

# **The Environmental Implications of Light at Night**

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# What is Light Pollution?

## Definition

- *Unwanted light that leaks into the environment at night.*

# Causes

- **Street lighting.**
- **Security lighting, including that installed by inconsiderate neighbours.**
- **Commercial lighting (usually high-rise office buildings).**
- **Advertising, involving illuminated bill boards, flashing signs, outdoor T.V. screens, skybeams and lasers.**
- **Decorative lighting: this includes floodlighting, and so-called art involving the use of night-time illumination.**
- **Sports lighting.**

# Effects (1)

## 1) Wastage

### a) Wastage of energy, leading to global warming and climate change.

- This works hand-in-glove with rising levels of greenhouse gases [carbon dioxide (CO<sub>2</sub>) and methane (CH<sub>4</sub>)].
- According to lighting industry sources 19% of all energy consumed goes on lighting. In Europe this amounts to 59,760TWh per annum.
- In the Italian town of Certaldo, electricity consumption due to street lighting is at least 60%: (Fiaschi, et al, 2012). Other communities are probably similar or worse, especially in developing countries where environmental concerns are of little or no consequence.
- *Consequently, light pollution is an inconvenient truth.*

## Effects (2)

- b) Climate change will cause polar land ice will melt and sea levels to rise. Coastal areas may become inundated, and populations will have to relocate. (e.g. Bangladesh). Conflicts may arise as people fight over accommodation, food, land, and resources.**
  
- c) Wastage of money; the energy consumed has to be paid for. As much as sixty percent of all municipal expenditure goes on street lighting. Much of this is unnecessary and could be better spent on health, education, pensions, welfare and sensible urban regeneration.**

# Effects (3)

## 2) Environmental

- a) **Sky glow.** Increased street lighting increases the ambient sky background, rendering all but the brighter stars invisible. Flashing signs will create an oscillating sky background signal.
- b) **Glare.** Bad lighting (from badly aimed street, security and decorative lighting) damages night vision by ruining one's dark adaptation. This makes it increasingly difficult to see. Oncoming car headlights are a good example.

The next two images show examples of sky-glow and glare. The first image shows the glow from the Saudi city of Tabuk at a distance of 80km.

# Skyglow (l) and Glare (r)

l) The city of Tabuk from 80km r) Glare from a light on the gable end of a house.

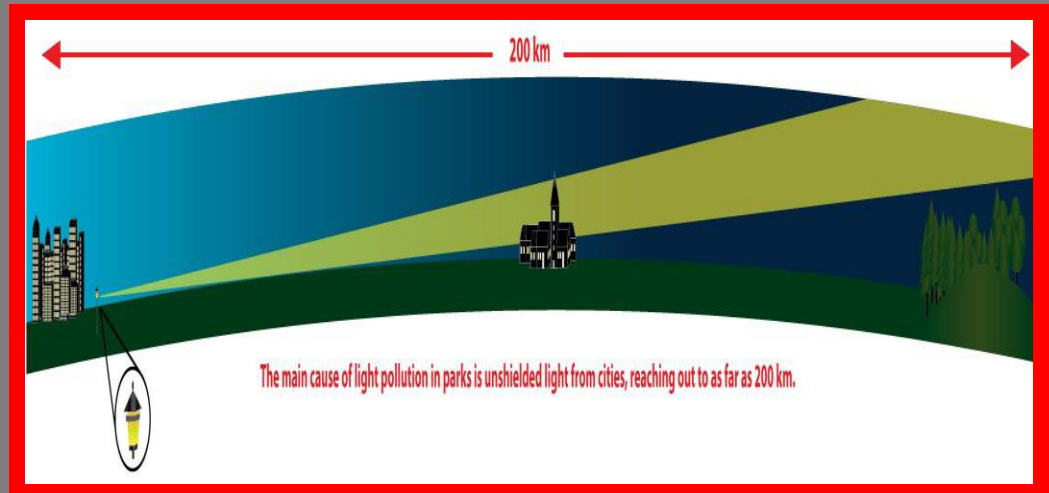
Images: C. Henshaw.



# How far does it go?

Image credit: Andrej Mohar.

- Light pollution can be highly penetrative.
- Light travels in straight lines.
- The earth's surface does not.
- Consequently even 90 degree full cut-off lighting will pollute, illuminating the cloud ceiling at great distances even though the light source is below the horizon of the observer.
- Some cities can be detected from as far away as 200km.





# So where does it all go?

- Once the light has been used in illumination it escapes into the environment, causing light pollution.
- That which is not absorbed by the environment escapes into space. Either way the energy is wasted.
- The following images taken by orbiting satellites show the extent of light pollution in (left) the UK and (right) Europe and the Middle East.

# LP from Space

Images: NASA.



# Jeddah, Saudi Arabia at Night.

from over the Red Sea, on Turkish Airlines flight TK0094.

Image: Colin Henshaw, September 13<sup>th</sup>, 2013.



# These images show there's simply no getting away from it.

- *So what damage does it do?*
- It illuminates the cloud ceiling, turning it orange.
- It drowns out the fainter stars so that they are no longer visible. Did anyone ever ask why?
- Urban and sub-urban dwellers can no longer see the Milky Way, Zodiacal Light, or the Gegenschein, that should be visible on any dark night.
- This begs the question: “When did you last see the Milky Way?” Or even “Have you ever seen it?”
- The following images show the Gegenschein, and the Milky Way as it should be seen.

# Gegenschein

Image: C. Henshaw.



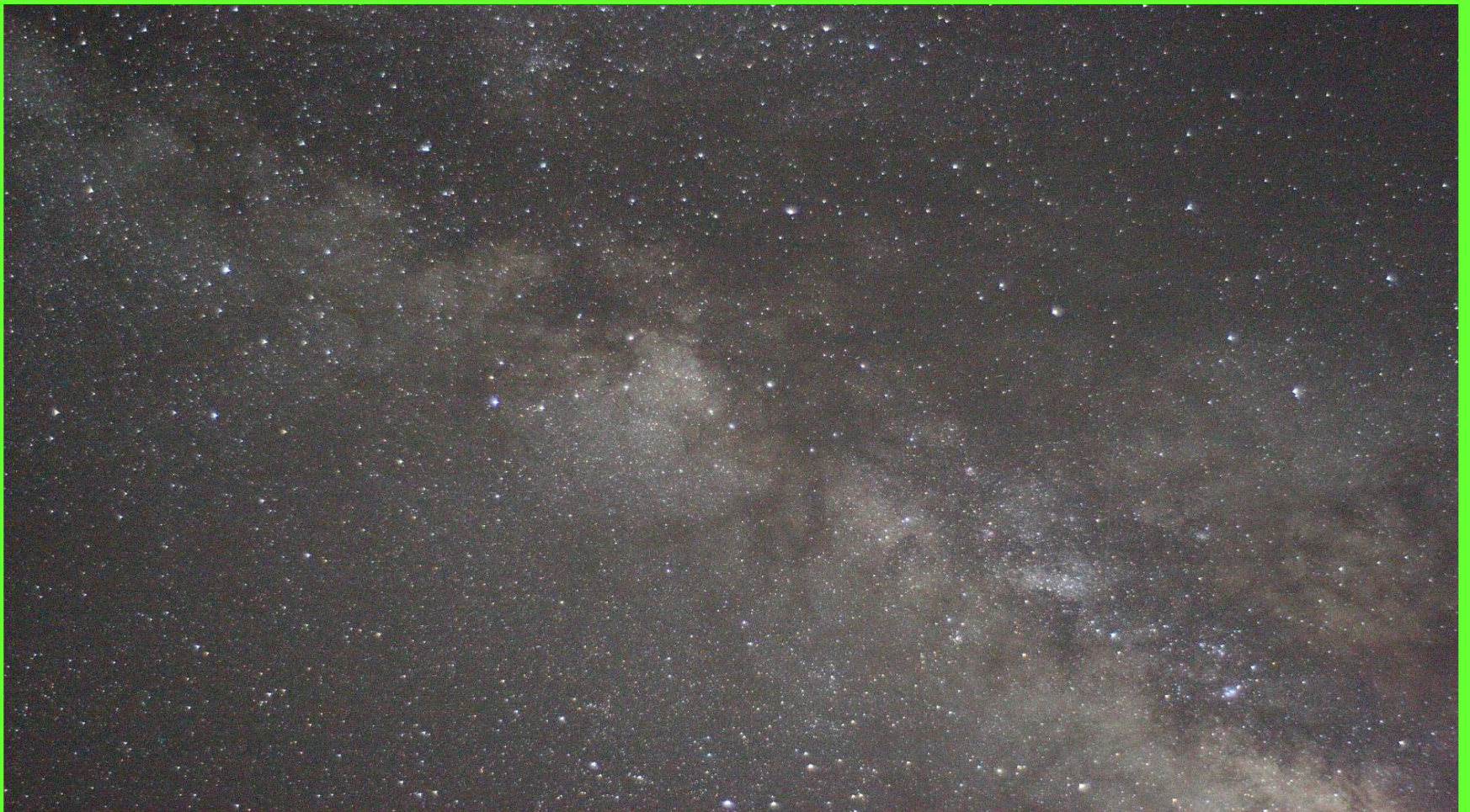
- **Gegenschein is caused by sunlight reflected from dust particles lying in the plane of the Earth's orbit, but diametrically opposed to the Sun in the sky.**
- **It should be seen on any clear, dark and Moonless night, when it is not near the Milky Way.**
- **The last confirmed sighting from England was by Patrick Moore from London during the war-time blackout. Now extinct.**
- **This image taken from perfect skies in Saudi Arabia in November 2013.**



# The Milky Way

Views like this have not been seen from England for 50 years.

Image: C. Henshaw.



# Ecological effects (1)

## 3) Ecological

Even if renewable energy is used to illuminate cities, light pollution would still be damaging as *it is the light itself which is harmful.* It can affect many different kinds of organisms

### a) *Insects.*

- *These are positively phototactic (attracted to lights) and will fly around them until they are either too tired to feed or to procreate.*
- *They will then die.*
- *Over longer periods (several decades) of intensive all-night lighting, insects will be swept up over a wide area, and their numbers will decline. Declines in common insects have been reported by environmental organisations over the past few decades.*

# Ecological effects (2)

- *If areas are intensively lit, even diurnal (day-flying) insects are affected, as the intense light tricks them into thinking it is daylight, extending their normal period of activity. Glow-worms decline in light polluted areas, as lighting confuses their mating behaviour. They are only common in dark areas.*
- *Dung Beetles need to see the Milky Way in order to navigate. If they can't see it either due to moonlight or light pollution, they become disorientated. This probably applies to other insects as well.*
- *Some insects are negatively phototactic and are repelled by lights. So are woodlice. As more places are lit up, these species will find fewer places to hide or breed.*
- *The effect of lighting is such that industrialised countries are sterile today compared to what they were fifty years ago.*



# Which kind of lighting is most damaging? (1)

- **Low pressure sodium (SOX) street lighting is the least damaging as it produces a monochromatic orange light to which insects are least sensitive.**
- **However, all other forms of lighting are broad spectrum, containing large proportions of blue and ultraviolet light that are highly damaging to insects.**
- **In the early years most lighting was of this type, then in the 1960's it began to be replaced by low pressure sodium.**
- **Later on the low pressure sodium was replaced by high pressure sodium that again contains a higher proportion of blue that is supposed to give better colour rendition. This maintained the environmental damage caused by the earlier forms of lighting.**
- **This is now being replaced with LED lighting that is again rich in blue. Low colour temperature amber LEDs would be less harmful.**

## Which kind of lighting is most damaging? (2)

- Uffen (1994) pointed that though sodium lighting is less attractive to insects, observation has revealed that normal flight patterns are completely inhibited in the presence of such lighting, effectively sterilising wide areas. This fact may be more insidious than the attractiveness of insects to lights.
- In addition to this, security lighting and floodlighting use halogen lamps that are again rich in ultra-violet and very damaging to insects. Consequently it is not a good idea to illuminate rural churches and public buildings.
- Commercial lighting often uses fluorescent strip lighting that again is rich in blue and ultraviolet that is damaging to insects. Empty offices not in use at night are often left with their lights switched on.
- All types of lighting are used in cities, so insect populations can be expected to decline.

**L: Insects attracted to light. R: Diurnal butterflies attracted to light.**

Images: C. Henshaw.



# Further effects (cont'd)

## b) Higher Order Consumers.

- Spiders, amphibians, reptiles, birds, bats and other small mammals all feed on insects.
- If insect numbers go down, so do the numbers higher order consumers.

# Further effects (cont'd)

- *The decline of insects and higher order consumers correlates negatively with the expansion of lighting over the past forty years.*
- *Light pollution sucks up insects as if it were a vacuum cleaner. (Eisenbeis, 2006).*

# Lighting also kills birds

Image Credit: Leonard J. Friedland.

- The opposing image shows birds that died as a result of colliding with brightly illuminated office and apartment buildings.
- Concerns about the problem is being raised by the Fatal Light Awareness Programme in Canada.



# Effect on Bats (1)

- Bats roost in places like church towers and steeples. Illuminating these structures at night with floodlighting disturbs their feeding and foraging cycles. It is a criminal offence in the UK to disturb bats.
- According to Jones, J., (2000), bats forage twice a night, after dusk and before dawn. Some species may benefit initially from insects attracted to lights, but the lighting will kill insects over the long term and the bats will have nothing to feed on.
- In Suffolk, several bat species declined after the installation of street lighting.
- Artificial lighting at night increases the chances of predation, as diurnal species such as kestrels have been seen hunting along illuminated motorways at night.

## Effect on Bats (2)

- **Illumination along the borders of woodland and river banks discourages bats from visiting their foraging areas where they find food.**
- **European studies have shown that continuous lighting along roads creates barriers which bats cannot cross. For example, Daubenton's bats move their flight paths to avoid street lamps. In Europe, in areas where there are foraging bats, stretches of road are left unlit to avoid isolation of bat colonies.**
- **If stretches of road were left unlit to prevent this from happening, it begs the question as to why it was necessary to illuminate the road in the first place.**



## **Effect on Bats (3)**

- **Street lights can kill as many as 150 insects per night and in large cities this will result in high rates of insect mortality.**
- **Bats will therefore not find enough to eat and may not build up enough reserves of fat to keep them going during the winter hibernation period.**
- **In the United States foraging bats have been seen hunting during the winter period, with no hope of finding anything to eat.**

## Effect on Bats (4)

- Reduced food intake will result in heightened immune deficiency in bats, rendering them more prone to opportunistic infections. Hibernating bats roost in crowded colonies containing large numbers of bats, enabling infections to spread rapidly.
- Outbreaks of White Nose Syndrome, caused by a fungus, *Pseudogymnoascus destructans*, has decimated bat colonies in the north eastern United States.
- Bats eat large numbers of mosquitoes, so reduced bat populations may result in increased numbers of mosquitoes and mosquito-borne infections in humans.

# White Nose Syndrome in North American Bats.

Credit: Nancy Heaslip, New York Department of Environmental Conservation.



# Effect on other Mammals (1)

- *In 2014 it was reported that light pollution adversely affected the reproductive cycle of the grey mouse lemur, *Microcebus murinus*, that lives in the forests of south western Madagascar.*
- *Experiments were carried out in which mouse lemurs were exposed to artificial lighting that mimicked street lighting, and it was found that their reproductive cycles were compromised causing them to become sexually active out of season.*

# Effect on other Mammals (2)

- *This was thought to be due to the effect on melatonin production, which only occurs during darkness.*
- *Melatonin is involved in regulating mammalian reproduction.*
- *Mouse lemurs breed during the long days of summer, and during winter, with its longer nights, melatonin supresses reproductive behaviour.*
- *However, if the animals are exposed to excessive amounts of light at night, this cycle is disrupted.*

# Effect on other Mammals (2)

- *Since both lemurs and humans are primates, this lead the investigators to speculate that chronic light exposure in humans could impact on human reproduction as well.*
- *Exposure to light at night in humans is known to affect menstrual cycles, reduced fertility, spontaneous abortions and premature births.*

# Effect on Migration Patterns (1)

- *Migration patterns in animals is now known to be severely compromised by excessive lighting in our cities.*
- *This is now well established in birds that are known to use starlight as well as the Earth's magnetic field to navigate.*
- *Birds can easily become confused by the bright lights of cities and awareness of this has been raised by the Fatal Light Awareness Programme in Canada.*
- *Birds are often confused by the lights of tall buildings during migrations, leading to many avian fatalities.*
- *Fledgling seabirds are now known to be fatally attracted to urban lighting on their first flights towards the sea.*

## Effect on Migration Patterns (2)

- *This has been demonstrated in Australia with short-tailed shearwaters, Ardenna tenuirostris, with Cory's shearwater, Calonectris diomedea, on the island of Tenerife in the Canary Islands, and Barau's Petrel, Pterodroma barau, on Reunion Island in the Indian Ocean.*
- *This mortality inevitably results in declines in the populations of these birds. The problem is obviously widespread and as seen in Canada affects many other bird species as well.*
- *Celestial navigation also occurs in insects. It has been reported that dung ball rolling behaviour in African dung beetles is influenced by the visibility of the Milky Way at night.*
- *The beetles are no longer able to navigate in straight lines when the sky is overcast. If dung beetles are now known to use the night sky to navigate, it is certain that similar behaviour will also occur in other insects.*
- *Since light pollution from cities drowns out the fainter stars and the Milky Way, such behaviour in insects is will inevitably be compromised, leading to their decline in those areas.*



# Effect on Migration Patterns (3)

Image Credit: Jim Richardson + F.L.A.P.



# Effect on Migration Patterns (4)

- *Light pollution could also affect the regeneration of tropical rain forests by disrupting the seed dispersal behaviour of fruit bats.*
- *In Costa Rica it was found that fruit bats avoided foraging in illuminated areas, thereby having a negative impact on ecosystems.*
- *Under dark conditions fruit bats would produce a copious rain of seeds that would help rain forests re-colonise land that had previously been cleared.*
- *The researchers therefore recommended that dark refuges connected by dark corridors be set up to reduce the impact of light pollution by enabling light-sensitive species such as bats to migrate from one sensitive area to another.*

# Effect on plants (1)

- *Declines in insects are serious because many of them are important as pollinators. A reduction in insect populations will mean a reduction in successful pollinations, leading further to a reduction in plant diversity (Henshaw, 1994 and Biesmeijer et al, 2006).*
- *This has likewise been reported by environmental organisations.*
- *Reduced biodiversity in plants may then backfire on insects as many of them are directly or indirectly dependent on them for food. Consequently their decline will accelerate.*
- *The rôle of insects as pollinators is very important in crop production, and their absence may jeopardise crops.*
- *As much as 35% of all crop production depends on pollinators of one kind or another - usually insects, but to a lesser extent birds and bats.*

## Effect on plants (2)

- *Light at Night can also affect germination, flowering and abscission cycles in plants by interfering with phytochrome production, thereby preventing plants from adjusting to the seasons.*
- *Phytochromes are plant hormones that govern photoperiodism in plants enabling them to measure the hours of darkness and anticipate when to bloom, produce seeds, or drop their leaves in autumn.*
- *Disruption of phytochrome production will therefore have serious implications for crop production, such as strawberry plants failing to bloom.*

## Effect on plants (3)

- *Deciduous trees exposed to artificial light tend to retain their leaves in winter.*
- *If normal photoperiodism is disrupted, then this will lead to further declines in plant diversity and concomitant effects on animals dependant on them for food. This could well include ourselves.*
- *Many animals are also dependant on trees for their natural habitat, so if trees are adversely affected they will have nowhere to live and consequently their numbers will decline.*
- *Budburst in deciduous trees in the U.K. is advanced by 7.5 days in illuminated areas and this may have further adverse effects on those animals dependent on them for food and habitation.*

# Effect on plants (3)

- *Photoperiodism in plants requires exposure to visible red light (625 to 760nm, and infra-red (760nm to 850nm). Artificial lighting, particularly towards the red end of the spectrum such as sodium lighting will therefore have an effect on photoperiodism in plants, including trees.*
- *Photosynthesis depends on shorter wavelength light (blue – 400 – 450nm and red – 625 – 700nm). Green light has little or no effect on plants as this is largely reflected by the green pigment chlorophyll.*
- *Artificial light is not intense enough to affect photosynthesis, but orange lighting from street lights extends day-length, affects flowering patterns, and extends the period of growth into winter when the plant can be damaged by frosts and low temperatures.*
- *Furthermore continuous lighting is more damaging than part-time lighting.*

# Climate Change (1)

- As quoted earlier, industry sources state that lighting accounts for 19% of all energy consumption, and in the Italian town of Certaldo, electricity consumption due to street lighting stands at 60%: (Fiaschi, et al, 2012).
- Whatever the true statistics may be, the fuel used to produce this energy will produce carbon dioxide that will contribute to climate change.
- Governments concerned about this issue can do no better than to insist that all unnecessary lighting is switched off. This is one of the simplest ways of reducing the problem.

# Climate Change (2)

- Though energy production from renewable sources (solar, wind, tides, etc) *may* help to reduce carbon dioxide emissions, *it will not solve the problem of light pollution.*
- *What people must realise is that light at night in itself is harmful to the environment.*
- It is expanding at a rate of 6% per annum as more communities in developing countries gain access to electricity (Hoelker et al, 2010). This trend must be reversed with immediate effect.



# **The Lighting Industry attempts to pander to environmental concerns.**

- **The lighting Industry continues to develop cheaper and more efficient forms of lighting.**
- **In energy terms this has benefits in that less energy is consumed.**
- **However if the new lights are cheaper, consumers may purchase more lights for the original price of one.**
- **This results in more light pollution and more ecological degradation.**

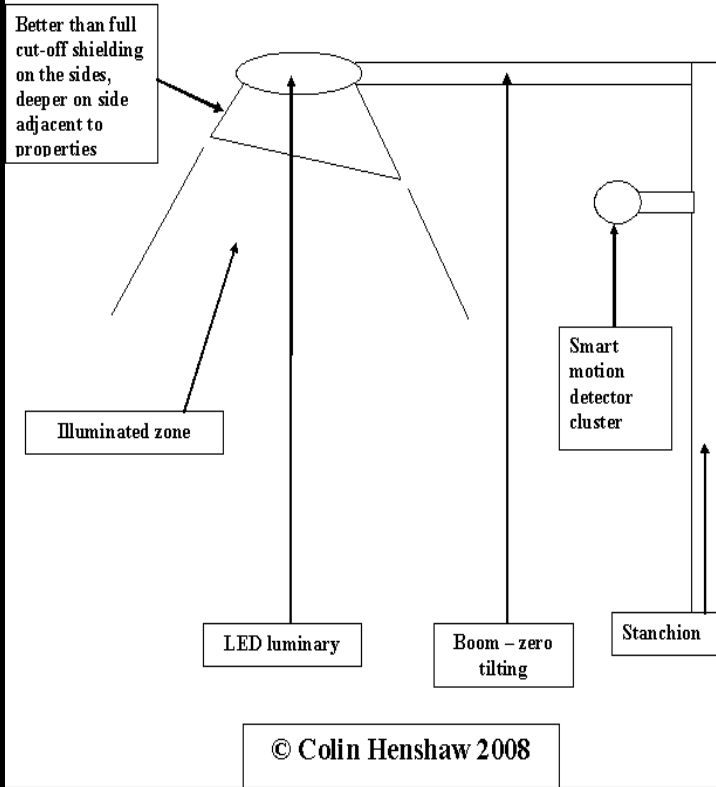
# Lighting technology (1)

- If lighting is deemed to be necessary, it should be designed in such a way as to minimise its impact on the environment:
- Adoption of 45° full cut-off lighting to minimise spillage out of the area intended to be lit.
- Motion operated in residential and suburban areas.

# Lighting Technology (2)

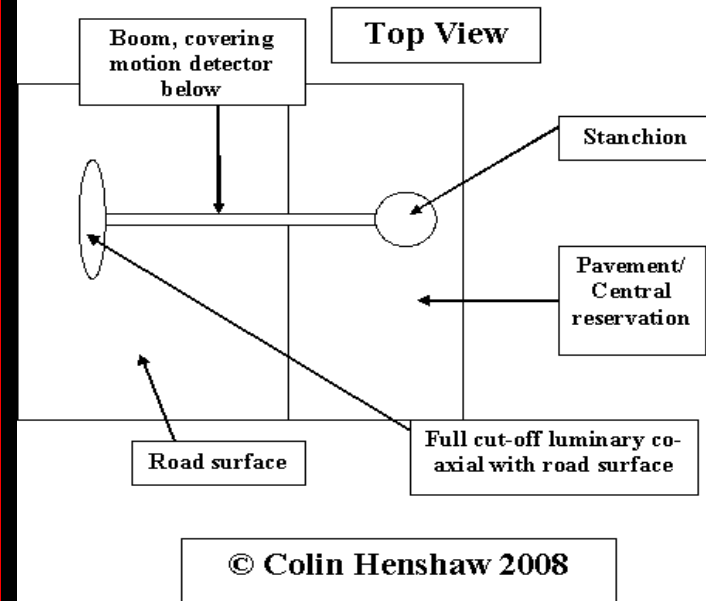
**Fig 1. Anti-Light Pollution Street Light suitable for Residential Areas.**

This light is motion operated so it only comes on when it is needed.



**Fig 2. Anti-Light Pollution Street Light suitable for Residential Areas.**

The luminary should be co-axial with the road, so that it throws an oval footprint along the road surface where it is needed. All conventional street lights throw an illuminated oval footprint perpendicular to the road, so they tend to illuminate properties behind the light where it is not wanted. Such lighting also illuminates the stanchion, scattering light away from the zone intended to be lit. The luminary is composed of LED's that can be motion operated.



# Major threats:

Image: : Greenshine New Energy Ltd., <http://www.streetlamp-solar.com/supera-series.html>

- **Overpopulation.** This is unsustainable and leads to increased urbanisation and energy abuse.
- **The optimum human carrying capacity of the Earth is about 2,500 million people.** There are 7,000 million people now so we have exceeded our carrying capacity by nearly 300%. 9,000 million by 2050....
- **Solar powered street lighting.** This can lead to the illumination of areas that otherwise would never have been lit, and will compromise ecosystems in those areas



# So what can be done? (1)

- The mitigation of the environmental effects of light at night requires a universal culture change in our attitudes towards outdoor lighting.
- What has been shown here demonstrates it is highly damaging.
- *Lighting should only be installed sparingly, on needs must basis, where needed, when needed, in the correct amounts and using appropriate smart lighting technology.*
- Most lighting at the moment does not meet these requirements. Lighting standards imposed by the lighting industry and municipalities are all wrong and need to take into consideration the needs of the environment.

# So what can be done? (2)

- We need to use less lighting, in order to conserve natural resources and protect the environment. *Darkness at night is normal.*
- Local authorities considering dimming would be better switching lights off altogether. Why dim lights when it is better to switch them off when they are not needed?
- Motion operated lighting and lighting curfews from 11.00p.m. till dawn need to be introduced in residential and suburban areas. Lighting in rural areas should be avoided unless there is absolutely no other alternative.
- LED Lighting can meet many of these requirements, provided low colour temperature (ideally 2000K and not exceeding 2700K) amber LED lights are installed to reduce the impact of blue component.

## So what can be done? (3)

- **Planners should consider alternatives to lighting to improve road safety. When all is said and done, cars have headlights.**
- **These include: cat's eyes, reflective signage and lane markers, LED road-studs, baffles or raised crash barriers on the central reservation of motorways, speed humps and speed limits on the approaches to recognised hazards, and smart road lighting as envisaged by Daan Roosgaarde.**
- **These methods (and others) obviate the need for lighting, especially in sensitive areas. They consume little or no energy and require little or no maintenance after installation. Conventional lighting systems may become obsolete.**
- **Pedestrians should wear bright clothing and carry torches at night to enable them to see and be seen.**
- **Forms of lighting that do not serve a useful purpose should be eliminated. If people will not self-regulate, then stringent legislation needs to be introduced.**

# Conclusions

- It has been demonstrated here that lighting has serious environmental implications, and is a contributor to climate change. One of the easiest ways to mitigate climate change is to eliminate unnecessary lighting.
- It is a green issue, so environmental organisations in addition to astronomers need to campaign against it. Though light pollution cannot be eliminated entirely, technology is now available that can mitigate its worst effects.
- Public outreach campaigns by environmentalists need to be pro-active in creating awareness of the problem amongst the general public, the lighting industry, commerce, industry, municipalities, sporting and artistic communities and any other parties that may be tempted to abuse light.
- Otherwise they will be considered as campaigns by a minor interest groups and may be construed as being a tyranny by a minority
- Thank you for your time and trouble.