

House of Lords Science and Technology Committee inquiry into the effects of artificial light and noise on human health

Call for evidence

Submission by the charity LightAware

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Summary

About LightAware

This response to the call for evidence by the House of Lords Inquiry into the effects of artificial light and noise on human health has been prepared by LightAware, a registered charity, SC046160 (www.lightaware.org).

LightAware was founded in 2015 to respond to the needs of those whose lives and health have been profoundly affected by the ban on incandescent lighting and the introduction of LED technology. LightAware's charitable objectives are:

- To raise awareness about the effects of artificial lighting on human health and wellbeing.
- To stimulate discussion and investigation into the effects of artificial lighting on human health and wellbeing.
- To promote equality and diversity through encouraging provision of access to civic life for those excluded by sensitivity to artificial lighting.

LightAware has recently published 'The story so far' which sets out what we do and the history of the charity.

About light-disability and light-sensitivity

Many health conditions have some form of sensitivity to light as a recognised medical symptom. These conditions include lupus, autism, migraine, ME and a range of other skin and neurological conditions. People with light sensitivity as a symptom can react to a range of different types of light. Some react to sunlight, some to UV, and some to specific types of artificial light, such as certain kinds of LEDs. In some cases people may react to all LEDs.

In addition there is another group of people who have had no previous health issues who start to have health problems when they are exposed to new forms of lighting. Symptoms include eye pain, agonising headaches, skin burning and rashes, dizziness, fainting and vomiting.

For both groups, reactions can be extremely severe and debilitating,

Sensitivity to LEDs has been recognised by the EU and subsequently by the UK Government in the Eco-Design Regulations (SI 1095/2021), which list photosensitivity as a reason for continued access to non-LED lighting for domestic use.

For some sufferers, the severity of their physical reactions to LED lighting means they have to avoid even minimal exposure and the adverse impact on their day-to-day life is extreme and long-lasting, thus reaching the threshold to count as a disability under the Equality Act.

They become unable to access much of normal life, including places of employment, recreation, worship, education and healthcare. In some cases, they can no longer access

the streets around their home due to the installation of new streetlighting or external LED lighting or ad-boards. Some light-disabled people are, in effect, in permanent lockdown. This may result in devastating social exclusion with serious consequences for their mental and physical health. We have included a selection of light-sensitive individuals' experience of the effects on their health of LED street lighting at Appendix 1, drawn from LightAware's Streetlighting Survey carried out in 2020. In addition, a series of case studies of the impact of poor-quality lighting on light disabled individuals is on our website at <https://lightaware.org/2018039-lightaware-case-studies/>

About our response

Because the nature and focus of our charity is about the health impacts of lighting, we are only competent to respond to the request about the effects of artificial light on human health. We do not have the knowledge or expertise to respond to questions about noise pollution.

Because our response is quite extensive, we have provided a summary of our response to the questions in the call for evidence. To assist the committee, we have structured the summary and detailed response using the questions asked by the committee as headings for our evidence.

If requested, LightAware would be pleased to provide oral evidence to the Committee.

Answers to questions in the call for evidence

1. What is the state of the evidence base regarding the causes and impacts of light pollution in the UK as it relates to human health?

What are the mechanisms by which light pollution has an impact on human health? What are the negative impacts it can have?

The main mechanisms by which external LED light pollution has adverse impacts on human health are associated with:

- **Extreme brightness** (high luminance) of exposed LED chips commonly used in external lighting. This causes glare leading to eye pain for some and headache and migraine for others. This is exacerbated because unlike other lighting, which obeys the inverse square law – if you are twice as far away the beam is only a quarter as bright – LEDs work differently. LED light intensity falls off more slowly making them blinding over longer distances.
- **Flicker** – although LED lighting does not need to flicker (and most street lighting is flicker free) some external LED light sources flicker badly – these can be easily identified using the video function of a mobile phone on a slow-motion setting. Flicker causes headaches and migraines and leads to stress and discomfort for some people on the autistic spectrum.
- **Spectrum** - a spike at the blue wavelength, common to many external LEDs, which disrupts circadian rhythms by suppressing the sleep hormone melatonin. Blue light also causes adverse health impacts in some people, including some suffering from

lupus and from various skin conditions. In addition a portion of the blue light spectrum has been shown to trigger migraines and cause discomfort in people with this condition.¹

An estimate of the number of light sensitive people in the UK was made in 2012 by the Spectrum Alliance for light-sensitivity, a grouping of UK charities supporting medical conditions where sensitivity to some forms of light is a recognised symptom. They estimated that around 2 million people (3.25 per cent of the UK population) suffered adverse health effects due to compact fluorescent lighting. Although fewer people are likely to be affected by LED lighting, it is likely to be of a similar order of magnitude as the main drivers of light-sensitivity, such as flicker, glare and spectral effects are similar.

There are also a smaller number of people who suffer more severe symptoms, such as disabling migraines, seizures and severe skin conditions who are effectively light-disabled. More research is required to establish the reasons for such hypersensitivity to LED light pollution.

Although the EU's SCHEER report concluded "there is no evidence of direct adverse health effects from LEDs in normal use by the general population", this conclusion was disingenuous in that it excluded children, older people and light sensitive individuals from the "general population". Furthermore, under the heading 'vulnerable populations' it concluded that "Children have a higher sensitivity to blue light and although emissions may not be harmful, blue LEDs may be very dazzling for young children. Older people may experience more problems with glare". In addition, blue rich LED street lights are a powerful disruptor of people's circadian rhythms which can cause disturbed sleep and a large number of other health impacts. Therefore light pollution has impacts on everyone, although to different degrees:

- A small number of people are light-disabled.
- Up to 3 per cent of the population are light-sensitive and can suffer illness and social exclusion.
- One third of the population are children or older people. Children are very sensitive to blue light from LEDs and older people have more difficulty seeing because of light scattering within the eye.
- The entire population may have their circadian rhythms affected by white/blue external LEDs.^{2 3}

¹ American Medical Association. 2016. Human and environmental effects of light emitting diode (LED) community lighting. Report of the Council on Science and Public Health. Chicago (IL): American Medical Association

² Scientific Committee on Health, Environmental and Emerging Risks (SCHEER), Opinion on Potential risks to human health of Light Emitting Diodes (LEDs), European Union, 2018.

³ 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) April 2019.

What are the primary sources of light pollution ...?

While people can, to some extent, choose the type of lighting they have in their homes (The EU and UK Government have recognised this by including an exemption in legislation that banned all non-LED lighting), they have little or no choice about external lighting. People have contacted LightAware to complain about the following sources of light pollution (most common first):

- LED street lighting
- LED advertising screens
- LED vehicle headlights
- LED shop and garage lighting
- LED traffic lights and other LED road signs

Most councils introduced LED street lighting without consultation or considering its impact on public health and the environment. Research undertaken by LightAware based on a survey of over 120 councils found that although over 97 per cent of councils have installed LED street lighting only 30 per cent consulted their residents beforehand and less than half piloted its introduction.

Very few councils assessed the potential impacts on their residents. Only 17 per cent conducted a Health Impact Assessment, 22 per cent an Environmental Impact Assessment, 32 per cent an Equality Impact Assessment and 21 per cent a Disability Impact Assessment

In most cases, councils installed blue light rich LEDs despite the prior publication of scientific reports and procurement guidance by the EU and other health agencies warning of their adverse health and environmental impacts. Over half of councils (55 per cent) use solely LEDs with a colour temperature of 4000K or above, which have the greatest negative impact on human health and the environment. These make up around three-quarters of street lighting in the UK. Only 5 per cent were under 3000K.⁴

LED vehicle headlights are particularly problematic. Light is not distributed evenly across the headlight's beam but is concentrated in the centre (on the axis). This means that vehicle headlights that appear dimmed on approach can suddenly become blinding if the centre of the beam shines directly into a driver's eyes, for example when a vehicle travels over the brow of a hill, round a bend, or over a bump. Research published by the RAC in March 2022 found 89 per cent of drivers think that some or most vehicle headlights on the UK's roads are too bright with 88 per cent saying they get dazzled by them while driving. The problem is getting worse with 63 per cent saying it's happening more often than a year or two ago and 64 per cent thinking they risk causing other drivers to have collisions.⁵

⁴ A bright idea? Adverse health, social and environmental impacts associated with LED street lighting, LightAware, www.lightaware.org, February 2021

⁵ <https://media.rac.co.uk/pressreleases/blinded-by-the-lights-nearly-one-in-four-drivers-think-most-car-headlights-are-too-bright-3166996>

Is there evidence that light pollution is worsening ...?

There is a considerable amount of evidence from remote sensing satellites that light pollution is getting worse. Around 7% of the land in Europe suffers from light pollution levels that are high enough to prevent viewing of the Milky Way but unfortunately around 60% of the European population live in these polluted areas.⁶

A significant amount of light pollution is being missed as lighting installations shift to LED. This is because, unlike traditional sodium lamps, LED emits a significant portion of its light output in the 400-500nm range. Unfortunately, the sensitivity of the satellite mounted VIIRS DNB (Visible Infrared Imaging Radiometer Suite Day Night Band) sensor used to measure light pollution is only useful between 500 and 900nm. So one consequence of a shift to more energy efficient, LED based street lighting could be that there is a perceived drop in light pollution levels measured by VIIRS DNB that may or may not be true.^{7 8}

How reliable is our evidence base for these impacts ...?

The long-term impact of external LED lighting on the health of the general population is untested. However, several challenges are becoming apparent, including significant negative impacts on the health and well-being of light-disabled and light-sensitive individuals. Surveys of drivers by the RAC and AA drivers show that most drivers believe road safety is being compromised by excessive glare from LED vehicle headlights.

LightAware believe that the introduction of external LED lighting in the UK, particularly LED street lighting has been rushed through without an adequate consideration of the long-term effect of the resulting light pollution on people's health. The 2017 Annual Report of the Chief Medical Officer supports this view.⁹

Does the UK have a sufficient research base ...?

There is some research undertaken in the UK, for example Professor Arnold Wilkins at the University of Essex has undertaken a considerable amount of research into the impact of flicker on headache and migraine, both from fluorescent and LED lighting. This demonstrates that LED and CFL flicker is a major cause of migraine in susceptible individuals.

However, LEDs are a much newer technology and evidence on the health impacts caused by their unusually high glare and non-uniform spectrum is needed. This was recognised by SCHHER report which concluded that "Since the use of LED technology is still evolving,

⁶ Revision of the EU Green Public Procurement Criteria for Road Lighting and traffic signals, European Union, 2019.

⁷ First Estimation of Global Trends in Nocturnal Power Emissions Reveals Acceleration of Light Pollution Remote Sens. 2021, 13(16), 3311; <https://doi.org/10.3390/rs13163311>

⁸ Artificially lit surface of Earth at night increasing in radiance and extent Sci Adv. 2017 Nov; 3(11): e1701528.

⁹ Annual Report of the Chief Medical Officer 2017, Health Impacts of All Pollution – what do we know? Chapter 4 page 5.

the Committee considers that it is important to closely monitor the risk of adverse health effects from long-term LED use by the general population”.

2. Where does light pollution intersect with public policy in the UK? Is the existing regulatory regime effective?

Are the Government agencies, departments, or local authorities currently responsible for monitoring and regulating light pollution appropriately resourced?

No, the private sector, central and local government, and individuals have introduced external LED lighting to achieve savings without taking account of its adverse health and ecological impacts. Councils did not adequately consult residents with light sensitive conditions before its introduction. LightAware believes that introducing external LED lighting without proper consideration of its adverse impacts on health are infringing the human rights of light-disabled and light-sensitive people whose health and well-being is adversely affected. A major example is the increasing use of large LED screens across our cities, with no research into their health impacts or proper consideration of planning controls on their use.

If one examines the market research for LEDs it is clear that the manufacturers of external LED lighting, including decorative lighting, envisage huge increases in the market for external lighting, driven by the increased efficiency of LEDs. Without planning controls and legislation it is clear that the current increase in night time lighting is just a small indication of what is to follow. If action isn't taken swiftly the issue of external light pollution will increase exponentially in coming years to an extent which will wipe out any energy savings from the increased efficiency of individual lights. The UK Government should set a national target for light pollution, in the same way as the Environment Act now requires national targets to be set on water and air pollution.

To be effective, health and environmental policies on light pollution require a holistic multidisciplinary approach that considers the health, social, economic, public safety, and ecological impacts of the introduction of recent technologies such as external LED lighting. So far, its introduction has been driven by financial savings without regard to its wider social, health and ecological impacts or the impact of massively increased lighting use. It is time to remedy this shocking state of affairs.

Is there sufficient expertise within organisations charged with regulating or enforcing regulations on artificial lighting?

In our experience no. For example, we have evidence that Councils' roads and lighting engineers have dismissed the health concerns of residents out of hand. Where light disabled and light sensitive individuals have made progress in getting their needs addressed it has usually been through the auspices of councils' equalities offices who have a greater understanding of the impact of external lighting on light-disabled individuals and of the Equality Act. We have come across cases where the council were fully aware of the devastating impact of their policies on an individual but went ahead because only one person was affected.

Have there been any changes to Government policy following the Royal Commission on Environmental Pollution's 2009 report into artificial light in the environment? Have these been adequate?

1. The main change to government policy has been the increased demand by the EU to increase the 'efficiency' of lighting by outlawing light sources not achieving a lumens per watt target. Since Brexit, the UK Government has been set on increasing the Minimum Energy Performance Standards (MEPS) beyond that set by the EU. The UK government is now consulting on plans to increasing the target 120 lumens per Watt in 2023 and 140 lumens per watt in 2027.
2. LightAware believes that these one-dimensional targets lead to poorer quality lighting and increase health impacts unnecessarily. They also make light as a commodity 'cheaper' and in the absence of measures to restrict external lighting, have led to the increase in external lighting and light pollution. The impact of these changes since the Royal Commission's 2009 report are summarised below.
 - Glare has increased considerably because of the increasing use of unshielded LED chips in street lighting and other applications.
 - In theory, light trespass should be reduced by the use of LEDs, but increasing light profligacy may negate this.
 - Light clutter has increased considerably, in particular the use of large roadside LED screens with moving images can prove a much greater distraction than the static illuminated advertising common in 2009.
 - Light profligacy has increased considerably because of the reduced unit cost of lighting as a commodity. In addition, because the area illuminated by LED street lighting is so tightly defined, more people are attaching external lighting to their homes and gardens for security reasons. Badly directed external lighting has become a major problem for light-sensitive and light-sensitive people and legislation on lighting nuisance is inadequate.
 - Sky glow evidence here is contradictory. The journal Science reports that, globally, the average night sky got brighter by 9.6% per year from 2011 to 2022, which is equivalent to doubling the sky brightness every 8 years. However within the UK some areas have shown a reduction in light pollution, perhaps due to the increase in people working at home during and since the covid epidemic.
 - Remote sensing by satellites shows that this indicator of light pollution has worsened. However the dark skies movement and creation of dark skies parks, for example in Kielder Forest, Dumfries and Galloway and Cumbria has led to improvements in some areas.¹⁰

¹⁰ Artificially lit surface of Earth at night increasing in radiance and extent Sci Adv. 2017 Nov; 3(11): e1701528.

What role should planning authorities play in determining plans or restrictions on light pollution? Are the current guidelines on light pollution set under the Government's advice for planning authorities adequate?

The All-Party Parliamentary Group for Dark Skies made recommendations in its report Ten Dark Sky Policies for the Government. While we fully support these recommendations, there are few protections for light-sensitive and light-disabled people included in the planning guidelines. In particular, planning consents for developments should ensure that health and disability impact assessments are undertaken to ensure that the proposals do not adversely affect light-disabled or light-sensitive individuals, for example by ensuring that individuals are not trapped in their homes by inferior quality lighting and that they have 'lifeline routes' to amenities.

The legislation covering lighting nuisance should be amended to ensure that light-disabled people are protected. LightAware have found that, for example, autistic individuals badly affected by flashing decorative lights are helpless when their neighbours install such lighting. Councils refuse to take any action for light nuisance because 'the average person would not be affected by this lighting' leaving individuals trapped indoors for months.

3. What recommendations would you make for changing Government policy on light pollution?

What are the possible interventions that could be deployed to mitigate the effects of light pollution and how well understood are their effects?

The UK government should:

- set rigorous standards for brightness (glare), flicker and colour temperature of external lighting, including a ban on exceeding a peak luminance threshold. This should ensure that:
 - Highways authorities reduce glare from current LED street lighting to an acceptable level, for example by fitting diffusers.
 - Legal limits are established for the amount of blue light that luminaires can have in their spectrum by limiting colour temperature of external lighting (including street lighting) to 2300K.
 - Local authorities should have a duty to ensure all external lighting in their area meets flicker standards and should have enforcement powers, including penalties for non-compliance.
- direct the National Institute for Health Protection to sponsor University research to establish how external LED lighting is causing ill-health for susceptible individuals and set standards for external lighting to ensure that light-sensitive people can safely leave their homes. This should include research into:
 - **Migraine** - the mechanism by which LEDs cause migraines in sensitive individuals.
 - **Light sensitive lupus** - a minority are unable to tolerate even small amounts of exposure to external LED lighting. Research to determine the cause these of impacts and appropriate standards set for the spectrum of external LED lighting.

- **Autistic spectrum** – LEDs have a detrimental impact on some people on the autistic spectrum and effect educational outcomes, for school-aged people on the autistic spectrum. Research should be undertaken to establish the cause.
- **Photosensitive epilepsy** - a small number of people suffer from photosensitive epilepsy where seizures are triggered by flashing lights or contrasting light and dark patterns. In a small number of people LEDs can also be a trigger. Although it appears to be rare the impact on the affected individuals can be devastating and research to establish the cause and mitigations would be welcome.

The UK Government and devolved administrations should:

- strengthen their planning policy frameworks and make specific references to the control of light pollution and introduce a requirement to undertake Health Impact Assessments, Equality Impact Assessments and Disability Impact Assessments before approving development with significant external lighting. The scope of the planning permission process should be expanded by introducing regulations for exterior lighting and introducing a requirement to undertake health, equality and disability impact assessments before approving developments with significant external lighting.
- strengthen lighting Statutory Nuisance Provisions to remove the requirement for lighting to 'affect a normal person' to enable local authorities to protect light-disabled and light-sensitive individuals from nuisance outdoor lighting and light pollution.
- should set rigorous limits for the size and brightness of LED advertising screens and ban the use of moving images near public highways. Local people should be allowed local ballots as to whether LED screens themselves above a certain size should be permitted in their area.
- Introduce a legal requirement for a national target for reducing light pollution, in the same way as the Environment Act requires national targets on reducing air pollution and water pollution.
- should emphasise the role of education, professional bodies, cultural institutions and NGOs to achieve widespread public awareness of the issue of light pollution and its impacts on human health.

Local Authorities should

- minimise light pollution in their areas and ensure that designated dark skies areas are supported. This could include encouraging the creation of 'Dark Skies' areas by having referendums in rural areas as to whether to have street lighting at all or to switch off street lighting after a particular time.
- introduce a moratorium on the roll out of external LED street lighting and maintain current street lighting until it reaches the end of its useful life or until such time that safe replacements can be found. Councils should retain a supply of parts to help them maintain current street lighting. Where street lighting has come to the end of its economic life and needs to be upgraded, councils should consult communities about replacement street lighting, including:

- an assessment to ensure that it meets the Public Sector Equality Duty
- undertaking Regulatory Impact Assessments covering equalities, health, disability, and the environment
- identifying light sensitive residents and taking steps ensure they are not socially excluded, including retaining conventional street lighting in their neighbourhood
- in rural areas, encouraging the creation of ‘Dark Skies’ areas and having local referendums as to whether to have street lighting at all or to switch it off or dim it after a particular time.
- undertake a thorough Impact Assessments to ensure LED streetlights are not causing harming the health of residents. Assessments should be part of a holistic multidisciplinary approach that considers the health, social, economic, and ecological impacts of the introduction of new lighting technologies. If (after public consultation and regulatory impact assessments have been completed) alternatives to LED lighting are not available, councils should retain non-external LED lighting in the neighbourhoods of light-sensitive people. They should include retaining lighting equipment removed from areas where LED lighting has been installed to maintain sufficient stock for this purpose.

Are there any interventions that have been pursued effectively in other countries that could be replicated in the UK?

In France, the “Decree of 27 December 2018” on the prevention, reduction and limitation of light pollution sets an important standard in western Europe for the protection of night-time darkness through controls on the emission of light in outdoor spaces and the establishment of technical requirements for the design and operation of outdoor lighting installations and imposes these regulations on both public and private property owners.

The Decree is the result of extensive public consultations with stakeholders through the process of crafting the Decree and craft a policy that respects the requirements of French law while remaining sensitive to the needs of French people.

The provisions include:

- outdoor lighting curfews
- limits on the allowed emission of light directly into the night sky
- reduced glare
- restrictions on the emission of blue light
- setting allowable maximum illumination levels
- light trespass into dwellings is prohibited, regardless of its source
- the use of skybeams, lasers, and similar high-intensity light is generally prohibited
- night-time lighting of waterways is generally prohibited.

Introduction

1. Individuals across the UK (and beyond) have contacted LightAware to complain that light pollution from modern lighting technologies is causing them ill health and leading to their social isolation, some individuals have been forced to move home and others have lost their jobs. Their main external lighting complaints relate to:
 - LED street lighting
 - LED advertising screens
 - LED Shop and garage lighting
 - LED traffic lights and other LED road signs
 - LED vehicle headlights
2. LightAware believe that the introduction of external LED lighting in the UK, particularly LED street lighting has been rushed through without an adequate consideration of the effect of the resulting light pollution on people's health and wellbeing or its full long-term environmental impact.
3. Since the introduction of LED lighting, the cost of light, if considered as a commodity, has fallen sharply and this has resulted in increased night-time illumination and light pollution. Reductions in electricity use due to the replacement of older technologies by more energy efficient lighting are now being outweighed by the increased use of LEDs in new situations. It is a classic example of the rebound effect, where efficiency gains from new technologies lead to increased resource use in the long-term.
4. In many cities giant LED screens are replacing old fashioned billboards, creating significant light pollution and distraction for drivers. In addition, LED screens are becoming ubiquitous, in bus shelters shop windows and even on the sides of buses.
5. A recent example is the planned MSG Sphere concert hall in Stratford, East London – which includes a 21,500-capacity concert hall. The building is planned to consist of a dome the width of the London Eye and the height of Big Ben, covered by a giant screen powered by 36 million LEDs. What will be the impact on the health of local residents?
6. Information from remote sensing satellites shows that light pollution is increasing at two per-cent per year and has become a major health and ecological challenge.¹¹ A ground-breaking study of global light pollution and the rise of LED outdoor lighting technology published in Science Advances, found both light pollution and lighting energy consumption are increasing over much of the planet, challenging widely-held assumptions that improvements in the energy efficiency of outdoor lighting lead to a decrease in energy consumption. More recent publications reveal that the power of global

¹¹ Artificially lit surface of Earth at night increasing in radiance and extent. Christopher C. M. Kyba et al, Science Advances 22 Nov 2017: Vol. 3, no. 11.

satellite observable light emissions increased from 1992 to 2017 by at least 49%. They estimated that with the hidden impact of the transition to solid-state light-emitting diode (LED) technology, which increases emissions at visible wavelengths undetectable to existing satellite sensors, this suggests that the true increase in radiance in the visible spectrum may be as high as globally 270% and 400% on specific regions. ¹²

External LED lighting is different from other types of lighting

7. Since the Royal Commission on Environmental Pollution's 2009 report into artificial light in the environment, there has been a revolution in external lighting. In particular, all light sources other than LED have been effectively banned by legislation introduced by the EU and by the UK Government
8. LED lighting is very different from earlier lighting sources in that it is produced using semiconductors. LEDs can be manufactured with different spectral characteristics and at different colour temperatures (Colour temperature is a way to describe the light appearance provided by a light bulb, warmer or cooler). This is important because different colour temperatures have different physical psychological and biological effects.
9. Because it is such a new technology, there has been no long-term research into LED safety and its health and environmental impacts. In particular the light propagation and distribution characteristics of LED lighting means it cannot be regarded as a like for like replacement of other lighting technologies (Box 1). There are four fundamental issues with the current design of external LED lighting. These are:
 - CCT (or more accurately, spectral content distribution)
 - Luminance (excessive brightness and glare)
 - Non-uniform light distribution
 - Flicker
10. These problems can (and should) be alleviated with changes in luminaire design and specification. However, it should not have become the external lighting of choice until it has been developed sufficiently to mitigate its health impacts on light-disabled and light-sensitive people.

Box 1

LED lighting is a semiconductor light source

A light-emitting diode (LED) is a semiconductor light source that emits light when current flows through it. Each LED emits light of only one particular colour. In street lights, this is usually blue, to make white street lights, a powerful blue LED is shone on to compounds called phosphors that absorb blue light and emit yellow light. This yellow light combines with the blue light and appears white to the eye. Most white-light sources emit a range of wavelengths, which, when combined, produce the colour of light perceived by the human eye.

¹² First Estimation of Global Trends in Nocturnal Power Emissions Reveals Acceleration of Light Pollution, Remote Sens. 2021, 13(16), 3311; <https://doi.org/10.3390/rs13163311>

The resulting shade of white depends on the blend of phosphors and is measured on the colour-temperature scale. Colour temperature is conventionally expressed in Kelvins, using the symbol K, a unit of measure for absolute temperature. It is measured on a numbered scale, where the higher the number, the 'cooler,' or bluer the light, the lower the number, the 'warmer,' or yellower the light. Examples of the colour temperatures of different forms of lighting include:

- 1700K – Low pressure sodium lamps
- 2400K – Standard incandescent lamps
- 2550K – Soft white incandescent lamps
- 2700K – Soft white LED street lights
- 3000K – Warm white LED street lights
- 4000K – Neutral white LED street lights (the most commonly used type)
- 5000K – Cool white LED street lights, Tubular fluorescent lamps
- 6000K – Sunlight.

Early "white" LEDs were very blue and harsh on the eye. Adding more phosphors to a 'white' LED makes its light look warmer and less harsh, but at the expense of reduced efficiency, as energy is lost in converting high-energy blue photons to lower-energy photons. This means that 'warmer' LEDs are slightly more expensive to run and achieve marginally lower electricity savings.

Unlike other forms of lighting, LEDs are highly directional with light emitted in an arc of around 60 degrees, rather than 360 degrees common in other lighting. LED light is usually emitted from a small, flat, surface, rather than a large, curved one. Because of this the vast majority of LED luminaire designs suffer from the acute drawbacks as they attempt to illuminate wide areas, some distance away from a small, flat light source.

Also, LED light is not distributed evenly across its beam but concentrated on its axis. This causes problems of glare, for example, car headlights can be blinding to pedestrians and oncoming traffic when cars go over a speed bump or over the brow of a hill and shine directly in people's eyes. A recent RAC survey found that "the headlights of some newer cars are so bright they are causing a road safety hazard for drivers with as many as two-thirds (65 per cent) of motorists saying they regularly get dazzled by oncoming headlights even though they are dipped".¹³ There are similar issues with external LED lighting where areas directly under the light are brightly illuminated, but with poor illumination between lights (the zebra effect). White LEDs also affect circadian rhythms and cause sleep disturbance when they shine into people's homes.

In addition, glare from external LED lighting can be felt over much greater distances. While most lighting is a point source and obeys the inverse square law – if you are twice as far away the beam is only a quarter as bright – LEDs work differently, they are a flat source and light intensity falls off more slowly, leading to LEDs being blinding over longer distances. This is particularly true for LED vehicle headlights where beams are focused.

¹³ <https://www.mynewsdesk.com/uk/rac/pressreleases/motorists-claim-to-being-regularly-left-dazzled-by-modern-vehicle-headlights-2458363>.

1. What is the state of the evidence base regarding the causes and impacts of light pollution in the UK as it relates to human health?

What are the mechanisms by which light pollution has an impact on human health – for example, by disrupting circadian rhythms? What are the negative impacts it can have?

11. There are several publications that highlight the impact of light pollution on human health. One of the earliest in 2016 was published by the American Medical Association (AMA) Council on Science and Public Health which conformed the impacts to human health and the environment caused by LEDs that emit excessive amounts of blue light. Their report “Human and Environmental Effects of Light Emitting Diode Community Lighting provides rigorous scientific evidence on the threats associated with exposure to blue-rich white light sources.¹⁴
12. 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. It reported that blue-rich white LED street lighting is five times more disruptive to our sleep cycle than conventional street lighting and that large surveys showed that brighter residential night-time lighting is associated with reduced sleep, impaired daytime functioning and a greater incidence of obesity.
13. The AMA report encouraged 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 CCT of outdoor lighting to 3000 Kelvin (K) or lower.
14. The EU Scientific Committee on Health, Environmental and Emerging Risks (SCHEER) published its opinion on Potential risks to human health of Light Emitting Diodes (LEDs) in June 2018. The report concluded that:
 - “There is no evidence of direct adverse health effects from LEDs in normal use by the general population”, this conclusion was disingenuous in that it excluded

¹⁴ American Medical Association. 2016. Human and environmental effects of light emitting diode (LED) community lighting. Report of the Council on Science and Public Health. Chicago (IL): American Medical Association

children, older people and light sensitive individuals from the “general population”. Leading to the widespread misconception that LEDs were safe for all.

- Furthermore, under the heading ‘vulnerable populations’ it concluded that ‘Children have a higher sensitivity to blue light and although emissions may not be harmful, blue LEDs may be very dazzling for young children. Older people may experience more problems with glare. Some people appear to be susceptible to flicker and many people experience the phantom array effects caused by flickering LEDs when they move their head or eyes’.
- there is no evidence of direct adverse health effects from LEDs in normal use (lighting and displays) by the general healthy population (i.e. the adult population excluding children, older people and people suffering from light sensitive conditions).
- Some people report that they are sensitive to flicker from LEDs.
- Children have a higher sensitivity to blue light and although emissions may not be harmful, blue LEDs (between 400 nm and 500 nm) may be very dazzling and may induce photochemical retinopathy, which is a concern especially for children below three years of age.
- Older people may experience discomfort with exposure to light that is rich in blue light.
- Either discomfort glare or disability glare can be temporarily caused by vehicle LED lights, and particularly daylight running lights and headlights.
- Light sources that emit more short-wavelength light, as do some types of LEDs, will have a larger effect on the circadian rhythms at equal optical radiance, duration, and timing of exposure. ¹⁵

15. The SCHEER report makes clear the potential adverse health effects of blue light. It is surprising therefore that councils in the UK have continued to procure street lighting with a substantial blue component, particularly when suitable alternatives are available.

16. The revision of the EU Green Public Procurement Criteria for Road Lighting and traffic signals was published in 2019 after the SCHEER report. It is applicable in the UK until the UK Government produces its own post-Brexit guidance. The guidance on procuring street lighting provides clear advice that “*in order to reduce the risk of human annoyance, the CCT of light sources shall be $\leq 3000\text{K}$ and a dimming or switch-off programme shall be implemented*”. ¹⁶

17. These procurement criteria also point out that only around 7% of the land in Europe suffers from light pollution levels that are high enough to prevent viewing of the Milky

¹⁵ Scientific Committee on Health, Environmental and Emerging Risks (SCHEER), Opinion on Potential risks to human health of Light Emitting Diodes (LEDs), European Union, 2018.

¹⁶ Revision of the EU Green Public Procurement Criteria for Road Lighting and traffic signals, European Union, 2019.

Way but unfortunately around 60% of the European population live in these polluted areas. In addition, a significant amount of light pollution is being missed as lighting installations shift to LED. This is because, unlike traditional sodium lamps, LED emits a significant portion of its light output in the 400-500nm range. Unfortunately, the sensitivity of the satellite mounted VIIRS DNB (Visible Infrared Imaging Radiometer Suite Day Night Band) sensor used to measure light pollution is only useful between 500 and 900nm. So one consequence of a shift to more energy efficient, LED based street lighting could possibly be that there is a perceived drop in light pollution levels measured by VIIRS DNB that may or may not be true.

18. A third major health study produced by the French Government's institute for health resulted in the ANSES report (2019). It concluded that "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). 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."¹⁷
19. Although the report warns about the risks of blue light from mobile phones and tablets as a key risk for children, they conclude that even very low levels of exposure to blue light in the evening or at night disrupt biological rhythms. This is significant evidence that the introduction of 4000K LED street lighting can have a disruptive effect on children's sleep.
20. Taking messages from these reports together with those from our survey, LightAware can only conclude that there are significant health impacts from external LED lighting. Those councils installing 4000K street lighting were either unaware of the health impacts of LED or saw financial savings as a higher priority.
21. Light pollution in the UK is now primarily caused by external LED lighting, with other external light sources effectively banned. The main health risks associated with LED-based lighting systems are caused by:
 - their high luminance (a large amount of light emitted by a point source leading to excessive brightness and glare)
 - stroboscopic effects (flicker)
 - CCT (their unusual emission spectrum, with a high proportion of blue light in the external lighting installed so far)
 - Non-uniform light distribution - LED light is not distributed evenly across its beam but concentrated on its axis leading to glare.

¹⁷ 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) April 2019.

These are discussed separately below in more detail, but it is likely that the combination of these effects is a significant cause of the adverse health and environmental impacts described.

High luminance can cause problems with glare

22. The human eye can adapt to a wide range of light levels from bright sunlight to almost total darkness. However, comfortable vision requires a limited range of light levels at any particular time and excessive light levels and luminance contrasts can lead to glare. Many external lighting sources have their high-luminance LED chips visible, which can be a source of glare for dark adapted eyes. Glare can be experienced as disability glare or discomfort glare:

- **Disability glare** affects the ability to see and leads to some degree of temporary loss of vision and is produced by high luminance in a lower luminance scene, for example at night when a car with LED headlights comes over the brow of a hill or goes over a speed bump.¹⁸
- **Discomfort glare** causes irritation, anxiety, visual fatigue, and eyestrain and can adversely affect wellbeing¹⁹ Depending on an individual's sensitivity it can also cause dry or watery eyes, itchiness, tense muscles, breakdown of vision, blurred or double vision, headaches and fatigue.

Glare from LED vehicle headlights is a particularly problematic source of light pollution

23. Research published by the RAC in March 2022 found 89 per cent of drivers think that some or most vehicle headlights on the UK's roads are too bright with 88 per cent saying they get dazzled by them while driving. The problem is getting worse with 63 per cent saying it's happening more often than a year or two ago and 64 per cent thinking they risk causing other drivers to have collisions.²⁰

24. The concern is that the human eye has evolved to allow it to adapt to a wide range of light levels from bright sunlight to almost total darkness. But it cannot adapt in a short space of time. Comfortable vision requires a limited range of light levels at any particular time and excessive changes and contrasts in light levels in a brief period cause disabling glare. The problem with LED headlights is that they are incompatible with dark adapted human eyesight – particularly so for older drivers.

25. A specific problem with LED vehicle headlights is that light is not distributed evenly across the headlight's beam but is concentrated in the centre (on the axis). This means that vehicle headlights that appear dimmed on approach can suddenly become blinding if

¹⁸ The Lighting Handbook. London, Society of Light and Lighting, 2009.

¹⁹ Stone PT. A model for the explanation of discomfort and pain in the eye caused by light. *Lighting Research and Technology*, 41, 2009, 109-121.

²⁰ <https://media.rac.co.uk/pressreleases/blinded-by-the-lights-nearly-one-in-four-drivers-think-most-car-headlights-are-too-bright-3166996>

the centre of the beam shines directly into a driver's eyes, for example when a vehicle travels over the brow of a hill, round a bend, or over a bump. This is made worse by manufacturers taking advantage of the high luminance of LED chips to make very small headlights with a very narrow piercingly bright centre to the LED beam. This is usually done as part of 'branding' to make cars stand out in the market, but it reduces safety by increasing LEDs headlights' capacity to create disability glare.

26. When drivers are exposed to the centre of a LED headlight beam their pupils rapidly constrict to adjust to the bright light. But the dilation of the drivers' pupils to readjust to darkness happens more slowly, meaning people 'drive blind' for a time. The Royal Society for the Prevention of Accidents says: "Between the ages of 15 and 65, the time it takes to recover from glare increases from one to nine seconds." A vehicle traveling at sixty miles an hour can travel over 250 yards in this time. This headlight-caused night-blindness is one reason many older people choose not to drive at night.
27. The bluer spectrum of light from LED headlights disables the night adapted vision of the human eye to a greater extent than that of conventional halogen headlights – pupil size is more strongly correlated to blue light than yellow light.²¹
28. In addition, LED headlights are blindingly bright over a greater distance than the halogen lighting they replace. While most lighting obeys the inverse square law – if you are twice as far away the beam is only a quarter as bright – LEDs work differently, and light intensity falls off much more slowly, leading to LEDs being blinding over longer distances.
29. An extreme example of glare is daylight-running lights on cars. These are clearly visible to other road users and pedestrians. At night, if they do not dim, they can be dazzling and more so for young children (who have higher transmission of light through to the retina) and for older people (who will suffer from scattering of the light, particularly in the lens of the eye). Older drivers, in particular, will be dazzled by oncoming vehicles with the risk that they may not see hazards until too late. The problem is exacerbated by fog and rain.
30. The glare from LED headlights and daylight running lights also causes migraines in light sensitive and light-disabled individuals, with some individuals giving up driving completely as a result.

LED flicker from external lighting can cause migraines and also presents a safety hazard

31. Circuitry within the LEDs converts mains alternating current to the low voltage direct current required by the LED. Unfortunately, some circuitry is inadequate in reducing the variation in the power supply and this generates flicker. LEDs vary in their degree of flicker; some do not flicker at all while others flicker very badly. In general, LED street lighting does not flicker but shop displays and other cheaper external lighting often flickers badly. There is no reason LEDs can't be flicker free, except cost. The Swedish

²¹ J Cogn. 2018; 1(1): 16. Pupillometry: Psychology, Physiology, and Function Sebastiaan Mathôt

Government has calculated that the cost of eliminating flicker is equivalent to around 10 pence per LED unit.²²

32. Flicker is mainly perceived towards the edges of the visual field, which is more sensitive to motion. Flicker can cause ill-health, even if it is so rapid that you are unaware of it. It can cause headaches, eyestrain, migraines, fatigue and disturbs the control of eye movements. Unlike other light sources, which may flicker slightly, the flicker from LEDs can change almost instantly between bright and dark. In some circumstances, people see a trail of the same image of a lamp repeated one after the other, each time their eyes move across it, known as a phantom array, it is particularly noticeable with the LED tail lights of cars.²³

33. Flicker can also disrupt the movement control of the eyes and force the brain to work harder, causing discomfort and migraine in some people. Flicker stresses the nervous system and rapid changes in light subconsciously activate the alarm system and have different effects on people depending on the frequency. This explains the anxiety and stress many people feel when exposed to flickering LEDs. For people suffering from migraine, LED flicker commonly induces feelings of dizziness and pain within 20 minutes, but for some it can be instantaneous.²⁴

34. To ensure both public health and safety, it is important that external lighting is flicker free. Unfortunately, some external lighting flickers badly and should be replaced as a matter of priority. Checking for flicker is relatively simple with a smartphone camera, and apps are available for that allow users to measure the degree and frequency of flicker. LightAware would encourage people to report flickering street lights to their local council. Because of the severe health impacts of flickering LEDs on people suffering from migraine and epilepsy, councils' should have powers to enforce the removal of flickering LEDs as a health hazard.

35. Decorative external lighting that is designed to flicker can cause significant health issues for sensitive individuals. This sometimes switched on all day and night. One of the biggest triggers for those people with epilepsy is Christmas lights, especially those lights that are flickering or flashing. People with epilepsy are sensitive to 16-25 Hz frequency lights. Decorative lighting also has adverse health impacts for people on the Autistic Spectrum and people suffering from migraine. There are currently no regulations for these lights. As an alternative, environmentally friendly candles should be used for the celebration periods. Furthermore, it will also help in conserving energy.

Some of the LED sources assessed by Public Health England and others vary in illuminance at a frequency of 100 hertz. At the extreme, the LEDs switch on and off 100 times per second. This is of concern for a number of reasons. Some people seem to be very sensitive to this light modulation, resulting in headaches, migraine and less specific feelings of malaise.

Annual Report of the Chief Medical Officer 2017

²² https://www.eceee.org/static/media/uploads/site-2/news/swecovernotesvm_study_181212.pdf

²³ Flicker can be perceived during saccades at frequencies in excess of 1 kHz, Lighting Research and Technology 45(1):124-132 February 2013, J. E. Roberts, Arnold J Wilkins,

²⁴ "Light flicker: Determination and Assessment. Discussion Peter Erwin Discussion Paper Oct 2017.

External LED light pollution can cause sleep disturbance

36. A core health concern about external LED lighting is the disruption of people's circadian rhythms leading to disturbed sleep patterns. Humans have a natural body clock that has an approximate 24-hour cycle. At dusk, and in the absence of electric lighting, humans begin the transition to night-time physiology to prepare for sleep. The blood concentration of the hormone melatonin rises, body temperature drops, sleepiness grows, and hunger subsides.

Our village is in the process of changing the streetlamps to LED. The Parish Council has agreed not to change the lamp in the road where I live and plan to keep the 'old' bulbs from the lamps being changed so that there are spare supplies for the one in my road.

Jennifer, East Midlands

37. In the early 2000s a new type of sensor was discovered in the eye, in addition to the rods and cones, which was also sensitive to light. These intrinsically photosensitive retinal ganglion cells (iPRGCs) were identified as the main sensors for entraining our circadian rhythms. Light is the main trigger that ensures that our circadian rhythms are properly maintained and retinal light exposure is the dominant synchronizer of the human circadian system. Recent evidence has revealed that the human circadian system is more sensitive to evening light than previously thought and that there are also substantial differences between individuals in light-sensitivity.^{25 26}

38. Unfortunately, many LED street lights and other external lighting has a spectrum containing a spike at the wavelength that most effectively suppresses melatonin during the night (Figure 1). It is estimated that a "white" LED lamp is up to 5 times more powerful in disrupting circadian physiology than a high-pressure sodium light.²⁷

Street lights in my area/street were changed over 4 years ago from sodium halide. Their effect on me was so devastating I have barely left the house or even opened my front door in the evening since they were installed. I can also be affected during the day as many LEDs are actually on permanently, presumably because they are defective or have light-sensitivity settings that are inappropriate.

Jane, North-East England

39. Recent large surveys have found that brighter residential night-time lighting is associated with reduced sleep time, dissatisfaction with sleep quality, night-time awakenings, excessive sleepiness, impaired daytime functioning, and obesity. Disruption of the circadian system can have a major impact on sleep quality and daytime alertness, which in turn impacts wellbeing and safety. It is a bit like having permanent jet lag.²⁸

²⁵ Phillips, A. J. K. et al. High sensitivity and interindividual variability in the response of the human circadian system to evening light. Proc. Natl. Acad. Sci. USA 116, 12019–12024. <https://doi.org/10.1073/pnas.1901824116> (2019).

²⁶ Boivin, D. B., Duffy, J. F., Kronauer, R. E. & Czeisler, C. A. Dose–response relationships for resetting of human circadian clock by light. Nature 379, 540–542 (1996).

²⁷ Human and Environmental Effects of Light Emitting Diode (LED) Community Lighting, American Medical Association, 2016.

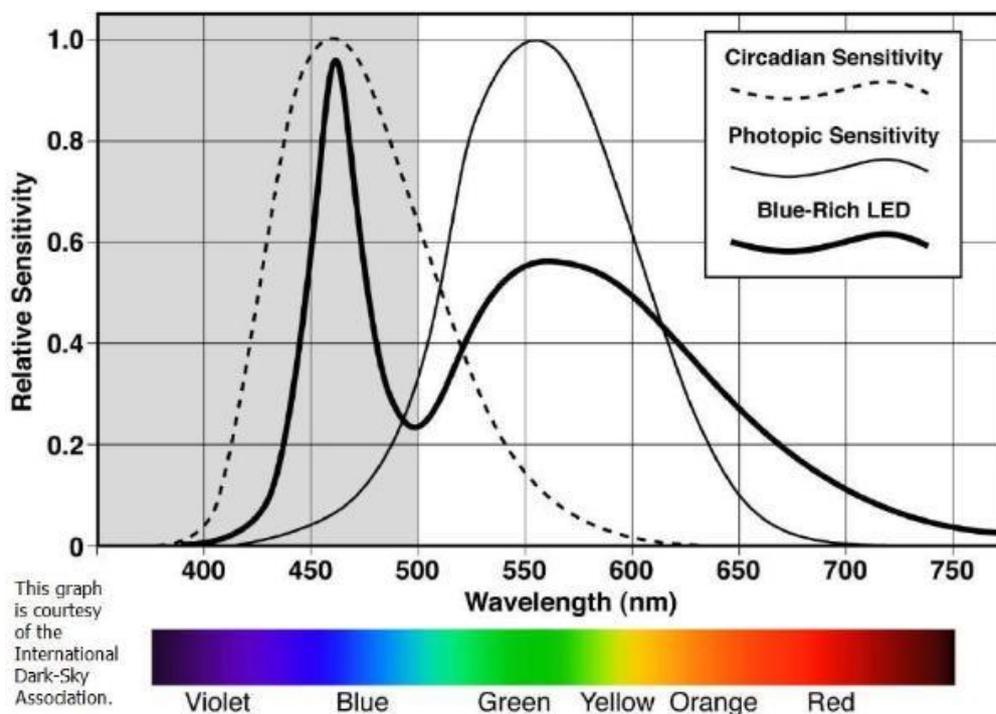
²⁸ Outdoor artificial light at night, obesity, and sleep health: Cross-sectional analysis in the KoGES study Chronobiology International, The Journal of Biological and Medical Rhythm Research, Volume 33, 2016 - Issue 3

40. The human eye is not equally sensitive to all wavelengths in normal daylight vision, known as photopic vision, the eye has a peak sensitivity at 555 nanometres (green). LED street lights producing a peak of blue light, which is the hardest colour to see (Figure 1). A lot of the blue light produced by LEDs is not useful for human vision which may partially account for the comments about 'prison lighting' (although it is useful for CCTV cameras).

Figure 1

Human photopic and circadian sensitivity curves displayed against a typical blue-rich LED light source spectrum

Blue rich LEDs have a peak at the wavelength that effects human sleep wake cycles but is less suitable for human vision.



Source: International Dark Sky Association.

External LED light pollution exacerbates a number of light sensitive illnesses

41. As well as these effects on the population as a whole discussed above, people suffer from different types of light-sensitivity that are exacerbated by external LED lighting (Box 2). People suffering from illnesses involving different types of light sensitivity have contacted LightAware for advice about their problems with LED street lights and other external lighting. Councils' responses have varied; some have been helpful, for example by maintaining sodium lighting in their local area, but others have been less helpful and some people have been forced to move home to escape their effects.

I don't often go out after dark unless I know there's a 'safe route' through ok lighting. This affects my work and social life and that of my family
Angela, Central Scotland

Box 2

Illnesses that can be triggered or made worse by external LED light pollution

Migraine

Light sensitivity is so common in people with migraine that it is itself a diagnostic criterion for the illness. Migraine is estimated to affect one in seven people in the UK and can cause many symptoms, including a throbbing one-sided headache, nausea and vomiting and visual disturbances. For many migraineurs (32 – 40 per cent) light-sensitivity is intricately linked to their condition.

LED lighting may have greater flicker than traditional light sources and some can effectively switch on and off hundreds of times every second. Poorly specified or poorly installed external LED lighting can be too bright, creating glare which caused migraines in susceptible individuals and eye pain in others.

Systemic Lupus erythematosus (lupus)

Lupus is an autoimmune disease in which the body's immune system mistakenly attacks healthy tissue. About one person in 3,500 has lupus and it is more common in women than in men. Up to 70 per cent of people with lupus have some skin symptoms. Lupus UK estimates that about 30,000 sufferers are adversely affected by fluorescent lighting. LEDs can be better than fluorescent lighting for some as they don't emit UV light, but some lupus sufferers cannot tolerate LEDs either. Cool white and bright white LEDs used in external lighting emit short-wavelength blue light, which is risky for many lupus sufferers. Lupus sufferers who cannot go out in sunlight can be effectively trapped in their homes at night as well.

Skin disorders

People who suffer from Xeroderma pigmentosum (XP), and some people with chronic actinic dermatitis (also known as chronic photosensitive dermatitis) also have their conditions made worse by LED lighting.

Autistic Spectrum Condition

Many people on the autistic spectrum have sensory issues that can affect one or more of the senses that can be either over-developed (hypersensitive) or under-developed (hyposensitive). Both can affect how people experience environments. Fluorescent lighting has been shown to have a particularly negative affect on individuals on the autistic spectrum and flickering LED lighting can also be distressing. Sensitivity to light can manifest in diverse ways. Physical symptoms may include:

- lower tolerance for light
- discomfort from fluorescent, LED and other artificial light
- light avoidance behaviours (e.g. shielding eyes)
- afterimages and visual snow
- headaches or migraine.

Other signs may include increased anxiety, repetitive behaviours as well as poor eye contact or eye movement. These types of sensory disruptions can lead to social problems and worsening educational outcomes, for school-aged people on the autistic spectrum

. Source: *LightAware*

It is difficult to estimate the number of people severely affected by external LED light pollution, but everyone is affected to some extent

42. Although LightAware has been contacted by many people who have been affected by external LED light pollution, it is difficult to estimate how many people are affected. The reasons include only a small minority of people with a problem will contact LightAware; people not being aware of what is causing their pain and discomfort; and people contacting other relevant charities, such as the Migraine Trust or Lupus UK eclipse or the National Autistic Society.

43. An estimate of the number of light sensitive people in the UK was made in 2012 by the Spectrum Alliance for light-sensitivity, a grouping of charities including Lupus UK, Eclipse Support Group, ElectroSensitivity UK (ES-UK), the XP Support Group, Lupus Europe, Migraine Action and supported by the National Autistic Society, Research Autism and Right to Light. Together they estimated the number of light sensitive people having health problems exacerbated by compact fluorescent lighting (CFL) and found that around 2 million people (3.25 per cent of the UK population) suffered adverse health effects. Although fewer people are likely to be affected by LED lighting, the number is likely to be of a similar order of magnitude as the main drivers of light-sensitivity, such as flicker, glare and spectral effects are similar. However, further research is needed to quantify the number of people affected.

(LED street lights) cause my heart to race, make me feel nauseated, dizzy, disorientated, make my skin hot and inflamed and cause my nerves to become heightened in my skin and immense itching which also affects my sleep. Exposure to artificial lighting can cause my Lupus to flare.
Jennifer, East Midlands

44. As well as light-sensitive people, many others will be affected by high blue-content LED lighting. Although the EU's SCHEER report concluded that 'There is no evidence that the general public is at a risk of direct adverse health effects from LEDs when the lights are in normal use', their media release neglected to mention that the definition of 'general public' excluded children, the elderly and light sensitive people, who were classed separately as 'vulnerable populations'.

45. The SCHEER report concluded under the heading 'vulnerable populations' that "*Children have a higher sensitivity to blue light and although emissions may not be harmful, blue LEDs may be very dazzling for young children. Older people may experience more problems with glare. Some people appear to be susceptible to flicker and many people experience the phantom array effects caused by flickering LEDs when they move their head or eyes.*" In addition to the 'vulnerable populations' above, as discussed earlier, blue rich LED street lights are a powerful disruptor of people's circadian rhythms which can cause disturbed sleep and a large number of other health impacts, creating a 'hierarchy of harm' (Figure 2).²⁹

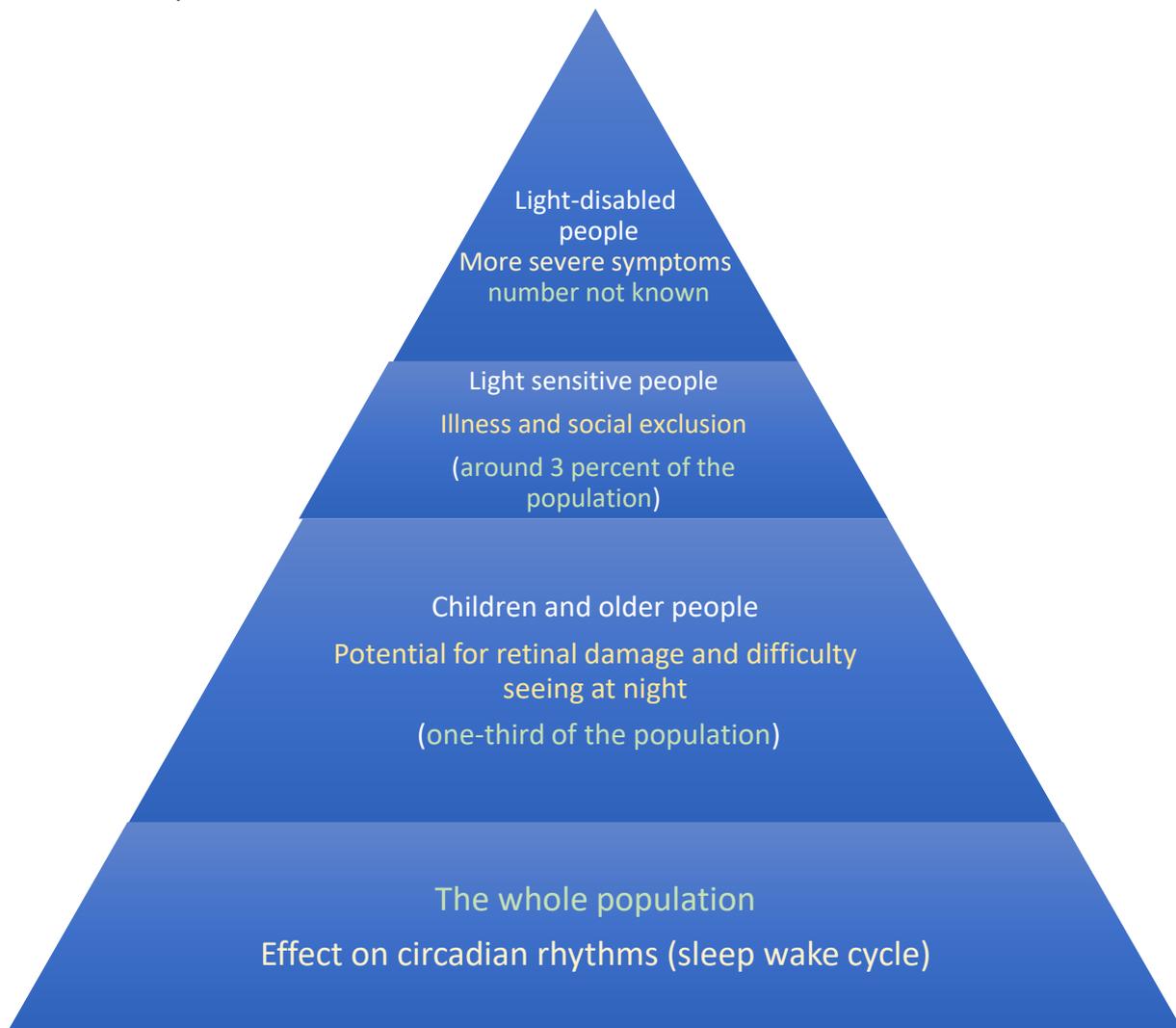
²⁹ Scientific Committee on Health, Environmental and Emerging Risks (SCHEER), Opinion on Potential risks to human health of Light Emitting Diodes (LEDs), European Union, 2018.

46. There are also a smaller number of people who suffer more severe symptoms, such as disabling migraines, seizures and severe skin conditions who are effectively light-disabled. More research is required to establish the reasons for such hypersensitivity to LED light pollution.

Figure 2

The ‘hierarchy of harm’, high blue content External LED lighting impacts on us all

Although only a small percentage of people are severely affected, external LED light pollution has health impacts on us all.



Source: LightAware, Spectrum Alliance

What are the primary sources of light pollution and how well do we understand them? Is there evidence regarding which types of artificial light, in terms of frequency, duration of exposure, or intermittency, are the most harmful?

47. The main types of light pollution caused by these sources include:

- Sky Luminance – this occurs when upward light is diffused through clouds, mists, and airborne particles in the atmosphere.
- Sky Aura - is related to lighting effects caused by light reflection from areas local to the lighting installation - a particular issue with external LED lighting.
- Urban Sky Glow - the brightening of the night sky over inhabited areas.

48. External LED lighting can cause light pollution via direct emission, scattering and reflection. However, most modern streetlights restrict all upward light emission, so that the greatest component of street lighting pollution arises from ground reflection. This depends on the type of ground cover (and can be greatly increased by snow cover in winter). Although external LED lighting can be effectively directed at the ground, the high blue content of current external LED lighting is unfortunately more prone to reflection and scattering.

49. The bluest sources, such as 4000k and above external lighting, produce 15 to 20 per cent more radiant sky glow than high pressure sodium (HPS or low-pressure sodium (LPS). This effect is compounded for visual observation (as practiced by casual stargazers and amateur astronomers) by the shift of dark-adapted human vision toward increased sensitivity to shorter wavelengths. In a relatively dark suburban or rural area, where the eyes can become completely or nearly completely dark-adapted, the brightness of the sky glow produced by artificial lighting can appear 3–5 times brighter for blue-rich light sources as compared to HPS and up to 15 times as bright as compared to LPS.³⁰

50. However, street lighting is not the only cause of sky glow, the reduction in the cost of LED lighting has led to increased use of LED lighting for other external uses such as security lighting, street signs, floodlighting at sports and leisure facilities, decorative lighting, advertising lighting and the illumination of historic buildings and lighting in greenhouses to extend the growing season. In addition, it is becoming common to use LED lighting in parks during the winter and in some parts of the UK even forest trails have been subjected to LED illumination. All of these contribute to light pollution and to ill health and social exclusion for light-disabled and light-sensitive people.

51. In 2010, the Council for the Protection of Rural England and the British Astronomical Association's Commission for Dark Skies ran a survey to find out how people's lives are

³⁰ International Dark-Sky Association, Visibility, Environmental, and Astronomical Issues Associated with Blue-Rich White Outdoor Lighting, May 2010.

affected by light pollution. The survey revealed that the main causes of light nuisance are road lighting (89 per cent), domestic security lighting (79 per cent), streetlights that are more than five years old (77 per cent) together with businesses, sports grounds, and supermarkets, 82 per cent of respondents said that the offending lights were left on all night. They also produce a detailed interactive map of light pollution across the UK. ^{31 32}

52. The 2017 Annual Report of the Director of Public Health in England has included a section on how light pollution can have serious ecological consequences for humans, wildlife, and the climate.³³
53. While research is continuing, it is becoming apparent that both bright days and dark nights are necessary to maintain healthy hormone production, cell function, and brain activity, as well as normal feeding, mating, and migratory behaviour for animals (including humans) and birds. Light pollution drastically alters their night-time environment by turning night into day. This has had a dramatic impact on nocturnal ecology. For example, nocturnal animals sleep during the day and are active at night to enable them to avoid predators. External light pollution can affect this delicate predator /prey balance.

Direct health effects of light pollution

54. However, the main effects on human health of external light pollution generally result from direct interaction with the light sources rather than by sky glow, etc and result from glare, flicker and the spectrum of the light rather than indirectly from sky glow.
55. People have contacted LightAware to complain about the following sources of light pollution (most common first):
- LED street lighting
 - LED vehicle headlights
 - LED advertising screens
 - LED shop and garage lighting
 - LED traffic lights and other LED road signs
56. All new external lighting in the UK is now LED and our earlier answers to the questions posed by the House of Lords Science and Technology Committee detail how LED external lighting can be harmful . However there is considerable flexibility in the type of LEDs that can be manufactured and the way they are run in terms of glare, flicker and colour temperature. For example:
- It is possible to run LED chips at less than maximum power, which reduces glare and increases efficiency and the lifetime of the chip

³¹ Night Blight: Mapping England's light pollution and dark skies, Campaign to protect rural England.

³² <https://www.nightblight.cpre.org.uk/maps/>

³³ Annual Report of the Director of Public Health in England 2017.

- It is also possible to manufacture LEDs at a lower colour temperature than the 4000K usually used for street lighting. This results in less skyglow and reduces the impact on sensitive individuals.
- It is also possible to change the spectrum of LEDs to create a more 'natural' spectrum without so many peaks and troughs at particular wavelengths and a 'redder' spectrum.

57. All of these changes will reduce light pollution and also reduce the adverse impacts on light sensitive individuals with only marginal impacts on cost and efficiency. LightAware's concern is that the relentless focus on cost and 'lumens per watt' has resulted in the production of very cheap, very nasty external lighting.

58. To be effective, environmental policies and practices require a holistic multidisciplinary approach that considers the health, social, economic, and ecological impacts of the introduction of new technologies as well as their cost and carbon emissions

Is there evidence that light pollution is worsening, – for example, with the introduction of LEDs and cheaper forms of lighting, or lighting with a different wavelength spectrum?

59. External LED lighting is radically different from the technologies it has replaced. Because it is such a significant change to the lighting environment of all residents, LightAware believes councils should have piloted its introduction and consulted widely with residents and other stakeholders prior to its introduction. But many did not.

60. When devising new policies, programmes and projects, public sector bodies need to think about their implications for health, their impact on equalities, people with disabilities, and on the environment. The amount of effort this requires will vary according to the magnitude of any likely change and the difficulty of assessing the potential impacts. In general the process should be to:

- identify any the likely impacts
- assess their magnitude and where they are likely to occur
- value them in monetary terms if this is helpful
- consider uncertainty, risk and their impact on people and the economy
- present the results clearly for the relevant decision makers to consider.

61. It is important to conduct these regulatory impact assessments because many people who are light-sensitive have hidden disabilities. Without undertaking these assessments councils cannot consider their needs in decision-making processes. For example, without a Disability Impact Assessment, councils could fall foul of equalities legislation by failing to anticipate the potential for disability discrimination if light sensitive people react badly to LED lighting. In addition, they would be culpable of failing to make reasonable adjustment if they install lighting and cause detriment to light-sensitive individuals. Street

lighting also has significant environmental impacts, for example all bats, their resting and breeding sites are protected and councils disturbing them will be in breach of environmental law.

62. A Health Impact Assessment (HIA) is a way to identify and improve the health consequences of any defined policy or proposed development, including unintended and unanticipated consequences. A HIA includes explicit consideration of how impacts may affect diverse groups in the population. They produce evidence-based recommendations to inform decision-makers on how they can promote and protect the health and wellbeing of local communities they serve.³⁴

63. In understanding the potential impacts of a policy on health and wellbeing it is important to consult with stakeholders including members of the local community, local health, education, and other professionals with an understanding of the community. However, only 17 per cent of councils in our survey conducted a health impact assessment before introducing external LED lighting. Similarly, one would also expect councils to conduct an assessment to ensure that the lighting meets requirements under the Equality Act 2010. It is appalling that so few councils have undertaken regulatory assessments.

Local Authorities have been replacing mercury and sodium street lights with LEDs. If this is done purely on the basis of energy efficiency and cost, it is possible to end up with installations that may not be fit for purpose
Annual Report of the Chief Medical Officer 2017

64. Similarly, councils should undertake assessments of the impact of policies LightAware's survey showed that:

- only 22 per cent of councils undertook an Environmental Impact Assessment.
- 32 per cent conducted an Equality Impact Assessment
- 21 per cent conducted a Disability Impact Assessment
- 28 per cent conducted an assessment of the impact on their Obligations under the Public Sector Equality Duty to ensure that it did not cause discrimination.

65. LightAware also believes that councils should have taken account of 'inclusive by design' features when making significant changes to the street lighting environment.³⁵ Inclusive Design is the design of an environment so that it can be accessed and used by as many people as possible, regardless of age, gender, and disability. It applies to surrounding open spaces, wherever people go about everyday activities. This includes shops, offices, hospitals, leisure facilities, parks, and streets. To do this, built environment professionals, including lighting engineers should involve potential users at all stages of the design process. Where possible, it is important to involve disabled people, including people with hidden disabilities, such as lupus sufferers, in the design process.

66. The revision of the EU Green Public Procurement Criteria for Road Lighting and traffic signals was published in 2019 after the SCHEER report. It is applicable in the UK until

³⁴ Health Impact Assessment of Government Policy. A guide to carrying out a Health Impact Assessment of new policy as part of the Impact Assessment process. Department of Health.

³⁵ See <https://inclusivedesign.scot/what-is-inclusive-design/#scot-leg>.

the UK Government produces its own post-Brexit guidance. The guidance on procuring street lighting provides clear advice that “in order to reduce the risk of human annoyance, the CCT of light sources shall be $\leq 3000\text{K}$ and a dimming or switch-off programme shall be implemented”.³⁶

How reliable is our evidence base for these impacts – are there areas where we are less confident or additional studies that are needed?

67. In her 2017 Annual Report to Local Authorities, the Chief Medical Officer for England said “Local Authorities have been replacing sodium street lights with LEDs. If this is done purely on the basis of energy efficiency and cost, it is possible to end up with installations that may not be fit for purpose. Some streetlight luminaires have LED sources that can be seen physically projecting below the luminaire, becoming a glare source or light pollution”. Our survey shows that, unfortunately the Chief Medical Officer for England’s warning has not been heeded.³⁷
68. In late 2019, LED street lights made up almost half (49 per cent) of street lights, with high pressure sodium lighting making up twenty-one percent of the total). LED street lights now make up over 80 per cent of councils’ street lighting with the majority being 4000K or over and around 7 per cent being 2700K or less, the standard set for lighting in residential areas.³⁸
69. Although LED lighting is widely promoted as having lower energy consumption, because of the way LEDs produce light they also lead to reduced levels of illumination. Many people do not like the ambiance usually produced by the LEDs with colour temperatures of 4000 Kelvins or higher. It is often called ‘prison lighting’ because of its cold soulless feel. Because LED is a very new technology, it needs to be planned and installed with a high level of expertise. A number of people have complained about lights in the wrong places causing patches of no light at all, and other areas that are too bright.
70. An additional danger is the loss of night vision because of the accommodation reflex of drivers’ eyes. As drivers emerge from an unlighted area into a pool of light, their pupils quickly constrict to adjust to the brighter light, but as they leave the pool of light the dilation of their pupils to adjust to the darkness is much slower, so their vision is impaired. As a person gets older the eye’s recovery speed gets slower, so driving time and distance under impaired vision increases. This is one reason why many older people

³⁶ Revision of the EU Green Public Procurement Criteria for Road Lighting and traffic signals, European Union, 2019.

³⁷ Annual Report of the Chief Medical Officer 2017, Health Impacts of All Pollution – what do we know? Chapter 4 page 5.

³⁸ Revision of the EU Green Public Procurement Criteria for Road Lighting and traffic signals, EU, 2019.

choose not to drive at night. It is exacerbated by LED vehicle headlights and street lighting and may lead to increased social isolation for older people. ³⁹

71. Glare is another widespread problem. A French government report published in 2013 indicated that a luminance level higher than 10,000 cd/m² causes visual discomfort whatever the position of the lighting unit in the field of vision. As 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. ⁴⁰
72. A common problem is that, to reduce costs, some councils specify very small luminaires (typically 16 LEDs) at high drive currents, which with inevitably result in high luminance and glare. Glare could be reduced by, for example, specifying a 24 LED luminaire at lower drive current to achieve the same output.
73. For current installations, one option would be to fit diffusers, another to be to push for councils to 'upgrade' their luminaires to the larger specification with dimming. Councils need to be held accountable for the problems they have caused and, where there is a complaint from the public and they must take ownership. Merely sticking shields on luminaires or ignoring residents' complaints is not acceptable, in some cases, will be in breach of disability discrimination legislation.

³⁹ Scientific Committee on Health, Environmental and Emerging Risks (SCHEER), Opinion on Potential risks to human health of Light Emitting Diodes (LEDs), European Union, 2018.

⁴⁰ ANSES, the French Agency for Food, Environmental and Occupational Health & Safety, September 2013

2 Where does light pollution intersect with public policy in the UK? Is the existing regulatory regime effective?

Are the Government agencies, departments, or local authorities currently responsible for monitoring and regulating light pollution appropriately resourced? Is there sufficient expertise within organisations charged with regulating or enforcing regulations on artificial light?

74. No, the private sector, central and local government, and individuals have introduced external LED lighting to achieve savings and reduce carbon emissions without taking account of its adverse health and ecological impacts. Councils did not adequately consult residents with light sensitive conditions before its introduction. LightAware believes that introducing external LED lighting without proper consideration of its adverse impacts on health, is infringing the human rights of light-disabled and light-sensitive people whose health and well-being is adversely affected.

I contacted the council and they told me that the person in charge of street lighting safety had left.

**Julia
Cambridgeshire**

75. To be effective, health and environmental policies on light pollution require a holistic multidisciplinary approach that considers the health, social, economic, public safety, and ecological impacts of the introduction of new technologies such as external LED lighting. So far, its introduction has been driven by financial savings and poorly focused carbon reduction targets without regard to its wider social, health and ecological impacts. It is time to remedy this shocking state of affairs.

Have there been any changes to Government policy following the Royal Commission on Environmental Pollution's 2009 report into artificial light in the environment? Have these been adequate?

76. The main change to government policy has been the increased demand by the EU to increase the 'efficiency' of lighting by outlawing light sources not achieving a lumens per watt target. Since Brexit the UK Government has been set on increasing the Minimum

Energy Performance Standards (MEPS) beyond that set by the EU. The UK government is now consulting on plans to increase the target 120 lumens per Watt in 2023 and 140 lumens per watt in 2027.

77. LightAware believes that these one-dimensional targets lead to poorer quality lighting and increase health impacts unnecessarily. They also make light as a commodity ‘cheaper’ and in the absence of measures to restrict external lighting, have led to the increased external lighting and light pollution. The impact of these changes since the Royal Commission’s 2009 report are summarised below in Box 3.

A central aim of the “lighting revolution” (the transition to solid-state lighting technology) is decreased energy consumption. This could be undermined by a rebound effect of increased use in response to lowered cost of light. Science Advances, 22 Nov 2017.

Box 3

Changes since the Royal Commission’s 2009 report

Royal Commission on Environmental Pollution’s 2009 description of light pollution	Change since 2009 (mainly due to the introduction of LED lighting)
Glare: The excessive contrast between bright and dark areas in the field of view.	Glare has increased considerably because of the increasing use of unshielded LED chips in street lighting and other applications
Light trespass: Unwanted light, for example from adjacent properties and activities.	Light trespass should be reduced by the use of LEDs, but increasing light profligacy may negate this.
Light clutter: The excessive grouping of lights, for example in roadside advertising which can prove a dangerous distraction to motorists.	Light clutter has increased considerably, in particular the use of large roadside LED screens with moving images can prove a much greater distraction than the static illuminated advertising used in 2009.
Light profligacy: Over-illumination which wastes energy and money.	Light profligacy has increased considerably because of the reduced unit cost of lighting as a commodity. In addition, because the area illuminated by LED street lighting is tightly defined, more people are attaching external lighting to their homes and gardens. Badly directed external lighting has become a major problem for light-sensitive and light-sensitive people and legislation on lighting nuisance is inadequate.
Sky glow: A combination of reflected and refracted light from the atmosphere. A major effect of sky glow at night is to reduce contrast in the sky. This is the most pervasive form of light pollution and can affect areas many miles from the original light source.	Sky glow evidence here is contradictory, the journal Science reports that, globally, the average night sky got brighter by 9.6% per year from 2011 to 2022, which is equivalent to doubling the sky brightness every 8 years. However within the UK some areas have shown a reduction in light pollution, perhaps due to the increase in

	people working at home during and since the covid epidemic.
An absence of darkness: Artificial light makes experiencing natural night-time lighting conditions impossible in many parts of the country	Remote sensing by satellites shows that this indicator of light pollution has worsened, however the dark skies movement and creation of dark skies parks, for example in Kielder Forest, Dumfries and Galloway and Cumbria has led to improvements in some areas.

Source: LightAware

What role should planning authorities play in determining plans or restrictions on light pollution? Are the current guidelines on light pollution set under the Government's advice for planning authorities adequate?

78. The All-Party Parliamentary Group for Dark Skies made recommendations in its report Ten Dark Sky Policies for the Government. While we fully support these recommendations, there are few protections for light-sensitive and light-disabled people included in the planning guidelines. In particular, planning consents for developments should ensure that health and disability impact assessments are undertaken to ensure that the proposals do not adversely affect light-disabled or light-sensitive individuals, for example by ensuring that individuals are not trapped in their homes by poor quality lighting and that they have 'lifeline routes' to amenities.
79. In addition the legislation covering lighting nuisance should be amended to ensure that light-disabled people are protected. LightAware have found that, for example, individuals on the autistic spectrum are badly affected by flashing lights decorative lights are helpless when their neighbours install such lighting. Councils' refuse to take any action for light nuisance because 'the average person would not be affected by this lighting' leaving individuals trapped indoors for months.

3. What recommendations would you make for changing Government policy on light pollution?

What are the possible interventions that could be deployed to mitigate the effects of light pollution and how well understood are their effects?

The UK government should:

- set rigorous standards for brightness (glare), flicker and colour temperature of external lighting, including a ban on exceeding a peak luminance threshold. This should ensure that:
 - Highways authorities reduce glare from current LED street lighting to an acceptable level, for example by fitting diffusers.
 - Legal limits are established for the amount of blue light that luminaires can have in their spectrum by limiting colour temperature of external lighting (including street lighting) to 2300K.
 - Local authorities should have a duty to ensure all external lighting in their area meets flicker standards and should have enforcement powers, including penalties for non-compliance.
- direct the National Institute for Health Protection to sponsor University research to establish how external LED lighting is causing ill-health for susceptible individuals and set standards for external lighting to ensure that light-sensitive people can safely leave their homes. This should include research into:
 - **Migraine** - the mechanism by which LEDs cause migraines in sensitive individuals.
 - **Light sensitive lupus** - a minority are unable to tolerate even small amounts of exposure to external LED lighting. Research to determine the cause these of impacts and appropriate standards set for the spectrum of external LED lighting.
 - **Autistic spectrum** – LEDs have a detrimental impact on some people on the autistic spectrum and effect educational outcomes, for school-aged people on the autistic spectrum. Research should be undertaken to establish the cause.
 - **Photosensitive epilepsy** - a small number of people suffer from photosensitive epilepsy where seizures are triggered by flashing lights or contrasting light and dark patterns. In a small number of people LEDs can also be a trigger. Although it

appears to be rare the impact on the affected individuals can be devastating and research to establish the cause and mitigations would be welcome.

The UK Government and devolved administrations should:

- strengthen their planning policy frameworks and make specific references to the control of light pollution and introduce a requirement to undertake Health Impact Assessments, Equality Impact Assessments and Disability Impact Assessments before approving development with significant external lighting. The scope of the planning permission process should be expanded by introducing regulations for exterior lighting and introducing a requirement to undertake health, equality and disability impact assessments before approving developments with significant external lighting.
- strengthen lighting Statutory Nuisance Provisions to remove the requirement for lighting to 'affect a normal person' to enable local authorities to protect light-disabled and light-sensitive individuals from nuisance outdoor lighting and light pollution.
- should set rigorous limits for the size and brightness of LED advertising screens and ban the use of moving images near public highways. Local people should be allowed local ballots as to whether LED screens themselves above a certain size should be permitted in their area.
- Introduce a legal requirement for a national target for reducing light pollution, in the same way as the Environment Act requires national targets on reducing air pollution and water pollution.
- should emphasise the role of education, professional bodies, cultural institutions and NGOs to achieve widespread public awareness of the issue of light pollution and its impacts on human health.

Local Authorities should

- minimise light pollution in their areas and ensure that designated dark skies areas are supported. This could include encouraging the creation of 'Dark Skies' areas by having referendums in rural areas as to whether to have street lighting at all or to switch off street lighting after a particular time.
- introduce a moratorium on the roll out of external LED street lighting and maintain current street lighting until it reaches the end of its useful life or until such time that safe replacements can be found. Councils should retain a supply of parts to help them maintain current street lighting. Where street lighting has come to the end of its economic life and needs to be upgraded, councils should consult communities about replacement street lighting, including:
 - an assessment to ensure that it meets the Public Sector Equality Duty
 - undertaking Regulatory Impact Assessments covering equalities, health, disability, and the environment
 - identifying light sensitive residents and taking steps ensure they are not socially excluded, including retaining conventional street lighting in their neighbourhood

- in rural areas, encouraging the creation of ‘Dark Skies’ areas and having local referendums as to whether to have street lighting at all or to switch it off or dim it after a particular time.
- undertake a thorough Impact Assessments to ensure LED streetlights are not causing harming the health of residents. Assessments should be part of a holistic multidisciplinary approach that considers the health, social, economic, and ecological impacts of the introduction of new lighting technologies. If (after public consultation and regulatory impact assessments have been completed) alternatives to LED lighting are not available, councils should retain non-external LED lighting in the neighbourhoods of light-sensitive people. They should include retaining lighting equipment removed from areas where LED lighting has been installed to maintain sufficient stock for this purpose.

Are there any interventions that have been pursued effectively in other countries that could be replicated in the UK?

Reducing light pollution in France

80. Light pollution standards in France could be effectively replicated in the UK. In France, The “Decree of 27 December 2018 on the prevention, reduction and limitation of light pollution sets an important standard in western Europe for the protection of night-time darkness through controls on the emission of light in outdoor spaces. It established robust national-level policies The Decree establishes technical requirements for the design and operation of outdoor lighting installations and imposes these regulations on both public and private property owners.
81. An important aspect of the French law is a strict lighting curfew prohibiting the illumination of industrial facilities during the early hours of the day and additionally obliging all exterior lighting to be switched off one hour after the last employee has left the office building. The phasing in of these policies has started in 2019 and it is planned to make them completely mandatory by 2025.
82. The provisions include:
- **Outdoor lighting curfews.** Curfews specify times of the night at which lighting must be dimmed or extinguished completely, more restrictive local adaptations” can be made at the direction of local officials.
 - **Limits on the allowed emission of light directly into the night sky.** The Upward Light Ratio (ULR) is limited in most cases to less than 1% of the total emission of a given fixture.
 - **Reduced glare.** Outdoor lighting must conform to a requirement that at least 95% of the light emission is confined to angles at or below approximately 14.5 degrees from the horizontal. This substantially cuts down on light in the so-called ‘glare zone’ of lighting and discourages lighting design that intends to direct light to areas especially far from the installation point of the fixture.

- **Restrictions on the emission of blue light.** The Decree requires that, in all instances, the colour temperature (CCT) of light does not exceed 3000K. Additional requirements for protected areas such as nature reserves and parks set the CCT threshold at 2700K for the “built environment” of towns and villages, and 2400K otherwise.
- **Allowable illumination levels.** In order to prevent use of excessive lighting that can compromise public safety, the Decree limits the amount of light used in any installation to no more than 35 lumens per square meter of illuminated target surface. For suburban and rural settings, the allowed limit scales downward proportionately to as low as 10 lumens per square meter.
- **Light trespass** into dwellings is prohibited, regardless of its source.
- The use of skybeams, lasers, and similar high-intensity light is generally prohibited.
- Night-time lighting of waterways is generally prohibited, including light shining out to sea.[]

83. These policies position France ahead of all but a handful of nations in terms of their comprehensive nature. They were phased in beginning on the first day of 2020, and compliance with all of the Decree’s provisions is mandatory by the start of 2025. To aid in enforcing the new rules, it obligates property owners to supply to compliance officials relevant “ information necessary to verify the conformity of lighting installations

Appendix. Survey of Light sensitive individuals' experience of pollution from LED street lighting

A number of people have contacted LightAware about their problems caused when LED streetlighting was introduced in their area. As LED street lighting is a major source of external light pollution, we feel that this provides valuable feedback to the House of Lords inquiry of the impact of light pollution on sensitive individuals.

We asked them to describe their experiences using the following questions:

- What effects do LED street lights have on you?
- Are any street lights better or worse?
- What have you done to avoid these effects?
- How has this affected your life?

Their comments are included in full and unaltered below. We have changed their names to preserve their privacy. The LightAware website also contains a number of case studies of how people's lives have been affected new lighting technology (see <https://lightaware.org/2018/03/9-lightaware-case-studies/>).

What effects do LED street lights have on you?

The intense whiteness and glare from many LED street lights make me feel immediate pain and discomfort and after a while I feel sick and get headaches, I also find it very difficult to get off to sleep and I often lay awake all night if I have been exposed to LED lights.

Tom, Manchester

Migraine, burning red rash, nausea, circulation slowing so cold, followed by fatigue, joint pain.

Elizabeth, Southern England

They make me feel sad and gloomy when out at night, some very bright ones make me feel sick and dizzy and 'flinchy'.

Angela, Central Scotland

All new street lights, including LEDs, make me feel disorientated, lose my balance and be unable to sense my feet. On the few occasions I have been under them I have to hold onto another person to stop myself falling. After being exposed I suffer a migraine.

Jane, North-East England

I am extremely affected by the light flickering of LED streetlamps. The provocation of my nystagmus (eye movement disorder) by alternating light stimuli significantly disturbs my vision as well as my orientation and, in addition, leads to violent health reactions in case of an "overdose". A stressful over-stimulation of my physiological perception is usually followed by dizziness, nausea, whole-body trembling, dazedness, booming noises in the ear, severe eye pain with redness, stabbing headaches, up to migraine and fever with cold sweat. Loss of vision also occurs. After such a reaction to flickering light, I need about two to three days to recover if I am in good health.

Michael, Germany

Most LED Street lighting makes me feel really awful and unable to function well, with migraines, dizziness, pain, extreme discomfort, being on edge, and a substantial general feeling of malaise. Non- LED Street lights are totally fine for me!

Gordon, Oxfordshire

They cause my heart to race, make me feel nauseated, dizzy, disorientated, make my skin hot and inflamed and cause my nerves to become heightened in my skin and immense itching which also affects my sleep. Exposure to artificial lighting can cause my Lupus to flare. **Jennifer, East Midlands**

Eye strain and headaches

Alan, London

Some lights are better than others but the bad ones give me a terrible headache and nausea that kicks in after 2- or 3-minutes exposure and takes a week to go away. The symptoms are like recovering from gastroenteritis and I am unable to socialise or leave the house for a week until they go away.

Julia, Cambridgeshire

They make my skin burn, make me feel queasy, cause an unsteady gait and my joints hurt.

Jasmine, East Midlands

For me LED street lights trigger migraine. acute light-sensitivity, shock, and emotional distress. **Emily, Lancashire**

Are any street lights better or worse?

Some do appear to be better than others though I am not an expert it is clearly unnatural to have a daylight white type light at night. I feel that if the glare was much less and controlled by better diffused and shading so you could not see the emitter in your field of view as well as being a much more orange colour that would help and improve conventional road safety as I know of at least one traffic accidents caused by streetlight glare. I believe many flicker at a high frequency that may be part of the problem for me and understand that this flicker is completely avoidable. I had no issues with incandescent, halogen, CFL or sodium lighting so they are clearly issue with LED technology that are not fully understood and controlled.

Tom, Manchester

None as good as old sodium halide. But with LEDs the cooler the colour temperature the worse the effect.

Elizabeth, Southern England

Bright blue/white ones are much worse.

Angela, Central Scotland

I don't know because street lights in my area/street were changed over 4 years ago from sodium halide. Their effect on me was so devastating I have barely left the house or even opened my front door in the evening since they were installed. I can also be affected during the day as many LEDs are actually on permanently, presumably because they are defective or have light-sensitivity settings that are inappropriate.

Jane, North-East England

I didn't have these problems with the sodium vapour lamps. But the old mercury vapour lamps are also terrible.

Michael, Germany

All LED Street lighting makes me feel awful and ill, weather cool or warm white. It's all way too harsh and intense.

Gordon, Oxfordshire

No.

Jennifer, East Midlands

About the same as I avoid them where possible and fortunately, I still have sodium on my street so it hasn't impacted my home life. However, if they were installed in my street I would likely have to move.

Alan, London

The ones in my street are not good but there are not many of them so mostly the street is in darkness, which is actually better. The ones in Jesus Green are just awful though and have the effect that I described in question 1 (They give me a terrible headache and nausea that kicks in after 2- or 3-minutes exposure and takes a week to go away). If I want to cycle across the park after dark, I have to cycle in the dark across the grass well away from the lights, which is a great personal safety risk, quite apart from the risk of my bike hitting a deep ditch and flipping me off. **Julia, Cambridgeshire**

No

Jasmine, East Midlands

In Lancashire where I live, the council have installed Urbis Schreder Teceo street lighting on the main roads. These are the worst LED street lights I have ever encountered. It takes me three weeks of extreme pain and distress to recover from even a short exposure to these lights. They are like a blue floodlight. The LED Street lights on the side streets are lower in height and less glaring. Direct exposure to one of these will give me a shorter migraine event, between 3 days and a week. Either way, after the headache subsides, for some time I find I am still much more sensitive to LED and other bright lights than normal,

and this means that I can end up ill for months as migraine is triggered repeatedly. This has happened for several years at the time the clocks go back and lighting gets harder to avoid.

Emily, Lancashire

What have you done to avoid these effects?

I have to avoid being exposed to light from the LED street lights if at all possible. I can no longer drive or go out on foot at night at all. I have had extensive consultations with ophthalmologists and neurologist and I have nothing fundamentally wrong with me though the effects of many LED light on me are clear and life limiting.

Tom, Manchester

As in the day UV proof mask and clothing and amber glasses and wide brimmed hats, but avoidance whenever possible.

Elizabeth, Southern England

I avoid certain streets and town centres, choose who I visit by what their street lights are.

Angela, Central Scotland

I do not leave my house or open the front door to callers when the street lights are on. In winter this is particularly isolating. It is very difficult to avoid the lights that are on during the day.

Jane, North-East England

Before the LED street lights come on in the evening, I need to be safe at home to avoid eye and headaches, vegetative disorders, accidents, and injuries.

If, on the other hand, the LED street lights are switched on during the day when it is cloudy or raining, I have to cancel appointments (e.g. a medical examination) if no one can accompany me safely.

Michael, Germany

I generally have to avoid driving and walking outside when the LED lights are on to avoid ill symptoms.

Gordon, Oxfordshire

I avoid going out during times when streetlamps are lit. I have had my car windows fitted with UV filter film and on occasions I am accompanied I travel in the back of the car.

Jennifer, East Midlands

Lobbied council to ensure my street maintained safe sodium streets lights. Wear a baseball cap to cut out the light. Avoid walking at night or standing under these lights.

Alan, London

I no longer cycle or walk in the streets after dark.

Julia, Cambridgeshire

I don't go out and expose myself to the street lighting

Jasmine, East Midlands

I made the decision several years ago, that I would simply no longer leave the house after dark. This practically means making sure I am home by 2.30pm in midwinter. At the time of writing, my immediate area is still lit by sodium street lights. On the rare occasions I do go out of my area after dark, I have to get a taxi and cover my eyes with a tight scarf so that no light enters. This makes me feel vulnerable, and it is not fool proof. Staying in seems the best policy.

Emily, Lancashire

How has this affected your life?

I was already unable to work due to LED lighting in offices but losing the freedom to be outside or even look outside at dawn and dusk is a further disability I am having inflicted upon me. The winter months are a particularly difficult time as I have to draw the blinds and curtains in the middle of the afternoon to avoid feeling ill.

Tom, Manchester

Stay at home more. I have to avoid sunlight but bright/cool white LEDs worse than sunlight, night where there are street lights worse than day.

Elizabeth, Southern England

I don't often go out after dark unless I know there's a 'safe route' through ok lighting. This affects my work and social life and that of my family.

Angela, Central Scotland

Because the lights make me so ill that I cannot go out after dark this means that, particularly in winter when nights are long, I am housebound for most of every day. This means no social life, no ability to go for a walk in the evening or early morning. If a family member had an emergency, I would not be able to drive them to a hospital. More trivially, I can't answer the door to local children doing trick or treat and I feel it makes me seem very miserly.

Jane, North-East England

So far, the flickering LED vehicle lighting has had a massive impact on me. The widespread conversion to LED street lights has now further limited my radius of action.

Michael, Germany

Profoundly! I am now cut out of life! For example, during my wife's year of battling against cancer, I wasn't able to drive or accompany her to many of her hospital appointments especially during the darker winter months because of the new LED lighting. I had to find members of the community to do this for me instead. It also means I am not able to go out to work or help with family shopping anymore!

Gordon, Oxfordshire

My quality of life is impacted greatly due to me being unable to go anywhere when streetlamps are lit. I can only go out during daytime hours which restricts any social or practical daily living events. I am unable to give lifts to my children outside of daytime

hours, my friends and family are very understanding but have to work around my needs.

Jennifer, East Midlands

Restricts my mobility at night.

Alan, London

My life is very constrained anyway because I can no longer visit any public buildings, shops, libraries, churches, or schools because of the lighting. Until recently I could at least enjoy the outdoors, but that is becoming increasingly tricky as the outdoor lights are changed over and driving me indoors.

Julia, Cambridgeshire

Any essential journeys need to be done during daylight hours which restricts my ability to go out during the evening to undertake normal activities of daily living. My life has been restricted significantly and has increased the sense of isolation.

Jasmine, East Midlands

This has been a devastating change in my life, it means I am excluded from work or leisure outside the house, things like visiting friends, going to classes or meetings, or even just walking through town are impossible, as is teaching in the homes of my students which is something I can do in the summer. It has been a huge adjustment, and very upsetting, but it is so much better than living with constant pain which was what was happening in winter before. And I have learned to appreciate the rhythm of the year much more now that I effectively hibernate.

Emily, Lancashire

If you have contacted your local council about LED street lights, what type of response have you received?

I engaged with my council and after initially being fobbed off they accepted there were health problems and offered to make some changes locally to help me they changed the 4000k LEDs in my village for constant current, 3000k, with better quality diffusers and some with directional shields to reduce glare towards my property. The changes helped it that I can now go out at night to for example put the bins out but I still need to wear sunglasses and would try to avoid going out as this gives me the best of getting a good night's sleep. I appreciate the council did try to help me but the wider issue is that something on a national or global scale needs to be done there are clearly issues with LED technology that are not understood and the constant drive to save energy has meant common sense has gone out of the window as with any new technology history has taught us a cautious approach is needed; let's not have another asbestos.

Tom, Manchester

No. We were lucky to live in a country lane with no street lights, we now live in a private close with no street lights. Have helped others to write to the council with mixed results.

Elizabeth, Southern England

I haven't yet!

Angela, Central Scotland

When it was proposed to introduce LEDs on our local promenade (I live on the coast), there was a public meeting to discuss the proposals. I was unable to attend but a friend explained about the likely adverse health effects on some residents and that lights were in any case not necessary on the prom. He was told by the elected mayor that everyone wants these lights. In other words, the possibility of anyone becoming ill was deemed to be irrelevant, so they were installed.

Jane, North-East England

My request has been examined by the city council. The final report expressed regret for my situation. However, as the city identifies itself as a consumer in the report, my intolerance to flickering lighting in barrier-free building projects cannot be taken into account. After all, the city has to take what the lighting market offers. The priority here is to save costs - not the welfare of the citizens.

Michael, Germany

After years of lobbying my council, they have switched some of the external LED lighting on my street back to amber sodium lights. But there's no guarantee that they will continue to do so and it hardly helps that LED lights are now almost everywhere!

Gordon, Oxfordshire

Our village is in the process of changing the streetlamps to LED. The Parish Council has agreed not to change the lamp in the road where I live and plan to keep the 'old' bulbs from the lamps being changed so that there are spare supplies for the one in my road.

Jennifer, East Midlands

As above the only concession was to maintain sodium in my street but this could be time limited as we don't know when suppliers will phase out. They've installed LED in most other parts of the borough so makes it difficult and forces me to wear hats/avoid prolonged periods walking most streets in my areas.

Alan, London

I contacted the council and they told me that the person in charge of street lighting safety had left.

Julia, Cambridgeshire

I have been in very regular contact with my council for the last 8 years. They have been supportive. After long and in-depth communications and me submitting medical evidence, they have agreed to keep the sodium lighting in my street and a few surrounding streets so that at least I don't have LED street lights shining into my house. They have made a commitment to keep my streets as sodium for the meantime at least. They have not been open to reconsidering the roll out of external LED lighting in general, but we are in negotiation about the roll out in my area, and they are trialling some more orange coloured LED street lights to see if they are acceptable to me.

Emily, Lancashire