

Light pollution and dark sky conservation

Table of contents

Light pollution and dark sky conservation	1
Introduction	2
Light emitting diodes (LEDs)	3
Impact of artificial light at night	5
Socioeconomic	6
Ecological	7
Physiological	7
Mitigating light pollution	8
Light pollution and policy	9
Further reading	10

Definitions.

- **Light pollution** is the brightening of the night sky, due to man-made lighting, and is especially significant in urbanised areas. Artificial light at night has a disruptive effect on the biological clocks of all living things and inhibits the observation of stars, planets, and other celestial objects.
- **Artificial light** refers to human-made light and can emanate from sources including fire, candlelight, gaslight, and electric lamps etc. One often refers to the latter when talking about light pollution.
- The **circadian rhythm** is a natural, internal process that responds to day and nighttime conditions and regulates the sleep-wake cycle, repeating every ~24 hours. It can refer to any physical, mental, and behavioural change that originates within humans and other organisms.
- A lamp's **colour temperature** is measured in degrees Kelvin (K), and shows how warm or cool a light is. Lamps with a colour temperature of less than 3,200 K are pinkish and considered warm. Lamps with a colour temperature greater than 4,000 K are bluish-white and considered cool.
- **Glare** is an intense and blinding light that reduces our ability to see.
- **Incandescent lamps** produce light by a filament being heated to a high temperature by electric current.
- **LED**: light emitting diode (a semiconductor diode which glows when a voltage is applied).
- **Skyglow** is a diffuse brightening of the night sky, caused by light from sources on the ground (not from light sources like the Moon). It is commonly found inside and surrounding built-up areas.

Relevance. Light pollution is very low in Namibia, providing a rich opportunity for tourists to enjoy stellar nightscapes that they are unlikely to experience at home. From the point of view of sustainable development and environmental conservation, it is important to create awareness about the detrimental impacts of light pollution, which may encourage tourists to reduce artificial lighting in their own communities.

Interesting facts and figures.

- 83% of the world's population live under light polluted skies.
- In the most populated places only a few stars may be visible to the naked eye at night, compared to several thousand in Dark Sky Oases.
- 30% of outdoor lighting in the US is wasted, costing \$3.3 billion a year.
- Satellites have measured a 49% increase in light emissions between 1992-2017. This figure is likely to be significantly higher, as satellites cannot detect the blue emissions from LEDs¹.
- When LEDs are used, they should have a colour temperature of less than 2700 Kelvin, for health and environmental reasons.
- When using light at night, ask yourself three questions:
 - Is it really necessary? If yes, where exactly is it needed and why?
 - Are the lights well shielded?
 - Can I use a timer or motion sensors to minimise unnecessary use?

Introduction

Life on Earth has lived and evolved without the presence of human-made light for billions of years. Humans, flora, and fauna operate on daily cycles of night and day – biodiversity depends on this balance in order to thrive. In only a few decades, artificial light at night has become a prominent source of pollution, harming the health and wellbeing of humans, disrupting entire ecosystems, and damaging our cultural heritage with the night sky.

In many countries, light pollution has been on the rise since the end of WWII, due to increased street lighting, commercial lighting (e.g. factories, ports, and sports facilities), and flood lighting for heritage buildings. Today, 83% of all people are living under light polluted skies (Fig. 1) and the Milky Way is entirely obscured for a third of the global population. The use of artificial night lighting shows no sign of slowing, increasing at a rate of 2% per year, twice the rate of population growth².

Some of the main arguments for using artificial lighting is the need to maintain safety and reduce crime. So far, there is little-to-no evidence that shows street lighting improves road safety. In fact, it may have the opposite effect: bright road lighting introduces glare and could

¹ <https://doi.org/10.3390/rs13163311>

² <https://www.science.org/doi/10.1126/sciadv.1701528>

decrease safety on the road, by temporarily impairing the vision of drivers, cyclists, pedestrians, and other road users. Other studies have struggled to find evidence that supports the belief that night-lighting reduces or prevents crime.

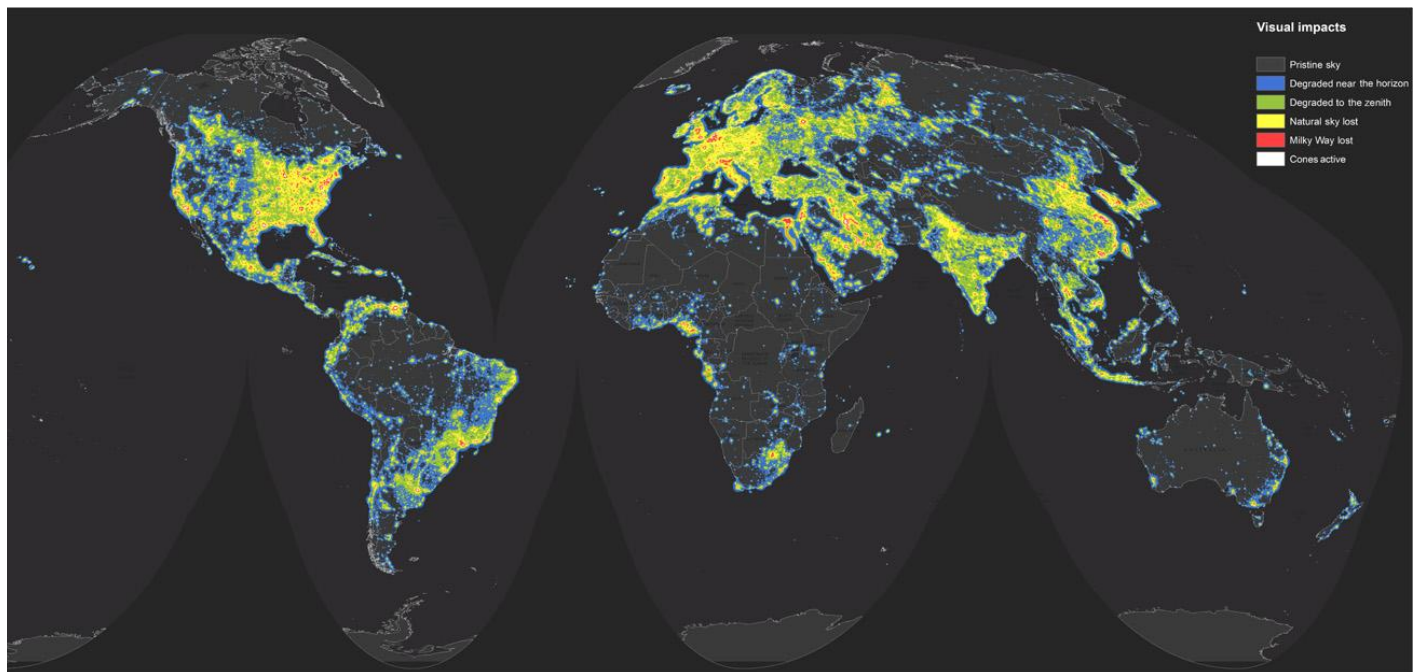


Fig. 1. Light pollution worldwide: in the most populated places only a few stars may be visible to the naked eye at night, compared to several thousand in Dark Sky Oases. Red/yellow show the most extreme levels, while grey/blue shows little-to-no light pollution. Credit: Falchi et al. (2016)³.

Wherever possible, the use of artificial light at night must be questioned and minimised, by considering when, where, and how lighting is being used. Reducing light pollution has additional benefits: it saves money and reduces carbon emissions. It is also relatively easy to reduce or eliminate light pollution, compared to other forms of pollution.

Light emitting diodes (LEDs)

In the past decade, light pollution has been made much worse, driven by a sharp uptake of light-emitting diodes (LEDs). For a long time, commercial lighting was largely inefficient – incandescent lamps, for example, convert less than 5% of their energy into visible light. So people have looked to LEDs, which use up to 80% less energy than incandescents, as an appealing energy efficient alternative and apparently environmentally friendly solution.

LEDs, however, are causing more harm than good – they are often high-intensity and poorly directed. LEDs also emit strong emission at blue wavelengths, higher than what we receive from the natural light of a sunset, which is devastating to the health of living things (Fig 2.). The blue

³ <https://www.science.org/doi/10.1126/sciadv.1600377>

light scatters high into the atmosphere – causing five times more skyglow than incandescents – and contributes to glare and light intrusion.

Not all LEDs are bad, however. When choosing an LED you can look at its colour temperature – the higher the temperature, the more blue light they emit. LEDs with a colour temperature of less than 2700 Kelvin give off a warm colour and are considered to be much safer to use: the lower the temperature the better.

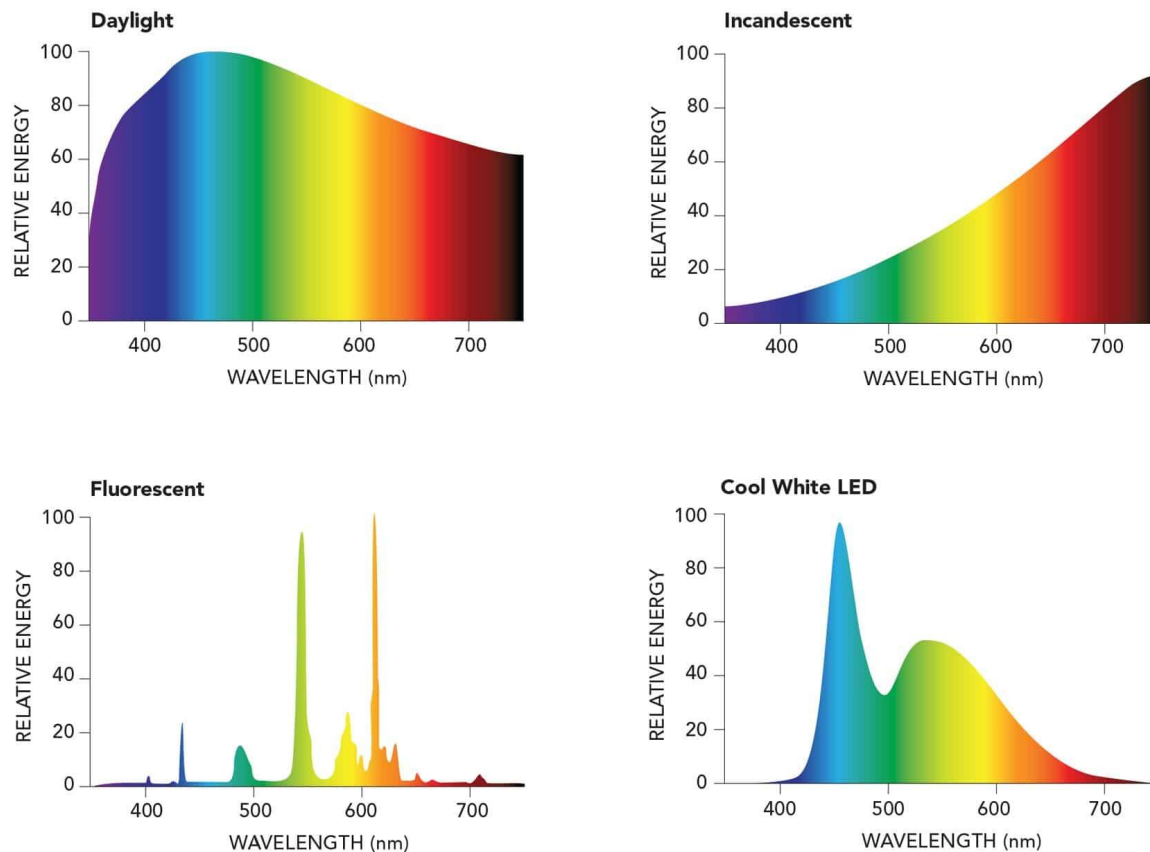


Fig 2. Spectral distribution of typical daylight, incandescent, fluorescent and cool white LED lamps. Credit: Healthe 2019.

Impact of artificial light at night

The impacts of artificial light at night can be summarised according to three main aspects: socioeconomic, ecological, and physiological (Fig 3). It's also interesting to explore light pollution in the context of the sustainable development goals, as portrayed in Fig 4.

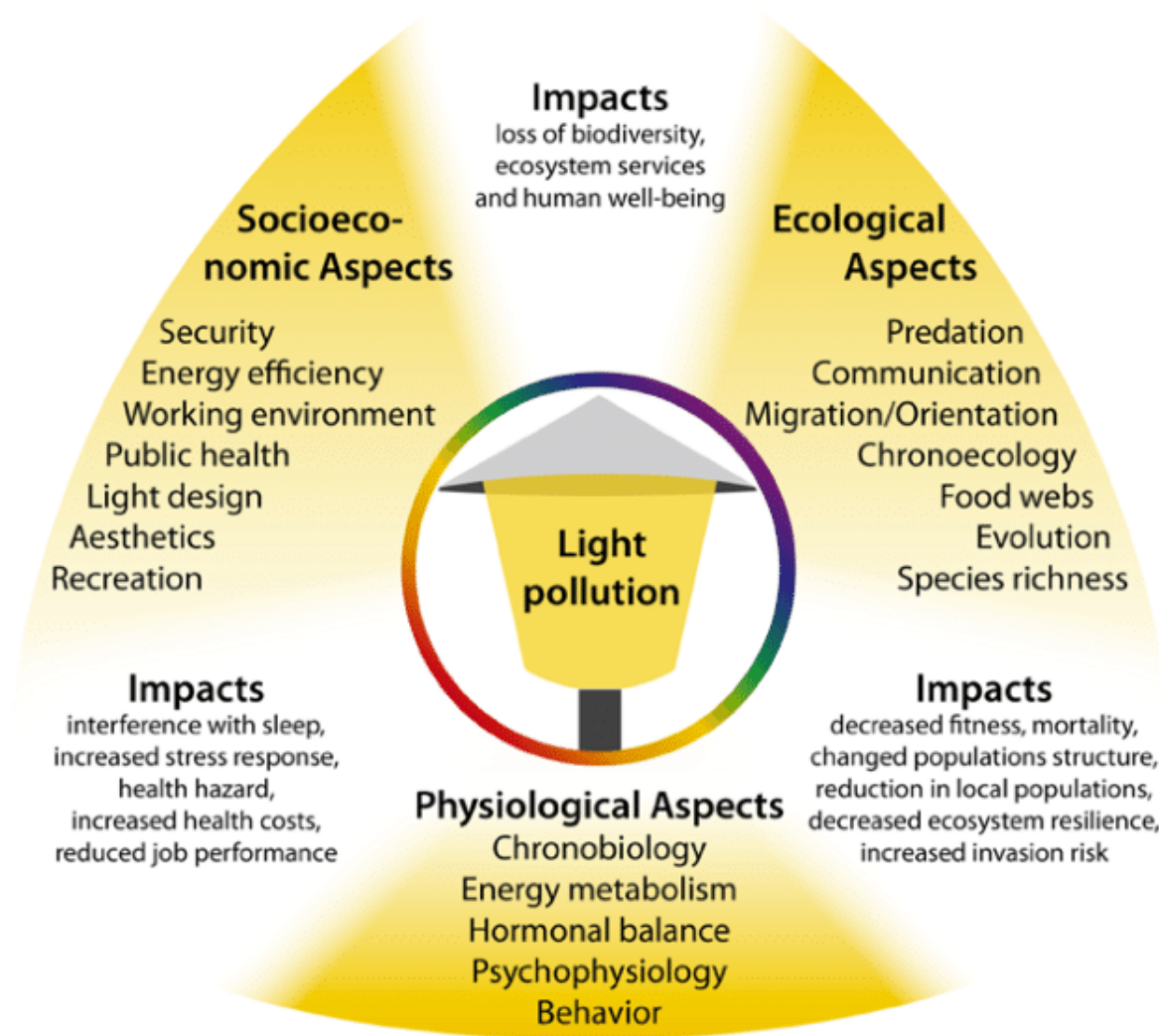


Fig. 3. Light pollution can be summarised by three main aspects: ecological, physiological, and socioeconomic. Credit: Hölker (2010)⁴.

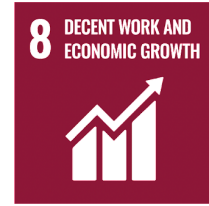
⁴ <http://www.ecologyandsociety.org/vol15/iss4/art13/>



Light pollution is detrimental to our health, meanwhile dark sky activities can promote good health and well-being.



DST brings ample opportunity for astronomy and light pollution education, both for locals and tourists.



Dark sky tourism creates jobs and opportunities for rural communities throughout the year.



DST promotes investment in infrastructure in rural areas and fosters innovation for the sharing of astronomy knowledge.



Studies have shown that anthropogenic light likely has a detrimental impact on seafloor ecosystems.



Light pollution harms many ecosystems, from disrupting the migration of birds to the hatching of sea turtles.

Fig. 4. Light pollution in the context of the sustainable development goals. Credit: UN.

Socioeconomic

When used inappropriately, nighttime lighting is a waste of money, energy and carbon emissions.

- In the USA, around 35% of light at night is wasted, amounting to \$3.3 billion, or 21 million tonnes of carbon dioxide per year. We would need to plant 875 million trees annually to offset the greenhouse gases produced by this superfluous light⁵.
- In the UK, local councils spent an estimated £613 million on street lighting in 2014-15⁶, accounting for 15-30% of a council's total carbon emissions.

On the other hand, the absence of light pollution offers many benefits. A dark, starry nightscape can offer greater well being, via improved life satisfaction and happiness⁷. Our view of the heavens is also deeply ingrained in our heritage: it embodies aesthetic, cultural, historical, inspirational, recreational, scientific, and spiritual values⁸.

The act of observing naked eye objects – stars, planets, meteors, comets, and even other galaxies – transcends borders and time. The study of celestial objects is both ancient and

⁵ darksky.org/light-pollution/energy-waste/

⁶

gov.uk/government/statistics/local-authority-revenue-expenditure-and-financing-england-2014-to-2015-budget

⁷ doi.org/10.1080/21550085.2021.1904496

⁸ doi.org/10.2753/JEI0021-3624440104

universal; astronomy has cross-cultural appeal and has been a globally inclusive scientific endeavour for centuries. It is also important to note that light pollution is not only ground-based – mega-constellations contribute to artificial night sky brightness and the loss of our cultural heritage from above.

Ecological

Artificial light at night interferes with the circadian rhythms of living things (Fig. 4). Nocturnal species are particularly affected – around 30% of vertebrates and more than 60% of invertebrates are nocturnal. Light pollution disrupts the movements of insects, how they forage, reproduce and pollinate, and drives their decline. This then threatens pollination networks and negatively impacts plant reproduction. Light pollution alters the migration patterns of birds and the behaviours of bats, and disorients dung beetles. It also affects navigation, reproduction habits, predator-prey interactions, and communication of marine species, including sea turtles – the list goes on and on. These impacts are not only lethal to individual species, but inevitably damage ecosystems overall. Thus, light pollution is a major risk factor for biodiversity and consequently, the global food supply.

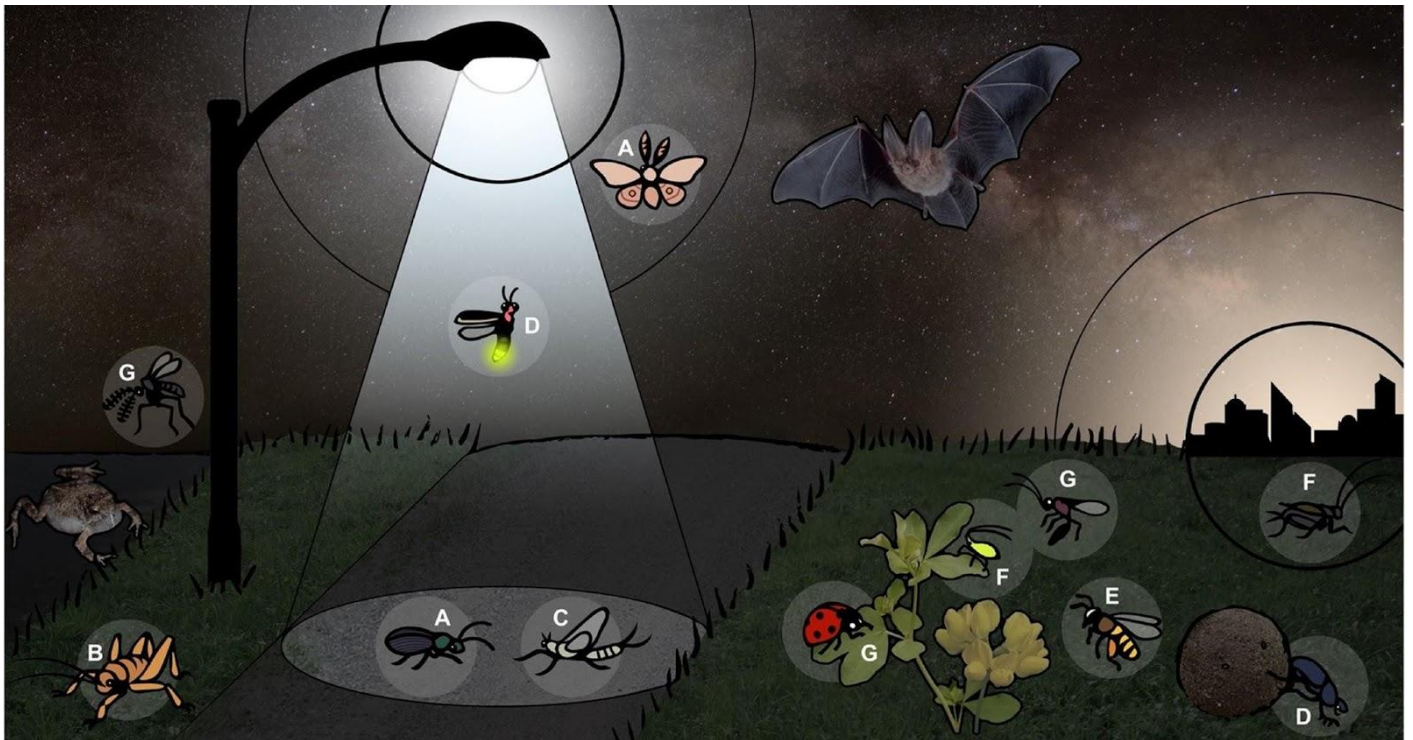


Fig. 4. Light pollution affects all living things. Credit: Owens et al. 2020.

Physiological

For humans (and many other vertebrates), the presence of blue light suppresses the production of melatonin, which plays a crucial role in regulating circadian rhythms. This means that

melatonin tells the body that it's time to sleep, the hormone is also important for starting to turn on the body's repair mechanisms.

When exposed to this blue light outside of daytime hours, research has already found a wide array of detrimental effects on our human physiology. This includes the disruption of sleep cycles, metabolism, reproduction, blood pressure, emotional balance, the immune system and cell renewal processes. Other research goes on to suggest that exposure to artificial light at night can lead to sleep disorders, depression, obesity and the progression of some cancers. In extreme cases, excessively bright blue light can also cause retinal damage.

Mitigating light pollution

There are five things to consider when trying to reduce light pollution (nicely depicted in Figs 5 and 6):

1. Is the use of light in a particular location absolutely necessary?
2. If necessary, light should be shielded so that it is directed only where it is needed.
3. Lighting should be as dim as possible.
4. Lighting should only be on when it is needed (by using timers, or smart lighting such as motion sensors).
5. Lighting should use warmer colours (i.e. low colour temperatures less than 2,700 K).



Fig. 5. Five principles for responsible outdoor lighting. Credit: Illuminating Engineering Society, International Dark Sky Association.

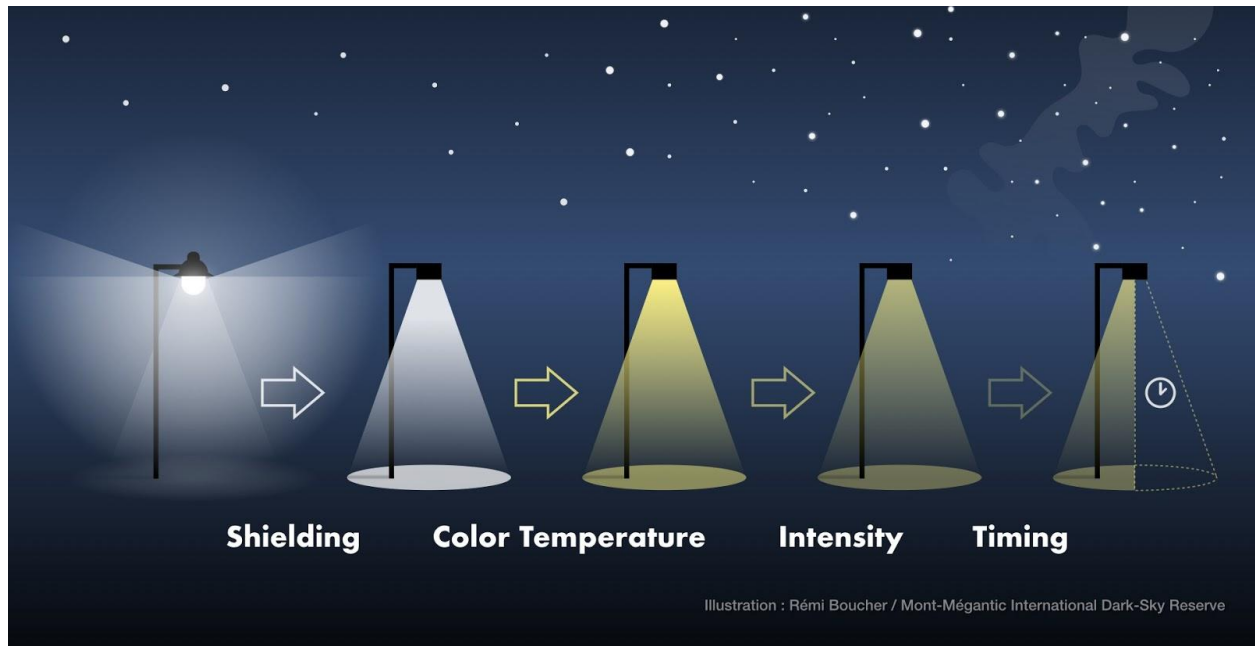


Fig. 6. Illustration showing how light pollution can be minimised with shielding, lower colour temperature and intensity, and appropriate timing. Credit: Rémi Boucher / Mont-Mégantic International Dark-Sky Reserve.

Light pollution and policy

If light pollution is so bad, then what are governments and policymakers doing about it? So far, a handful of countries have noticed the need to introduce light pollution legislation, which has resulted in the creation of lighting ordinances or bye-laws.

In France, for example, the law features a curfew on outdoor lighting; encourages the use of smart technology like motion sensors; limits upward light and glare; sets thresholds on the use of LEDs above 2400, 2700, or 3000 K (location dependant); restricts the lumen levels of installations; and prohibits light trespass, the use of skybeams, and night lighting over bodies of water⁹. Liechtenstein, South Korea and Mexico also have laws on light pollution.

There's still a long way to go, and to speed this process up, people can put pressure on the government and local establishments to act, by advocating for darker skies. Awareness can be raised further by incorporating light pollution topics into school curricula. Many different stakeholders should be brought together to exchange knowledge, such as: local councillors, teachers, the police, developers, planners, tourism bodies, conservationists, ...

Moreover, clear communication is needed to overcome misinformed ideas about artificial light at night. One of the main arguments against reducing nighttime lighting is that it helps to prevent crime or increases safety on the roads – but these are great misnomers. Studies on light

⁹ darksky.org/france-light-pollution-law-2018/

pollution in the UK and Switzerland found no relationship between no or lower illumination and crime rates^{10,11}. Both works similarly found no relationship between the number of traffic collisions and darkness. In contrast, another study found an increase in road accidents with street lighting in the city of Birmingham¹². In all, healthy lighting design is an important ethical issue that the general public deserve to know about, so that they can be empowered to act.

Further reading

- [Dark and Quiet Skies for Science and Society – Report and recommendations](#)
- [Light Pollution A Global Discussion 2018](#)

¹⁰ <http://dx.doi.org/10.1136/jech-2015-206012>

¹¹ <https://doi.org/10.1016/j.envsci.2018.07.011>

¹² <http://dx.doi.org/10.1136/jech-2019-212208>