC) at any time upon thirty (30) days' prior written notice to Customer. In addition, the following incidents shall be deemed to immediately terminate a Project: (i) closure, abandonment, destruction or material damage to the Facility for which Project Work is being performed; (ii) reduction or elimination of energy savings or other modification to the Project that, in the Authority's opinion, renders the Project ineligible under the Authority's requirements for inclusion in its Energy Services Program , whether due to removal, by-passing or alteration of equipment or due to any unforeseen event; (iii) discovery of asbestos or other hazardous material in Customer's Facility that impedes the execution of the Work; and (iv) failure by Customer to make payment to Authority when due and such payment default continues for a period of thirty (30) days after written notice thereof by Authority to Customer.

3.4 Actions Upon Project Termination or Cancellation. In the event that a Project is canceled or terminated in whole or in part subsequent to execution of a CPC but prior to completion of such Project, Authority shall:

(a) Discontinue or direct Service Provider(s) to discontinue all Work and the placement of all orders for materials, equipment or labor otherwise required for the Project or terminated part of the Project, as applicable;

(b) Cancel or direct Service Provider to cancel all existing orders and subcontracts related to performance of the Project or terminated part of the Project, as applicable;

(c) Take actions reasonably necessary, or as directed by Customer in writing, for the protection and preservation of the Work and all Project-related equipment, materials and property within Authority's or Service Provider's possession and control; and

(d) Issue a Final CPC covering (i) that portion of the Total Reimbursement Cost (excluding the Authority Program Fee) actually incurred by Authority at or prior to such termination/cancellation both for the performed and for the terminated portion(s) of the Work (including, but not limited to, non-cancelable material and equipment not yet incorporated into the Work); (ii) the costs for any additional services performed by Authority or Service Provider pursuant to 3.4(c) hereof; (iii) any wind-down costs incurred by Authority and its Service Providers and Subproviders as a result of the termination/cancellation, along with Service Providers' and Subproviders' reasonable and customary overhead and profit on the Work not executed; and (iv) the Authority Program Fee. The Authority Program Fee for a Project that is terminated or canceled prior to completion shall be as set forth in the Compensation Schedule, unless otherwise agreed upon by the Parties in the CPC.

ARTICLE IV

ENVIRONMENTAL PROVISIONS

4.1 Hazardous Materials and Disposal of Waste and Debris.

(a) General Responsibilities. With respect to Authority Implemented Work, Authority shall require that Service Provider and/or Subprovider (as applicable) be responsible for environmental air monitoring and thoroughly cleaning the job site, including the removal of Waste and Debris generated as a result of a Project. Such removal may involve the management, transportation and disposal of Waste and Debris. If in the course of performing the scope of the Project Work as described in the CPC for any Authority Implemented Work, Authority encounters existing Hazardous Materials, including but not limited to Waste, any such materials shall be handled, transported and disposed of in accordance with applicable local, state and federal laws and regulations, as well as Authority's policies and procedures.

(b) Customer is Generator of Waste. The Customer acknowledges that, in accordance with USEPA and NYS DEC regulations, it is, and remains the Generator of, and holds title to, any Waste encountered during Work performed pursuant to this Master Agreement. If the Customer holds a Hazardous Waste "Generator Identification Number" for the specific site where work is being performed (as defined in Section 3010 of Subtitle C of RCRA), that number will be utilized for any and all hazardous waste disposal. If a Hazardous Waste "Generator Identification Number" does not exist, one may need to be obtained from the USEPA for each site from which Authority removes Waste. The Customer authorizes Authority, where required by USEPA and/or NYS DEC regulations, to apply in the name of the Customer for Hazardous Waste Generator Identification Numbers in order to dispose of Waste pursuant to this Master Agreement and to act as the contact Party for such applications. To the extent that the Customer is the generator of the Waste, a duly authorized representative of the Customer must sign such applications when requested by Authority. The Customer also authorizes Authority, where required by USEPA and/or NYS DEC regulations, to prepare, in the name of the Customer, any manifests or other forms required for the disposal of the Waste generated pursuant to activities under this Master

Agreement. A duly authorized representative of the Customer shall sign any manifests or other shipping records required to ship Waste offsite for disposal.

(c) Notification and Cost of Waste Disposal. With respect to Authority Implemented Work, Authority shall advise Customer (whenever possible, in advance of removal) where material determined to be Waste has been encountered which must be disposed of pursuant to USEPA and NYS DEC regulations. Authority shall keep the Customer fully informed of Authority's activities on its behalf and shall provide the Customer with copies of all applications and other materials provided or received in connection with actions taken pursuant to this authorization. The direct costs of Waste disposal will be included in the Final CPC. Any costs to Authority relating to the Project that may arise subsequent to the time the Final CPC is executed (or deemed executed) under present or future laws or regulations due to pollution, clean-up or otherwise at the site of disposal shall be borne by the Customer. If, however, such costs are due to the negligence or willful acts of Authority's Service Provider or Subprovider or due to the willful acts of Authority, the Customer shall not be responsible. With respect to Authority Implemented Work, Authority shall use reasonable diligence in overseeing the removal and disposal of Waste, shall maintain complete and accurate records thereof, and shall make those records available to the Customer upon request. In addition, any existing equipment determined by the Customer to be useful to the Customer may, at the Customer's request, be retained by the Customer and shall be the sole responsibility of the Customer.

(d) Customer Disposal of Waste. Notwithstanding the foregoing, the Customer shall have the option of disposing of Waste and Debris generated as a result of a Project at its own expense in accordance with all applicable local, state and federal laws and regulations, as well as Authority's policies and procedures.

4.2 Remediation. The Customer shall be responsible for the performance of any Remediation required under applicable local, state and federal Environmental Laws in order to address the existence or suspected existence of Hazardous Substances in, on, or under the job site that are discovered or encountered during Work performed and any Release or threatened Release in, on, under, over or migrating to, from or through the job site. The Customer shall promptly take all actions as are necessary to perform Remediation of any such Release or Discovery, and such other work as may be required by any Governmental Authority to safeguard the health, safety or welfare of any persons, the land and any improvements thereon or there under, from any Release or threatened Release or Discovery. In the case any Remediation is required, the Customer shall be responsible for restoring the affected portion or portions of the job site, together with any and all affected soil and groundwater, to the functional and topographical condition that existed prior to the Release and Remediation, as well as to the condition required by Environmental Laws, and as necessary to satisfy the requirements of any Governmental Authority exercising jurisdiction with respect to the job site for such Release or Discovery.

4.3 Environmental Indemnification. Customer shall be solely responsible for any and all loss, damage or injury to persons or property and for any cleanup costs associated with any site where Waste and Debris are disposed of or comes to be situated including, but not limited to, response and remedial costs. In addition, to the extent permitted by law, the Customer shall, at its sole cost and expense, indemnify, defend and hold harmless Authority and the State of New York against any loss, liability (including, without limitation, judgments, attorney's fees, court costs,

penalties or fines), or expenses of any type (including, but not limited to, required corrective actions) which Authority or the State of New York incurs because of injury to, or death of any person, or on account of damage to property, or any other claim arising out of, in connection with, or as a consequence of (a) the disposition or use of retained equipment by the Customer or anyone for whose acts the Customer may be liable, and (b) any cleanup costs associated with any site where Waste and Debris are disposed of or come to be situated traceable to such Waste and Debris including, but not limited to, response and remedial costs.

ARTICLE V

RECOVERY OF COSTS/REPAYMENT OBLIGATION

5.1 Project Cost. Authority shall initially pay for and/or incur costs for all components of the Total Reimbursement Costs applicable to a Project at the selected Customer Facility. Customer agrees to pay the Authority the Total Reimbursement Costs specified in the respective CPC as reconciled by the Final CPC.

5.2 Total Reimbursement Costs. The following components of the Total Reimbursement Costs may be delineated in a CPC for a particular Project:

(a) Material Cost. The Material Cost represents the cost of materials, equipment, fixtures, tools, construction equipment and machinery, water, heat, utilities, transportation and other facilities necessary for the proper execution and completion of the Work, whether temporary or permanent and whether or not incorporated or to be incorporated into the Work.

(b) Labor Cost. The Labor Cost represents (i) the sum of all wages paid to skilled trade and craft workers, plus employee benefits, payroll taxes, insurance and related costs; or (ii) the fees paid to skilled trade and craft workers that are not employees, in each case as represented on the Service Providers' or Subproviders' invoice.

(c) Project Contingency. The Project Contingency, or a portion thereof, actually applied by the Authority to the Project as set forth in a Contingency Work Order.

(d) Service Provider Fees. The Service Provider Fees represent the costs associated with the payment of Service Providers, Subproviders and other third party professionals based on actual invoices, individual billing rates based on hourly increments, or a percentage fee applied to certain Project costs, plus reimbursable expenses;

(e) Authority Program Fee. The Authority Program Fee reimburses Authority for services provided by Authority during the implementation of a Project. The Authority Program Fee can be based on a percentage fee applied to certain Project costs, a lump sum fee, individual billing rates based on hourly increments and/or other fee arrangements identified in the Compensation Schedule.

(f) Short-Term Interest. Short-Term Interest reimburses the Authority for costs incurred in connection with financing the delivery of a Project. It is based on the underlying source of funds chosen by the Authority, in its sole discretion, to finance a Project during its

implementation and may vary depending upon the actual financing product the Authority selects. In addition to the actual interest expense incurred by the Authority on the short-term debt issued for Project expenses, Short-Term Interest may include additional fees for administering the financing program including but not limited to costs incurred to secure liquidity facilities, remarketing services, purchase of an interest rate cap(s), issuing and payment agents and other financing related costs and credit premiums, if any.

(g) Other Project-Related Costs. Other Project-related costs may include Authority Material Handling Fee, Waste disposal costs, additional Project-specific insurance, surety bond costs, specialty services and other Project-specific costs not otherwise included in any of the above categories.

5.3 Billing. The specific billing method for each Project is set forth in the CPC and/or the long-term financing agreement associated with the particular Project. The final repayment amount due to the Authority will be the Total Reimbursement Costs as reconciled in a Final CPC to reflect adjustments to account for payments made or additional charges incurred by Customer and will constitute the Customer's Short-Term Repayment Obligation. In the event a Project is terminated before completion, Authority shall issue a Final CPC as provided in Section 3.4(d).

5.4 Payment.

(a) Payments. Customer shall pay any invoiced amounts to Authority within thirty (30) days of Customer's receipt of Authority's invoice. Any outstanding amounts not paid within such thirty (30) day period shall accrue additional Short-Term Interest until the date when payment is made in full. Such additional Short-Term Interest will be reflected on subsequent invoices and/or the Final CPC.

(b) Late Payment. Customer's final Short-Term Repayment Obligation shall be fully repaid on or before the Short-Term Repayment Obligation Maturity Date. Any amount due and unpaid on the Short-Term Repayment Obligation Maturity Date shall be subject to a late payment charge determined as the greater of (i) interest in accordance with the late payment rate set forth in State Finance Law §179(g); or (ii) the late charges payable under the terms of Authority's electric service, in accordance with provision 454.6 (b) of Authority's Rules and Regulations for Power Service, as such regulation may be amended from time to time. Authority, in its sole discretion, may waive the application of such late payment charge for a Project upon sufficient justification demonstrated by Customer.

5.5 Grants and Funding. Authority may pursue and apply for grants or other available funding for the respective Project, where applicable, when authorized by Customer. The Customer may assign the right to receive such grants or other available funding to the Authority, and the Authority may, at its sole discretion, accept such assignment. If Authority accepts such assignment, the Authority will apply the funds to reduce the Total Reimbursement Costs, provided the funds are actually received by the Authority by the Short Term Repayment Obligation Maturity Date.

5.6 Long-Term Financing for Capital Projects. Should Customer require financing to satisfy its Short Term Repayment Obligation for a Capital Project, the Customer may apply for permanent long-term financing through any of the financing products offered by the Authority to

convert Customer's Short-Term Repayment Obligation to a Long-Term Repayment Obligation. Authority may agree to such financing, in its sole discretion. Regardless of whether the Customer elects to utilize any of the Authority's available financing products, the Customer is responsible for satisfying its Short Term Repayment Obligation within the time constraints set forth herein.

If the Customer is interested in any of the Authority's long-term financing products, it must indicate its interest by marking the appropriate section of the CPC for the design phase of a Capital Project. To be eligible for the Authority's long-term financing products, Customer must comply with the Authority's policies and procedures for long term repayment. If Customer's long-term financing application is approved by the Authority, the Parties' obligations with respect to long-term financing will be set out in a separate loan agreement with terms and conditions agreed to by the Parties. This long-term financing option will allow the Customer to convert the Short-Term Repayment Obligation to a Long-Term Repayment Obligation.

ARTICLE VI

INSURANCE REQUIREMENTS.

Authority's agreements with the Service Providers shall provide that the Service Provider or Subproviders shall obtain and maintain the policies of insurance with the identified limits set forth in Section 6.1, unless additional policies of insurance and/or higher limits are required under the applicable CPC. The costs of such insurance will be part of the Total Reimbursement Costs.

6.1 Insurance Requirements:

(a) Workers' Compensation (inclusive of New York State disability benefits) and Employer's Liability coverage;

(b) Commercial General Liability insurance policy, including Contractual Liability and Products/Completed Operations Liability coverages, with limits of not less than $2,000,000 per occurrence for bodily injury and not less than $2,000,000 for property damage, such policies naming Authority, Customer and the State of New York as additional insureds under the policy;

(c) Automobile Liability coverage with a minimum limit of $1,000,000 per accident; and

(d) if required under the applicable CPC:

(i) Pollution Liability, including coverage for asbestos abatement, with minimum limits of $1,000,000 per occurrence;

(ii) Professional Liability insurance with a minimum limit of $1,000,000; and

(iii) Builder's risk insurance in the amount of the estimated Total Reimbursement Cost to be issued on a replacement cost basis without optional deductibles and

will include the interests of Customer, Authority, and the Service Providers. Such insurance shall be maintained until final payment has been made by Customer to Authority.

6.2 Adjustments. The types of insurances required and/or policy limits listed in Sections 6.1 above may be adjusted as Customer and Authority deem appropriate in connection with a specific CPC. The form and sufficiency of each insurance policy required to be obtained hereunder by the Service Provider or Subprovider shall be subject to approval by Authority. Authority shall hold all Certificates of Insurance submitted to the Authority by its Service Providers and Subproviders with respect to any Project implemented under this Master Agreement.

6.3 Customer Insurance Requirements. With specific regard to the ESP equipment, for so long as any portion of Customer's Short-Term or Long-Term Repayment Obligation, as applicable, remains unpaid, Customer shall procure an all risk policy of insurance which will insure the equipment for full replacement cost value against loss while the equipment is in Customer's care, custody and control. The insurance policy shall name Authority and the State of New York as additional insured and loss payees, and shall contain a full waiver of subrogation against Authority, its agents, Service Providers, Subproviders and the State of New York. Customer shall also procure a Commercial General Liability insurance policy with minimum limits of $5,000,000 per occurrence for bodily injury and property damage naming Authority and the State of New York as additional insured. In lieu of obtaining all risk and commercial general liability insurance, Customer may request in writing to Authority to self-insure against risk of loss. Authority may approve or deny such request in its sole discretion. Customer agrees to provide any relevant documents or information requested by Authority in order for Authority to make the determination that Customer has sufficient resources to self-insure. The decision to self-insure will not relieve Customer of any of the obligations imposed herein and shall afford Authority the protection against loss and rights it would have received, if Customer had obtained such policies of insurance.

ARTICLE VII

WARRANTIES, DAMAGES, LIABILITY, ETC.

7.1 Service Provider's Warranty Requirements. Authority's agreements with its Service Providers shall provide that all Work performed and any materials provided by the Service Providers under the agreements shall be free from any defects. Such agreements shall further provide that any defective Work or materials identified within one (l) year after (i) execution (or deemed execution) by the Parties of a Substantial Completion and Operation Transfer Report or (ii) if no such report must be signed, completion of the Project, shall be promptly corrected, repaired, replaced, re-performed or otherwise remedied by the Service Provider and/or Subprovider(s) at no additional expense to Customer. Authority's agreements with Service Providers shall also provide that any manufacturers' warranties for equipment installed at Customer's Facilities be assigned to Customer.

Authority shall have no obligation to assist Customer with any warranty claims against a Service Provider or equipment manufacturer. Customer shall coordinate any warranty claims directly with the respective Service Provider or equipment manufacturer.

7.2 Authority Warranty Disclaimer. THE WARRANTY PROVIDED BY SERVICE PROVIDER AND THE ASSIGNED WARRANTIES OF THE EQUIPMENT MANUFACTURERS ARE EXPRESSLY IN LIEU OF ALL OTHER WARRANTIES. AUTHORITY EXPRESSLY EXCLUDES ALL OTHER WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, DESCRIPTION OR QUALITY NOT EXPRESSLY SET FORTH HEREIN, TO THE EXTENT PERMITTED BY LAW. NO AFFIRMATION OF AUTHORITY, BY WORDS OR ACTION, SHALL CONSTITUTE A WARRANTY. DESCRIPTIONS, SPECIFICATIONS, DRAWINGS, AND OTHER PARTICULARS FURNISHED TO CUSTOMER ARE ONLY ESTIMATES AND DO NOT CREATE A WARRANTY.

7.3 Projected Energy Savings. Authority and its Service Providers shall use their best efforts to prepare accurate engineering estimates. After energy efficiency Work is completed in Customer's Facility, it is the intent and expectation of the Parties that Customer's annual energy usage for that Facility shall not increase above the pre-installation level except due to changes in rates or increases in usage not related to the implementation of the ESP Work. Customer is responsible for providing Authority with accurate information concerning the operation of its Facility. Customer understands that the projected energy savings are based upon such Customer input. It is Customer's sole responsibility to ensure that the expected energy savings meet Customer's satisfaction at the time the CPC for a Project is executed.

AUTHORITY HEREBY DISCLAIMS ANY AND ALL LIABILITY FOR ANY ENERGY SAVINGS PROJECTED BY AUTHORITY OR OTHERWISE EXPECTED BY CUSTOMER THAT CANNOT BE ACHIEVED.

7.4 Uncontrollable Forces. Authority shall not be responsible for delays or failures in performance resulting from occurrences beyond its reasonable control including, but not limited to, acts of God, strikes, walkouts, acts of war, or any law, regulation, or action of any court or governmental authority, fire, malfunctions in communication lines or computer hardware, power failures, shipping or delivery delays or other events caused by those not party to this Master Agreement (including, without limitation, any Third Parties, and any Service Providers or Subproviders of Authority). In the event Authority or the Service Providers or Subproviders are unable to fulfill any obligations hereunder by reason of such uncontrollable forces, Customer will be notified in writing and the completion dates described in the CPC will be extended by the amount of additional time reasonably necessary to complete the Work. If necessary, Authority will issue a Contingency Work Order or a Change Order, as applicable.

7.5 Damages, Indemnification by Service Provider.

(a) Damages. Authority's agreements with the Service Providers shall include a provision that all damage of whatever nature resulting from the performance of the Work or resulting to the Work during its progress, from whatever cause shall be borne by the Service Provider, and all Work performed shall be solely at the Service Provider's risk until the Work has been finally inspected and accepted by Authority. The Service Provider, however, shall not be responsible for damages resulting from gross negligence or willful misconduct of officials or employees of Authority or Customer.

(b) Indemnification. Authority's agreements with the Service Providers will include a provision that to the extent permitted by law, the Service Provider shall assume the entire responsibility and liability for and defense of, and pay and indemnify, Authority, Customer, and the State of New York (where a Project undertaken for Customer is located on property of New York State), against any loss, damage, expense or liability and will hold each of them harmless from and pay any loss, damage, cost or expense (including without limitation, judgments, attorney's fees, and court costs) which Authority, Customer or the State of New York incur because of injury to or death of any person or on account of damage to property, or any claim arising out of, in connection with, or as a consequence of, the performance of the Work and/or any act or omission of the Service Provider or any of its Subproviders, employees, agents or anyone directly or indirectly employed by the Service Provider or anyone for whose acts the Service Provider may be liable.

7.6 Limitation of Authority's Liability.

(a) Obligation to Exhaust Remedies against Service Provider. In the event of any alleged Authority liability to Customer, Customer shall first pursue and exhaust all remedies in law against the Service Providers and Subproviders and under the insurance identified in Article VI above and carried by the Service Providers and Subproviders before making any claim or taking any action against Authority.

(b) Exclusion of Indirect, Incidental, Consequential Damages. To the fullest extent permitted by law, Authority shall not be liable to Customer, for any indirect, special, incidental, or consequential damages of any kind (including without limitation, any loss of property or equipment, loss of profits or revenue, loss of use of equipment or power systems, cost of capital, cost of purchased or replacement power or temporary equipment, including additional expenses incurred in using existing facilities) related to or arising in connection with this Master Agreement or any other Transaction Document executed in connection herewith, regardless of the form of action (whether in contract, tort or otherwise), even if Authority has been advised of the possibility of such damages.

(c) Total Liability Cap. The Parties agree that in no event shall Authority's total liability (whether in contract, tort or otherwise) for all claims relating to a Project exceed ten percent (10%) of the Total Reimbursement Costs for such Project set forth in the respective CPC.

(d) No Limitation of Service Provider/Subprovider Liability. Nothing in this Section 7.6 shall be construed as limiting the liability of a Service Provider or Subprovider to Authority or Customer in connection with the performance of such Service Provider's or Subprovider's Work on Customer's premises.

7.7 Customer's Responsibility for Project Equipment and Performed Work. Upon delivery at Customer's Facility, Customer shall be responsible for all damage to all Project materials, supplies and equipment of every description and all Work performed at Customer's site unless such damages are caused by Authority or its Service Providers or Subproviders.

ARTICLE VIII

INTELLECTUAL PROPERTY RIGHTS

8.1 Intellectual Property; Proprietary Information.

(a) Intellectual Property Rights. Neither Party shall acquire, directly or by implication, any ownership of any Background Intellectual Property Rights of the other Party. Each Party shall retain title to any Intellectual Property Rights developed, authored, conceived or reduced to practice independently and solely by that Party during the performance of this Master Agreement without the other Party's Background Intellectual Property Rights. Notwithstanding any of the foregoing, it is agreed by the Parties that Authority shall be the sole owner of all Intellectual Property Rights related to any Project which is jointly developed, invented or otherwise generated during the performance of this Master Agreement or any Transaction Document.

(b) Work Product; Proprietary Information. Unless and until Customer has repaid its Short-Term or Long-Term Repayment Obligation, as applicable, the Facility data, evaluations, design and other information produced by Authority or its Service Providers in connection with a Project shall be the property of Authority. Customer shall have the right to use any such proprietary information for the maintenance of Project installations in its Facilities. Upon payment in full by Customer, such information shall become the property of Customer. Any information identified as confidential which is exchanged by Authority and Customer shall be duly protected by the recipient to the extent permitted by law. It is understood that the Public Officers Law and other statutes and regulations regarding Freedom of Information may require the disclosure of information in certain situations.

ARTICLE IX

TERM AND TERMINATION

9.1 Term. This Master Agreement shall end on the tenth anniversary of the date first shown in the preamble above unless earlier terminated in writing by either Party in accordance with the terms of this Master Agreement.

9.2 Termination of Master Agreement. Unless otherwise provided in this Master Agreement, either Authority or Customer may terminate this Master Agreement at any time upon one hundred twenty (120) days' prior written notice to the other Party.

9.3 Pending Projects. Authority and Customer acknowledge that a Project implemented pursuant to a CPC executed during the Term of this Master Agreement may extend beyond the expiration or early termination of this Master Agreement. Provided that the Project was commenced pursuant to a CPC that was executed during the Term of this Master Agreement, then this Master Agreement will be extended, as it applies to such CPC only and for the sole purpose of completing the Project. The Project implemented pursuant to such CPC may continue until completed or otherwise terminated earlier pursuant to the terms and conditions of this Master Agreement.

9.4 Extension. This Master Agreement may be renewed at the end of the current term for an additional period, such additional period not to exceed a period equal to the original Term, to be mutually determined by the Parties in writing and signed by an authorized officer or designee of Authority and Customer.

ARTICLE X

GENERAL OBLIGATIONS OF THE PARTIES

10.1 Authorized Representatives.

(a) Customer's Authorized Representative. For each Project, Customer shall designate a Customer's Authorized Representative and shall inform Authority in writing accordingly. If Customer desires to change its Customer Authorized Representative, it must notify Authority in writing (in accordance with notice requirements set forth herein) at least five (5) business days prior to such change. Customer's Authorized Representative shall coordinate the Project on behalf of Customer and assist Authority and the Service Providers and Subproviders with the implementation of the Project in the selected Facilities of Customer. Customer's Authorized Representative shall be responsible to obtain all necessary approvals, authorizations, and signatures of Customer with respect to any CPC, Change Order, Final CPC and other Transaction Document.

(b) Authority's Authorized Representative. For each Project, Authority shall designate an Authority's Authorized Representative and shall inform Customer accordingly. Authority's Authorized Representative shall coordinate the Project on behalf of Authority and communicate with Customer. Authority will inform Customer of any changes to its Authorized Representative.

10.2 Authority Obligations. With respect to any Authority Implemented Work, Authority shall comply with the following:

(a) Reporting and Information. Authority shall keep Customer informed as to the progress of the Work and shall provide Customer with periodic reports of all activities by the Service Providers and Subproviders at Customer's Facilities. Authority and its Service Providers shall meet with representatives of Customer upon reasonable notice to discuss any matters concerning the Projects.

(b) Permits, Licenses, Authorizations. Authority shall require that the Service Providers and Subproviders obtain and maintain all permits, licenses and authorizations required to perform the Work in Customer's Facilities and that they will comply with all applicable local, state and federal laws, guidelines and regulations, including applicable local, state and federal building, fire and electrical codes and standards. Any costs associated with permits and licenses that must be obtained by Service Provider or Subprovider for a specific Project will be reflected in the Total Reimbursement Costs. Notwithstanding the foregoing, neither Authority nor Service Provider (or Subprovider) shall be responsible for closing out open permits obtained by Service Provider (or Subprovider) due to existing deficiencies or code violations in Customer's Facility which are outside the Project scope.

(c) Service Provider/Subprovider Performance. Authority shall require its Service Providers and Subproviders to comply with regulations governing access to and performance of the Work in the selected Customer Facilities and to perform such Work in such a manner as not to unreasonably interfere with Customer's business at the Facilities. Authority shall also require its Service Providers and Subproviders to comply with Customer's operational and safety requirements, which in certain instances may require substantial supervision and control over the site by Customer.

(d) Records. Authority's Service Providers shall maintain accurate records of Project Work for a period of six (6) years after completion of a Project.

10.3 Customer Obligations. With respect to any Project entered into in connection with this Master Agreement, Customer shall have the following rights and obligations:

(a) Right to Inspect. Customer and Customer's Authorized Representative may observe and inspect all Work in any of Customer's Facilities and shall have the right to attend all Project job meetings, upon written notice of its intent to attend a particular meeting.

(b) Attendance at Meetings. Upon reasonable request and notice from Authority or Service Provider, Customer shall attend meetings scheduled by Authority or Service Provider to discuss any Project-related matters.

(c) Site Rules and Regulations. Customer must promptly notify Authority of any site specific construction, safety, technical or other requirements and restrictions related to its Facility(ies) prior to the start and during the Project. If Customer becomes aware of any defect in the Work or any failure of Authority or the Service Provider or Subprovider to meet the respective Project requirements, the Customer shall give prompt notice to Authority.

(d) Access. Customer shall provide Authority and its Service Providers safe, proper and timely access to the Facility as necessary to perform the Work. Upon Authority's request, Customer's Authorized Representative will accompany Authority and its Service Providers to Customer Facilities. Customer shall promptly provide verbal and written notice of limitations or changes in site access.

(e) Permits and Licenses.

(i) Customer shall provide Authority or Service Provider with such assistance (including, but not limited to, all necessary information requested by Service Provider) as may be required for Authority or Service Provider to obtain all permits, licenses and authorizations necessary to perform the Work in accordance with all applicable local, state and federal laws, regulations, codes and standards applicable to the Facility.

(ii) Customer shall be responsible and shall hold all licenses, permits, authorizations and regulatory approvals necessary for the lawful conduct of its business as presently conducted, and shall comply with all applicable statutes, laws, ordinances, rules and regulations of all governmental bodies, agencies and subdivisions having, asserting or claiming jurisdiction over it, with respect to any part of the conduct of its business and corporate affairs.

(f) Project Equipment. As long as Customer's Short-Term or Long-Term Repayment Obligation, as applicable, remains outstanding, (i) Customer will keep all Project-related equipment free from any and all liens, claims, encumbrances, and the like; (ii) Customer will not grant a security interest in such equipment to any party without the prior written consent of Authority; (iii) the equipment will remain at the Facility site as designated in a CPC; (iv) Customer will not sell, offer for sale, transfer, or dispose of such equipment without notice to Authority; (v) Customer will not use or permit any person to use the equipment in a manner prohibited by law or in a manner which would void any manufacturer's warranty; (vi) Customer agrees to maintain the equipment in good order and repair at all times, and will not waste or destroy the equipment or any part of it; and (vii) Customer will keep the equipment insured in accordance with the requirements set forth in Section 6.3 hereof.

(g) Coordination. Customer shall be responsible for facilitating coordination with Third Parties as required. Furthermore, Customer shall promptly resolve any disputes or issues that arise with any Third Parties. Customer shall be responsible for any changes to the Project schedule, the scope of Work and/or the Total Reimbursement Costs resulting from any delays due to unresolved disputes or issues with Third Parties pursuant to Section 2.6 hereof.

(h) Review and Approval. Customer will promptly review any documents submitted to it by Authority requiring Customer's decision and shall render any required decision pertaining thereto without undue delay.

(i) Assistance; Timely Performance. Customer shall cooperate with Authority and its Service Providers and Subproviders and provide Authority with such other assistance as necessary to facilitate the performance of the Work. Customer shall perform all obligations set forth in this Master Agreement and any other Transaction Document in a timely manner so as to permit the orderly progress of the Projects. Authority shall not be responsible for any Project delays due to Customer's non-compliance with its obligations set forth herein or in a Transaction Document.

ARTICLE XI

MISCELLANEOUS

11.1 Disputes. In the event of any dispute regarding ESP Work at any Customer Facility, Work there may be suspended by Authority until the matter is resolved to the mutual satisfaction of the Parties in accordance with the procedures set forth in Section 11.2 hereof. In the event the Parties are unable to resolve any such dispute after good faith efforts, the Work at that Facility shall terminate and Authority shall issue a Final CPC as provided in Section 3.4(d) hereof.

11.2 Dispute Resolution. The Parties shall use good faith efforts to settle promptly all disputes arising under this Master Agreement or in connection with any ESP Work. In the event that any dispute, including but not limited to a billing dispute, a dispute regarding the quality of the Work, or a dispute regarding the interpretation of this Master Agreement, arises and cannot be resolved in the normal course of business by operating personnel within twenty (20) days after commencement of a dispute, either Party may give the other Party formal notice of the dispute in accordance with the notice requirements set forth herein. In the event that such notice is given,

the Parties shall attempt to resolve the dispute by negotiation between representatives who have the necessary authority to resolve the dispute in question. Within twenty (20) days after delivery of the notice, the receiving Party shall consider all information relevant to the dispute and shall submit to the other Party (in accordance with the notice requirements set forth herein) a proposal for resolution. Thereafter, the representatives shall confer in person or by telephone, promptly and no later than five (5) days after receipt of the proposal for resolution, to attempt to resolve the dispute. All reasonable requests for information by one Party to another Party will be honored. To the extent that disputes are not resolved pursuant to this process, the Parties reserve all rights under law or equity to seek and pursue remedies through the judicial process.

11.3 Publicity.

(a) Public Announcements. No marketing, publicity, promotion, social media, or advertising regarding this Master Agreement, or any Project undertaken pursuant to this Master Agreement, will be issued by Customer without Authority's prior written approval, which approval will not be unreasonably withheld. Any responses to news media inquiries or social media activities developed by Customer, related to this Master Agreement, or any Project undertaken pursuant to this Master Agreement, must be coordinated with Authority for review and approval prior to their release. Letters, speeches, news and/or press releases, articles for publication, website and social media postings, etc., related to this Master Agreement, or any Project undertaken pursuant to this Master Agreement, must be coordinated with Authority for review and approval prior to their release. Any and all communications, whether verbal, electronic or written, must be submitted to Authority's Corporate Communication Business Unit for prior review and approval. Customer agrees to abide by these terms regarding public announcements during the term of this Master Agreement and for a period of two (2) years following the expiration or termination of this Master Agreement.

(b) Signage. The parties agree that Authority may, at no cost to Customer, install and maintain appropriate publicity signage at or in the vicinity of a Project. Customer will cooperate with Authority, and/or any third-party vendor designated by Authority, by timely responding to any questions regarding the design, manufacture, installation and maintenance of the signage. Customer will provide ordinary maintenance to the signage and promptly notify Authority after Customer becomes aware of any damage that may occur to the signage. The publicity signage may include the identity of the Project, including a brief statement highlighting the Project, any applicable Authority program, New York State program or other initiative under which the Project is implemented and the identity of the parties supporting the Project, including those parties' respective logos. The publicity signage is intended to be placed in an area of Customer's designation with significant public visibility within close proximity to the Project. Authority will be responsible for removing the publicity signage upon the conclusion of a Project, or such earlier time as either Party deems it appropriate.

11.4 Notices. All notices permitted or required hereunder or in connection with any Transaction Document shall be in writing and transmitted either: (i) via certified or registered United States mail, return receipt requested; (ii) by personal delivery; (iii) by expedited delivery service; or (iv) by e-mail, with a copy sent via U.S. Mail.

Such notices shall identify the Master Agreement and the Transaction Document to which it relates, and be addressed as follows or to such different addresses as the Parties may from time-to-time designate in accordance herewith:

To Authority:
NEW YORK POWER AUTHORITY
PROCUREMENT DIVISION
Name: John Canale
Title: Vice President, Strategic Supply Management
Address: 123 Main Street, 5th Floor, White Plains, NY 10601
E-Mail Address: john.canale@nypa.gov

with a copy to:
NEW YORK POWER AUTHORITY
LAW DEPARTMENT
Name: Debra Hopke, Esq.
Title: Principle Attorney
Address: 123 Main Street, 11th Floor, White Plains, NY 10601
E-Mail Address: debra.hopke@nypa.gov

To Customer:
TOWN OF HIGHLANDS
Name: Kelly Pecoraro
Title: Comptroller
Address: 254 Main Street, Highland Falls, NY 10928
E-Mail Address: kpecoraro@highlands-ny.gov

Any such notice shall be deemed to have been given either at the time of personal delivery or, in the case of expedited delivery service or certified or registered United States mail, as of the date of first attempted delivery at the address and in the manner provided herein, or in the case of email, upon receipt. The Parties may, from time to time, specify any new or different address in the United States as their address for purpose of receiving notice under this Master Agreement (and any Transaction Document) by giving fifteen (15) days written notice to the other Party sent in accordance herewith. The Parties agree to mutually designate individuals as their respective representatives for the purposes of receiving notices under this Master Agreement.

11.5 No Waiver. The failure of any Party to insist upon strict adherence to any term of this Master Agreement or any Transaction Document executed in connection herewith on any occasion shall not be considered a waiver nor deprive that Party of the right thereafter to insist upon strict adherence to that term or any other term of this Master Agreement.

11.6 Assignment. This Master Agreement and any Transaction Document executed in connection herewith may not be assigned, transferred nor conveyed by either Party without the prior written consent of the other Party. Any attempted assignment, transfer or conveyance without such consent shall be entirely void ab initio and have no force or effect.

11.7 Governing Law; Venue. This Master Agreement (and any Transaction Document executed in connection herewith) and any and all disputes arising in connection herewith (whether in contract, tort or otherwise) shall be governed by and construed in accordance with the laws of the State of New York without giving effect to any choice or conflict of laws provision or rule that would cause the application of the laws of any jurisdiction other than New York. Any action at law, or in equity, for the enforcement of this Master Agreement (and any Transaction Document executed in connection herewith) or any dispute arising in connection herewith shall be instituted only in a court of competent jurisdiction located in the County of Albany, State of New York.

11.8 No Third Party Beneficiaries. Nothing contained in this Master Agreement shall, directly or indirectly, create a contractual relationship with, or give any claim or right of action in favor of, any third party (including, without limitation, any Service Provider or Subprovider) against Authority.

11.9 Severability. The invalidity or unenforceability of any provisions of this Master Agreement or of any Transaction Document executed in connection herewith shall not affect the validity or enforceability of any other provisions of this Master Agreement or Transaction Document, as applicable, which other provisions shall remain in full force and effect.

11.10 Survival of Provisions. The articles that contain provisions related to the following will survive the expiration, termination or completion of this Master Agreement: Conflict and Order of Precedence; Recovery of Costs and Repayment Obligation, Warranty, Damages, Liability, Ownership of Installed Work and Intellectual Property, Publicity; and Governing Law, Venue.

11.11 Not Construed Against Drafter. Authority and Customer acknowledge that they have read this Master Agreement, have had the opportunity to review it with an attorney of their respective choice, and have agreed to all its terms. Under these circumstances, Authority and Customer agree that the rule of construction that a contract be construed against the drafter shall not be applied in interpreting this Master Agreement and that in the event of any ambiguity in any of the terms or conditions of this Master Agreement, including any exhibits or schedules hereto, such ambiguity shall not be construed for or against any Party hereto on the basis that such Party did or did not author same.

11.12 Headings. The articles and section headings contained in this Master Agreement are for reference purposes only and shall not affect the meaning or interpretation of this Master Agreement.

11.13 Counterparts. This Master Agreement may be executed in counterparts via inked signature or electronic mark, each of which shall be deemed an original, but all of which together shall constitute one and the same instrument. The fully executed Master Agreement may be delivered using pdf or similar file type transmitted via electronic mail, cloud based server, e-signature technology or other similar electronic means.

(SIGNATURE PAGE FOLLOWS)

IN WITNESS WHEREOF, the parties hereto have duly executed this Master Agreement as of the effective date first written above.

POWER AUTHORITY OF THE STATE OF NEW YORK		TOWN OF HIGHLANDS	
By:	John Canale John Canale (Jul 23, 2019)	By:	MERVIN R. LIVSEY mERVIN R. LIVSEY (Jul 23, 2019)
Name:	John Canale	Name:	Mervin Livsey
Title:	Vice President, Strategic Supply Management	Title:	Supervisor
Date:	Jul 23, 2019	Date:	Jul 23, 2019

Signature Page to Master Cost Recovery Agreement No. _______________

NEW YORK STATE OF OPPORTUNITY. | NY Power Authority

EXHIBIT A

STATEWIDE COMPENSATION SCHEDULE

As compensation for services rendered by the Authority under the Master Agreement, the Customer will pay the Authority Program Fee as set forth below.

A. CAPITAL PROJECTS

I. AUTHORITY PROGRAM FEE

For Capital Projects, the Authority Program Fee is calculated as a percentage of the cumulative sum of all costs related to a Project, including, but not limited to all Material Costs; Labor Costs; Service Provider Fees; the amount of the Project Contingency applied as a Project cost; and other Project-related costs and expenses. The Authority Program Fee is in addition to all such costs related to a Project. The Authority Program Fee percentage will be fixed upon execution of the CPC for the installation phase.

1. Authority Program Fee when Service Provider performs Work

The following table sets forth the Authority Program Fee where the Authority delivers a Project using one or more Service Providers to perform audit, design, construction management and/or installation.

Project Size (in millions)	Authority Program Fee
$0 - $3M	12.5%
$3M - $6M	12.0%
$6M - $12.5M	11.5%
$12.5M - $40M	11.0%
$40M - $60M	10.5%
> $60M	10.0%

2. Authority Program Fee when Authority and Service Provider perform Work

The following table sets forth the Authority Program Fee where the Authority will be performing design and construction management with its own forces using one or more Service Providers to perform installation. If the Authority procures material directly in lieu of using one of its Service Providers, there will be an additional Material Handling Fee of 1.5% charged on the Material Cost of the Project.

Project Size (in millions)	Authority Program Fee
$0 - $3M	27.5%
$3M - $6M	27.0%
$6M - $12.5M	26.5%
$12.5M - $40M	26.0%

\$40M - \$60M	25.5%
> \$60M	25.0%

3. Authority Program Fee when Authority provides Audit Services Only

The Authority Program fee for providing Audit services not contemplated as part of a full project (i.e. design, construction management and/or installation) is calculated as twenty-five percent (25%) of the costs related to the Audit.

II. MILESTONE PAYMENTS

To the extent applicable, the Authority Program Fee will be paid on milestones as detailed in the CPC or as otherwise mutually agreed upon.

III. AUTHORITY FEE IN THE EVENT OF PROJECT TERMINATION

1. Termination at or after Audit Phase

If a Project is terminated at or after the audit phase, but prior to moving forward with any design or implementation, the Authority's Program Fee is calculated as twenty-five percent (25%) of the actual costs associated with such audit.

2. Termination during Design, Procurement or Installation Phase

If a Project is terminated in whole or part during the design, procurement or installation phase, the Authority's Program Fee for the Project will be the cumulative percentage value at the current milestone (as if it had been achieved) and calculated based on the estimated Project costs, including, but not limited to all Material Costs; Labor Costs; Service Provider Fees; the amount of the Project Contingency applied as a Project cost; and other Project-related costs and expenses up through the current milestone (as if it had been achieved). For the purposes of calculating the Authority's Program Fee, the then current milestone is assumed complete once the Project is canceled.

The following table sets forth the Authority Program Fee percentage segmented by milestone.

Milestone	% of Authority's Program Fee	Cumulative Authority Program Fee Percentage
30% Design	10%	10% + (audit cost)
90% Design	15%	25% + (audit cost)
100% Design & Bidding	15%	40% + (audit cost)
Construction CPC Preparation	10%	50% + (audit cost)
Construction (25% completion)	10%	60% + (audit cost)
Construction (50% completion)	15%	75% + (audit cost)

Construction (75% completion)	15%	90% + (audit cost)
Construction (100% completion)	10%	100% + (audit cost)

B. ADVISORY SERVICES PROJECTS

I. AUTHORITY PROGRAM FEE

The Authority Program Fee for the Advisory Services will be calculated according to one of the following methods as set forth in the CPC for the Project:

Time and Materials: The Authority's Program Fee maybe based on actual time and cost of material incurred by Authority or its Service Providers in connection with a Project based on rates defined in the Project CPC.

Lump Sum: The Authority's Program Fee may be based on the percentage complete of a lump sum or milestones defined in the Project CPC.

Unit Price: The Authority's Program Fee maybe based on the unit prices defined in the Project CPC.

Percent of Materials and Labor: The Authority's Program Fee maybe based on a percentage of Service Provider Material Costs and Labor Costs as defined in the Project CPC.

Other Mechanisms: The Authority's Program Fee may be based on an evolving cost recovery mechanisms not defined in this Master Agreement. If other mechanisms are selected, the Authority's Program Fee will be based on mutual Authority and Customer agreement and will be defined in the Project CPC.

II. PROJECT TERMINATION

If a Project is terminated in whole or part prior to completion of a Project, the Authority's Program Fee will be based on the Project costs incurred by Authority up until the date of termination. For the purposes of calculating the Authority's Program Fee, as applicable, the then current milestone is assumed complete once the Project is canceled.

NEW YORK STATE OF OPPORTUNITY. | NY Power Authority

EXHIBIT B

CAPITAL PROJECT TERMS AND CONDITIONS

1. Application. In addition to the terms and conditions set forth in the main body of this Master Agreement, these Capital Project Terms and Conditions shall apply to all Capital Projects provided by Authority or Service Provider to Customer under the Master Agreement.

2. Capital Project Services. Capital Projects are generally delivered through the services of qualified installation Service Providers or Subproviders under contract with the Authority. Capital Project services may include any or all of the following services (as more fully described below): audit, design, construction management, equipment procurement, installation, commissioning, disposal of Waste, financing and other Project related services required to install a Project.

3. Audit.

(a) Scope. After Customer has identified potential Projects for Authority's and Customer's consideration, Customer may request that Authority perform an audit of the Facility. The audit will help identify opportunities for implementing ESP measures and will be scheduled by Customer's Authorized Representative and/or the appropriate Facility manager. The scope of the audit will be set forth in a CPC which shall be executed by an authorized officer or designee of Authority and Customer prior to commencement of any audit Work. In some instances, the audit will involve a complete inventory of the systems which are currently used in normal operation, while in others a more targeted approach will be taken. The audit may also include an analysis of whether hazardous materials and Waste related to those systems are likely to be present or generated as a result of installing a Project.

(b) Audit Report. Based upon the results of the audit, a written report will be furnished to Customer. The report will include an estimate of the Total Reimbursement Costs as well as estimates of the potential Total Annual Energy Savings and environmental or sustainability benefits, as applicable, that Customer can reasonably expect through implementation of the recommendations made in the report. If, after analysis of the report by Authority and Customer, Authority, in its sole discretion, determines that the Project either (1) does not meet Authority's eligibility criteria, or (2) is not appropriate at such Facility, activity there will cease.

(c) Deferment of Total Reimbursement Costs for Audit Work. Upon completion of the audit Work, if Customer and Authority decide to proceed to the next phase, Customer and Authority will execute a CPC reflecting the scope of such next Project phase. By executing the CPC, Customer acknowledges its concurrence with the audit results. Subject to Authority's approval, Customer may request that payment of the Total Reimbursement Costs for the audit Work, be deferred and included in the Total Reimbursement Costs of the CPC for the next Project phase.

4. Project Design.

(a) General. If agreed upon by the Parties in a CPC, Authority shall prepare a Project design. Customer will be asked to review all aspects of the design and specifications. Where deemed appropriate by Authority and Customer, the Service Provider will arrange for geotechnical surveys (i.e., soil tests, borings, and related evaluations), surveys of the site (i.e., to determine physical characteristics of the site, such as utility locations), and/or demonstration installations (i.e., the installation of sample lighting fixtures or other equipment) of selected measures in Customer's Facility, all at Customer's sole risk.

(b) Milestones and Milestone Completion Reports. Authority will submit the Project design documents to the Customer at 30%, 60%, 90% and "final" design milestones, or according to the milestone schedule set forth in the respective CPC. Upon completion of each design milestone, Customer and Authority (or their duly authorized representatives) shall promptly review the design Work, or applicable portions thereof and Customer and Authority shall jointly sign a Milestone Completion Report. It shall be Customer's responsibility to determine that the proposed design meets Customer's needs.

(c) Deferment of Total Reimbursement Costs for Design Work. Unless otherwise set forth in the CPC for a Project, Authority may invoice the Customer for the Total Reimbursement Costs for the performed design Work through the milestone(s), if any, set forth in the CPC (plus any Total Reimbursement Costs incurred during the audit, if such costs were deferred and rolled over). Customer may request payment deferral if Customer approves Authority to proceed to the next milestone or the next Project phase. With Authority's approval, Customer's Short-Term Repayment Obligation will be deferred and rolled into the next milestone invoice, or at design completion, become part of the Total Reimbursement Costs of the CPC for the next Project phase.

(d) Ownership of Design Work Upon Early Termination. If Customer terminates the design Project prior to its completion, upon receipt of Customer's final payment, Authority will deliver to Customer all design plans and documents completed through the date of termination. Customer's use of such design plans and documents will be subject to any copyrights of the Authority and/or the designer. By using any incomplete or unfinished design plans and/or documents that have not been sealed with the licensed design professional's stamp upon delivery to Customer, Customer accepts full and complete responsibility for such design and further agrees to hold Authority harmless from its use of such incomplete or unfinished design plans and/or documents.

5. Procurement. After Authority and Customer agree on the Project's design and technical specifications, Authority or the Service Provider will competitively solicit, using the Authority's procurement guidelines, bids for the Work as set forth in the design documents. The resulting final design, specifications and bid price shall be incorporated into a CPC for the Project. Authority's contracts with its Service Providers will require compliance with the Authority's guidelines regarding the competitive solicitation of the services of Subproviders for Customer's Facilities, including the selection of minority and women-owned business enterprises. The services of Subproviders and equipment procurement will be obtained through a competitive bid process conducted by the Service Provider with Authority oversight. In the event Customer

decides not to proceed with the installation Project, Customer shall reimburse Authority for the costs of any Work undertaken by Authority and/or its Service Provider in connection with the procurement process and the associated cost and expense of same.

6. Installation.

(a) General. After Authority and Customer have entered into a CPC for installation Work, the Service Provider and/or its Subproviders will perform the Work pursuant to the design and technical specifications set forth in such CPC.

(b) Substantial Completion and Operation Transfer Report. After Customer has inspected, tested and accepted the Project equipment, or portion thereof, installed by the Service Provider, the Parties will execute a Substantial Completion and Operation Transfer Report for the completed portion of the Work signifying (i) that Customer accepts responsibility for operation and maintenance of the installed equipment, (ii) that the Project, or specified portion thereof, is substantially complete, and (iii) the commencement of any warranty period.

(c) Final Inspection Report. Upon completion of the Work, Customer and Authority (or their duly authorized representatives) shall promptly inspect the entire Facility, or applicable portions thereof. Authority or its Service Providers will confirm that the Work has been satisfactorily completed according to the provisions of this Master Agreement and the applicable CPC. Authority and Customer shall jointly sign a Final Inspection Report.

7. Maintenance and Post-Installation Audit. Authority will provide Customer with information regarding the maintenance of Project installations and recommendations for appropriate replacement equipment to be used in those installations to facilitate proper usage and, if applicable, energy savings at Customer's Facilities. After the Project installations are completed, Customer shall use reasonable efforts to see that such maintenance and materials instructions are followed at its Facilities. While any portion of the Customer's Short-Term Repayment Obligation remains outstanding, Authority may, upon reasonable notice to Customer, audit installations in Customer's Facilities to evaluate compliance with such maintenance and materials instructions.

8. Project Closeout for Capital Projects. Notwithstanding the terms set forth in the CPC or Final CPC, the Customer shall, within the time specified in the Final CPC, (a) repay the Short-Term Repayment Obligation or (b) convert the Short-Term Repayment Obligation to a Long-Term Repayment Obligation and enter long term repayment consistent with the Authority's policies and procedures. The Customer shall make payment of that portion of the Short-Term Repayment Obligation that is not converted to the Long-Term Repayment Obligation upon receipt of the Authority's invoice and in accordance with the terms of this Master Agreement. The Short Term Repayment Obligation, as set forth in the Final CPC, shall include the Authority's estimate of Short-Term Interest to be accrued between the issuance of the Final CPC and conversion to long term repayment.

9. Authority Obligations. In addition to the obligations otherwise set forth herein and the respective CPC, Authority shall require the Service Provider to adhere to the Project's design

and technical specifications as set forth in the CPC and minimize any interference with the normal operations at Customer's Facility.

10. Customer Obligations. In addition to the obligations otherwise set forth herein and the respective CPC, Customer shall promptly review all completed installations. Customer shall review and approve, as may be required, any corrective or restoration Work resulting from improper work by the Service Provider.

11. Customer-Supplied Equipment and/or Work. Customer and Authority may agree in the CPC for the provision of Customer materials and/or completion of Customer work in connection with a Project, independent of Authority. If so, then Customer shall be responsible for any changes to the Project schedule, scope of Work or any increase in the Total Reimbursement Costs caused by Customer due to non-delivery of Customer materials or non- or late performance of Customer work and Authority shall issue any necessary Contingency Work Order or Change Order, as applicable. Authority may suspend its Work on the Project until Customer approves such Change Order. Furthermore, if the Customer does not meet the Project schedule with respect to Customer materials and/or Customer work, Authority has the right to terminate the Project if the delay is not cured within fifteen (15) days of written notice thereof by Authority to Customer and turn it over to Customer for completion without any liability on the part of Authority.

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NEW YORK STATE OF OPPORTUNITY. | NY Power Authority

EXHIBIT C

ADVISORY SERVICES TERMS AND CONDITIONS

1. Application. In addition to the terms and conditions set forth in the main body of this Master Agreement, these Advisory Services Terms and Conditions shall apply to all Advisory Services Projects provided by Authority or Service Provider to Customer pursuant to the Master Agreement.

2. Advisory Services. Upon Customer's request, Authority may provide any or all of the Advisory Services described below. Advisory Services may be provided by Authority employees and/or Service Providers with expertise in the area as determined by Authority. Authority and Customer will cooperate in good faith during the performance of such Advisory Services.

3. Description of Services

(a) *Review*. Review of information provided by the Customer regarding, among other things, Customer's site conditions, future plans for modifications to facilities, operations and/or usage, historical utility data, any relevant strategic plans or initiatives, and other relevant requirements that are specific to Customer.

(b) *Meetings*. Participate in meetings and conference calls as mutually agreed upon by the parties as being in the best interests of the Project or as otherwise detailed in the Customer Project Commitment.

(c) *Site Observations*. Observe Customer's facilities, physically or remotely via electronic means as determined by the Authority to assess the condition of existing equipment and physical site conditions.

(d) *Analysis*. Analyze data presented by Customer and/or collected by or on behalf of the Authority. Outreach to appropriate third parties as necessary to coordinate and/or collect additional data.

(e) *Advice and Guidance*. Deliver oral or written advice, guidance and other recommendations communicated via in person meetings, telephone conversations, or correspondence.

(f) *Deliverables and Reports*. Prepare reports, memorandums, and other documents that memorialize the advice, guidance and recommendations delivered to the Customer and support the Customer's underlying project, where applicable.

The foregoing descriptions are given by way of example and not by way of exclusion. Advisory Services may include services that have not yet been developed or approved by Authority

to date, provided such services are described in a CPC signed by both Parties to this Master Agreement.

4. Further Assistance; Information. In addition to the obligations set forth herein and the respective CPC, Customer shall provide Authority and/or Service Providers with such assistance as may be required to perform the Advisory Services. This may include, but is not limited to, providing access to the Customer's Facility(ies), information such as historical utility data, maintenance logs, existing feasibility studies, reports, equipment drawings or any other information or services reasonably requested by Authority and/or Service Providers.

* * * * * *

Signature: mERVIN R. LIVSEY
mERVIN R. LIVSEY (Jul 23, 2019)

Email: blivsey@highlands-ny.gov

Title: Town of Highlands Supervisor

Company: Town of Highlands

Signature: John Canale
John Canale (Jul 23, 2019)

Email: john.canale@nypa.gov

Title: VP Strategic Supply Management

Company: New York Power Authority

Arencibia, Stephanie (Molly)

From:	Laino, Jeffrey <Jeffrey.Laino@nypa.gov>
Sent:	Tuesday, July 23, 2019 8:52 AM
To:	Richard Sullivan
Subject:	FW: [EXTERNAL]Town of Highlands_ES_MCRA_2019 between New York Power Authority , mERVIN R. LIVSEY and John Canale is Signed and Filed!
Attachments:	Town of Highlands_ES_MCRA_2019 - signed.pdf; NYPA Street Lighting Authorization to Proceed.pdf

Hi Richie,
See attached signed MCRA. Also attached is the Authorization to Proceed. Once I receive the ATP I can initiate the project and get an engineer assigned to the project so we can schedule a kick off meeting.
Thank you for your help with moving this along!!
Jeff

From: New York Power Authority <echosign@echosign.com>
Sent: Tuesday, July 23, 2019 8:39 AM
To: Canale, John <John.Canale@nypa.gov>; Parille, Lindsay <Lindsay.Parille@nypa.gov>; mERVIN R. LIVSEY <blivsey@highlands-ny.gov>
Cc: Paine, John <John.Paine@nypa.gov>; Laino, Jeffrey <Jeffrey.Laino@nypa.gov>
Subject: [EXTERNAL]Town of Highlands_ES_MCRA_2019 between New York Power Authority , mERVIN R. LIVSEY and John Canale is Signed and Filed!

Town of Highlands_ES_MCRA_2019 between New York Power Authority , mERVIN R. LIVSEY and John Canale is Signed and Filed!

From: NEW YORK POWER AUTHORITY - Lindsay Parille (New York Power Authority)
To: John Canale, NEW YORK POWER AUTHORITY - Lindsay Parille and mERVIN R. LIVSEY

Cc: New York Power Authority John Paine and jeffrey.laino@nypa.gov

Attached is a final copy of **Town of Highlands_ES_MCRA_2019**.

Copies have been automatically sent to all parties to the agreement.

You can view the document in your Adobe Sign account.

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- Exchange, Sign, and File Any Document. In Seconds!
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NEW YORK STATE OF OPPORTUNITY. | NY Power Authority

ANDREW M. CUOMO
Governor

JOHN R. KOELMEL
Chairman

GIL C. QUINIONES
President and Chief Executive Officer

April 5, 2019

Supervisor Bob Livsey
Town of Highlands
254 Main Street
Highland Falls NY 10928

RE: Energy Services Program
Authorization to Proceed with turn-key street light project
Town of Highlands– LED Street Lighting

Dear Supervisor Livsey,

The New York Power Authority (NYPA) is excited to support the Town of Highlands in identifying and implementing a comprehensive street lighting upgrade. Improving the existing street lights is a widely used and effective strategy to achieve the goal of reducing energy consumption, lowering utility costs, and improving light quality throughout the community.

Consistent with the Master Cost Recovery Agreement, NYPA provides a turn-key solution to upgrade the Town of Highlands's existing street lights to energy efficient LED technology. NYPA is pleased to offer these services to replace approximately 167 existing street light fixtures with new high efficient LED technology.

By signing below, the Town of Highlands authorizes NYPA to proceed with the full turn-key solution of the LED street lighting project, which includes the final design report, conducting bids for materials and installation labor, providing construction management, and commissioning the final project. When the design and bidding is completed, you will receive an Initial Customer Installation Commitment (ICIC) for your review and signature. At this point, if you choose to proceed to project implementation all development costs will be rolled into the overall project. Conversely, should you decide not to proceed with the implementation of the project, the Town of Highlands agrees to reimburse NYPA for all costs incurred up to the termination date for the development, design and bidding of the project. The cost of developing the design and for bidding the materials and labor will be determined during the next phase. NYPA will be fully transparent through this process and provide complete documentation as to how it determined all project costs.

By signing below, affirm that you agree to these conditions:

NEW YORK STATE OF OPPORTUNITY. | NY Power Authority

Joseph Rende	
(Name, printed)	(Name, printed)
Senior Director, Customer Business Development	
(Title)	(Title)
(Signature)	(Signature)
(Date)	(Date)

NEW YORK STATE OF OPPORTUNITY. | NY Power Authority

Master Cost Recovery Agreement No. ________________
Effective Date: ________________

ENERGY SERVICES PROGRAM

MASTER COST RECOVERY AGREEMENT

BETWEEN

POWER AUTHORITY OF THE STATE OF NEW YORK

AND

TOWN OF HIGHLANDS

ENERGY SERVICES PROGRAM
MASTER COST RECOVERY AGREEMENT

This Master Cost Recovery Agreement (this "Master Agreement"), dated Jul 23, 2019 ______________________________, is entered into by and between POWER AUTHORITY OF THE STATE OF NEW YORK, a corporate municipal instrumentality of the State of New York with offices located at 123 Main Street, White Plains, New York 10601 ("Authority") and the Town of Highlands, a municipality with offices located at 254 Main Street, Highland Falls, NY 10928 ("Customer").

WHEREAS, Public Authorities Law §1005(17) permits the Authority, as deemed feasible and advisable by the Trustees, to finance and design, develop, construct, implement, provide and administer energy-related projects, programs and services for any public entity and certain other specified entities; and

WHEREAS, the Trustees have authorized the establishment of the Authority's Energy Services Program ("ESP") to include, among other things, energy efficiency projects and services, clean energy technology projects and services and high-performance and sustainable building projects and services (including technologies that reduce air and other pollution and conserve materials and resources such as water); and the construction, installation and/or operation of facilities or equipment done in connection with any such projects, programs or services; and

WHEREAS, Public Authorities Law §1005(17) permits Customer, a public entity, to enter into an energy services contract with the Authority for such energy-related projects, programs and services as authorized by Public Authorities Law; and

WHEREAS, Authority and Customer desire to work together to develop and implement Projects contemplated under the ESP and to enter into this Master Agreement as more particularly set forth herein.

NOW, THEREFORE, Authority and Customer (sometimes referred to herein collectively as the "Parties" and individually as a "Party"), in consideration of the mutual covenants and conditions contained herein and in these recitals, hereby agree as follows:

DEFINITIONS

The following definitions apply for all purposes of this Master Agreement:

"Advisory Services" means the consulting services provided by Authority or Service Providers to assist Customer in its efforts to reduce energy consumption and associated operations and maintenance costs, to realize environmental benefits, including but not limited to the reduction of air pollution; to conserve natural resources; and/or facilitate the use of clean energy sources at Customer's Facilities.

"Advisory Services Terms and Conditions" means the additional terms and conditions set forth in Exhibit C applicable to Advisory Services Projects provided by Authority or Service Provider to Customer hereunder.

"Ancillary Documents" means documents, other than this Master Agreement and the Customer Project Commitment (and documents that modify them, such as Change Orders and Contingent Work Orders), covering information necessary for the implementation of a specific Project, such as authorizations, Substantial Completion and Operation Transfer Reports, Milestone Completion Reports and Final Inspection Reports, etc.

"Authority's Authorized Representative" means an individual designated by Authority in accordance with Section 10.1(b) to coordinate a Project on behalf of Authority and to communicate with Customer concerning such Project.

"Authority Implemented Work" means Work undertaken by Authority for Customer as more fully set forth in a CPC (subject to the terms and conditions of this Master Agreement and any applicable Transaction Document) through the services of qualified Service Providers or Subproviders engaged by Authority.

"Authority Material Handling Fee" is a fee applied by the Authority to the cost of materials purchased directly by the Authority for a Project, where applicable, to reimburse the Authority for procurement, material handling, storage and/or restocking. The amount of such fee, when applicable to a Project, will be set forth in the CPC, as superseded by the Final CPC.

"Authority Program Fee" mean Authority's fee applicable to each Project. Details of the Authority Program Fee will be set forth in the Compensation Schedule, attached hereto as Exhibit A, and the amount of such fee will be set forth in the CPC, as superseded by the Final CPC.

"Background Intellectual Property Rights" means Intellectual Property Rights of a Party owned, controlled, acquired, developed, invented, generated, authored, conceived or reduced to practice prior to the date of this Master Agreement, or acquired parallel to and independent of this Master Agreement or any Transaction Documents entered into under this Master Agreement.

"Capital Project" is a Project involving the design, construction, installation and/or modification of facilities and/or equipment in Customer's Facility.

"Capital Project Terms and Conditions" means the additional terms and conditions set forth in Exhibit B applicable to Capital Projects provided by Authority or Service Provider to Customer hereunder.

"Change Order" is a Transaction Document that memorializes a modification to the CPC that cannot be made by Contingency Work Order, setting forth agreed-upon additions, deletions or revisions to the Work, and the cost and/or time impact to the Project.

"Compensation Schedule" is a schedule attached hereto as Exhibit A setting forth details about the Authority Program Fee and other relevant Project costs, where applicable, for the different services offered by Authority under this Master Agreement.

"Contingency Work Order" is a Transaction Document that memorializes the Authority's use of the Project Contingency for a Project, such use to be reflected on subsequent CPCs that are executed for the particular Project.

"Customer's Authorized Representative" means an individual designated by Customer in accordance with Section 10.1(a), to coordinate a Project on behalf of Customer and to assist Authority, its Service Providers and Subproviders with the implementation of the Project.

"Customer Project Commitment" or "CPC" is a Transaction Document containing terms and conditions for one or more specific Projects at a Customer's Facility(ies) that includes, at a minimum, the location of Customer's Facility, a detailed scope of Work (including a description of milestones, if any), the projected Project costs and any specific payment terms applicable to the Project.

"Debris" shall mean unregulated materials removed from a Customer Facility and unsuitable for further use.

"Environmental Laws" means all current and future federal, state and local laws (including common law), treaties, regulations, rules, ordinances, codes, decrees, judgments, directives, orders (including consent orders), environmental permits, and obligations and other requirements imposed by any "Governmental Authority" (as defined herein), including New York State Department of Environmental Conservation ("NYS DEC") Technical Administrative Guidance Memoranda and other guidance documents issued or published by any Governmental Authority, in each case, relating to pollution, protection of the environment, natural resources, or protection of human health and safety from conditions in the environment, the presence, "Release" (as defined herein) of, threatened Release of, or exposure to, "Hazardous Substances" (as defined herein), or to the generation, manufacture, processing, distribution, use, treatment, storage, transport, recycling or handling of, or arrangement for such activities with respect to, Hazardous Substances.

"Environmental Liabilities" means all liabilities, obligations, damages, losses, claims, actions, suits, judgments, orders, fines, penalties, fees, expenses, and costs, relating to environmental conditions or activities, including (i) Remediation costs, engineering costs, environmental consultant and expert fees, laboratory fees, permitting fees, investigation costs, defense costs, and reasonable attorneys' fees and expenses; (ii) any claims, demands, and causes of action relating to or resulting from any personal injury (including wrongful death), property damage (real or personal) or natural resource damage; and (iii) any penalties, fines or costs associated with the failure to comply with any Environmental Law.

"Energy Services Program" or "ESP" includes energy efficiency projects and services; clean energy technology projects and services; high-performance and sustainable building programs and services (including technologies that reduce air and other pollution, conserve materials and resources such as water); and the construction, installation and/or operation of facilities or equipment done in connection with any such project, programs and services.

"Facility" means the building, structure or premises owned and/or operated by Customer that may benefit from Customer's participation in Authority's ESP Program.

"Final CPC" means the document that reflects the final reconciliation of Project costs and all amendments to the CPC that is issued by Authority to Customer upon completion of the Work for a Project.

"Final Inspection Report" means the report, if any, to be executed by Authority and Customer after completion of a Project.

"Hazardous Substances" means (i) any petroleum, petroleum products or byproducts, and all other regulated hydrocarbons (including without limitation, petrochemicals and crude oil), or any fraction thereof, coal ash, radon gas, asbestos, asbestos-containing material, urea formaldehyde, polychlorinated biphenyls, chlorofluorocarbons, and other ozone-depleting substances; and (ii) any chemical, material, substance, product or waste (including thermal discharges and hazardous waste) that is prohibited, limited, or regulated by or pursuant to any Environmental Laws.

"Intellectual Property Rights" means any and all intellectual property rights, including, but not limited to rights in any and all of the following: (i) technical information and know-how; (ii) discoveries, improvements, enhancements, upgrades, inventions, (whether or not patentable); (iii) patents, patent applications, patent disclosures, and any other patentable subject matter; (iv) copyrights, applications to register copyrights, works of authorship and any other copyrightable works; (v) trademarks, trade names, trade dresses, brand names, logos and similar marks; (vi) any sketches, drawings, outlines, drafts; (vii) computer software (including source code, executable code, databases, data and related documentation); (viii) trade secrets and know-how; and (ix) all improvements or modifications to any of the foregoing.

"Labor Cost" is that portion of the Total Reimbursement Costs for installation labor performed by Service Provider and Subprovider in connection with the Work performed in connection with a Project pursuant to a CPC based on this Master Agreement. Such costs will be detailed in each CPC.

"Long-Term Repayment Obligation" means the obligation of Customer to repay Authority in accordance with and subject to the terms of a loan agreement after conversion of a Short-Term Repayment Obligation.

"Material Cost" is that portion of the Total Reimbursement Costs related to equipment, materials and supplies in connection with the Work performed in connection with a Project pursuant to a CPC based on this Master Agreement. Such costs will be detailed in each CPC.

"Milestone Completion Report" means a document generated by Authority or Service Provider that identifies a milestone(s) satisfactorily completed during the progress of a Project or phase of a Project (i.e., design, construction, or otherwise), signifies Customer's concurrence with the completion of such milestone and represents Customer's authorization to proceed to the next milestone or phase of the Work, as applicable.

"Other Agreement" means any stand-alone agreements entered into between the Parties at any time, including, without limitation, non-disclosure agreements, privacy agreements, or grant agreements, but shall not include any Master Cost Recovery Agreement, Energy Efficiency Services Agreement or other agreements governing services under the ESP entered into by the Parties prior to the execution of this Master Agreement.

"Project" means any project or service undertaken through Authority's ESP pursuant to a CPC based on this Master Agreement.

"Project Contingency" means a defined budget to be utilized at the Authority's discretion in accordance with Section 2.3 hereof for, among other things, unexpected costs and expenses that may arise during the performance of a Project (usually calculated as a percentage of Material Cost and Labor Cost).

"Release" means any actual or threatened release, spill, emission, emptying, escape, leaking, dumping, injection, pouring, deposit, disposal, discharge, dispersal, leaching, or migration into the environment or within any building, structure, facility, or fixture and/or the exacerbation of any preexisting condition of Hazardous Substances.

"Remediation" means the investigation (including any feasibility studies or reports), cleanup, removal, abatement, transportation, disposal, treatment (including in-situ treatment), management, stabilization, neutralization, collection, or containment of Hazardous Substances and any Release(s), that may be required to satisfy Environmental Laws, in each case, including, without limitation, any closure, restoration or monitoring, operations and maintenance activities, including any engineering or institutional controls, that may be required by any Governmental Authority after the completion of such investigation, study, cleanup, removal, transportation, disposal, treatment, neutralization, collection, or containment activities as well as the performance of any and all obligations imposed by any Governmental Authority in connection with such investigation, cleanup, removal, transportation, disposal, treatment (including in situ treatment), management, stabilization, neutralization, collection, or containment (including any such obligation that may be imposed pursuant to an Environmental permit or a consent order).

"Service Provider(s)" means a third party provider of goods and/or services that Authority, acting as the contracting entity, contracts with through its procurement policies, procedures and guidelines to perform Work in connection with a Project at Customer Facilities.

"Service Provider Fees" means the costs associated with the payment to Service Providers, its Subproviders and other third party professionals for Work performed with respect to a specific Project. Service Provider Fees will be detailed in each CPC.

"Short-Term Interest" is a cost component of the Total Reimbursement Costs of a Project representing the costs incurred by the Authority in connection with financing the delivery of a Project during the time within which such funds remain unpaid by Customer.

"Short-Term Repayment Obligation" refers to Customer's obligation to reimburse Authority for the costs of delivering a Project, as identified in the Final CPC.

"Short-Term Repayment Obligation Maturity Date" means the date set forth in the Final CPC, no later than ninety (90) days following the approval of the Final CPC.

"Specific Subject Matter" shall mean intellectual property rights, Authority's liability and limitation thereof, Project warranties, and amendments to this Master Agreement and/or any Transaction Documents.

"Subprovider(s)" refers to individuals or entities retained by the Service Provider(s) to perform all or part of the Work.

"Substantial Completion and Operation Transfer Report" is a document signed by the Parties signifying that the equipment and/or facilities installed at the Project have been inspected, tested and accepted by Customer.

"Third Party" means any utility company, permit agency, governmental authority having jurisdiction over a Project, any contractor or service provider hired by Customer, or any other third party that is not a Service Provider or Subprovider but is, directly or indirectly, involved in or whose approval is required in connection with, a Project and not under contract, directly or indirectly, with the Authority.

"Total Annual Energy Savings" is the estimated net reduction in Customer's annual usage of (a) energy service, (b) other utilities including, but not limited to, water and sewer, and (c) any related operation or maintenance savings, if applicable, resulting from the installation of one or more energy conservation measures in accordance with this Master Agreement.

"Total Reimbursement Costs" is the sum of all of the costs of a Project as set forth in the CPC and Final CPC, including, but not limited to, to the extent applicable to such Project: (1) Material Cost; (2) Labor Cost; (3) the amount of the Project Contingency applied as a Project cost; (4) Service Provider Fees; (5) Authority Program Fee; (6) Short-Term Interest; and (7) other Project-related costs and expenses.

"Transaction Document(s)" means with respect to a Project, this Master Agreement and any related Customer Project Commitment and any document that modify them, such as Change Orders and Contingency Work Orders.

"Waste" refers to waste PCBs (as defined by the United States Environmental Protection Agency ("USEPA") in 40 CFR Part 761) and hazardous waste (as defined by the USEPA in 40 CFR Part 261 and the NYS DEC in 6 NYCRR Part 371) as well as other material regulated for purposes of release, reuse, disposal, or recycling (e.g. CFCs, ethylene glycol, mercury, oil, asbestos), which form a part of the equipment removed from Customer Facilities due to implementing the Work. Disposal of such Waste shall be conducted in accordance with the provisions set forth in Article IV.

"Work" means the services performed for Customer for a selected Customer Facility pursuant to this Master Agreement and the other Transaction Documents for a Project. The scope of Work shall be described in the CPC, as amended by subsequent Change Orders, Contingency Work Orders, and the Final CPC.

ARTICLE I

SCOPE AND APPLICATION OF AGREEMENT; ORDER OF PRECEDENCE

1.1 Transaction Documents. In connection with each Project, the Parties will, either concurrently with or subsequently to this Master Agreement, enter into one or more Customer Project Commitments, or similar memoranda, that define a specific Project(s) and the costs and fees associated with such Project, and associated Ancillary Documents. Except as otherwise expressly set forth therein, all Transaction Documents, upon execution by the Parties, shall be

governed by the terms and conditions of this Master Agreement. Each Transaction Document shall contain a specific reference to this Master Agreement and CPC, as applicable. This Master Agreement does not obligate Authority to accept requests for Projects issued by Customer or obligate any Party to enter into a CPC.

1.2 Entire Agreement. Subject to the provisions of Section 1.4 below, with respect to a Project, this Master Agreement (including Exhibits A, B, and C and any other exhibits, schedules or appendices hereto) and any Transaction Document which specifically references a Project, constitute the entire agreement between Authority and Customer concerning such Project, and supersedes all prior negotiations, representations, contracts and agreements concerning such Project.

1.3 Conflict and Order of Precedence. In the event of a conflict between the terms of this Master Agreement and the terms and conditions set forth in another Transaction Document, or between the terms of two or more Transaction Documents in effect for a Project, the order of precedence shall be a follows: (i) the terms of the CPC for such Project (as amended by Contingency Work Orders and/or Change Orders and as superseded by the Final CPC) but solely with respect to the price (i.e., the Project's Total Reimbursement Costs), payment terms, and scope of Work (including description of milestones) of the Project; (ii) the terms of this Master Agreement; (iii) the remaining terms of the Project CPC; and (iv) the terms of any Ancillary Document. Notwithstanding the foregoing, the Parties agree that with respect to Specific Subject Matters, if the terms of a Transaction Document concerning a Specific Subject Matter are more favorable to Authority than the respective terms set forth in this Master Agreement, the more favorable terms of the Transaction Document shall prevail with respect to the Project to which it relates. (By way of example, if a Transaction Document includes a term that disclaims any warranties by Authority (or Service Provider) for Work performed, such term would prevail over the warranties set forth in Section 7.1. hereof.)

1.4 Other Agreements. This Master Agreement supersedes all Master Cost Recovery Agreements, Energy Services Agreements or other agreements governing services under the ESP entered into by the Parties prior to the execution of this Master Agreement. Notwithstanding the foregoing, this Master Agreement does not supersede and does not apply to any Other Agreements existing between Customer and Authority. Any projects which Authority has undertaken or undertakes at Customer Facilities pursuant to such Other Agreements, or under prior Energy Services Agreements under which projects remain incomplete as of the date of this Master Agreement, shall be governed by those agreements and related documents, unless otherwise agreed in writing. Termination of this Master Agreement shall have no effect on the Other Agreements which will remain in full force and effect according to their respective terms.

1.5 Amendments. This Master Agreement and any other Transaction Document executed in connection herewith may be amended only in writing signed by an authorized officer or designee of Authority and Customer.

ARTICLE II

GENERAL PROJECT STRUCTURE

2.1 Customer Project Commitment or CPC. For each Project undertaken under this Master Agreement, the parties will enter into one or more CPC(s), each of which will state the specific terms and conditions applicable to such Project, segregating the Project into logical phases to be performed consecutively. Each CPC will include, at a minimum, the phasing plan setting forth how the Project will proceed, the location of Customer's Facility, scope of Work, (including description of milestones, if any), projected Total Reimbursement Costs, and payment terms.

The Authority is not obligated to commence any Work for a particular Project unless or until a CPC is executed by Authority and Customer. Notwithstanding the foregoing, the Parties may agree to expedite the commencement of a portion of the Work associated with a particular Project prior to the execution of a CPC provided that the Parties memorialize such agreement prior to the commencement of such Work in a writing that sets forth the specific items of Work to be commenced and the associated cost of such Work. In such event, Customer agrees to bear the costs of any Work undertaken by Authority or its Service Providers for Customer in preparation for or with respect to such Project or potential Project even if no CPC is ultimately executed.

2.2 Final CPC. As soon as practicable following completion of the Work and receipt of all invoices associated with a Project, Authority will generate a Final CPC which will include all Contingency Work Orders, and all agreed-upon Change Orders, if any. The Final CPC will reconcile the Total Reimbursement Costs set forth in the CPC on the basis of Authority's actual costs and will supersede all prior CPCs. The Final CPC shall also describe the Project-specific terms for the Work completed at the Facility or Facilities, Customer's Short-Term Repayment Obligation, and the final repayment terms. Authority and Customer shall execute such Final CPC, which shall be "deemed executed" unless Customer disputes such Final CPC in writing within forty-five (45) days of the Authority's transmission thereof. If Customer timely disputes the Final CPC, then the Parties shall endeavor to resolve the dispute as expeditiously as possible in accordance with the procedures set forth in Section 11.2; provided, however, that Customer shall pay any undisputed amounts of Customer's Short-Term Repayment Obligations set forth in the Final CPC in accordance with Article V hereof.

2.3 Contingency Work Order. If unexpected costs and expenses arise during the performance of a Project, the Authority may utilize the Project Contingency, provided that (i) the scope modifications, if any, are consistent with the general nature of the Project; (ii) the modifications do not render the Project ineligible under the Authority's Energy Services Program requirements; and (iii) the cumulative increased Project costs do not exceed the Project Contingency. Contingency Work Orders may be utilized to account for, among other things, remedial work required due to design or construction omissions (whether remedial work is caused by omissions of Authority, its Service Providers or Customer) to the extent that the requirements set forth above are met. If the requirements for a Contingency Work Order are not met, Authority and Customer may negotiate a Change Order as described in Section 2.4 below.

As the Project Contingency is utilized, the Authority will issue a Contingency Work Order, which shall be effective upon issuance and automatically update the terms of the respective CPC without the need for express Customer approval. Any objections to the manner in which the Authority is utilizing the Project Contingency must be raised by the Customer in writing to the Authority within seven (7) days of the Authority's issuance of any such Contingency Work Order, or such other period of time identified in the Contingency Work Order. Failure to comply with this notice requirement by the Customer will be deemed a waiver of any claim that (i) the Project Contingency was used improperly; or (ii) that payment on account of such Contingency Work Order is disputed. Upon request, the Authority will provide Customer with periodic reports that establish an accounting of how the Project Contingency is being utilized.

2.4 Change Order. Any party to a CPC may at any time by written notice to the other party request modifications to the Work described in the executed CPC. Authority shall provide Customer with a written analysis of the effects of the requested modification(s) and, provided that the requested modification(s) do not materially alter the general scope of the Project, the Parties will negotiate a Change Order to the CPC. No Change Order shall take effect until it is approved within the time period specified in the Change Order by Authority and by Customer in accordance with Customer's procedures to authorize amendments to the CPC. In the event of a dispute over a request for a Change Order, Authority may elect to proceed with the Work in accordance with the scope of Work as set forth in the CPC (as revised by agreed-upon Change Orders and/or Contingency Work Orders), or the dispute may be treated under the provisions of Section 11.1 hereof.

2.5 Unforeseen Circumstances or Conditions. In the event that circumstances or conditions at Customer's Facility are encountered after a CPC is executed, that may require changes to the Project schedule and/or result in an increase to the Total Reimbursement Costs of the Project, Authority shall as soon as practicable notify Customer. The CPC shall be revised by a Contingency Work Order or a Change Order, as applicable, to incorporate necessary changes to the Project schedule, the scope of Work and/or any increase in the Total Reimbursement Costs, as a result of the existence of the unforeseen circumstance or condition. Customer shall assume any increase in costs as part of its Short-Term Repayment Obligation.

2.6 Third Party Obligations. The Authority shall not be held responsible for any action or failure to act of Customer, its officers, employees, agents, representatives or any Third Party, including, but not limited to, any delay in issuance or any non-issuance of a permit or approval necessary to perform or close out the Work under a Project. Any changes to the Project schedule or scope of Work or any increase in the Total Reimbursement Costs caused by such act or failure to act, shall be Customer's responsibility. If the Third Party conduct necessitates the issuance of a Change Order to compensate the Authority for any changes to the Project schedule, scope of Work or Total Reimbursement Costs resulting from such act or failure to act, Authority may suspend its Work on the Project until Customer approves such Change Order. If Customer fails to approve the Change Order within thirty (30) days of its issuance or the Project is suspended as a result for more than ninety (90) days, Authority, in its sole discretion, may terminate all Project Work and issue a Final CPC as provided in Section 3.4(d) below.

2.7 Execution and Disputes Regarding Reports. The execution of a Milestone Completion, Final Inspection, Substantial Completion and Operation Transfer Report or similar

report(s) shall not be unreasonably withheld by either Party, and the Parties shall endeavor to fully execute such report within thirty (30) days after its submittal to Customer or it shall be deemed executed unless it was disputed by Customer in writing within such thirty (30) day period. In the event of any disputes by Customer with respect to such report(s), the Parties shall endeavor to resolve such dispute as expeditiously as possible in accordance with Sec. 11.1 hereof.

2.8 Limitation on Work in Certain Premises. Absent the express written consent of Authority, no Work of any kind shall be performed in any premises of Customer used for private business use within the meaning of Section 141(b) of the U.S. Internal Revenue Code of 1986, as amended.

2.9 Eligibility Criteria. Projects will be undertaken on an individual basis in Customer's Facilities as deemed feasible and advisable by Authority and mutually agreed to by Authority and Customer. A Project will not proceed unless it satisfies (as determined by Authority in its sole discretion) Authority's requirements related to reduction in overall primary energy costs, energy conservation, results in environmental benefits and/or other requirements of the Authority's Energy Services Program, then in effect.

ARTICLE III

SUSPENSION AND TERMINATION OF PROJECTS

3.1 Suspension of Work.

(a) Suspension by Customer. Customer may direct Authority to suspend Work at any Customer Facility by written notice to Authority. Authority, and the Service Providers and Subproviders, will thereupon cease Work at that Facility as soon as practicable.

(b) Suspension by Authority. In addition to any other right by Authority to suspend Work on a Project set forth herein, Authority may suspend Work at any Customer Facility if any of the following occurs: (i) Customer fails to make payment to Authority when due; and such payment default continues for a period of ten (10) days after written notice thereof by Authority to Customer; (ii) circumstances or conditions at Customer's Facility are discovered after a CPC is executed which require changes to the Project and/or result in an increase to the Project's Total Reimbursement Costs that cannot be covered by the use of any remaining Project Contingency budgeted for the Project; (iii) a Third Party's act or failure to act causes a delay to the critical path of the Project schedule that continues for a period of thirty (30) days after written notice thereof by Authority to Customer; (iv) a delay caused by a Force Majeure event continues for a period of fifteen (15) consecutive days; (v) the existence of a hazard not caused by Authority or its Service Provider(s) that threatens the safety and protection of the site, its inhabitants or the public; or (vi) the existence of an unforeseen circumstance or condition the correction of which could reasonably be expected to (A) create an unreasonable risk for Authority or Service Provider not ordinarily associated with projects of similar size and scope (as determined by Authority); (B) create a threat to life or safety of the inhabitants or the public in general, or (C) violate applicable federal, state or local laws, regulations, codes or standards.

(c) Liability for Cost Increase as Result of Suspension. The suspension of Work by either Party pursuant to the provisions of this Section 3.1 may adversely impact the Project schedule, the scope of Work and/or the Total Reimbursement Costs. The CPC may be revised by a Contingency Work Order or Change Order, as applicable, to incorporate any necessary changes. Customer shall assume any increase in the Total Reimbursement Costs in full as part of its Short-Term Repayment Obligation unless the suspension was caused by the gross negligence or willful misconduct of Authority, its Service Provider or Subprovider, in which case Customer will not be responsible for any increase in the Total Reimbursement Costs to the extent such increase is caused by such gross negligence or willful misconduct.

(d) Resumption of Work After Suspension. In the event Work on a Project was suspended by a Party (whether pursuant to this Section 3.1 or otherwise), Authority and Customer have to agree in writing that Work shall resume before any Work on the Project can continue. In the event Work is suspended for more than ninety (90) days, Authority, in its sole discretion, may terminate Work for that Project and Authority shall issue a Final CPC as provided in Section 3.4(d) below.

3.2 Emergency. If an emergency results in or could reasonably be expected to result in personal injury or loss of life or damage or harm to property or public safety, Customer, acting in good faith in order to prevent, avoid or mitigate personal injury or loss of life or damage or harm to property or public safety may direct a Service Provider to suspend Work. Customer shall provide written notification to Authority of the suspension and events leading up to the suspension within eight (8) hours after the emergency has been stabilized. Sections 3.1(c) and (d) shall also be applicable to a suspension under this Section 3.2.

3.3 Termination of a Project. Authority may terminate a Project (and the related CPC) at any time upon thirty (30) days' prior written notice to Customer. In addition, the following incidents shall be deemed to immediately terminate a Project: (i) closure, abandonment, destruction or material damage to the Facility for which Project Work is being performed; (ii) reduction or elimination of energy savings or other modification to the Project that, in the Authority's opinion, renders the Project ineligible under the Authority's requirements for inclusion in its Energy Services Program , whether due to removal, by-passing or alteration of equipment or due to any unforeseen event; (iii) discovery of asbestos or other hazardous material in Customer's Facility that impedes the execution of the Work; and (iv) failure by Customer to make payment to Authority when due and such payment default continues for a period of thirty (30) days after written notice thereof by Authority to Customer.

3.4 Actions Upon Project Termination or Cancellation. In the event that a Project is canceled or terminated in whole or in part subsequent to execution of a CPC but prior to completion of such Project, Authority shall:

(a) Discontinue or direct Service Provider(s) to discontinue all Work and the placement of all orders for materials, equipment or labor otherwise required for the Project or terminated part of the Project, as applicable;

(b) Cancel or direct Service Provider to cancel all existing orders and subcontracts related to performance of the Project or terminated part of the Project, as applicable;

(c) Take actions reasonably necessary, or as directed by Customer in writing, for the protection and preservation of the Work and all Project-related equipment, materials and property within Authority's or Service Provider's possession and control; and

(d) Issue a Final CPC covering (i) that portion of the Total Reimbursement Cost (excluding the Authority Program Fee) actually incurred by Authority at or prior to such termination/cancellation both for the performed and for the terminated portion(s) of the Work (including, but not limited to, non-cancelable material and equipment not yet incorporated into the Work); (ii) the costs for any additional services performed by Authority or Service Provider pursuant to 3.4(c) hereof; (iii) any wind-down costs incurred by Authority and its Service Providers and Subproviders as a result of the termination/cancellation, along with Service Providers' and Subproviders' reasonable and customary overhead and profit on the Work not executed; and (iv) the Authority Program Fee. The Authority Program Fee for a Project that is terminated or canceled prior to completion shall be as set forth in the Compensation Schedule, unless otherwise agreed upon by the Parties in the CPC.

ARTICLE IV

ENVIRONMENTAL PROVISIONS

4.1 Hazardous Materials and Disposal of Waste and Debris.

(a) General Responsibilities. With respect to Authority Implemented Work, Authority shall require that Service Provider and/or Subprovider (as applicable) be responsible for environmental air monitoring and thoroughly cleaning the job site, including the removal of Waste and Debris generated as a result of a Project. Such removal may involve the management, transportation and disposal of Waste and Debris. If in the course of performing the scope of the Project Work as described in the CPC for any Authority Implemented Work, Authority encounters existing Hazardous Materials, including but not limited to Waste, any such materials shall be handled, transported and disposed of in accordance with applicable local, state and federal laws and regulations, as well as Authority's policies and procedures.

(b) Customer is Generator of Waste. The Customer acknowledges that, in accordance with USEPA and NYS DEC regulations, it is, and remains the Generator of, and holds title to, any Waste encountered during Work performed pursuant to this Master Agreement. If the Customer holds a Hazardous Waste "Generator Identification Number" for the specific site where work is being performed (as defined in Section 3010 of Subtitle C of RCRA), that number will be utilized for any and all hazardous waste disposal. If a Hazardous Waste "Generator Identification Number" does not exist, one may need to be obtained from the USEPA for each site from which Authority removes Waste. The Customer authorizes Authority, where required by USEPA and/or NYS DEC regulations, to apply in the name of the Customer for Hazardous Waste Generator Identification Numbers in order to dispose of Waste pursuant to this Master Agreement and to act as the contact Party for such applications. To the extent that the Customer is the generator of the Waste, a duly authorized representative of the Customer must sign such applications when requested by Authority. The Customer also authorizes Authority, where required by USEPA and/or NYS DEC regulations, to prepare, in the name of the Customer, any manifests or other forms required for the disposal of the Waste generated pursuant to activities under this Master

Agreement. A duly authorized representative of the Customer shall sign any manifests or other shipping records required to ship Waste offsite for disposal.

(c) Notification and Cost of Waste Disposal. With respect to Authority Implemented Work, Authority shall advise Customer (whenever possible, in advance of removal) where material determined to be Waste has been encountered which must be disposed of pursuant to USEPA and NYS DEC regulations. Authority shall keep the Customer fully informed of Authority's activities on its behalf and shall provide the Customer with copies of all applications and other materials provided or received in connection with actions taken pursuant to this authorization. The direct costs of Waste disposal will be included in the Final CPC. Any costs to Authority relating to the Project that may arise subsequent to the time the Final CPC is executed (or deemed executed) under present or future laws or regulations due to pollution, clean-up or otherwise at the site of disposal shall be borne by the Customer. If, however, such costs are due to the negligence or willful acts of Authority's Service Provider or Subprovider or due to the willful acts of Authority, the Customer shall not be responsible. With respect to Authority Implemented Work, Authority shall use reasonable diligence in overseeing the removal and disposal of Waste, shall maintain complete and accurate records thereof, and shall make those records available to the Customer upon request. In addition, any existing equipment determined by the Customer to be useful to the Customer may, at the Customer's request, be retained by the Customer and shall be the sole responsibility of the Customer.

(d) Customer Disposal of Waste. Notwithstanding the foregoing, the Customer shall have the option of disposing of Waste and Debris generated as a result of a Project at its own expense in accordance with all applicable local, state and federal laws and regulations, as well as Authority's policies and procedures.

4.2 Remediation. The Customer shall be responsible for the performance of any Remediation required under applicable local, state and federal Environmental Laws in order to address the existence or suspected existence of Hazardous Substances in, on, or under the job site that are discovered or encountered during Work performed and any Release or threatened Release in, on, under, over or migrating to, from or through the job site. The Customer shall promptly take all actions as are necessary to perform Remediation of any such Release or Discovery, and such other work as may be required by any Governmental Authority to safeguard the health, safety or welfare of any persons, the land and any improvements thereon or there under, from any Release or threatened Release or Discovery. In the case any Remediation is required, the Customer shall be responsible for restoring the affected portion or portions of the job site, together with any and all affected soil and groundwater, to the functional and topographical condition that existed prior to the Release and Remediation, as well as to the condition required by Environmental Laws, and as necessary to satisfy the requirements of any Governmental Authority exercising jurisdiction with respect to the job site for such Release or Discovery.

4.3 Environmental Indemnification. Customer shall be solely responsible for any and all loss, damage or injury to persons or property and for any cleanup costs associated with any site where Waste and Debris are disposed of or comes to be situated including, but not limited to, response and remedial costs. In addition, to the extent permitted by law, the Customer shall, at its sole cost and expense, indemnify, defend and hold harmless Authority and the State of New York against any loss, liability (including, without limitation, judgments, attorney's fees, court costs,

penalties or fines), or expenses of any type (including, but not limited to, required corrective actions) which Authority or the State of New York incurs because of injury to, or death of any person, or on account of damage to property, or any other claim arising out of, in connection with, or as a consequence of (a) the disposition or use of retained equipment by the Customer or anyone for whose acts the Customer may be liable, and (b) any cleanup costs associated with any site where Waste and Debris are disposed of or come to be situated traceable to such Waste and Debris including, but not limited to, response and remedial costs.

ARTICLE V

RECOVERY OF COSTS/REPAYMENT OBLIGATION

5.1 Project Cost. Authority shall initially pay for and/or incur costs for all components of the Total Reimbursement Costs applicable to a Project at the selected Customer Facility. Customer agrees to pay the Authority the Total Reimbursement Costs specified in the respective CPC as reconciled by the Final CPC.

5.2 Total Reimbursement Costs. The following components of the Total Reimbursement Costs may be delineated in a CPC for a particular Project:

(a) Material Cost. The Material Cost represents the cost of materials, equipment, fixtures, tools, construction equipment and machinery, water, heat, utilities, transportation and other facilities necessary for the proper execution and completion of the Work, whether temporary or permanent and whether or not incorporated or to be incorporated into the Work.

(b) Labor Cost. The Labor Cost represents (i) the sum of all wages paid to skilled trade and craft workers, plus employee benefits, payroll taxes, insurance and related costs; or (ii) the fees paid to skilled trade and craft workers that are not employees, in each case as represented on the Service Providers' or Subproviders' invoice.

(c) Project Contingency. The Project Contingency, or a portion thereof, actually applied by the Authority to the Project as set forth in a Contingency Work Order.

(d) Service Provider Fees. The Service Provider Fees represent the costs associated with the payment of Service Providers, Subproviders and other third party professionals based on actual invoices, individual billing rates based on hourly increments, or a percentage fee applied to certain Project costs, plus reimbursable expenses;

(e) Authority Program Fee. The Authority Program Fee reimburses Authority for services provided by Authority during the implementation of a Project. The Authority Program Fee can be based on a percentage fee applied to certain Project costs, a lump sum fee, individual billing rates based on hourly increments and/or other fee arrangements identified in the Compensation Schedule.

(f) Short-Term Interest. Short-Term Interest reimburses the Authority for costs incurred in connection with financing the delivery of a Project. It is based on the underlying source of funds chosen by the Authority, in its sole discretion, to finance a Project during its

implementation and may vary depending upon the actual financing product the Authority selects. In addition to the actual interest expense incurred by the Authority on the short-term debt issued for Project expenses, Short-Term Interest may include additional fees for administering the financing program including but not limited to costs incurred to secure liquidity facilities, remarketing services, purchase of an interest rate cap(s), issuing and payment agents and other financing related costs and credit premiums, if any.

(g) Other Project-Related Costs. Other Project-related costs may include Authority Material Handling Fee, Waste disposal costs, additional Project-specific insurance, surety bond costs, specialty services and other Project-specific costs not otherwise included in any of the above categories.

5.3 Billing. The specific billing method for each Project is set forth in the CPC and/or the long-term financing agreement associated with the particular Project. The final repayment amount due to the Authority will be the Total Reimbursement Costs as reconciled in a Final CPC to reflect adjustments to account for payments made or additional charges incurred by Customer and will constitute the Customer's Short-Term Repayment Obligation. In the event a Project is terminated before completion, Authority shall issue a Final CPC as provided in Section 3.4(d).

5.4 Payment.

(a) Payments. Customer shall pay any invoiced amounts to Authority within thirty (30) days of Customer's receipt of Authority's invoice. Any outstanding amounts not paid within such thirty (30) day period shall accrue additional Short-Term Interest until the date when payment is made in full. Such additional Short-Term Interest will be reflected on subsequent invoices and/or the Final CPC.

(b) Late Payment. Customer's final Short-Term Repayment Obligation shall be fully repaid on or before the Short-Term Repayment Obligation Maturity Date. Any amount due and unpaid on the Short-Term Repayment Obligation Maturity Date shall be subject to a late payment charge determined as the greater of (i) interest in accordance with the late payment rate set forth in State Finance Law §179(g); or (ii) the late charges payable under the terms of Authority's electric service, in accordance with provision 454.6 (b) of Authority's Rules and Regulations for Power Service, as such regulation may be amended from time to time. Authority, in its sole discretion, may waive the application of such late payment charge for a Project upon sufficient justification demonstrated by Customer.

5.5 Grants and Funding. Authority may pursue and apply for grants or other available funding for the respective Project, where applicable, when authorized by Customer. The Customer may assign the right to receive such grants or other available funding to the Authority, and the Authority may, at its sole discretion, accept such assignment. If Authority accepts such assignment, the Authority will apply the funds to reduce the Total Reimbursement Costs, provided the funds are actually received by the Authority by the Short Term Repayment Obligation Maturity Date.

5.6 Long-Term Financing for Capital Projects. Should Customer require financing to satisfy its Short Term Repayment Obligation for a Capital Project, the Customer may apply for permanent long-term financing through any of the financing products offered by the Authority to

convert Customer's Short-Term Repayment Obligation to a Long-Term Repayment Obligation. Authority may agree to such financing, in its sole discretion. Regardless of whether the Customer elects to utilize any of the Authority's available financing products, the Customer is responsible for satisfying its Short Term Repayment Obligation within the time constraints set forth herein.

If the Customer is interested in any of the Authority's long-term financing products, it must indicate its interest by marking the appropriate section of the CPC for the design phase of a Capital Project. To be eligible for the Authority's long-term financing products, Customer must comply with the Authority's policies and procedures for long term repayment. If Customer's long-term financing application is approved by the Authority, the Parties' obligations with respect to long-term financing will be set out in a separate loan agreement with terms and conditions agreed to by the Parties. This long-term financing option will allow the Customer to convert the Short-Term Repayment Obligation to a Long-Term Repayment Obligation.

ARTICLE VI

INSURANCE REQUIREMENTS.

Authority's agreements with the Service Providers shall provide that the Service Provider or Subproviders shall obtain and maintain the policies of insurance with the identified limits set forth in Section 6.1, unless additional policies of insurance and/or higher limits are required under the applicable CPC. The costs of such insurance will be part of the Total Reimbursement Costs.

6.1 Insurance Requirements:

(a) Workers' Compensation (inclusive of New York State disability benefits) and Employer's Liability coverage;

(b) Commercial General Liability insurance policy, including Contractual Liability and Products/Completed Operations Liability coverages, with limits of not less than $2,000,000 per occurrence for bodily injury and not less than $2,000,000 for property damage, such policies naming Authority, Customer and the State of New York as additional insureds under the policy;

(c) Automobile Liability coverage with a minimum limit of $1,000,000 per accident; and

(d) if required under the applicable CPC:

(i) Pollution Liability, including coverage for asbestos abatement, with minimum limits of $1,000,000 per occurrence;

(ii) Professional Liability insurance with a minimum limit of $1,000,000; and

(iii) Builder's risk insurance in the amount of the estimated Total Reimbursement Cost to be issued on a replacement cost basis without optional deductibles and

will include the interests of Customer, Authority, and the Service Providers. Such insurance shall be maintained until final payment has been made by Customer to Authority.

6.2 Adjustments. The types of insurances required and/or policy limits listed in Sections 6.1 above may be adjusted as Customer and Authority deem appropriate in connection with a specific CPC. The form and sufficiency of each insurance policy required to be obtained hereunder by the Service Provider or Subprovider shall be subject to approval by Authority. Authority shall hold all Certificates of Insurance submitted to the Authority by its Service Providers and Subproviders with respect to any Project implemented under this Master Agreement.

6.3 Customer Insurance Requirements. With specific regard to the ESP equipment, for so long as any portion of Customer's Short-Term or Long-Term Repayment Obligation, as applicable, remains unpaid, Customer shall procure an all risk policy of insurance which will insure the equipment for full replacement cost value against loss while the equipment is in Customer's care, custody and control. The insurance policy shall name Authority and the State of New York as additional insured and loss payees, and shall contain a full waiver of subrogation against Authority, its agents, Service Providers, Subproviders and the State of New York. Customer shall also procure a Commercial General Liability insurance policy with minimum limits of $5,000,000 per occurrence for bodily injury and property damage naming Authority and the State of New York as additional insured. In lieu of obtaining all risk and commercial general liability insurance, Customer may request in writing to Authority to self-insure against risk of loss. Authority may approve or deny such request in its sole discretion. Customer agrees to provide any relevant documents or information requested by Authority in order for Authority to make the determination that Customer has sufficient resources to self-insure. The decision to self-insure will not relieve Customer of any of the obligations imposed herein and shall afford Authority the protection against loss and rights it would have received, if Customer had obtained such policies of insurance.

ARTICLE VII

WARRANTIES, DAMAGES, LIABILITY, ETC.

7.1 Service Provider's Warranty Requirements. Authority's agreements with its Service Providers shall provide that all Work performed and any materials provided by the Service Providers under the agreements shall be free from any defects. Such agreements shall further provide that any defective Work or materials identified within one (l) year after (i) execution (or deemed execution) by the Parties of a Substantial Completion and Operation Transfer Report or (ii) if no such report must be signed, completion of the Project, shall be promptly corrected, repaired, replaced, re-performed or otherwise remedied by the Service Provider and/or Subprovider(s) at no additional expense to Customer. Authority's agreements with Service Providers shall also provide that any manufacturers' warranties for equipment installed at Customer's Facilities be assigned to Customer.

Authority shall have no obligation to assist Customer with any warranty claims against a Service Provider or equipment manufacturer. Customer shall coordinate any warranty claims directly with the respective Service Provider or equipment manufacturer.

7.2 Authority Warranty Disclaimer. THE WARRANTY PROVIDED BY SERVICE PROVIDER AND THE ASSIGNED WARRANTIES OF THE EQUIPMENT MANUFACTURERS ARE EXPRESSLY IN LIEU OF ALL OTHER WARRANTIES. AUTHORITY EXPRESSLY EXCLUDES ALL OTHER WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, DESCRIPTION OR QUALITY NOT EXPRESSLY SET FORTH HEREIN, TO THE EXTENT PERMITTED BY LAW. NO AFFIRMATION OF AUTHORITY, BY WORDS OR ACTION, SHALL CONSTITUTE A WARRANTY. DESCRIPTIONS, SPECIFICATIONS, DRAWINGS, AND OTHER PARTICULARS FURNISHED TO CUSTOMER ARE ONLY ESTIMATES AND DO NOT CREATE A WARRANTY.

7.3 Projected Energy Savings. Authority and its Service Providers shall use their best efforts to prepare accurate engineering estimates. After energy efficiency Work is completed in Customer's Facility, it is the intent and expectation of the Parties that Customer's annual energy usage for that Facility shall not increase above the pre-installation level except due to changes in rates or increases in usage not related to the implementation of the ESP Work. Customer is responsible for providing Authority with accurate information concerning the operation of its Facility. Customer understands that the projected energy savings are based upon such Customer input. It is Customer's sole responsibility to ensure that the expected energy savings meet Customer's satisfaction at the time the CPC for a Project is executed.

AUTHORITY HEREBY DISCLAIMS ANY AND ALL LIABILITY FOR ANY ENERGY SAVINGS PROJECTED BY AUTHORITY OR OTHERWISE EXPECTED BY CUSTOMER THAT CANNOT BE ACHIEVED.

7.4 Uncontrollable Forces. Authority shall not be responsible for delays or failures in performance resulting from occurrences beyond its reasonable control including, but not limited to, acts of God, strikes, walkouts, acts of war, or any law, regulation, or action of any court or governmental authority, fire, malfunctions in communication lines or computer hardware, power failures, shipping or delivery delays or other events caused by those not party to this Master Agreement (including, without limitation, any Third Parties, and any Service Providers or Subproviders of Authority). In the event Authority or the Service Providers or Subproviders are unable to fulfill any obligations hereunder by reason of such uncontrollable forces, Customer will be notified in writing and the completion dates described in the CPC will be extended by the amount of additional time reasonably necessary to complete the Work. If necessary, Authority will issue a Contingency Work Order or a Change Order, as applicable.

7.5 Damages, Indemnification by Service Provider.

(a) Damages. Authority's agreements with the Service Providers shall include a provision that all damage of whatever nature resulting from the performance of the Work or resulting to the Work during its progress, from whatever cause shall be borne by the Service Provider, and all Work performed shall be solely at the Service Provider's risk until the Work has been finally inspected and accepted by Authority. The Service Provider, however, shall not be responsible for damages resulting from gross negligence or willful misconduct of officials or employees of Authority or Customer.

(b) Indemnification. Authority's agreements with the Service Providers will include a provision that to the extent permitted by law, the Service Provider shall assume the entire responsibility and liability for and defense of, and pay and indemnify, Authority, Customer, and the State of New York (where a Project undertaken for Customer is located on property of New York State), against any loss, damage, expense or liability and will hold each of them harmless from and pay any loss, damage, cost or expense (including without limitation, judgments, attorney's fees, and court costs) which Authority, Customer or the State of New York incur because of injury to or death of any person or on account of damage to property, or any claim arising out of, in connection with, or as a consequence of, the performance of the Work and/or any act or omission of the Service Provider or any of its Subproviders, employees, agents or anyone directly or indirectly employed by the Service Provider or anyone for whose acts the Service Provider may be liable.

7.6 Limitation of Authority's Liability.

(a) Obligation to Exhaust Remedies against Service Provider. In the event of any alleged Authority liability to Customer, Customer shall first pursue and exhaust all remedies in law against the Service Providers and Subproviders and under the insurance identified in Article VI above and carried by the Service Providers and Subproviders before making any claim or taking any action against Authority.

(b) Exclusion of Indirect, Incidental, Consequential Damages. To the fullest extent permitted by law, Authority shall not be liable to Customer, for any indirect, special, incidental, or consequential damages of any kind (including without limitation, any loss of property or equipment, loss of profits or revenue, loss of use of equipment or power systems, cost of capital, cost of purchased or replacement power or temporary equipment, including additional expenses incurred in using existing facilities) related to or arising in connection with this Master Agreement or any other Transaction Document executed in connection herewith, regardless of the form of action (whether in contract, tort or otherwise), even if Authority has been advised of the possibility of such damages.

(c) Total Liability Cap. The Parties agree that in no event shall Authority's total liability (whether in contract, tort or otherwise) for all claims relating to a Project exceed ten percent (10%) of the Total Reimbursement Costs for such Project set forth in the respective CPC.

(d) No Limitation of Service Provider/Subprovider Liability. Nothing in this Section 7.6 shall be construed as limiting the liability of a Service Provider or Subprovider to Authority or Customer in connection with the performance of such Service Provider's or Subprovider's Work on Customer's premises.

7.7 Customer's Responsibility for Project Equipment and Performed Work. Upon delivery at Customer's Facility, Customer shall be responsible for all damage to all Project materials, supplies and equipment of every description and all Work performed at Customer's site unless such damages are caused by Authority or its Service Providers or Subproviders.

ARTICLE VIII

INTELLECTUAL PROPERTY RIGHTS

8.1 Intellectual Property; Proprietary Information.

(a) Intellectual Property Rights. Neither Party shall acquire, directly or by implication, any ownership of any Background Intellectual Property Rights of the other Party. Each Party shall retain title to any Intellectual Property Rights developed, authored, conceived or reduced to practice independently and solely by that Party during the performance of this Master Agreement without the other Party's Background Intellectual Property Rights. Notwithstanding any of the foregoing, it is agreed by the Parties that Authority shall be the sole owner of all Intellectual Property Rights related to any Project which is jointly developed, invented or otherwise generated during the performance of this Master Agreement or any Transaction Document.

(b) Work Product; Proprietary Information. Unless and until Customer has repaid its Short-Term or Long-Term Repayment Obligation, as applicable, the Facility data, evaluations, design and other information produced by Authority or its Service Providers in connection with a Project shall be the property of Authority. Customer shall have the right to use any such proprietary information for the maintenance of Project installations in its Facilities. Upon payment in full by Customer, such information shall become the property of Customer. Any information identified as confidential which is exchanged by Authority and Customer shall be duly protected by the recipient to the extent permitted by law. It is understood that the Public Officers Law and other statutes and regulations regarding Freedom of Information may require the disclosure of information in certain situations.

ARTICLE IX

TERM AND TERMINATION

9.1 Term. This Master Agreement shall end on the tenth anniversary of the date first shown in the preamble above unless earlier terminated in writing by either Party in accordance with the terms of this Master Agreement.

9.2 Termination of Master Agreement. Unless otherwise provided in this Master Agreement, either Authority or Customer may terminate this Master Agreement at any time upon one hundred twenty (120) days' prior written notice to the other Party.

9.3 Pending Projects. Authority and Customer acknowledge that a Project implemented pursuant to a CPC executed during the Term of this Master Agreement may extend beyond the expiration or early termination of this Master Agreement. Provided that the Project was commenced pursuant to a CPC that was executed during the Term of this Master Agreement, then this Master Agreement will be extended, as it applies to such CPC only and for the sole purpose of completing the Project. The Project implemented pursuant to such CPC may continue until completed or otherwise terminated earlier pursuant to the terms and conditions of this Master Agreement.

9.4 Extension. This Master Agreement may be renewed at the end of the current term for an additional period, such additional period not to exceed a period equal to the original Term, to be mutually determined by the Parties in writing and signed by an authorized officer or designee of Authority and Customer.

ARTICLE X

GENERAL OBLIGATIONS OF THE PARTIES

10.1 Authorized Representatives.

(a) Customer's Authorized Representative. For each Project, Customer shall designate a Customer's Authorized Representative and shall inform Authority in writing accordingly. If Customer desires to change its Customer Authorized Representative, it must notify Authority in writing (in accordance with notice requirements set forth herein) at least five (5) business days prior to such change. Customer's Authorized Representative shall coordinate the Project on behalf of Customer and assist Authority and the Service Providers and Subproviders with the implementation of the Project in the selected Facilities of Customer. Customer's Authorized Representative shall be responsible to obtain all necessary approvals, authorizations, and signatures of Customer with respect to any CPC, Change Order, Final CPC and other Transaction Document.

(b) Authority's Authorized Representative. For each Project, Authority shall designate an Authority's Authorized Representative and shall inform Customer accordingly. Authority's Authorized Representative shall coordinate the Project on behalf of Authority and communicate with Customer. Authority will inform Customer of any changes to its Authorized Representative.

10.2 Authority Obligations. With respect to any Authority Implemented Work, Authority shall comply with the following:

(a) Reporting and Information. Authority shall keep Customer informed as to the progress of the Work and shall provide Customer with periodic reports of all activities by the Service Providers and Subproviders at Customer's Facilities. Authority and its Service Providers shall meet with representatives of Customer upon reasonable notice to discuss any matters concerning the Projects.

(b) Permits, Licenses, Authorizations. Authority shall require that the Service Providers and Subproviders obtain and maintain all permits, licenses and authorizations required to perform the Work in Customer's Facilities and that they will comply with all applicable local, state and federal laws, guidelines and regulations, including applicable local, state and federal building, fire and electrical codes and standards. Any costs associated with permits and licenses that must be obtained by Service Provider or Subprovider for a specific Project will be reflected in the Total Reimbursement Costs. Notwithstanding the foregoing, neither Authority nor Service Provider (or Subprovider) shall be responsible for closing out open permits obtained by Service Provider (or Subprovider) due to existing deficiencies or code violations in Customer's Facility which are outside the Project scope.

(c) Service Provider/Subprovider Performance. Authority shall require its Service Providers and Subproviders to comply with regulations governing access to and performance of the Work in the selected Customer Facilities and to perform such Work in such a manner as not to unreasonably interfere with Customer's business at the Facilities. Authority shall also require its Service Providers and Subproviders to comply with Customer's operational and safety requirements, which in certain instances may require substantial supervision and control over the site by Customer.

(d) Records. Authority's Service Providers shall maintain accurate records of Project Work for a period of six (6) years after completion of a Project.

10.3 Customer Obligations. With respect to any Project entered into in connection with this Master Agreement, Customer shall have the following rights and obligations:

(a) Right to Inspect. Customer and Customer's Authorized Representative may observe and inspect all Work in any of Customer's Facilities and shall have the right to attend all Project job meetings, upon written notice of its intent to attend a particular meeting.

(b) Attendance at Meetings. Upon reasonable request and notice from Authority or Service Provider, Customer shall attend meetings scheduled by Authority or Service Provider to discuss any Project-related matters.

(c) Site Rules and Regulations. Customer must promptly notify Authority of any site specific construction, safety, technical or other requirements and restrictions related to its Facility(ies) prior to the start and during the Project. If Customer becomes aware of any defect in the Work or any failure of Authority or the Service Provider or Subprovider to meet the respective Project requirements, the Customer shall give prompt notice to Authority.

(d) Access. Customer shall provide Authority and its Service Providers safe, proper and timely access to the Facility as necessary to perform the Work. Upon Authority's request, Customer's Authorized Representative will accompany Authority and its Service Providers to Customer Facilities. Customer shall promptly provide verbal and written notice of limitations or changes in site access.

(e) Permits and Licenses.

(i) Customer shall provide Authority or Service Provider with such assistance (including, but not limited to, all necessary information requested by Service Provider) as may be required for Authority or Service Provider to obtain all permits, licenses and authorizations necessary to perform the Work in accordance with all applicable local, state and federal laws, regulations, codes and standards applicable to the Facility.

(ii) Customer shall be responsible and shall hold all licenses, permits, authorizations and regulatory approvals necessary for the lawful conduct of its business as presently conducted, and shall comply with all applicable statutes, laws, ordinances, rules and regulations of all governmental bodies, agencies and subdivisions having, asserting or claiming jurisdiction over it, with respect to any part of the conduct of its business and corporate affairs.

(f) Project Equipment. As long as Customer's Short-Term or Long-Term Repayment Obligation, as applicable, remains outstanding, (i) Customer will keep all Project-related equipment free from any and all liens, claims, encumbrances, and the like; (ii) Customer will not grant a security interest in such equipment to any party without the prior written consent of Authority; (iii) the equipment will remain at the Facility site as designated in a CPC; (iv) Customer will not sell, offer for sale, transfer, or dispose of such equipment without notice to Authority; (v) Customer will not use or permit any person to use the equipment in a manner prohibited by law or in a manner which would void any manufacturer's warranty; (vi) Customer agrees to maintain the equipment in good order and repair at all times, and will not waste or destroy the equipment or any part of it; and (vii) Customer will keep the equipment insured in accordance with the requirements set forth in Section 6.3 hereof.

(g) Coordination. Customer shall be responsible for facilitating coordination with Third Parties as required. Furthermore, Customer shall promptly resolve any disputes or issues that arise with any Third Parties. Customer shall be responsible for any changes to the Project schedule, the scope of Work and/or the Total Reimbursement Costs resulting from any delays due to unresolved disputes or issues with Third Parties pursuant to Section 2.6 hereof.

(h) Review and Approval. Customer will promptly review any documents submitted to it by Authority requiring Customer's decision and shall render any required decision pertaining thereto without undue delay.

(i) Assistance; Timely Performance. Customer shall cooperate with Authority and its Service Providers and Subproviders and provide Authority with such other assistance as necessary to facilitate the performance of the Work. Customer shall perform all obligations set forth in this Master Agreement and any other Transaction Document in a timely manner so as to permit the orderly progress of the Projects. Authority shall not be responsible for any Project delays due to Customer's non-compliance with its obligations set forth herein or in a Transaction Document.

ARTICLE XI

MISCELLANEOUS

11.1 Disputes. In the event of any dispute regarding ESP Work at any Customer Facility, Work there may be suspended by Authority until the matter is resolved to the mutual satisfaction of the Parties in accordance with the procedures set forth in Section 11.2 hereof. In the event the Parties are unable to resolve any such dispute after good faith efforts, the Work at that Facility shall terminate and Authority shall issue a Final CPC as provided in Section 3.4(d) hereof.

11.2 Dispute Resolution. The Parties shall use good faith efforts to settle promptly all disputes arising under this Master Agreement or in connection with any ESP Work. In the event that any dispute, including but not limited to a billing dispute, a dispute regarding the quality of the Work, or a dispute regarding the interpretation of this Master Agreement, arises and cannot be resolved in the normal course of business by operating personnel within twenty (20) days after commencement of a dispute, either Party may give the other Party formal notice of the dispute in accordance with the notice requirements set forth herein. In the event that such notice is given,

the Parties shall attempt to resolve the dispute by negotiation between representatives who have the necessary authority to resolve the dispute in question. Within twenty (20) days after delivery of the notice, the receiving Party shall consider all information relevant to the dispute and shall submit to the other Party (in accordance with the notice requirements set forth herein) a proposal for resolution. Thereafter, the representatives shall confer in person or by telephone, promptly and no later than five (5) days after receipt of the proposal for resolution, to attempt to resolve the dispute. All reasonable requests for information by one Party to another Party will be honored. To the extent that disputes are not resolved pursuant to this process, the Parties reserve all rights under law or equity to seek and pursue remedies through the judicial process.

11.3 Publicity.

(a) Public Announcements. No marketing, publicity, promotion, social media, or advertising regarding this Master Agreement, or any Project undertaken pursuant to this Master Agreement, will be issued by Customer without Authority's prior written approval, which approval will not be unreasonably withheld. Any responses to news media inquiries or social media activities developed by Customer, related to this Master Agreement, or any Project undertaken pursuant to this Master Agreement, must be coordinated with Authority for review and approval prior to their release. Letters, speeches, news and/or press releases, articles for publication, website and social media postings, etc., related to this Master Agreement, or any Project undertaken pursuant to this Master Agreement, must be coordinated with Authority for review and approval prior to their release. Any and all communications, whether verbal, electronic or written, must be submitted to Authority's Corporate Communication Business Unit for prior review and approval. Customer agrees to abide by these terms regarding public announcements during the term of this Master Agreement and for a period of two (2) years following the expiration or termination of this Master Agreement.

(b) Signage. The parties agree that Authority may, at no cost to Customer, install and maintain appropriate publicity signage at or in the vicinity of a Project. Customer will cooperate with Authority, and/or any third-party vendor designated by Authority, by timely responding to any questions regarding the design, manufacture, installation and maintenance of the signage. Customer will provide ordinary maintenance to the signage and promptly notify Authority after Customer becomes aware of any damage that may occur to the signage. The publicity signage may include the identity of the Project, including a brief statement highlighting the Project, any applicable Authority program, New York State program or other initiative under which the Project is implemented and the identity of the parties supporting the Project, including those parties' respective logos. The publicity signage is intended to be placed in an area of Customer's designation with significant public visibility within close proximity to the Project. Authority will be responsible for removing the publicity signage upon the conclusion of a Project, or such earlier time as either Party deems it appropriate.

11.4 Notices. All notices permitted or required hereunder or in connection with any Transaction Document shall be in writing and transmitted either: (i) via certified or registered United States mail, return receipt requested; (ii) by personal delivery; (iii) by expedited delivery service; or (iv) by e-mail, with a copy sent via U.S. Mail.

Such notices shall identify the Master Agreement and the Transaction Document to which it relates, and be addressed as follows or to such different addresses as the Parties may from time-to-time designate in accordance herewith:

To Authority:
NEW YORK POWER AUTHORITY
PROCUREMENT DIVISION
Name: John Canale
Title: Vice President, Strategic Supply Management
Address: 123 Main Street, 5th Floor, White Plains, NY 10601
E-Mail Address: john.canale@nypa.gov

with a copy to:
NEW YORK POWER AUTHORITY
LAW DEPARTMENT
Name: Debra Hopke, Esq.
Title: Principle Attorney
Address: 123 Main Street, 11th Floor, White Plains, NY 10601
E-Mail Address: debra.hopke@nypa.gov

To Customer:
TOWN OF HIGHLANDS
Name: Kelly Pecoraro
Title: Comptroller
Address: 254 Main Street, Highland Falls, NY 10928
E-Mail Address: kpecoraro@highlands-ny.gov

Any such notice shall be deemed to have been given either at the time of personal delivery or, in the case of expedited delivery service or certified or registered United States mail, as of the date of first attempted delivery at the address and in the manner provided herein, or in the case of email, upon receipt. The Parties may, from time to time, specify any new or different address in the United States as their address for purpose of receiving notice under this Master Agreement (and any Transaction Document) by giving fifteen (15) days written notice to the other Party sent in accordance herewith. The Parties agree to mutually designate individuals as their respective representatives for the purposes of receiving notices under this Master Agreement.

11.5 No Waiver. The failure of any Party to insist upon strict adherence to any term of this Master Agreement or any Transaction Document executed in connection herewith on any occasion shall not be considered a waiver nor deprive that Party of the right thereafter to insist upon strict adherence to that term or any other term of this Master Agreement.

11.6 Assignment. This Master Agreement and any Transaction Document executed in connection herewith may not be assigned, transferred nor conveyed by either Party without the prior written consent of the other Party. Any attempted assignment, transfer or conveyance without such consent shall be entirely void ab initio and have no force or effect.

11.7 Governing Law; Venue. This Master Agreement (and any Transaction Document executed in connection herewith) and any and all disputes arising in connection herewith (whether in contract, tort or otherwise) shall be governed by and construed in accordance with the laws of the State of New York without giving effect to any choice or conflict of laws provision or rule that would cause the application of the laws of any jurisdiction other than New York. Any action at law, or in equity, for the enforcement of this Master Agreement (and any Transaction Document executed in connection herewith) or any dispute arising in connection herewith shall be instituted only in a court of competent jurisdiction located in the County of Albany, State of New York.

11.8 No Third Party Beneficiaries. Nothing contained in this Master Agreement shall, directly or indirectly, create a contractual relationship with, or give any claim or right of action in favor of, any third party (including, without limitation, any Service Provider or Subprovider) against Authority.

11.9 Severability. The invalidity or unenforceability of any provisions of this Master Agreement or of any Transaction Document executed in connection herewith shall not affect the validity or enforceability of any other provisions of this Master Agreement or Transaction Document, as applicable, which other provisions shall remain in full force and effect.

11.10 Survival of Provisions. The articles that contain provisions related to the following will survive the expiration, termination or completion of this Master Agreement: Conflict and Order of Precedence; Recovery of Costs and Repayment Obligation, Warranty, Damages, Liability, Ownership of Installed Work and Intellectual Property, Publicity; and Governing Law, Venue.

11.11 Not Construed Against Drafter. Authority and Customer acknowledge that they have read this Master Agreement, have had the opportunity to review it with an attorney of their respective choice, and have agreed to all its terms. Under these circumstances, Authority and Customer agree that the rule of construction that a contract be construed against the drafter shall not be applied in interpreting this Master Agreement and that in the event of any ambiguity in any of the terms or conditions of this Master Agreement, including any exhibits or schedules hereto, such ambiguity shall not be construed for or against any Party hereto on the basis that such Party did or did not author same.

11.12 Headings. The articles and section headings contained in this Master Agreement are for reference purposes only and shall not affect the meaning or interpretation of this Master Agreement.

11.13 Counterparts. This Master Agreement may be executed in counterparts via inked signature or electronic mark, each of which shall be deemed an original, but all of which together shall constitute one and the same instrument. The fully executed Master Agreement may be delivered using pdf or similar file type transmitted via electronic mail, cloud based server, e-signature technology or other similar electronic means.

(SIGNATURE PAGE FOLLOWS)

IN WITNESS WHEREOF, the parties hereto have duly executed this Master Agreement as of the effective date first written above.

POWER AUTHORITY OF THE STATE OF NEW YORK		TOWN OF HIGHLANDS	
By:	John Canale John Canale (Jul 23, 2019)	By:	MERVIN R. LIVSEY mERVIN R. LIVSEY (Jul 23, 2019)
Name:	John Canale	Name:	Mervin Livsey
Title:	Vice President, Strategic Supply Management	Title:	Supervisor
Date:	Jul 23, 2019	Date:	Jul 23, 2019

Signature Page to Master Cost Recovery Agreement No. _______________

NEW YORK STATE OF OPPORTUNITY. | NY Power Authority

EXHIBIT A

STATEWIDE COMPENSATION SCHEDULE

As compensation for services rendered by the Authority under the Master Agreement, the Customer will pay the Authority Program Fee as set forth below.

A. CAPITAL PROJECTS

I. AUTHORITY PROGRAM FEE

For Capital Projects, the Authority Program Fee is calculated as a percentage of the cumulative sum of all costs related to a Project, including, but not limited to all Material Costs; Labor Costs; Service Provider Fees; the amount of the Project Contingency applied as a Project cost; and other Project-related costs and expenses. The Authority Program Fee is in addition to all such costs related to a Project. The Authority Program Fee percentage will be fixed upon execution of the CPC for the installation phase.

1. Authority Program Fee when Service Provider performs Work

The following table sets forth the Authority Program Fee where the Authority delivers a Project using one or more Service Providers to perform audit, design, construction management and/or installation.

Project Size (in millions)	Authority Program Fee
$0 - $3M	12.5%
$3M - $6M	12.0%
$6M - $12.5M	11.5%
$12.5M - $40M	11.0%
$40M - $60M	10.5%
> $60M	10.0%

2. Authority Program Fee when Authority and Service Provider perform Work

The following table sets forth the Authority Program Fee where the Authority will be performing design and construction management with its own forces using one or more Service Providers to perform installation. If the Authority procures material directly in lieu of using one of its Service Providers, there will be an additional Material Handling Fee of 1.5% charged on the Material Cost of the Project.

Project Size (in millions)	Authority Program Fee
$0 - $3M	27.5%
$3M - $6M	27.0%
$6M - $12.5M	26.5%
$12.5M - $40M	26.0%

$40M - $60M	25.5%
> $60M	25.0%

3. Authority Program Fee when Authority provides Audit Services Only

The Authority Program fee for providing Audit services not contemplated as part of a full project (i.e. design, construction management and/or installation) is calculated as twenty-five percent (25%) of the costs related to the Audit.

II. MILESTONE PAYMENTS

To the extent applicable, the Authority Program Fee will be paid on milestones as detailed in the CPC or as otherwise mutually agreed upon.

III. AUTHORITY FEE IN THE EVENT OF PROJECT TERMINATION

1. Termination at or after Audit Phase

If a Project is terminated at or after the audit phase, but prior to moving forward with any design or implementation, the Authority's Program Fee is calculated as twenty-five percent (25%) of the actual costs associated with such audit.

2. Termination during Design, Procurement or Installation Phase

If a Project is terminated in whole or part during the design, procurement or installation phase, the Authority's Program Fee for the Project will be the cumulative percentage value at the current milestone (as if it had been achieved) and calculated based on the estimated Project costs, including, but not limited to all Material Costs; Labor Costs; Service Provider Fees; the amount of the Project Contingency applied as a Project cost; and other Project-related costs and expenses up through the current milestone (as if it had been achieved). For the purposes of calculating the Authority's Program Fee, the then current milestone is assumed complete once the Project is canceled.

The following table sets forth the Authority Program Fee percentage segmented by milestone.

Milestone	% of Authority's Program Fee	Cumulative Authority Program Fee Percentage
30% Design	10%	10% + (audit cost)
90% Design	15%	25% + (audit cost)
100% Design & Bidding	15%	40% + (audit cost)
Construction CPC Preparation	10%	50% + (audit cost)
Construction (25% completion)	10%	60% + (audit cost)
Construction (50% completion)	15%	75% + (audit cost)

Construction (75% completion)	15%	90% + (audit cost)
Construction (100% completion)	10%	100% + (audit cost)

B. ADVISORY SERVICES PROJECTS

I. AUTHORITY PROGRAM FEE

The Authority Program Fee for the Advisory Services will be calculated according to one of the following methods as set forth in the CPC for the Project:

Time and Materials: The Authority's Program Fee maybe based on actual time and cost of material incurred by Authority or its Service Providers in connection with a Project based on rates defined in the Project CPC.

Lump Sum: The Authority's Program Fee may be based on the percentage complete of a lump sum or milestones defined in the Project CPC.

Unit Price: The Authority's Program Fee maybe based on the unit prices defined in the Project CPC.

Percent of Materials and Labor: The Authority's Program Fee maybe based on a percentage of Service Provider Material Costs and Labor Costs as defined in the Project CPC.

Other Mechanisms: The Authority's Program Fee may be based on an evolving cost recovery mechanisms not defined in this Master Agreement. If other mechanisms are selected, the Authority's Program Fee will be based on mutual Authority and Customer agreement and will be defined in the Project CPC.

II. PROJECT TERMINATION

If a Project is terminated in whole or part prior to completion of a Project, the Authority's Program Fee will be based on the Project costs incurred by Authority up until the date of termination. For the purposes of calculating the Authority's Program Fee, as applicable, the then current milestone is assumed complete once the Project is canceled.

NEW YORK STATE OF OPPORTUNITY. | NY Power Authority

EXHIBIT B

CAPITAL PROJECT TERMS AND CONDITIONS

1. Application. In addition to the terms and conditions set forth in the main body of this Master Agreement, these Capital Project Terms and Conditions shall apply to all Capital Projects provided by Authority or Service Provider to Customer under the Master Agreement.

2. Capital Project Services. Capital Projects are generally delivered through the services of qualified installation Service Providers or Subproviders under contract with the Authority. Capital Project services may include any or all of the following services (as more fully described below): audit, design, construction management, equipment procurement, installation, commissioning, disposal of Waste, financing and other Project related services required to install a Project.

3. Audit.

(a) Scope. After Customer has identified potential Projects for Authority's and Customer's consideration, Customer may request that Authority perform an audit of the Facility. The audit will help identify opportunities for implementing ESP measures and will be scheduled by Customer's Authorized Representative and/or the appropriate Facility manager. The scope of the audit will be set forth in a CPC which shall be executed by an authorized officer or designee of Authority and Customer prior to commencement of any audit Work. In some instances, the audit will involve a complete inventory of the systems which are currently used in normal operation, while in others a more targeted approach will be taken. The audit may also include an analysis of whether hazardous materials and Waste related to those systems are likely to be present or generated as a result of installing a Project.

(b) Audit Report. Based upon the results of the audit, a written report will be furnished to Customer. The report will include an estimate of the Total Reimbursement Costs as well as estimates of the potential Total Annual Energy Savings and environmental or sustainability benefits, as applicable, that Customer can reasonably expect through implementation of the recommendations made in the report. If, after analysis of the report by Authority and Customer, Authority, in its sole discretion, determines that the Project either (1) does not meet Authority's eligibility criteria, or (2) is not appropriate at such Facility, activity there will cease.

(c) Deferment of Total Reimbursement Costs for Audit Work. Upon completion of the audit Work, if Customer and Authority decide to proceed to the next phase, Customer and Authority will execute a CPC reflecting the scope of such next Project phase. By executing the CPC, Customer acknowledges its concurrence with the audit results. Subject to Authority's approval, Customer may request that payment of the Total Reimbursement Costs for the audit Work, be deferred and included in the Total Reimbursement Costs of the CPC for the next Project phase.

4. Project Design.

(a) General. If agreed upon by the Parties in a CPC, Authority shall prepare a Project design. Customer will be asked to review all aspects of the design and specifications. Where deemed appropriate by Authority and Customer, the Service Provider will arrange for geotechnical surveys (i.e., soil tests, borings, and related evaluations), surveys of the site (i.e., to determine physical characteristics of the site, such as utility locations), and/or demonstration installations (i.e., the installation of sample lighting fixtures or other equipment) of selected measures in Customer's Facility, all at Customer's sole risk.

(b) Milestones and Milestone Completion Reports. Authority will submit the Project design documents to the Customer at 30%, 60%, 90% and "final" design milestones, or according to the milestone schedule set forth in the respective CPC. Upon completion of each design milestone, Customer and Authority (or their duly authorized representatives) shall promptly review the design Work, or applicable portions thereof and Customer and Authority shall jointly sign a Milestone Completion Report. It shall be Customer's responsibility to determine that the proposed design meets Customer's needs.

(c) Deferment of Total Reimbursement Costs for Design Work. Unless otherwise set forth in the CPC for a Project, Authority may invoice the Customer for the Total Reimbursement Costs for the performed design Work through the milestone(s), if any, set forth in the CPC (plus any Total Reimbursement Costs incurred during the audit, if such costs were deferred and rolled over). Customer may request payment deferral if Customer approves Authority to proceed to the next milestone or the next Project phase. With Authority's approval, Customer's Short-Term Repayment Obligation will be deferred and rolled into the next milestone invoice, or at design completion, become part of the Total Reimbursement Costs of the CPC for the next Project phase.

(d) Ownership of Design Work Upon Early Termination. If Customer terminates the design Project prior to its completion, upon receipt of Customer's final payment, Authority will deliver to Customer all design plans and documents completed through the date of termination. Customer's use of such design plans and documents will be subject to any copyrights of the Authority and/or the designer. By using any incomplete or unfinished design plans and/or documents that have not been sealed with the licensed design professional's stamp upon delivery to Customer, Customer accepts full and complete responsibility for such design and further agrees to hold Authority harmless from its use of such incomplete or unfinished design plans and/or documents.

5. Procurement. After Authority and Customer agree on the Project's design and technical specifications, Authority or the Service Provider will competitively solicit, using the Authority's procurement guidelines, bids for the Work as set forth in the design documents. The resulting final design, specifications and bid price shall be incorporated into a CPC for the Project. Authority's contracts with its Service Providers will require compliance with the Authority's guidelines regarding the competitive solicitation of the services of Subproviders for Customer's Facilities, including the selection of minority and women-owned business enterprises. The services of Subproviders and equipment procurement will be obtained through a competitive bid process conducted by the Service Provider with Authority oversight. In the event Customer

decides not to proceed with the installation Project, Customer shall reimburse Authority for the costs of any Work undertaken by Authority and/or its Service Provider in connection with the procurement process and the associated cost and expense of same.

6. Installation.

(a) General. After Authority and Customer have entered into a CPC for installation Work, the Service Provider and/or its Subproviders will perform the Work pursuant to the design and technical specifications set forth in such CPC.

(b) Substantial Completion and Operation Transfer Report. After Customer has inspected, tested and accepted the Project equipment, or portion thereof, installed by the Service Provider, the Parties will execute a Substantial Completion and Operation Transfer Report for the completed portion of the Work signifying (i) that Customer accepts responsibility for operation and maintenance of the installed equipment, (ii) that the Project, or specified portion thereof, is substantially complete, and (iii) the commencement of any warranty period.

(c) Final Inspection Report. Upon completion of the Work, Customer and Authority (or their duly authorized representatives) shall promptly inspect the entire Facility, or applicable portions thereof. Authority or its Service Providers will confirm that the Work has been satisfactorily completed according to the provisions of this Master Agreement and the applicable CPC. Authority and Customer shall jointly sign a Final Inspection Report.

7. Maintenance and Post-Installation Audit. Authority will provide Customer with information regarding the maintenance of Project installations and recommendations for appropriate replacement equipment to be used in those installations to facilitate proper usage and, if applicable, energy savings at Customer's Facilities. After the Project installations are completed, Customer shall use reasonable efforts to see that such maintenance and materials instructions are followed at its Facilities. While any portion of the Customer's Short-Term Repayment Obligation remains outstanding, Authority may, upon reasonable notice to Customer, audit installations in Customer's Facilities to evaluate compliance with such maintenance and materials instructions.

8. Project Closeout for Capital Projects. Notwithstanding the terms set forth in the CPC or Final CPC, the Customer shall, within the time specified in the Final CPC, (a) repay the Short-Term Repayment Obligation or (b) convert the Short-Term Repayment Obligation to a Long-Term Repayment Obligation and enter long term repayment consistent with the Authority's policies and procedures. The Customer shall make payment of that portion of the Short-Term Repayment Obligation that is not converted to the Long-Term Repayment Obligation upon receipt of the Authority's invoice and in accordance with the terms of this Master Agreement. The Short Term Repayment Obligation, as set forth in the Final CPC, shall include the Authority's estimate of Short-Term Interest to be accrued between the issuance of the Final CPC and conversion to long term repayment.

9. Authority Obligations. In addition to the obligations otherwise set forth herein and the respective CPC, Authority shall require the Service Provider to adhere to the Project's design

and technical specifications as set forth in the CPC and minimize any interference with the normal operations at Customer's Facility.

10. Customer Obligations. In addition to the obligations otherwise set forth herein and the respective CPC, Customer shall promptly review all completed installations. Customer shall review and approve, as may be required, any corrective or restoration Work resulting from improper work by the Service Provider.

11. Customer-Supplied Equipment and/or Work. Customer and Authority may agree in the CPC for the provision of Customer materials and/or completion of Customer work in connection with a Project, independent of Authority. If so, then Customer shall be responsible for any changes to the Project schedule, scope of Work or any increase in the Total Reimbursement Costs caused by Customer due to non-delivery of Customer materials or non- or late performance of Customer work and Authority shall issue any necessary Contingency Work Order or Change Order, as applicable. Authority may suspend its Work on the Project until Customer approves such Change Order. Furthermore, if the Customer does not meet the Project schedule with respect to Customer materials and/or Customer work, Authority has the right to terminate the Project if the delay is not cured within fifteen (15) days of written notice thereof by Authority to Customer and turn it over to Customer for completion without any liability on the part of Authority.

* * * * *

NEW YORK STATE OF OPPORTUNITY. | NY Power Authority

EXHIBIT C

ADVISORY SERVICES TERMS AND CONDITIONS

1. Application. In addition to the terms and conditions set forth in the main body of this Master Agreement, these Advisory Services Terms and Conditions shall apply to all Advisory Services Projects provided by Authority or Service Provider to Customer pursuant to the Master Agreement.

2. Advisory Services. Upon Customer's request, Authority may provide any or all of the Advisory Services described below. Advisory Services may be provided by Authority employees and/or Service Providers with expertise in the area as determined by Authority. Authority and Customer will cooperate in good faith during the performance of such Advisory Services.

3. Description of Services

(a) Review. Review of information provided by the Customer regarding, among other things, Customer's site conditions, future plans for modifications to facilities, operations and/or usage, historical utility data, any relevant strategic plans or initiatives, and other relevant requirements that are specific to Customer.

(b) Meetings. Participate in meetings and conference calls as mutually agreed upon by the parties as being in the best interests of the Project or as otherwise detailed in the Customer Project Commitment.

(c) Site Observations. Observe Customer's facilities, physically or remotely via electronic means as determined by the Authority to assess the condition of existing equipment and physical site conditions.

(d) Analysis. Analyze data presented by Customer and/or collected by or on behalf of the Authority. Outreach to appropriate third parties as necessary to coordinate and/or collect additional data.

(e) Advice and uidance. Deliver oral or written advice, guidance and other recommendations communicated via in person meetings, telephone conversations, or correspondence.

(f) Deliverables and Reports. Prepare reports, memorandums, and other documents that memorialize the advice, guidance and recommendations delivered to the Customer and support the Customer's underlying project, where applicable.

The foregoing descriptions are given by way of example and not by way of exclusion. Advisory Services may include services that have not yet been developed or approved by Authority

to date, provided such services are described in a CPC signed by both Parties to this Master Agreement.

4. Further Assistance; Information. In addition to the obligations set forth herein and the respective CPC, Customer shall provide Authority and/or Service Providers with such assistance as may be required to perform the Advisory Services. This may include, but is not limited to, providing access to the Customer's Facility(ies), information such as historical utility data, maintenance logs, existing feasibility studies, reports, equipment drawings or any other information or services reasonably requested by Authority and/or Service Providers.

* * * * * *

Signature: mERVIN R. LIVSEY
mERVIN R. LIVSEY (Jul 23, 2019)

Email: blivsey@highlands-ny.gov

Title: Town of Highlands Supervisor

Company: Town of Highlands

Signature: John Canale
John Canale (Jul 23, 2019)

Email: john.canale@nypa.gov

Title: VP Strategic Supply Management

Company: New York Power Authority

Arencibia, Stephanie (Molly)

From: Laino effrey
Sent: Thursday No ember 2019 9: AM
To: Richard Sulli an
Subject: Setting u the kick off mtg

Arencibia, Stephanie (Molly)

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Arencibia, Stephanie (Molly)

From:	Laino, Jeffrey
Sent:	Thursday, Novem er 21, 2019 3:50 PM
To:	Richard Sullivan
Subject:	RE: Setting up the ic off mtg

Hey Richie, let's look at these days for the kick off meeting:
12/9-2PM
12/10-10:30AM
12/16 – 11:30AM
Hopefully one of these works, otherwise it would have to be after the new year.
Thanks,
Jeff

From: Laino, Jeffrey
Sent: Thursday, November 14, 2019 8:40 AM
To: Richard Sullivan <rsullivan@highlands-ny.gov>
Subject: RE: Setting up the kick off mtg

Good Morning Richie,
Just checking back with you on setting up the project kick off.
Let me know if one of these days works or suggest alternates for the following week.
Thanks,
Jeff

From: Laino, Jeffrey
Sent: Thursday, November 7, 2019 9:33 AM
To: Richard Sullivan <rsullivan@highlands-ny.gov>
Subject: Setting up the kick off mtg

Hi Richie,
We are looking to set up the street lighting project kick off meeting.
Does 1 of these dates work:
12/2-11:00AM
12/3-11:30AM
12/4-11:30AM

We need about 90 minutes to review the logistics of the project and plan field work and any special considerations related to your towns project.

Regards,
Jeff

Jeff Laino
Senior Key Account Executive, Key Account Management
New York Power Authority
123 Main Street
White Plains, NY 10601

(914) 287-3351 (office)
(914) 312-1260 (cell)
Jeffrey.Laino@nypa.gov
www.nypa.gov

Arencibia, Stephanie (Molly)

From:	Richard Sullivan <rsullivan@highlands-ny.gov>
Sent:	Saturday, November 23, 2019 2:31 PM
To:	Laino, Jeffrey
Subject:	Re: Setting up the kick off mtg

Hi Jeff,
My apologies, my work schedule for last month has been berserk , I've responded to few emails.
Originally I told supervisor 12/4, that date is gone so based on the fact that the supervisor owns a Restarant closed on Mondays, let's go with 12/9 afternoon 2:00 timeframe , Ill make sure Mr Livsey can do that time, we have a town board meeting that evening .
Expect a call Monday or Tuesday, let's go with 12/9, a new board will be in place as of 1/1/2020, I don't wish to wait until then, and apologize for my lack of time recently.
Obliged, Richie

Sent from my iPad

On Nov 21, 2019, at 3:50 PM, Laino, Jeffrey <Jeffrey.Laino@nypa.gov> wrote:

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(914) 312-1260 (cell)
Jeffrey.Laino@nypa.gov
www.nypa.gov

Arencibia, Stephanie (Molly)

From:	Laino, Jeffrey
Sent:	Monday, November 25, 2019 7:49 AM
To:	Richard Sullivan
Subject:	RE: Setting up the kick off mtg

Sounds good, please confirm so I can lock in the date with the project managers/engineer

---

From: Richard Sullivan <rsullivan@highlands-ny.gov>
Sent: Saturday, November 23, 2019 2:31 PM
To: Laino, Jeffrey <Jeffrey.Laino@nypa.gov>
Subject: Re: Setting up the kick off mtg

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My apologies, my work schedule for last month has been berserk , I've responded to few emails.
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(914) 287-3351 (office)
(914) 312-1260 (cell)
Jeffrey.Laino@nypa.gov
www.nypa.gov

Arencibia, Stephanie (Molly)

Subject:	Town of Highlands Street Lighting kick off meeting
Location:	254 Main Street Highland Falls NY 10928
Start:	Mon 12/9/2019 2:00 PM
End:	Mon 12/9/2019 3:30 PM
Recurrence:	(none)
Meeting Status:	Meeting organizer
Organizer:	Laino, Jeffrey
Required Attendees:	Richard Sullivan; Maya, David; Hermann, Charles; 'Bob Livsey'

-- Do not delete or change any of the following text. --

:KHQ LW V WLPH MRLQ \R

Meeting number (access code): 733 615 782
Meeting password: 3CKYf2SM

Join meeting

-RLQ E\ SKRQH
Tap to call in from a mobile device (attendees only)
+1-415-655-0003 US Toll
Global call-in numbers

If you are a host, go here to view host information.

Need help? Go to https://urldefense.proofpoint.com/v2/url?u=http-3A__help.webex.com&d=DwIGAg&c=7ytEQYGYryRPQxlWLDrn2g&r=FfnFA8xrXNwbDye5MvjW0tKo7DoKZq3TlG5zteal nvZ7ppAQ3Ad101dXWWghc-0lbbSadWj4g&s=fvG9Oov0NPAeIBiHRJTCdyA8TL5Jqi-Lxk0rcnYl8lE&e=

Arencibia, Stephanie (Molly)

From: r r
Sent: d r M
To: r
Subject: d d r

Arencibia, Stephanie (Molly)

From:	Bob Livsey <blivsey@highlands-ny.gov>
Sent:	Tuesday, November 2 , 2019 12: 2 PM
To:	Laino, Jeffrey
Subject:	[EXTERNAL]Accepted: Town of Highlands treet Lighting kick off meeting

Arencibia, Stephanie (Molly)

From:	Maya, David
Sent:	Tuesday, November 26, 2019 1:11 PM
To:	Laino, effrey
Subject:	Tentative: Town of Highlands Street Lighting kick off meeting

Arencibia, Stephanie (Molly)

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NEW YORK STATE OF OPPORTUNITY. | NY Power Authority

ANDREW M. CUOMO
Governor

JOHN R. KOELMEL
Chairman

GIL C. QUINIONES
President and Chief Executive Officer

April 5, 2019

Supervisor Bob Livsey
Town of Highlands
254 Main Street
Highland Falls NY 10928

RE: Energy Services Program
Authorization to Proceed with turn-key street light project
Town of Highlands– LED Street Lighting

Dear Supervisor Livsey,

The New York Power Authority (NYPA) is excited to support the Town of Highlands in identifying and implementing a comprehensive street lighting upgrade. Improving the existing street lights is a widely used and effective strategy to achieve the goal of reducing energy consumption, lowering utility costs, and improving light quality throughout the community.

Consistent with the Master Cost Recovery Agreement, NYPA provides a turn-key solution to upgrade the Town of Highlands's existing street lights to energy efficient LED technology. NYPA is pleased to offer these services to replace approximately 167 existing street light fixtures with new high efficient LED technology.

By signing below, the Town of Highlands authorizes NYPA to proceed with the full turn-key solution of the LED street lighting project, which includes the final design report, conducting bids for materials and installation labor, providing construction management, and commissioning the final project. When the design and bidding is completed, you will receive an Initial Customer Installation Commitment (ICIC) for your review and signature. At this point, if you choose to proceed to project implementation all development costs will be rolled into the overall project. Conversely, should you decide not to proceed with the implementation of the project, the Town of Highlands agrees to reimburse NYPA for all costs incurred up to the termination date for the development, design and bidding of the project. The cost of developing the design and for bidding the materials and labor will be determined during the next phase. NYPA will be fully transparent through this process and provide complete documentation as to how it determined all project costs.

By signing below, affirm that you agree to these conditions:

NEW YORK STATE OF OPPORTUNITY. | NY Power Authority

ANDREW M. CUOMO
Governor

JOHN R. KOELMEL
Chairman

GIL C. QUINIONES
President and Chief Executive Officer

Joseph Rende	MERVIN R. LIVSEY
(Name, printed)	(Name, printed)
Senior Director, Customer Business Development	TOWN SUPERVISOR
(Title)	(Title)
(Signature)	(Signature)
10/3/19	9-24-19
(Date)	(Date)

Arencibia, Stephanie (Molly)

From: Laino effrey effrey Laino ny a go
Sent: Wednesday Se te er M
To: Richard Sulli an
Subject: RE E TERN L Town of Highlands ES MCR etween New York ower uthority ER IN R LI SEY and ohn Canale is Signed and Filed

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Cc: ne o n o n ne n o no e re e re no n o
Subject: T To n o nd S MC bet een e or o er ut or t m S nd o n C n e S ned nd F ed

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Town of Highlands_ES_MCRA_2019 between New York Power Authority , mERVIN R. LIVSEY and John Canale is Signed and Filed!

From: NEW YORK POWER AUTHORITY - Lindsay Parille (New York Power Authority)
To: John Canale, NEW YORK POWER AUTHORITY - Lindsay Parille and mERVIN R. LIVSEY

Cc: New York Power Authority John Paine and jeffrey.laino@nypa.gov

Attached is a final copy of **Town of Highlands_ES_MCRA_2019**.

Copies have been automatically sent to all parties to the agreement.

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- Exchange, Sign, and File Any Document. In Seconds!
- Set-up Reminders. Instantly Share Copies with Others.
- See All of Your Documents, Anytime, Anywhere.

Arencibia, Stephanie (Molly)

From:	ichard ulli an <rsulli an highlands n .g >
Sent:	rida eptem er 2019 M
To:	ain effre
Subject:	e wn f Highlands M 2019 etween ew rk wer uth rit m . and hn anale is igned and iled

Hi e ,
I m s am ed at or , a NY A ro ect in Yon ers actua , I ca toda and get things or ed out .
Than s or atience, Richie

Sent rom m i hone

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- See ll of our Documents, nytime, nywhere.

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Arencibia, Stephanie (Molly)

From: Laino, Jeffrey <Jeffrey.Laino@nypa.gov>
Sent: Monday, September 9, 2019 7:12 AM
To: Richard Sullivan
Subject: RE: [EXTERNAL]Town of Highlands_ES_MCRA_2019 between New York Power Authority , mERVIN R. LIVSEY and John Canale is Signed and Filed!
Attachments: NYPA Street Lighting Authorization to Proceed.pdf

Richie, I received your voice mail, attached is what is needed, the Authorization to Proceed with the engineering design and bidding phases of the project. Once we receive this, we set up the project kick off meeting and mobilize.

Regards,
Jeff

From: Laino, Jeffrey
Sent: Friday, September 6, 2019 2:06 PM
To: 'Richard Sullivan' <rsullivan@highlands-ny.gov>
Subject: RE: [EXTERNAL]Town of Highlands_ES_MCRA_2019 between New York Power Authority , mERVIN R. LIVSEY and John Canale is Signed and Filed!

Thanks Richie!

From: Richard Sullivan <rsullivan@highlands-ny.gov>
Sent: Friday, September 6, 2019 5:57 AM
To: Laino, Jeffrey <Jeffrey.Laino@nypa.gov>
Subject: Re: [EXTERNAL]Town of Highlands_ES_MCRA_2019 between New York Power Authority , mERVIN R. LIVSEY and John Canale is Signed and Filed!

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I'm swamped at work, a NYPA project in Yonkers actually, Ill call today and get things worked out.
Thanks for patience, Richie

Sent from my iPhone

On Sep 4, 2019, at 4:15 PM, Laino, Jeffrey <Jeffrey.Laino@nypa.gov> wrote:

> Hey Richie,
> I hope all is well, any news on getting the authorization to proceed signed?
> Regards,
> Jeff
>
> ---
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> **From:** Laino, Jeffrey
> **Sent:** Monday, August 12, 2019 9:56 AM
> **To:** 'Richard Sullivan' <rsullivan@highlands-ny.gov>
> **Subject:** FW: [EXTERNAL]Town of Highlands_ES_MCRA_2019 between New York Power Authority , mERVIN R. LIVSEY and John Canale is Signed and Filed!
>
> Hi Richie,

Just checking on the signed ATP, needed to kick off the project.
Hope all is well.
Jeff

From: Laino, Jeffrey
Sent: Tuesday, July 23, 2019 8:52 AM
To: 'Richard Sullivan' <rsullivan@highlands-ny.gov>
Subject: FW: [EXTERNAL]Town of Highlands_ES_MCRA_2019 between New York Power Authority , mERVIN R. LIVSEY and John Canale is Signed and Filed!

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From: New York Power Authority <echosign@echosign.com>
Sent: Tuesday, July 23, 2019 8:39 AM
To: Canale, John <John.Canale@nypa.gov>; Parille, Lindsay <Lindsay.Parille@nypa.gov>; mERVIN R. LIVSEY <blivsey@highlands-ny.gov>
Cc: Paine, John <John.Paine@nypa.gov>; Laino, Jeffrey <Jeffrey.Laino@nypa.gov>
Subject: [EXTERNAL]Town of Highlands_ES_MCRA_2019 between New York Power Authority , mERVIN R. LIVSEY and John Canale is Signed and Filed!

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ANDREW M. CUOMO
Governor

JOHN R. KOELMEL
Chairman

GIL C. QUINIONES
President and Chief Executive Officer

April 5, 2019

Supervisor Bob Livsey
Town of Highlands
254 Main Street
Highland Falls NY 10928

RE: Energy Services Program
Authorization to Proceed with turn-key street light project
Town of Highlands– LED Street Lighting

Dear Supervisor Livsey,

The New York Power Authority (NYPA) is excited to support the Town of Highlands in identifying and implementing a comprehensive street lighting upgrade. Improving the existing street lights is a widely used and effective strategy to achieve the goal of reducing energy consumption, lowering utility costs, and improving light quality throughout the community.

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NY Power Authority

Joseph Rende	
(Name, printed)	(Name, printed)
Senior Director, Customer Business Development	
(Title)	(Title)
(Signature)	(Signature)
(Date)	(Date)

Arencibia, Stephanie (Molly)

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Sent:	Friday, September 6, 2019 2:06 PM
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Thank you for your help with moving this along!!
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Sent: Tuesday, July 23, 2019 8:39 AM
To: Canale, John <John.Canale@nypa.gov>; Parille, Lindsay <Lindsay.Parille@nypa.gov>; mERVIN R. LIVSEY <blivsey@highlands-ny.gov>
Cc: Paine, John <John.Paine@nypa.gov>; Laino, Jeffrey <Jeffrey.Laino@nypa.gov>
Subject: [EXTERNAL]Town of Highlands_ES_MCRA_2019 between New York Power Authority , mERVIN R. LIVSEY and John Canale is Signed and Filed!

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- See ll of our Documents, nytime, nywhere.

o ensure that you continue receiving our emails, please add echosign@echosign.com to your address book or safe list.

Arencibia, Stephanie (Molly)

From: Hermann, Charles
Sent: Monday, December 9, 2019 3:26 PM
To: rsullivan@highlands-ny.gov; blivsey@highlands-ny.gov
Subject: Public-Private Use Certification
Attachments: ES-ESN-0862 Town of Highlands - LED Street Lighting Public-Private Use Form 20191205.pdf

Richard, Bob,
Attached is the PPUC we spoke about at the meeting today to certify that the town (will) own the lights we will be replacing.

Please signa and return and let me know if you have any questions.

Chuck

Arencibia, Stephanie (Molly)

From:	Laino, Jeffrey
Sent:	Thursday, October 3, 2019 5:11 PM
To:	Richard Sullivan
Subject:	FW: Town of Highlands ATP
Attachments:	20191003165155248.pdf

Received today…….I'll be in touch soon to set up the engineering meeting.

From: Rende, Joseph
Sent: Thursday, October 3, 2019 5:07 PM
To: Laino, Jeffrey <Jeffrey.Laino@nypa.gov>
Cc: Scott, Jesse <Jesse.Scott@nypa.gov>; Luteran, Kevin <Kevin.Luteran@nypa.gov>; Benjamin, David <David.Benjamin@nypa.gov>
Subject: Town of Highlands ATP

Hi Jeff. I got this today in the mail. Countersigned. Good work. Keep them coming. Looking for a Jeff Laino hot streak!!!!

Regards, Joe.

Arencibia, Stephanie (Molly)

From:	Bob Livsey <blivsey@highlands-ny.gov>
Sent:	Thursday, September 26, 2019 1:41 PM
To:	Laino, Jeffrey
Cc:	Richard Sullivan; Justin Rider
Subject:	Re: [EXTERNAL]FW: Agreement

It's signed and in the mail

Sent from my iPhone

> On Sep 26, 2019, at 1:31 PM, Laino, Jeffrey <Jeffrey.Laino@nypa.gov> wrote:
>
> Good afternoon, Just following up on receipt of the attached.
> Thank you,
> Jeff
>
> -----Original Message-----
> From: Laino, Jeffrey
> Sent: Friday, September 20, 2019 9:56 AM
> To: 'Bob Livsey' <blivsey@highlands-ny.gov>; Justin Rider <JRider@riderweiner.com>; Richard Sullivan <rsullivan@highlands-ny.gov>
> Subject: RE: [EXTERNAL]FW: Agreement
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> Jeff
>
> -----Original Message-----
> From: Bob Livsey <blivsey@highlands-ny.gov>
> Sent: Friday, September 20, 2019 9:48 AM
> To: Justin Rider <JRider@riderweiner.com>; Richard Sullivan <rsullivan@highlands-ny.gov>; Laino, Jeffrey <Jeffrey.Laino@nypa.gov>
> Subject: [EXTERNAL]FW: Agreement
>
> ________________________________
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>
> CAUTION — External Email
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>
> ________________________________
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>
> Attached is permission to sign the agreement as per the minutes of July 22nd. I know I signed it, I don't know if it was mailed or emailed to the NYPA. This is the meeting that Deborah did the yelling at the end of the meeting while we were proceeding with passing the permission to sign. I will sign again and see that it is mailed and emailed.
>
> bob
>
> MERVIN R. LIVSEY
> Supervisor, Town of Highlands
> 254 Main Street
> Highland Falls, NY 10928
> 845 446-4280 x 312
> Fax 845 446 4298
> Cell 845 238 8074
> blivsey@highlands-ny.gov
>
> -----Original Message-----
> From: highlandscopier@town.new-windsor.ny.us [mailto:highlandscopier@town.new-windsor.ny.us]
> Sent: Friday, September 20, 2019 9:40 AM
> To: Bob Livsey <blivsey@highlands-ny.gov>
> Subject:
>
> -------------------
> CS 3501i
> [00:17:c8:24:7f:a9]
> -------------------
> <Town of Highlands_ES_MCRA_2019 - signed.pdf>

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> Subject:
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> -------------------
> CS 3501i
> [00:17:c8:24:7f:a9]
> -------------------
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Attachments: NYPA Street Lighting Authorization to Proceed.pdf

I meant the attached ATP

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Subject: [EXTERNAL]FW: Agreement

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Attached is permission to sign the agreement as per the minutes of July 22nd. I know I signed it, I don't know if it was mailed or emailed to the NYPA. This is the meeting that Deborah did the yelling at the end of the meeting while we were proceeding with passing the permission to sign. I will sign again and see that it is mailed and emailed.

bob

MERVIN R. LIVSEY
Supervisor, Town of Highlands
254 Main Street
Highland Falls, NY 10928
845 446-4280 x 312
Fax 845 446 4298
Cell 845 238 8074
blivsey@highlands-ny.gov

-----Original Message-----
From: highlandscopier@town.new-windsor.ny.us [mailto:highlandscopier@town.new-windsor.ny.us]
Sent: Friday, September 20, 2019 9:40 AM
To: Bob Livsey <blivsey@highlands-ny.gov>
Subject:

CS 3501i
[00:17:c8:24:7f:a9]

Arencibia, Stephanie (Molly)

From:	Bob Livsey <blivsey@highlands-ny.gov>
Sent:	Friday, September 20, 2019 10:03 AM
To:	Justin Rider; Richard Sullivan; Laino, Jeffrey
Subject:	[EXTERNAL]FW: [EXTERNAL]FW: Agreement
Attachments:	Town of Highlands_ES_MCRA_2019 - signed.pdf

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Gets more confusing as we move along. I already have the attached agreement. It was electronically signed by me and John Cananle.

MERVIN R. LIVSEY
Supervisor, Town of Highlands
254 Main Street
Highland Falls, NY 10928
845 446-4280 x 312
Fax 845 446 4298
Cell 845 238 8074
blivsey@highlands-ny.gov

-----Original Message-----
From: Laino, Jeffrey [mailto:Jeffrey.Laino@nypa.gov]
Sent: Friday, September 20, 2019 9:56 AM
To: Bob Livsey <blivsey@highlands-ny.gov>; Justin Rider <JRider@riderweiner.com>; Richard Sullivan <rsullivan@highlands-ny.gov>
Subject: RE: [EXTERNAL]FW: Agreement

Bob, see attached. We have the Energy Services Agreement(MCRA) signed. The MCRA is a general terms and conditions document and is non binding. It governs any actual project the Town and NYPA implement. In your case, the street lighting project now needs the Authorization to Proceed(ATP) document to commit the Town to working with NYPA on engineering and procurement phases of the work.
So, no need to sign the MCRA again, just the ATP, then we will schedule a project kick off meeting and start working on the project.
Regards,
Jeff

-----Original Message-----
From: Bob Livsey <blivsey@highlands-ny.gov>
Sent: Friday, September 20, 2019 9:48 AM

To: Justin Rider <JRider@riderweiner.com>; Richard Sullivan <rsullivan@highlands-ny.gov>; Laino, Jeffrey <Jeffrey.Laino@nypa.gov>
Subject: [EXTERNAL]FW: Agreement

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CS 3501i
[00:17:c8:24:7f:a9]

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Attachments:	Town of Highlands_ES_MCRA_2019 - signed.pdf

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To:	Justin Rider; Richard Sullivan; Laino, Jeffrey
Subject:	[EXTERNAL]FW: Agreement
Attachments:	Scan20190920094019.pdf

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[00:17:c8:24:7f:a9]

Arencibia, Stephanie (Molly)

From:	Laino, Jeffrey <Jeffrey.Laino@nypa.gov>
Sent:	Friday, September 20, 2019 9:23 AM
To:	Bob Livsey
Cc:	Richard Sullivan
Subject:	LED Street lighting Authorization to Proceed
Attachments:	NYPA Street Lighting Authorization to Proceed.pdf

Good Morning Supervisor,
Attached is the LED Street lighting Authorization to Proceed. After we receive this back from the Town, we will schedule a kick off meeting with the NYPA engineering team and start the project.
We did receive the Master Cost recovery Agreement last month. That is the general terms and conditions agreement under which the street lighting project falls.
Regards,

Jeff Laino
Business Development Representative, Key Account Management
New York Power Authority
123 Main Street
White Plains, NY 10601
(914) 287-3351 (office)
(914) 312-1260 (cell)
Jeffrey.Laino@nypa.gov
www.nypa.gov

Arencibia, Stephanie (Molly)

From:	Laino, Jeffrey <Jeffrey.Laino@nypa.gov>
Sent:	Wednesday, September 18, 2019 12:33 PM
To:	Richard Sullivan
Subject:	Signed MCRA
Attachments:	Town of Highlands_ES_MCRA_2019 - signed.pdf

Jeff Laino
Business Development Representative, Key Account Management
New York Power Authority
123 Main Street
White Plains, NY 10601
(914) 287-3351 (office)
(914) 312-1260 (cell)
Jeffrey.Laino@nypa.gov
www.nypa.gov

Arencibia, Stephanie (Molly)

From:	Laino, Jeffrey <Jeffrey.Laino@nypa.gov>
Sent:	Monday, September 9, 2019 7:12 AM
To:	Richard Sullivan
Subject:	RE: [EXTERNAL]Town of Highlands_ES_MCRA_2019 between New York Power Authority , mERVIN R. LIVSEY and John Canale is Signed and Filed!
Attachments:	NYPA Street Lighting Authorization to Proceed.pdf

Richie, I received your voice mail, attached is what is needed, the Authorization to Proceed with the engineering design and bidding phases of the project. Once we receive this, we set up the project kick off meeting and mobilize.

Regards,
Jeff

From: Laino, Jeffrey
Sent: Friday, September 6, 2019 2:06 PM
To: 'Richard Sullivan' <rsullivan@highlands-ny.gov>
Subject: RE: [EXTERNAL]Town of Highlands_ES_MCRA_2019 between New York Power Authority , mERVIN R. LIVSEY and John Canale is Signed and Filed!

Thanks Richie!

From: Richard Sullivan <rsullivan@highlands-ny.gov>
Sent: Friday, September 6, 2019 5:57 AM
To: Laino, Jeffrey <Jeffrey.Laino@nypa.gov>
Subject: Re: [EXTERNAL]Town of Highlands_ES_MCRA_2019 between New York Power Authority , mERVIN R. LIVSEY and John Canale is Signed and Filed!

Hi Jeff,
I'm swamped at work, a NYPA project in Yonkers actually, Ill call today and get things worked out .
Thanks for patience, Richie

Sent from my iPhone

On Sep 4, 2019, at 4:15 PM, Laino, Jeffrey <Jeffrey.Laino@nypa.gov> wrote:

> Hey Richie,
> I hope all is well, any news on getting the authorization to proceed signed?
> Regards,
> Jeff
>
> ---
>
> **From:** Laino, Jeffrey
> **Sent:** Monday, August 12, 2019 9:56 AM
> **To:** 'Richard Sullivan' <rsullivan@highlands-ny.gov>
> **Subject:** FW: [EXTERNAL]Town of Highlands_ES_MCRA_2019 between New York Power Authority , mERVIN R. LIVSEY and John Canale is Signed and Filed!
>
> Hi Richie,

Just checking on the signed ATP, needed to kick off the project.
Hope all is well.
Jeff

From: Laino, Jeffrey
Sent: Tuesday, July 23, 2019 8:52 AM
To: 'Richard Sullivan' <rsullivan@highlands-ny.gov>
Subject: FW: [EXTERNAL]Town of Highlands_ES_MCRA_2019 between New York Power Authority , mERVIN R. LIVSEY and John Canale is Signed and Filed!

Hi Richie,
See attached signed MCRA. Also attached is the Authorization to Proceed. Once I receive the ATP I can initiate the project and get an engineer assigned to the project so we can schedule a kick off meeting.
Thank you for your help with moving this along!!
Jeff

From: New York Power Authority <echosign@echosign.com>
Sent: Tuesday, July 23, 2019 8:39 AM
To: Canale, John <John.Canale@nypa.gov>; Parille, Lindsay <Lindsay.Parille@nypa.gov>; mERVIN R. LIVSEY <blivsey@highlands-ny.gov>
Cc: Paine, John <John.Paine@nypa.gov>; Laino, Jeffrey <Jeffrey.Laino@nypa.gov>
Subject: [EXTERNAL]Town of Highlands_ES_MCRA_2019 between New York Power Authority , mERVIN R. LIVSEY and John Canale is Signed and Filed!

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Town of Highlands_ES_MCRA_2019 between New York Power Authority , mERVIN R. LIVSEY and John Canale is Signed and Filed!

: fca . B9K MCF? DCK 9F 5I H<CF=HM! @]bXgUmDUf]``Y fBYk Mcf_ Dck Yf 5i h\cf]hmL
Hc. John Canale, NEW YORK POWER AUTHORITY - Lindsay Parille and mERVIN R. LIVSEY

7W New York Power Authority John Paine and jeffrey.laino@nypa.gov

Attached is a final copy of Hck b cZ <][\ `UbXg S9 GSA 7F5 S&S% .

Copies have been automatically sent to all parties to the agreement.

You can view h\Y XcWa Ybh in your Adobe Sign account.

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- Exchange, Sign, and File Any Document. In Seconds!
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- See All of Your Documents, Anytime, Anywhere.

Arencibia, Stephanie (Molly)

From: Laino, Jeffrey <Jeffrey.Laino@nypa.gov>
Sent: Wednesday, September 4, 2019 4:15 PM
To: Richard Sullivan
Subject: RE: [EXTERNAL]Town of Highlands_ES_MCRA_2019 between New York Power Authority , mERVIN R. LIVSEY and John Canale is Signed and Filed!

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Regards,
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Attachments:	Town of Highlands_ES_MCRA_2019 - signed.pdf; NYPA Street Lighting Authorization to Proceed.pdf

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From: Laino, Jeffrey <Jeffrey.Laino@nypa.gov>
Sent: Tuesday, July 16, 2019 10:02 AM
To: Richard Sullivan
Subject: FW: Please sign Town of Highlands_ES_MCRA_2019
Attachments: NYPA Street Lighting Authorization to Proceed.pdf

Hi Richie,
Just letting you know that the Town Supervisor has the MCRA. We will need the MCRA and the attached Authorization to Proceed in order to begin the design and procurement stages of the project, which can happen while the fixture purchase process with O&R gets completed.
Thank you,
Jeff

From: Parille, Lindsay
Sent: Tuesday, July 16, 2019 9:55 AM
To: Bob Livsey <blivsey@highlands-ny.gov>
Cc: Paine, John <John.Paine@nypa.gov>; Laino, Jeffrey <Jeffrey.Laino@nypa.gov>
Subject: RE: Please sign Town of Highlands_ES_MCRA_2019

Good morning,
I have canceled the agreement and reissued with the appropriate name. You should have received a new email from Adobe Sign.

Thank you,

Lindsay Parille
Power Contracts & Tariff Analyst

New York Power Authority
123 Main St.
White Plains, NY 10601
914.681.6256 l Lindsay.Parille@nypa.gov
www.nypa.gov

From: Bob Livsey <blivsey@highlands-ny.gov>
Sent: Tuesday, July 16, 2019 8:41 AM
To: Parille, Lindsay <Lindsay.Parille@nypa.gov>
Subject: RE: Please sign Town of Highlands_ES_MCRA_2019

On a “legal” document I should have my name as printed below, not Bob Livsey. I will cross out Bob Livsey and enter my proper name.

MERVIN R. LIVSEY
Supervisor, Town of Highlands
254 Main Street
Highland Falls, NY 10928

845 446-4280 x 312
Fax 845 446 4298
Cell 845 238 8074
blivsey@highlands-ny.gov

From: NEW YORK POWER AUTHORITY - Lindsay Parille [mailto:echosign@echosign.com]
Sent: Friday, July 12, 2019 4:48 PM
To: Bob Livsey <blivsey@highlands-ny.gov>
Subject: Please sign Town of Highlands_ES_MCRA_2019

NEW YORK POWER AUTHORITY - Lindsay Parille Has Sent You Hck b cZ <][\`UbXgS9GSA7F5S&$% to Sign

NEW YORK POWER AUTHORITY - Lindsay Parille (New York Power Authority) says:
"Please review and complete Town of Highlands_ES_MCRA_2019."

Click here to review and sign Hck b cZ <][\`UbXgS9GSA7F5S&$% .

After you sign Hck b cZ<][\`UbXgS9GSA7F5S&$% , the agreement will be sent to >c\b 7UbUY. Then, all parties will receive a final PDF copy by email.

If you need to delegate this document to an authorized party for signature, d`YUgY Xc bch Zcfk UfX h\]g Ya U]`. Instead, click here to delegate.

Arencibia, Stephanie (Molly)

From:	Parille, Lindsay <Lindsay.Parille@nypa.gov>
Sent:	Tuesday, July 16, 2019 9:55 AM
To:	Bob Livsey
Cc:	Paine, John; Laino, Jeffrey
Subject:	RE: Please sign Town of Highlands_ES_MCRA_2019

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Subject: Please sign Town of Highlands_ES_MCRA_2019

[redacted]

NEW YORK POWER AUTHORITY - Lindsay Parille Has Sent You Hck b cZ <][\`UbXgS9GSA7F5S&S% to Sign

NEW YORK POWER AUTHORITY - Lindsay Parille (New York Power Authority) says:
"Please review and complete Town of Highlands_ES_MCRA_2019."

Click here to review and sign Hck b cZ <][\`UbXgS9GSA7F5S&S% .

After you sign Hck b cZ<][\`UbXgS9GSA7F5S&S% , the agreement will be sent to >c\b 7UbUY. Then, all parties will receive a final PDF copy by email.

If you need to delegate this document to an authorized party for signature, d`YUgY Xc bch Zcfk UFX h\]g Ya U]`. Instead, click here to delegate.

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Sent: Friday, July 12, 2019 4:48 PM
To: Bob Livsey <blivsey@highlands-ny.gov>
Subject: Please sign Town of Highlands_ES_MCRA_2019

[redacted]

[redacted]

NEW YORK POWER AUTHORITY - Lindsay Parille Has Sent You Hck b˙ cZ <][\`UbXgS9GSA7F5S&$% to Sign

NEW YORK POWER AUTHORITY - Lindsay Parille (New York Power Authority) says:
"Please review and complete Town of Highlands_ES_MCRA_2019."

Click here to review and sign Hck b˙cZ <][\`UbXgS9GSA7F5S&$% .

After you sign Hck b`cZ< ][\`UbXgS9GSA7F5S&S% , the agreement will be sent to >c\b`7UbUY. Then, all parties will receive a final PDF copy by email.

If you need to delegate this document to an authorized party for signature, d`YUgY`Xc`bch`Zcfk UfX`h\]g`Ya U]`. Instead, click here to delegate.

Arencibia, Stephanie (Molly)

From:	Laino, Jeffrey <Jeffrey.Laino@nypa.gov>
Sent:	Wednesday, July 10, 2019 1:22 PM
To:	Richard Sullivan; Kelly Pecoraro; Bob Livsey
Subject:	RE: [EXTERNAL]LED process

Thanks Rich. I put in the contract request and you should receive the contract via email in a few days.
Just a note on the project time line. The physical installs of the new fixtures should indeed take about 3 weeks. The engineering design work actually takes a bit longer than that, but we can get the project all ready for actual installs while the purchase details are settled with your utility. NYPA can finance the purchase of the fixtures. That process will be articulated when we kick off the project but we cannot start installs until the town takes ownership.
Looking forward to the kick off meeting!!
Regards,

Jeff Laino
Customer Business Development Representative
New York Power Authority
123 Main Street
White Plains, NY 10601
(914) 287-3351 (office)
(914) 312-1260 (cell)
Jeffrey.Laino@nypa.gov
www.nypa.gov

From: Richard Sullivan <rsullivan@highlands-ny.gov>
Sent: Wednesday, July 10, 2019 12:00 PM
To: Kelly Pecoraro <kpecoraro@highlands-ny.gov>; Bob Livsey <blivsey@highlands-ny.gov>
Cc: Laino, Jeffrey <Jeffrey.Laino@nypa.gov>
Subject: [EXTERNAL]LED process

Good Morning Kelly ,
The process is something like this, and I've included a few contacts to help lessen the communication wonderment :
We must communicate, officially, our intent to acquire the streetlights from O & R, they have 60 days to respond with a number; Jeff gave an estimate in the proposal from April based on the 167 inventory I downloaded from O & R's portal .
Jeff/NYPA will send an executable document this week, so NYPA administrative work and O & R acquisition happen in parallel, NYPA will include acquisition costs in our package if we chose, which I believe we will go for that option.
At O & R I have spoken a few times with Teresa Johnson, 8457835573 , JohnsonThe@oru.com is her email , she's on vacation this week, if desired I'll call her next week to initiate acquisition. I have again included

NYPA workup in case you did not see it , and subsequent to events mentioned NYPA and the town will have a kickoff meeting.
Assuming all goes well, such things as increasing or decreasing # of lights will surface, Jeff mentioned different options for dimmers, and a pilot area for observance before buildout , but ultimately this is 2-3 weeks work for the contractor that NYPA assigns to this job, and I fully expect my name to be regularly singled out by opposition, I believe in what we are doing and hope anyone with concern drives down Strawtown Road in Clarkstown at night to get a true taste of what will manifest.
Jeff's office is

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New York Power Authority
123 Main Street
White Plains, NY 10601
(914) 287-3351 (office)
(914) 312-1260 (cell)
Jeffrey.Laino@nypa.gov
www.nypa.gov

Kelly and Bob :
Kelly Pecoraro
Comptroller
Town of Highlands
254 Main Street
Highland Falls, NY 10928
845-446-4280 ext 325|f 845-446-6507
Bob x 312 at same address.

Obliged, Richie

Arencibia, Stephanie (Molly)

From: Laino, Jeffrey <Jeffrey.Laino@nypa.gov>
Sent: Thursday, April 11, 2019 8:22 AM
To: Richard Sullivan
Subject: RE: [EXTERNAL]Presentation

No worries, my days get crazy too at times.
Whatever timeline the Town to make a decision is fine.
The Town should be requesting a purchase price from O&R by sending a letter to the Account Manager requesting a purchase price for the street lights. It is non binding but the process of purchasing takes about 6 months and NYPA cannot installing lights until the Town owns the old ones. We can do the design and bidding, but wouldnâ€™t be permitted to start installs.

-----Original Message-----
From: Richard Sullivan <rsullivan@highlands-ny.gov>
Sent: Wednesday, April 10, 2019 8:51 PM
To: Laino, Jeffrey <Jeffrey.Laino@nypa.gov>
Cc: Luteran, Kevin <Kevin.Luteran@nypa.gov>
Subject: Re: [EXTERNAL]Presentation

Pleasant Wednesday Jeff,
Sometimes I have days where I have no free time, sorry for delay .
Timeline- next meeting (Earth Day) after community input it is my job to steer public perception so no one kills this effort, I expect that to go well, and last eve I spoke with the supervisor, he really likes the project. The supervisorâ€™s son is on the Village of HF board, and that is who referred a bright LED in his backyard to me, the light was installed by O & R and Iâ€™ve subdued the original concern to both supervisor and his son based on options you presented.
In doing my diligence, Iâ€™ve contacted (long before you) O & R to see what they may offer, so my very best guess is either first meeting in May or possibly the second (near Memorial Day) the decision will be final, I wonâ€™t let it go beyond that timeframe.
Iâ€™ll send tomorrowâ€™s article in the local paper to you, and I may have a question or two over the next few weeks, I hope that timeline is plausible.
Obliged, Richie

Sent from my iPad

> On Apr 9, 2019, at 9:23 AM, Laino, Jeffrey <Jeffrey.Laino@nypa.gov> wrote:
>
> Good Morning Richie,
> Thank you for the email, it was my pleasure to present the NYPA street lighting proposal to the Supervisor and Council members last night. I hope all their questions were answered but please reach out to me if any additional questions arise.
> I am attaching the Authorization to Proceed and a sample Master Cost Recovery Agreement(MCRA). These are the 2 documents NYPA will need executed in order to begin the project implementation. I will have the contracting unit at NYPA email you an executable version of the MCRA upon request.
> What do you think the timeline is for the Town to make a decision on moving forward with the project?
> Let me know if there is anything else you need and please send me a link to any news articles regarding the project.
> Thank you and looking forward to working with you.
>
> Jeff Laino

> Customer Business Development Representative New York Power Authority
> 123 Main Street
> White Plains, NY 10601
> (914) 287-3351 (office)
> (914) 312-1260 (cell)
> Jeffrey.Laino@nypa.gov
> www.nypa.gov
>
>
>
>
> -----Original Message-----
> From: Richard Sullivan <rsullivan@highlands-ny.gov>
> Sent: Tuesday, April 9, 2019 5:37 AM
> To: Laino, Jeffrey <Jeffrey.Laino@nypa.gov>
> Cc: Luteran, Kevin <Kevin.Luteran@nypa.gov>
> Subject: [EXTERNAL]Presentation
>
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> forward to (abuse@nypa,gov)
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>
> Jeff,
> Not sure if Kevin is your associate, subordinate, or supervisor, but I wanted to let you know you were concise, germane , well poised and delivered a very well received workup, thank you.
> Just a bit on the Village of Highland Falls- in 2016 there was a different team in place, they had an electrician as a trustee who invited NYPA to implement a similar program , but once removed from power, the current team , who I like, ended that effort.
> I did speak with the village liaison to streetlights yesterday, and the village has over 250 lights, O and R is changing 7 per year , that would be a lame 30 year effort, and savings would be barely recognized. O and R does have some deal where for an extra $169 per light they will do more per year, and thatâ€™s about all I know about their program, or lack thereof.
> So as a good neighbor I kept the village out of it, I tried contacting their Point man since late Feb., no response until yesterday so the citizens you met last night will be charged with the task of inviting/ pressuring the village to participate, either way that is a separate body of government .
> I / we look forward to advancing this effort, and with a trustworthy body like NYPA , and the issue of maintenance after ownership being addressed by NYPA and included in your workup, I believe this will be at least plausible, hopefully executable project, and again thank you. When the local paper does an article on this (this Thursday), Iâ€™ll share an online copy if you desire.
> Have a great day, Richie
>
> Sent from my iPad
> <Sample 2017 MCRA - Statewide 07242017.pdf> <NYPA Street Lighting
> Authorization to Proceed.pdf>

Arencibia, Stephanie (Molly)

From:	Laino, Jeffrey <Jeffrey.Laino@nypa.gov>
Sent:	Tuesday, April 9, 2019 9:23 AM
To:	Richard Sullivan
Cc:	Luteran, Kevin
Subject:	RE: [EXTERNAL]Presentation
Attachments:	Sample 2017 MCRA - Statewide 07242017.pdf; NYPA Street Lighting Authorization to Proceed.pdf

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Have a great day, Richie

Sent from my iPad

Arencibia, Stephanie (Molly)

From:	Laino, Jeffrey <Jeffrey.Laino@nypa.gov>
Sent:	Tuesday, March 19, 2019 2:43 PM
To:	Richard Sullivan
Subject:	RE: [EXTERNAL]Streetlights
Attachments:	NYPA LED Street Lighting Cost and Savings Summary Town of Highlands.pdf; NYPA LED Street Lighting proposal.pdf

Hi Richie,
Attached is a project cost and savings summary and proposal to have the New York Power Authority implement a street lighting conversion project for the Town of Highlands.
NYPA proposes a turnkey project which means we will access one of our procured design engineering firms to be engineer of record, perform a design, recommend materials from our procured vendor, Philips, procure a labor installer by bidding the project to a pre vetted list of installation contractors, manage the installation of the new fixtures and finance the project. We can include the purchase of the existing fixtures from O&R in the financing as well so the Town has no out of pocket expense until the project is done.
All costs are estimated, including the purchase price of your old fixtures.
I am happy to meet to discuss the proposal and implementation process and attend a Board meeting as needed.
Looking forward to hearing back regarding next steps.
Regards,
Jeff

-----Original Message-----
From: Richard Sullivan <rsullivan@highlands-ny.gov>
Sent: Tuesday, March 12, 2019 9:00 AM
To: Laino, Jeffrey <Jeffrey.Laino@nypa.gov>
Subject: Re: [EXTERNAL]Streetlights

Good Morning Jeff,
I announced at last nights meeting that you are working up a proposal for us. When complete, we will talk, if part of the protocol is a town board meeting I want to insure interested public are present . Until then we look forward to your proposal, no urgency from our camp.
Richie

Sent from my iPhone

> On Mar 7, 2019, at 10:16 AM, Laino, Jeffrey <Jeffrey.Laino@nypa.gov> wrote:
>
> Thanks Richie, I think I have what I need to send you an estimate of the project costs and savings, should have to you by the end of next week.
> Regards,
> Jeff
>
> -----Original Message-----
> From: Richard Sullivan <rsullivan@highlands-ny.gov>
> Sent: Wednesday, March 6, 2019 3:48 PM
> To: Laino, Jeffrey <Jeffrey.Laino@nypa.gov>
> Cc: Kelly Pecoraro <kpecoraro@highlands-ny.gov>
> Subject: [EXTERNAL]Streetlights

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> Mr Jeff Laino,
> Wish I had more time, but Iâ€™m sending what I have , raw data with limited review.
> There are 3 months of bills, the town changed electric vendor in 2019 so Jan bill is incomplete.
> In reviewing conversions from lumens to watts for Tungsten to LED to Mercury Vapor, the O and R spreadsheet has watts attached to lamp lumens, those wattages donâ€™t always seem accurate, but my 31000 watts of total lighting comes from O and Râ€™s data.
> Also, some of that data varies from 2018 to 2019; the utility analysis group working on the towns analysis is nearly done, I suspect they have brought errors in inventory to the surface, hence.
> Please be it known that
> - no authority by the town board has been rendered to allow any money toward this proposal at this time.
> - the Village of Highland Falls is also looking into this, if this were to happen, I suspect equipment/ repairs after project were done would be shared, 167 lights is hard to justify a bucket truck just for that inventory. Your analysis may advise outside contractors for said repairs, I look forward to the full gambit of options.
> - the town has limited personnel in its DPW and many employees are part timers, in other words, we arenâ€™t wealthy, 93% of our land is PIPC and USMA lands.
>
> The quality of LED lights, expense associated, attraction for insects (or not), timeline, grant likelihood and amount, pole rental costs, sleep interference asserted by some studies, etc, I look forward to the plausibility of change.
> I have copied the comptroller and supervisor Bob Livsey, you initial findings can come to me, the liaison for this matter.
>
> Obliged, Richie
> 8456425587
> (any formats that arenâ€™t retrievable Iâ€™ll resend)
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Cc:	Kelly Pecoraro
Subject:	RE: [EXTERNAL]Streetlights

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8456425587
(any formats that arenâ€™t retrievable Iâ€™ll resend)

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Sent:	Wednesday, March 6, 2019 3:48 PM
To:	Laino, Jeffrey
Cc:	Kelly Pecoraro
Subject:	[EXTERNAL]Streetlights
Attachments:	Light pole analysis.pages; Streetlight inventory copy.numbers; ATT00001.txt; Deborah_ 000484.pdf; ATT00002.txt

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Obliged, Richie
8456425587
(any formats that arenâ€™t retrievable Iâ€™ll resend)

Arencibia, Stephanie (Molly)

From:	Laino, Jeffrey <Jeffrey.Laino@nypa.gov>
Sent:	Tuesday, February 26, 2019 11:38 AM
To:	Luteran, Kevin; Richard Sullivan
Cc:	Bob Livsey
Subject:	RE: [EXTERNAL]Street lights

Thanks for making the introduction, happy to develop an initial estimate of project costs and savings. Please send the items Kevin listed, this will allow me to prepare the estimate.
Looking forward to working with you.
Regards,

Jeff Laino
Customer Business Development Representative New York Power Authority
123 Main Street
White Plains, NY 10601
(914) 287-3351 (office)
(914) 312-1260 (cell)
Jeffrey.Laino@nypa.gov
www.nypa.gov

-----Original Message-----
From: Luteran, Kevin
Sent: Tuesday, February 26, 2019 8:48 AM
To: Richard Sullivan <rsullivan@highlands-ny.gov>; Laino, Jeffrey <Jeffrey.Laino@nypa.gov>
Cc: Bob Livsey <blivsey@highlands-ny.gov>
Subject: RE: [EXTERNAL]Street lights

Good Morning Richie,

Thank you for reaching out, I would like to introduce you to Jeff Laino, you may have met Jeff at the Association of Towns conference but he will be able to help put together a proposal for you. To get started we will need a 1-2 copies of your street light utility bill, as well as any information on any customer-owned lights. Also, please share the purchase price from the utility, if you havenâ€™t requested this information it is not a big deal, we have a pretty good sense of what the cost will be but I would encourage you to submit your request as soon as possible since it could take up to 90 days to receive. As a reminder there is no commitment to request you purchase price from your utility. For your convenience I have attached Jeff's contact information below,

Jeff Laino
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Feel free to reach out with any other questions,

Kevin

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Sent: Tuesday, February 26, 2019 7:51 AM
To: Luteran, Kevin <Kevin.Luteran@nypa.gov>
Cc: Bob Livsey <blivsey@highlands-ny.gov>
Subject: [EXTERNAL]Street lights

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Greetings,
I attended your presentation at the annual Association of Towns, and asked a few questions, one being the cost of a proposal ; it was indicated they are free of charge .

I am a town councilman, Town of Highlands, I have more than enough data as per your comments at the presentation to initiate a proposal, and I participated in a webinar last summer given by CT Male. I have a fairly good grasp on places like Kingston and Rhinebeck with thousands of street lights, Town of Highlands has 167 and a very small DPW, there is public interest in new ways of going Green, Iâ€™m concerned about pole rental costs and the burden of ownership , I look forward to discussion with no commitment .
Obliged, Richie Sullivan, Town of Highlands Councilman

8456425587
254 Main Street
Highland Falls, NY 10928
Town Supervisor Bob Livsey (Ccd)
Sent from my iPad

Arencibia, Stephanie (Molly)

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I am a town councilman, Town of Highlands, I have more than enough data as per your comments at the presentation to initiate a proposal, and I participated in a webinar last summer given by CT Male. I have a fairly good grasp on places like Kingston and Rhinebeck with thousands of street lights, Town of Highlands has 167 and a very small DPW, there is public interest in new ways of going Green, Iâ€™m concerned about pole rental costs and the burden of ownership , I look forward to discussion with no commitment .
Obliged, Richie Sullivan, Town of Highlands Councilman

8456425587
254 Main Street
Highland Falls, NY 10928
Town Supervisor Bob Livsey (Ccd)
Sent from my iPad

Arencibia, Stephanie (Molly)

From:	Luteran, Kevin <Kevin.Luteran@nypa.gov>
Sent:	Tuesday, February 26, 2019 8:48 AM
To:	Richard Sullivan; Jeffrey Laino (Jeffrey.Laino@nypa.gov)
Cc:	Bob Livsey
Subject:	RE: [EXTERNAL]Street lights

Good Morning Richie,

Thank you for reaching out, I would like to introduce you to Jeff Laino, you may have met Jeff at the Association of Towns conference but he will be able to help put together a proposal for you. To get started we will need a 1-2 copies of your street light utility bill, as well as any information on any customer-owned lights. Also, please share the purchase price from the utility, if you havenâ€™t requested this information it is not a big deal, we have a pretty good sense of what the cost will be but I would encourage you to submit your request as soon as possible since it could take up to 90 days to receive. As a reminder there is no commitment to request you purchase price from your utility. For your convenience I have attached Jeff's contact information below,

Jeff Laino
Customer Business Development Representative New York Power Authority
123 Main Street
White Plains, NY 10601
(914) 287-3351 (office)
(914) 312-1260 (cell)
Jeffrey.Laino@nypa.gov
www.nypa.gov

Feel free to reach out with any other questions,

Kevin

-----Original Message-----
From: Richard Sullivan <rsullivan@highlands-ny.gov>
Sent: Tuesday, February 26, 2019 7:51 AM
To: Luteran, Kevin <Kevin.Luteran@nypa.gov>
Cc: Bob Livsey <blivsey@highlands-ny.gov>
Subject: [EXTERNAL]Street lights

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