Natural Devon
Devon Local Nature Partnership

A simple guide to light, lighting and how to avoid environmental impacts

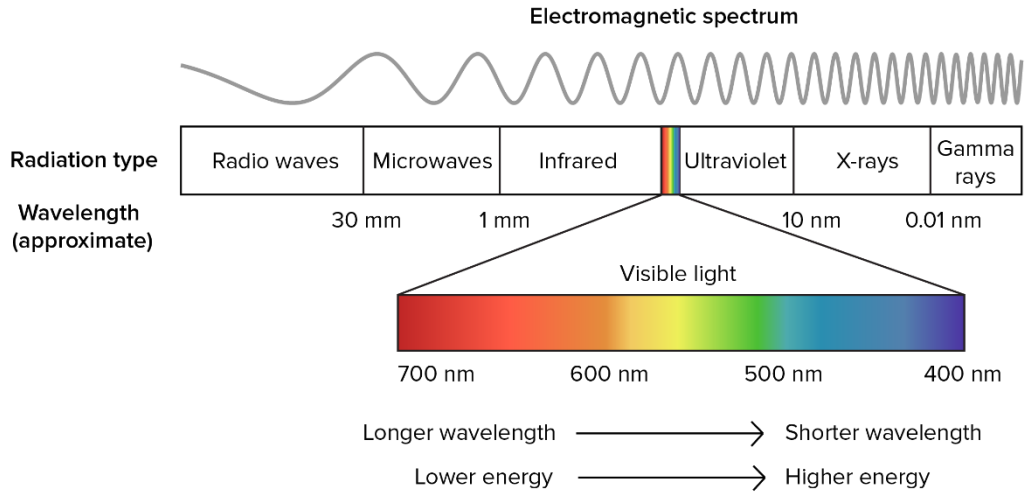
1. What is light and how does it help us to see?

Energy waves

Simplistically, light is waves (think of the sea!) of energy.

Natural light is largely a result of the energy emitted by the sun. This energy consists of waves of particles. No-one seems to be exactly sure what these particles are, other than being very (very) small. The particles are known as photons and the waves that they create are known as electromagnetic radiation.

These waves of energy vary hugely – see the diagram below. At one end of the spectrum are very long radio waves with low energy. At the other end of the spectrum there are short waves of energy (gamma rays) with very high energy. The wavelengths are measured in nano-metres (nm). This spectrum of waves is known the electromagnetic spectrum. Without these waves we would be cold and dark!



How do these waves help humans to see?

Most of the waves in the electromagnetic spectrum are invisible to humans. However, our eyes and brains work together to allow us to see waves from a tiny part of the spectrum when it is radiated from objects, luminance. This tiny part of the spectrum is known as visible light. Each wavelength of visible light appears to us as a different colour. As shown above the wavelength of visible light ranges from 700nm to 400nm. and appears as a spectrum from red to blue. We have probably

adapted to see this range of waves because they are the only ones that travel well through water, which is where our eyes first evolved millions of years ago.

Human eyes contain rods and cones. The rods only see in black, white and grey. Our cones detect colour but only function if triggered by visible waves with enough energy. The more energy the waves have the brighter the colour we see. You can test this out by taking a colourful or book or object into a dark room, everything should appear as a different type of grey as only your rods will be working

When waves hit an object, some are absorbed (heating the object) and others are radiated. Different objects contain different pigments which absorb different wavelengths. The radiated visible waves hit our eyes allowing us to see the object.

A red t-shirt absorbs all waves other than 700nm which it radiates. These 700nm waves hit our eyes and we see a red t-shirt. A t-shirt that radiates all visible light looks white (and keeps us cooler!). A t-shirt that absorbs all visible light looks black (and heats us up!)

Our eyes and brains have evolved to only use the 'visible' part of the spectrum to allow us to see. However, we are developing the technology to 'see' other wavelengths of light. All objects emit infrared radiation and we can use special cameras to convert infrared radiation into an image we can see.

Electromagnetic radiation with a shorter wavelength than visible light has more energy which is why it can damage human cells e.g. too much exposure to ultraviolet radiation from the sun can lead to skin cancer.

How do other species see?

Animals all have different eyes and brains and therefore all see the world in VERY different ways. We can try and make predictions about how different species see based on our knowledge of their rods and cones. However, we can't be certain as it is impossible to know how eyes and brains work together to create an image…….

Humans have three types of cones (red, green and blue) which allow us to see around 1 million colours. Other mammals see fewer colours e.g. dogs only have yellow and blue cones and can only see 10,000 colours. However, most other mammals have more rods than us and so are far better at distinguishing between objects in the dark. Many mammals also have a reflective layer in their eyes called a tapetum. This reflects photons of light around the eye and allows them to see more in the dark.

Insects have an extra cone that **allows them to see using ultra-violet wavelengths**. Many flowers have ultraviolet pigments to attract pollinating insects and guide them to the pollen and nectar. Many species of bird, just

The tapetum in the eyes of this cat are reflecting light to help it see better in the dark. This is what we see when a bright light is shone into the eyes of a mammal.

like insects can also see in ultraviolet and some bird plumages reflect UV light allowing them to signal to each other in ways we cannot see. For more information see our *Wildlife and Artificial Lighting* document.

Important! All species see very differently to us and to each other and all will therefore react differently if artificial lighting is introduced.

2.Light pollution

Light pollution from artificial lighting can impact our health, disrupt wildlife (see above), disturb tranquillity and is a waste of energy. Light pollution is increasing around the world and in the UK 96% of the land surface is affected by light pollution with 61% of people living in severely light polluted areas (defined as being able to see fewer than ten stars). You can see what light pollution is like in your area using this tool created by the countryside charity https://www.nightblight.cpre.org.uk/maps/

Light pollution can include:

1. Light Trespass – This is when lighting enters an area where it is not wanted for example if your neighbour's security lighting shines into your house. This is also called nuisance lighting.
2. Glare - A negative property of light caused by bright objects against a dark background or by very reflective objects. Lighting design has to meet national standards to minimise glare. Blue lighting is also found to cause more glare than warmer lighting.
3. Sky glow – Brightening of the night sky by artificial light. Blue light contributes more to sky glow than red light as the longer wavelengths of red light are more likely to scatter and be depleted over large distances.
4. Impacts on wildlife - Impacts of artificial lighting on wildlife are complex but on the whole artificial lighting has a negative impact on wildlife and should be avoided as much as possible. For more information see our short *Wildlife and Artificial Lighting guide*.

In summary to avoid impacts on the environment we should:

- **keep areas as dark as possible**
- **avoid using wavelengths from the UV/blue end of the spectrum – ideally 2700K or less**

See the final section for a list of actions you can take to reduce impacts.

3.Some useful lighting terms

For more technical terms see our *Lighting Glossary*

Brightness (the intensity of a light)

Lumen (lm) or luminous flux - the total amount of light that is radiated from a source. The higher the lumens the brighter the light source.

Lux (lx) - brightness at a certain location (= lumens per square meter). As you move away from the source of the light the brightness (and therefore lux value) will reduce. See the table below for an indication of different lux values in different situations (source: *Guidance Note 08/18 Bats and artificial lighting in the UK)*

Chart of example lux levels for reference

Lighting conditions	Lux level	Lighting conditions	Lux level
British summer sunshine	50,000	Typical side road lighting	5
Overcast sky	5,000	Minimum security lighting	2
Well-lit office	500	Twilight	1
Minimum for easy reading	300	Clear full moon	0.25 to <1
Passageway or outside working area	50	Typical moonlight/cloudy sky	0.1
Good main road lighting	5-20	Typical starlight	0.001
Sunset	10	Poor starlight	0.0001

Source: IPCCTV specialists use-IP Ltd

Colour

Colour Temperature - A numerical measure for the 'warmth' of light measured in Kelvins (K). The value relates to the colour of a piece of steel when heated to a particular temperature e.g. white/blue light has a colour temperature of 5000K as this is the temperature that steel turns to white/blue.

Light source/Colour	Colour Temperature (K)
Candle	1850
Sunrise	2300
Incandescent bulb	2700
Warm orange/yellow light	<3000
White light	3500
Flourescent bulb	4100
Midday sun	5500
Overcast Day	6500

A range of lights from a warm 'orange' colour temperature of 1000K at the Left-hand side to 10,000K 'blue' lighting at the right-hand side.

Colour rendition scores – A measure of the ability to see the 'true colours' of an object compared to in natural white light. > 75% is considered as excellent, below 55% is poor. Light sources which emit more wavelengths (and are therefore closer to natural white light) provide better colour rendition. It has been suggested that people feel safer when lighting provides high colour rendition.

Efficiency

Efficacy - the ability of a lamp to convert electrical energy into light measured as lumens per watt. Lamps with higher efficacy use less energy to illuminate a space.

Other

Luminaires - The external lamp housing designed to direct light to desired locations and reduce light trespass. A luminaire is designed with a system of reflectors and refractors to divert the light out of the lamp, and lenses and louvres to shield the direct source of light and reduce glare.

4. Types of artificial light – pros and cons

Low Pressure Sodium (LPS/SOX). The oldest type of streetlighting with continued widespread use. Production has however stopped.

Pros – no UV is emitted which is good for wildlife. High efficacy of 180 lumens per watt (lmW^{-1})

Cons - Only one wavelength of light is emitted (589nm - orange) resulting in low colour rendition. The lamps are often large making it difficult to direct light. Light isn't instant (they must warm up).

High Pressure Sodium (HPS/SON). Mainly used for streetlighting.

Pros - Emit a broader spectrum of light than SOX giving a pink/yellow colour and so have better colour rendition than LPS. They are smaller than SOX so the light can be more easily directed

Cons: Emit some UV radiation, approximately 0.3% of the total light. Less efficient than HPS 140lmw^{-1} and Light isn't instant (they have to warm up).

Metal Halide Mainly used in warehouses, sports centres and indoor car parks as well as some newer streetlights

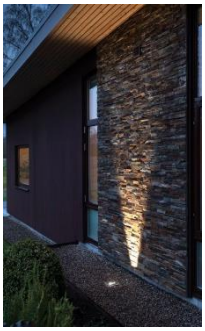
Pros – Emit a large spectrum of light and so have high colour rendition. Small lamps allowing light to be directed where it is wanted. Cheaper than LEDs.

Cons – Emit more UV than HPS (2-7% of total light). Light isn't instant (they have to warm up) Lower wattage lamps have a short lifespan lasting only 7,500 hours. The colour may vary from lamp to lamp and may shift over the life of the lamp and during dimming. They also contain mercury which is toxic if not disposed of properly.

Light Emitting Diode (LED) – Now used almost everywhere e.g. streetlighting, security lighting, homes & gardens, offices, sports pitches, flood lighting.

Pros– LEDs can be manufactured to emit any wavelength or combination of wavelengths in the visible range. The first LED streetlights installed in the UK emitted a white/blue light at 5000K. However, this was too 'cold' for the public and so 'warmer lights' are now often being installed, reducing blue/UV wavelength emissions but increasing costs. LEDs generally have a narrow beam of light so there is less unwanted light spill. LEDs produce instant light, are very efficient and have a longer lifespan than sodium and metal halide lamps.

Cons - LEDs are much more expensive than other types of lighting and they still emit some UV light particularly when the light has a higher colour temperature.



The images above are all examples of commercially available garden lights but these LEDs all direct at least part of the light upwards. This may contribute to skyglow, a type of light pollution. It would be better to have lighting that is directed downwards and, on a timer, with motion sensors so the lamp is only on when required.

Compact Fluorescent (CFL) – Generally used indoors and being used to replace filament light bulbs (incandescent lighting).

Pros - CFLs have a high efficiency, emit a wide range of wavelengths and therefore high colour rendition.

Cons – emit a small UV component of 0.1-1%. Whilst this has less effect on wildlife (as they are used indoors) it can still be disruptive to human health.

Phased out lighting – Although no longer produced some of the following may still be found as outdoor lighting and in buildings: Incandescent lamps (filament light bulbs), Tungsten Halogen, White high-pressure Sodium and Mercury lamps.

What can we do to reduce adverse impacts of artificial lighting?

1. **Avoid using lighting**! Artificial light is hugely beneficial in some situations. However, we should always think twice as to whether it is actually essential. If light really can't be avoided, then we should……

2. **Reduce light spill.** Design lighting to minimise light spill into areas where it isn't required e.g. through the design of the light fitting, use of walls / fences / dense vegetation to block light or shutting curtains at night.

3. **Ensure that lights are only on when required.** Use motion sensors, timers for street lighting or just switch off lights that aren't needed.

4. **Reduce brightness**. Lighting should only be bright enough to fulfil its function. Reduce brightness through choosing bulbs with lower lumens. If you are trying to keep an area dark for wildlife such as a dark corridor the light levels entering this habitat should not be greater than the normal night light levels or 0.4 lux vertically and 0.2 lux horizontally (source: *Guidance Note 08/18 Bats and artificial lighting in the UK)*

5. **Use warm lighting**. Where possible use warm LED lighting of 2700K or less to reduce the blue/UV component. Warmer light reduces impacts on wildlife, human health and sky glow. (source: *Guidance Note 08/18 Bats and artificial lighting in the UK)*

Footnote: This report has been pulled together for the LNP by Katy Ross and Sarah Jennings – who are definitely not lighting specialists. If there are any errors or omissions please email nature@devon.gov.uk to let us know.

Further Sources of Information

A review of the impacts of artificial light on invertebrates
British Standards – Design of Road Lighting
British Standards – Road lighting performance requirements
Commission for Dark Skies - Blinded by the light
Commission for Dark Skies – Good lighting guide
Getting Light right – Layman's guide to domestic security lighting

Guidance Note 1 for the reduction of obtrusive light 2020
Guidance Note 8 Bats and artificial lighting in the UK
Guidance note 9 Domestic exterior lighting: getting it right
International Dark-Sky Association - Visibility, Environmental, and Astronomical issues associated with blue-rich white outdoor lighting
Introduction to light and lighting
Protecting bats in waterside developments
The Countryside Charity – Mapping England's light pollution and dark skies
The Countryside Charity – Shedding Light
The Countryside Charity – Shedding Light a summary