

BLINDED BY THE LIGHT?

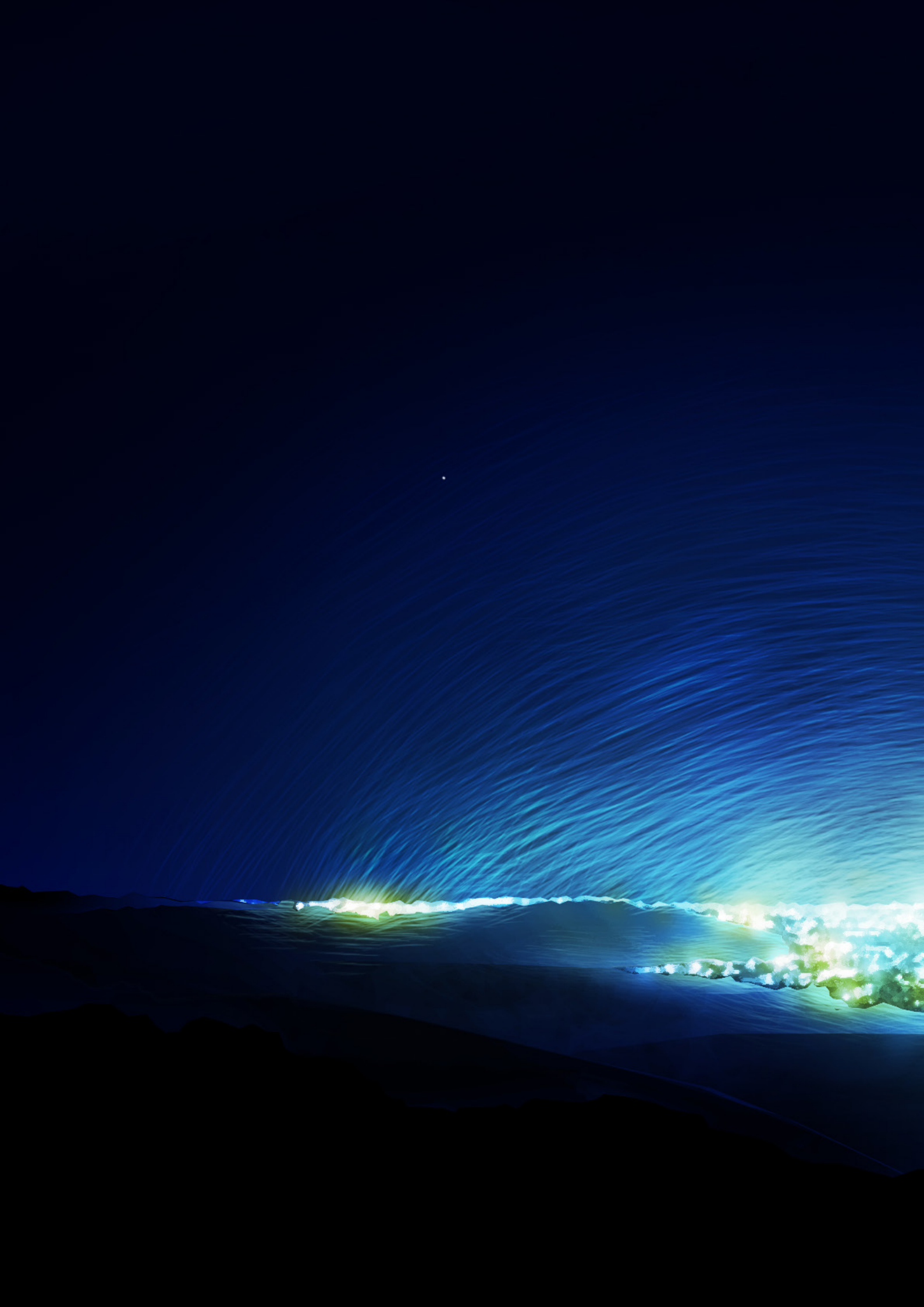
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British Astronomical Association



Commission for Dark Skies





Blinded by the Light?

A handbook for

friends of the natural environments of Earth and sky,

installers of considerate lighting,

campaigners against the misuse of artificial light,

and those adversely affected by light pollution.

This handbook is about an aspect of modern environmental degradation that has many facets. Wasted light not only steals the stars from our night skies; it risks the well-being of both humans and wildlife, and it has often unexpected social aspects.

“Issues relating to global health and sustainability must stay high on the agenda if we are to cope with an ageing and ever-increasing population, with growing pressure on resources, and with rising global temperatures. The risks and dangers need to be assessed and then confronted.”

Astronomer Royal Sir Martin Rees

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1) Introduction: The Problem

Environments of all kinds are being degraded almost everywhere on Earth.

Many wildlife populations are in massive decline, with an estimated 60% population collapse since the 1970s. Many species are in danger of extinction. The rate of decline is consistent with the five other great extinctions in Earth's history. We are living in the sixth.

Delicately balanced and non-renewable ecosystems are being destroyed in many places.

Carbon emissions (produced mostly by human activity) are causing rises in average global temperatures, threatening animal and human lives, water levels, food supplies and ecosystems. The changes are so rapid and extensive that CO₂ runaway could easily occur, eventually ending most life on Earth. Meanwhile, human populations increase at an alarming and unsustainable rate. We continue to waste energy at our peril.

Pollution is infiltrating the atmosphere, fresh water, oceans, soils, plants. Poisons, plastics and pollutants affect all living things, including humans. Noise and wasted artificial light impinge upon habitats. Natural darkness is being rapidly eroded, as the versatility and manageability of new LED lighting are neither appreciated nor applied worldwide. The stars themselves are no longer visible from large tracts of our planet.

Nineteenth-century inventors brought the benefits of artificial light to homes and streets. They could not have suspected that over a hundred years later their invention would be so sorely misapplied. Our 24-hour society sees cities and infrastructure grow, and swathes of wasted light have become visible from space on the night side of our planet. Over-bright and poorly aimed lights, mostly LEDs, are increasingly having a negative impact upon the environment, on biodiversity and on humans. Artificial light at night (sometimes abbreviated to ALAN) has its dark side.

We see that harm is happening, so we should act now to control the obvious degradation of all environments and pursue rigorous studies into effects and remedies. To ensure a future for our descendants we must boldly address environmental decline in all its aspects. Might the 21st be our final full century?

"We have cut ourselves off from our evolutionary and cultural patrimony – the light of the stars and the rhythms of day and night."

Verlyn Klinkenborg: Our Vanishing Night (National Geographic, November 2008)

"Issues relating to global health and sustainability must stay high on the agenda if we are to cope with an ageing and ever-increasing population, with growing pressure on resources, and with rising global temperatures. The risks and dangers need to be assessed and then confronted."

Astronomer Royal Sir Martin Rees

"If this generation lacks a comprehensive view of the cosmos, the future of life will be decided at random."

Yuval Noah Harari: 21 Lessons for the 21st Century

2) The Disappearing Universe

The unspoiled starry sky is, unofficially but undeniably, a site of special scientific interest, and an area of outstanding natural beauty. Ill-directed artificial light has quietly and rapidly stolen it away from most people in the developed world. In the United Kingdom, despite a little legislation about light intrusion into premises, the night sky, half of the nocturnal environment, remains the only part of that environment with no protection in law. At the time of writing (2019), the penalty for fly-tipping in the green fields of the British countryside is a substantial fine or even a prison term of up to five years; but veiling the beauty of a star-strewn sky with wasted light carries no penalty at all.

It is a sad paradox of modern life that telescopes can offer stunning images of the near and far universe, yet our lighting technology, if poorly designed and installed, steals our view of the stars above. Skyglow is the visible veiling of the night sky caused by scattering and reflection from atmospheric aerosols and droplets, even on what seem to be the clearest of nights. Astronomers have led the way in raising awareness of this phenomenon, but **light pollution is not just an astronomers' problem**, a fact that further chapters in this handbook will explore.

Thousands of stars should be visible to the unaided human eye from a dark place, but it has become, since the 1950s, increasingly difficult to find such places. There are sites in modern town centres where almost nothing outside the solar system is ever seen in the night sky.

For countless years, on every clear night, human beings were able to gaze in wonderment at the starry heavens, traversed by the Milky Way, lit by mysterious auroral displays and punctuated by the flashes of shooting stars. Nature's grandest free show has spurred us to consider our place in the great scheme, has given rise to many themes and aspects of our cultures and religions, and has inspired both artistic achievement and scientific endeavour.

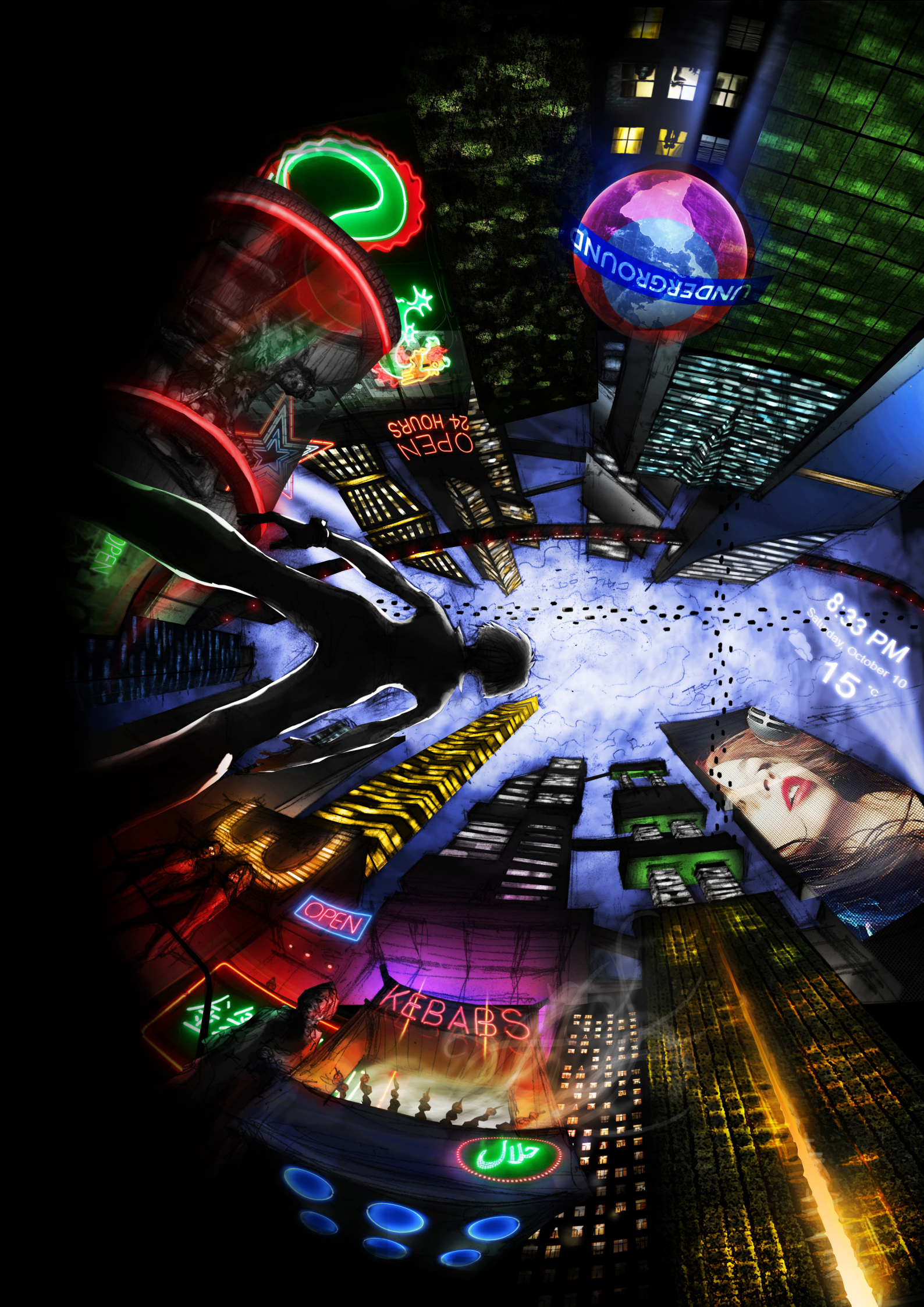
One of the things that nearly everybody 'knows' about the sunlit Earth is that astronauts can see the Great Wall of China from above our atmosphere. In fact, as they have confirmed, this is not the case. The Wall is a surprisingly narrow and mostly ruined structure, not strikingly different in colour from its surroundings. The wakes of ships, plumes of steam from power stations and similar extended objects contrasting strongly with darker backgrounds, are more likely to be seen from above the atmosphere than the Wall. However, as astronauts round the night side of the Earth, what they do see, spread across the darkness, are chains and patches of light, not all reflected from the ground, thrown up from our towns and cities, road networks, sports and industrial installations, and countless other sites. The energy that we so visibly waste is evidence of our inability to use lighting technology wisely.

If we are led to assume that the Earth is all that exists, and that stars and planets belong in picture books, on cinema and TV screens and computer monitors, because they cannot be seen in skies invaded by wasted upward light, we fall into an ultimate and dangerous vanity. We are divorced by skyglow from the reality of our very being.

Human beings, and indeed all living and inanimate things, are made of star-stuff. Nearly every atom in our bodies and in the things around us was created in some distant and probably long-dead star, or some explosive event whose reverberations have long since dissipated. Whatever is left of our material selves, when our planet finally sears in what Bertrand Russell called "the vast death of the solar system", will be redistributed, recycled, into the cosmic depths which we can no longer, in the twenty-first century, properly see and contemplate.

***"The light from distant stars and galaxies takes hundreds, thousands, even millions of years to reach us. What a tragedy to lose it in the last millisecond of its journey."
Bob Mizon Light Pollution: Responses and Remedies 2nd edition, 2012***





UNDERGROUND

8:33 PM
Saturday, October 10
15 °C



OPEN
24 HOURS

OPEN

KEBABS

حلل

OPEN

3) Environmental Aspects

“Too much lighting isn’t planned – it just happens.”

Ian Phillips, landscape architect and planner

The World Loses its Night

The evidence is clear that the 24-hour day and modern lighting practices are having very harmful effects not only to our own health and to our economy, but upon the nocturnal environment. Light pollution has not only robbed most of the world’s human population of a view of the Milky Way at night: it has been estimated that skyglow and intrusive light impinge upon more than two-thirds of the world’s crucial natural habitats. Rural areas are losing their night to wasted light escaping from elsewhere. Many studies show that wildlife and its natural environments are being badly affected. Rates of light pollution are increasing in Europe as the conversion to LED lighting is being mismanaged, and overbright, blue-rich types proliferate; in the Far East and the Middle East, where light pollution is spreading very rapidly, a very high proportion of wildlife habitats are threatened.

The current biodiversity crash is often ascribed to the negative affects upon wildlife, and especially insects, of habitat destruction, pesticides and other aspects of modern agriculture; but it cannot be ignored that, since more than half the world’s species are nocturnal, turning night into twilight or broad daylight can only be harmful to creatures of whatever size which have been evolving for millions of years in harmony with the circadian rhythm of day and night.

Ecology research scientist Dr Christopher Kyba warns that the advent of misused artificial light probably represents the most drastic change humans have made to the environments of nocturnal species. An enormous range of creatures, from the tiniest insects to large mammals, are having their foraging, breeding and circadian habits disrupted by the loss of the truly dark night. In towns and cities, increasingly excessive levels of lighting not only disrupt the sleeping patterns of humans but impact upon the survival chances of urban wildlife. An obvious example: songbirds singing at night as lighting triggers their dawn response. They become exhausted and feeding and breeding are affected. Dr Thomas Davies of Bangor University, Wales, is an interdisciplinary conservation ecologist with a special interest in human-environment interrelationships. He states that “the consensus among the scientific community is that skyglow is probably having very widespread impacts”.

Climate change – are we serious?

Across the globe on the 15th March 2019 many thousands of school students went on strike. They were protesting about inaction on climate change. Too few of us are acting to reduce greenhouse gases.

The independent Committee on Climate Change (www.theccc.org.uk) has stated that “meeting future carbon budgets and the UK’s 2050 target to reduce emissions by at least 100% of 1990 levels will require reducing domestic emissions by at least 3% of 2018 emissions, that is 50% higher than under the UK’s previous 2050 target and 30% higher than achieved on average since 1990. This is an indication of how substantial the step up in action must be to cut emissions in every sector.”

A carbon footprint calculator shows how we can take action, for example changing diets, insulating our homes, taking public transport more often... But our personal choices cover only about 20% of our total emissions. The footprint calculation adds another 80% to account for our collective impact, things we do as members of society, things like supply chain infrastructure for goods and services, powering schools, hospitals and other public facilities, defending ourselves, disposing of waste. It is not all bad news and many institutions have made significant carbon reductions. Technology is improving, not only to address climate change but for sound economic reasons.

One can point at good examples everywhere, but in most places change is too slow. Often, people cannot afford to make the long-term investments needed.

Go through almost any town in the early hours of the morning and you will notice lights on everywhere. Not only street lights, but also advertising panels, shop windows, 'security' lighting, spill from windows... And often there is no one about. Some places must be lit all the time, hospitals for example, but lighting elsewhere is wasteful. The 24/7 lifestyle is not something to be proud of if it causes excessive waste of energy. At some point we have to choose between marginal gains for the economy OR the planet.

There are many good reasons for introducing all-night lighting curfews, from midnight onwards say. For a start it would save carbon emissions by reducing electricity consumption and by discouraging needless overnight activity. Intrusive light prevents healthy sleep. Wildlife needs darkness. Nitrogen oxide and dioxide are potent greenhouse gases; they decompose more easily to less harmful gases under conditions of natural darkness. If the predicted increase in battery electric vehicles happens, then the National Grid capacity must increase, perhaps by 30%. Wasteful lighting will be competing for scarce, and thus expensive, electricity.

But the most important reason for switching off all-night lighting is that it would demonstrate to every one of us that the threat of climate change is really serious. Who knows, we might even change our behaviour. We must be able to face the youngsters and say that we are doing everything possible.

In December 2018 the French government passed the first national all-embracing light pollution law regulating the direction, brightness and spectral type of exterior lighting of all kinds. Other countries and regions have regulated lighting practices. Given the current urgent need to save energy as our planet warms, and the evidence that waste light is a contributory factor to the rapid decline in biodiversity (www.sciencedaily.com/releases/2018/06/180619122456.htm), we should be urging all administrations, both local and national, to save energy and reverse biodiversity decline by tackling waste light.



4) Lighting and Crime

“Who benefits from an outdoor ‘security’ light left on in the early hours of the morning? Is it the resident, fast asleep in bed, the police officer in a car ten miles away or the burglar selecting his tools beneath the light?”
Bill Eaves, CfDS Caithness

Ever since their remote ancestors crouched around campfires, aware of predators in the surrounding darkness, humans have associated light with safety and darkness with danger. We may, in the UK, have eliminated the carnivores that wanted to eat us, but there are still malefactors out there. Does darkness help them and endanger the potential victim? Are lighting and crime levels related? Lighting should not be installed in the hope that it will always deter criminals. Correctly positioned and angled lighting, which makes potential and actual offenders more visible to any onlooker, seems a sensible idea - assuming that witnesses are in fact present. Lights left on indoors, on timer switches to suggest someone is in, are a sensible measure. Equally sensible with exterior lighting is the reduction of glare in the direction of potential witnesses, and the avoidance of creating deep shadows, which can provide hiding places for malefactors. If suppliers of ‘security’ lighting took such aspects into account (which they largely do not), there might be a case to argue for lighting as a crime deterrent. Retailers continue to offer ‘security’ lights that have no directional control and are far too bright for the lighting task: most modern LED lights sold for domestic exterior use fall into this category. Dark-skies groups acknowledge the need for efficient, properly aimed and sensor-operated lights at night and have never called for the removal of any beneficial, unobtrusive light.

An insight into the role of street lights at crime scenes comes from August 2011, when in several city centres in England, night-time rioters looted shops in brightly-lit retail areas and in some places set fire to them. Street lights helped both the police and the rioters to see what they were doing. Interior lighting left on in the shops helped looters pillage them and make their escape. It worked both ways. Lighting itself has no bias: it will help both ‘good guys’ and ‘bad guys’ to see what they are doing.



Will these lights help the residents or the criminal at 3.a.m.? Always ask “Who benefits from my light being on?”

Most UK local authorities now switch off street lights after midnight as an energy- and cost-saving measure. Local and national newspapers often pick up on public uncertainties about this: "PLUNGED INTO DARKNESS" or "SWITCH-OFFS – CRIME-WAVE FEARS". Despite research showing that switch-offs generally decrease crime rates and have no effect on road accident rates, the media and some transport-related bodies continue to issue alarmist statements about these measures. They claim that darkness fosters criminality and causes road accidents. 'The science shows otherwise. In July 2015, researchers from The London School of Hygiene and Tropical Medicine and UCL showed that switch-offs do not increase car crashes or crime:

jech.bmj.com/content/69/11/1118

Lights should be no brighter than needed, and should illuminate only the area to be lit, for no longer than necessary.

If modern, well-directed lighting in streets and on buildings were shown to reduce crime, anti-light pollution campaigners, who have been promoting the benefits of well-designed lighting systems for years, would rejoice. However, evidence for such a relationship is sparse. Insurance firms do not ask whether a house has exterior lighting.

The UK planning régime includes exterior lighting insofar as it affects the daytime appearance of premises; its impact at night is not included, which seems a bizarre situation, and no mention of the fact that lighting and crime are not linked is made. Some relevant Government statistics can be found at:

www.ons.gov.uk/peoplepopulationandcommunity/crimeandjustice

Conclusions

Better, independent research is needed to quantify the effect of light on crime, and higher scientific standards are required – especially as large amounts of money are spent on lighting in the hope of a reduction in crime. The only thing that we can say for certain is that the common assumption that light will always deter criminals is incorrect.

When lighting is installed, the question must be asked "Who will benefit most from these lights? Criminals or potential victims?" There is still no proven link between lighting levels and crime rates, due to the complex nature of the subject, and simplistic conclusions cannot hide the fact that **crime is a societal problem rather than a lighting problem.**

Lighting should not be installed in the hope of crime being reduced. However, if light is needed for other reasons (for example, to help people use an area), then shielded lighting should be installed, of minimum brightness and minimum duration for the lighting task. Remember that lighting and dark skies need not be mutually exclusive - the use of modern full cut-off lights means lit areas are more satisfactory for all law-abiding people, with the likelihood of an optimum night sky.

"Police in the Bristol area have made a startling discovery - burglars fear the dark. Crime has gone down in some areas to the north of the city since street lights have been turned off during the night, because thieves apparently need the light to carry out their crimes. Parish councillors in Oldland agreed to the switch-off earlier this year which has already saved council taxpayers an estimated £16,000 in electricity bills. Councillor Ron Hardie, who represents Cadbury Heath, said: "The police have told us they have not seen any notable increase in crime. In fact, in some areas, there has been a reduction of 20 per cent. I understand from the police that burglars don't like it when it's dark. They like to be able to see their escape route and they like to 'case' premises before they strike. They would attract too much attention if they were using torches." Police figures show that in Frampton Cotterell, the crime rate has gone down by 50 per cent, in Thornbury by 28 per cent and Bradley Stoke, 17 per cent, compared with a year ago...". www.thisisbristol.co.uk

5) Light Pollution and Human Health

*"...I have been forced to sleep in the spare bedroom at the front. It has made me ill".
"...The neighbours and their persistent love of illumination... eventually ...forced me to leave where I was living".*

Letters to the CfDS from a Hertfordshire man



Image © by James Newton

This chapter is extracted from an article donated by Dr Steven W. Lockley, Ph.D., Neuroscientist and Assistant Professor of Medicine, Division of Sleep Medicine, Harvard Medical School.

Humans, like many other species, have evolved in the presence of the daily light-dark cycle generated by the Earth's rotation about its axis. This 24-hour light-dark signal has provided a powerful evolutionary pressure for adaptation to particular temporal niches, for example, adaptation to being day-active (diurnal), night-active (nocturnal), dawn- and dusk-active (crepuscular) and many variations thereon. Multiple specialised adaptations have evolved to optimise physiology and behaviour in relation to the time of day, solar orientation, season, and the amount of light or dark in the environment.

It is only relatively recently that humans have developed the capacity to generate light. Our ability to artificially light the night began about 250,000 years ago with the use of fire. Candles were developed about 5,000 years ago, and gas street lighting was possible beginning in the mid-1700s. In the last 120 years, however, our ability to alter environmental lighting dramatically expanded with the introduction of electric lighting. As described elsewhere in this handbook, access and exposure to artificial light at night has become pervasive in all industrialised nations and is becoming increasingly so in the developing world. This light affects all organisms exposed to it, not just humans, and the consequences of such a dramatic alteration in one of the most powerful environmental signals is not yet known. Given its relatively recent introduction, we are only at the beginning of understanding the impact of artificial light on human health. Research over the past 80 years, however, has shown that light exerts very powerful effects on human physiology, endocrinology and behaviour.

The major environmental time cue that resets circadian rhythms in mammals is the 24-hour light-dark cycle. Inappropriate light exposure can cause circadian rhythms to become desynchronised both from the environment and from each other, with potential adverse effects on physiology and metabolism. Light also changes the major biochemical signal for darkness, which is provided by the pineal melatonin rhythm. Under normal light-dark conditions, melatonin is produced by the pineal gland only during the night and provides an internal signal of night length. Light exposure during the night also inhibits melatonin production acutely, with suppression occurring immediately upon light exposure and stopping when the light is switched off. Under a natural light-dark environment, melatonin production would only occur at night in the dark and would not be suppressed by overnight light exposure. With the advent of artificial light, however, prolonged exposure to light during the melatonin secretion phase at night is a daily occurrence resulting in regular, chronic melatonin suppression. The cell cycle is also under circadian control and therefore disruption of cellular rhythmicity may make cells more susceptible to damage. Tumours also express circadian rhythms, and, in some cases, timed chemotherapy has been shown to be more potent than continuous infusion, likely due to increased susceptibility of tumour cells to damage at different times of day.

While inappropriate light exposure and circadian disruption due to shift work and jet-lag are well defined, the effects of inappropriate light exposure while living on more regular schedules have only just started to be explored. Given that dim light is capable of stimulating effects on human physiology, we cannot consider dim light an inert stimulus and must keep it in mind when reviewing the appropriateness of light environments. Studies are underway to measure the actual light levels that people are exposed to while indoors and, in urban environments, these light levels are likely to be significant, and even higher when individuals live closer to intrusive street lighting. Unnecessary horizontal and vertical street lighting permeates living spaces, particularly bedrooms. This light intrusion, even if dim, is likely to have measurable effects on sleep disruption and melatonin suppression. Even if these effects are relatively small from night to night, continuous chronic circadian, sleep and hormonal disruption may have longer-term health risks. Short- and long-term measures to reduce light pollution are therefore likely to have a beneficial effect on human health, in addition to reducing energy demands. While we have yet to understand fully the environmental and health impact of being exposed to light at night, the data to date suggest a detrimental effect of prolonged exposure to light at night.

6) The Cold Light of Night: LED Lighting

In recent years, worldwide, there has been a rapid change to LED (Light-Emitting Diode) exterior lighting. LEDs are energy efficient, long-lived and versatile. They are very small sources and are normally mounted in groups on road lights, with built-in optical lenses, making them potentially well-directed. They are often installed at higher brightness levels than previous designs, which were mostly sodium types. LEDs are often seen as the central yellow phosphor light source in domestic and commercial lighting units.

Most LED lighting has a blue-white colour, because of the high efficiency blue-type phosphors in the LEDs, which also match the peak dark-adapted eye response: that is, for the human eye, at low light levels where colour vision is only just partial. At full daylight levels the human eye has little sensitivity in the blue, while at low light levels as monochrome vision dominates, the opposite is true.

If blue light gets into the sky, then scattering is going to be very much greater than that from older orange/yellow sources. With good directional control, there is no need for direct light to go into the sky. Amounts of light reflected off the ground from roads and verges in rural areas will nominally be very small, as blue light is not reflected well by vegetation. However, it is reflected from concrete surfaces in more built-up areas, and if the lights are simply too bright for the lighting task, as so many are, reflections are increased.

Poorly directed LED lighting from tilted luminaires such as those often seen installed as sports and car park lighting or privately installed domestic and commercial exterior floodlighting (often erroneously referred to as 'security' lighting), causes a great deal of scattering in the atmosphere. In many areas these sources are the main contributors to glare, intrusion of light into premises and skyglow.



Car park floodlights in a rural area. Nearly half their emissions end up in the sky and surrounding countryside (Photo CfDS)

The trend over recent years has been for skyglow to become increasingly blue-white, most obviously towards the horizon from distant light sources. Scattering in slightly misty conditions gives the whole sky a blue-white sheen.

On a really clear night well-controlled LED lighting has only a small effect compared with previous designs.



Rural sports facility (Photo CfDS)

Effect of colour temperature

LED lighting is available in different colour temperatures. What is often called 'warm white' as opposed to 'cool white' has a correlated colour temperature (CCT) of around 3000-3500K, a lot less than that of blue-white (CCT over 4000K). The lower colour temperature has a yellowish colour and will cause a lot less scattering overall for the same basic ground brightness. It also causes a lot less glare.

Various organisations, including the International Dark-Sky Association and the American Medical Association, have long advocated the use of lower-CCT LEDs. There are many other consequences of the use of 'cool white' to the night-time environment and its inhabitants (see chapter 3). The lighting industry has been slow in responding to concerns about this.

Luminaire design: effect of angular distribution

The angular distribution of light from external luminaires is critical in the production of skyglow. Modern main-road luminaires tend to be mounted parallel to the ground ('cut-off', light directed below the horizontal). Older types of lights, particularly the orange low-pressure sodium designs, were not well controlled, with a significant fraction reaching the sky directly. Only if they had flat-glass casings mounted horizontally was there no emission above the horizontal.

Now, most LED road light designs are aimed only downwards, so their emissions reach the sky only if reflected off the ground or other surfaces. An asphalt road has a reflectivity of less than 8%, while green vegetation such as grass verges can be higher, depending on the source colour. A significant fraction of emissions from road lighting strikes areas away from the road. For vegetation, the maximum reflectivity is in the green-yellow spectral region and not blue or red. The latter is where photosynthesis operates, so all vegetation is very dark in red light, while bright in the near infrared where sunlight heating is rejected.

Every luminaire design has a photometry distribution profile provided by the manufacturer. Highways England lays down specific criteria for the overall fractions of light from any angle from vertically down, requiring complete cut-off. This is not met for tilted luminaires or those LEDs on curved mountings for widening the illuminated area.

The same applies for emissions from sports and other facilities. If asymmetric full cut-off types are not used, then light from tilted fittings reaches the sky, causing significant atmospheric scatter.

Effect of distant sources

Any light reaching the sky directly causes a great deal of scattering over great distances, beyond the local horizon. It is also wasted light and so wasted energy in not illuminating the intended ground area. That which is near horizontal and just above contributes most to sky glow. In the UK, one is never far from a town or city. Even in the apparently darkest rural areas, the zenith sky brightness is affected by cities and towns up to hundreds of kilometres away beyond the horizon.

Therefore the darkest areas tend to be remote from human habitation and screened by topographical features or close to the open sea.

7) Taking Action about Light Nuisance

(see also Appendix 2)

Those troubled by intrusive light and skyglow find that it is not easy to pursue and succeed with complaints to the owners of offending lights, usually local councils, neighbours, sports facilities and local commercial premises.

In late 2009 and early 2010 the Campaign to Protect Rural England (CPRE) and the British Astronomical Association's Commission for Dark Skies (CfDS) produced a survey on the effects of light pollution on people's lives. The two organisations looked into various aspects: sources of nuisance light, the problems they cause and action people have taken to remedy the situation.

Respondents were asked how they felt about the light pollution and the measures they had taken to deal with the problem. They felt generally angry (on a spectrum from "irritated" to "absolutely desperate!") and frustrated that there seemed little they could do, despite the legislation in Section 102 of the Clean Neighbourhoods and Environment Act 2005, which gives local authorities power to deal with many forms of nuisance lighting. Complaints of lack of interest and response from councils were common.

Some people troubled by intrusive light had resorted to erecting screens or installing thick curtains, which goes against a well-established principle of the law of nuisance: it is the polluter who should remedy the situation. Some respondents had moved house to escape from light intrusion, having encountered intransigence from offending neighbours, or not having wished to cause friction with them about their lights.

One respondent summed up the huge cost to the environment above of light pollution thus: "Unfortunately, thicker curtains and blinds do not address the problem of light pollution of the sky. Where is the starlit sky I used to see when I was a little girl in the '40s and '50s?"

What is a 'lighting nuisance'?

Some forms of artificial light were made a statutory nuisance in section 102 of the Clean Neighbourhoods and Environment Act 2005.

If someone's life is being negatively affected by excessive light this can qualify as a lighting nuisance, although it may not fall under the official criteria for a statutory nuisance. For example, if a street light is shining into a bedroom window it can affect quality of sleep but it is exempt from the statutory nuisance criteria.



Action points for residents and astronomers

Unnecessary glare from exterior lighting can be easily demonstrated by suggesting that owners look at them from a distance while you walk towards the property, disappearing behind the wall of light. They will realize that theirs is an 'anti-light', concealing rather than revealing, and they may well do something about it. In the case of road lighting, reassure neighbours that part-night switch-offs have been shown to have a generally positive effect on crime rates (see chapter 4). If people are worried about crime in lit areas, ask them to consider what role the lights play in the decisions of criminals.

Astronomers may not be able to convince all their neighbours, especially in high-crime areas, that a darker environment can be as much of a deterrent, if not more, to wrongdoers as a brightly lit one, but make the point that a real human being outside on a clear night is a far better security device than any lamp: an astronomer can take action if (s)he sees or hears anything suspicious, but a 'security' light cannot.

Many neighbours have re-angled or re-sited lamps after looking through an astronomer's telescope: occasional star parties will sensitise neighbours to the existence and value of the environment above. Perhaps astronomers could even arrange for offending 'security' lights to be triggered while showing their owner the night sky, so that the effect can be appreciated first-hand.

If polite personal approaches fail, contact the Environmental Health Officer of your local council and, in the case of light intrusion, invoke the Clean Neighbourhoods and Environment Act 2005 (see above). If officials charged with the protection of the environment seem to have little knowledge of any legislation, consult the CfDS website for further advice. The night sky has no protection in law, but sympathetic individuals on some councils have been known to intercede in the case of skyglow, on behalf of astronomers. DEFRA officials have stated (Lighting and Law conference, Bath, 2005) that astronomers should not be considered as hypersensitive or as a special case, and they have as much right to pursue their activities without disturbance as anyone else.

Alert local media to the problem caused. Contact local action and pressure groups. If local intervention is not forthcoming, contact the CfDS*. Concerned astronomers often report the offenders' assumption, despite reasoned arguments, that they are against lighting. So, early on in any discussion or presentation, introduce the fact that good-quality lighting means a more evenly lit environment; discuss the demerits of glare, and the possibilities of concealment through glare or too-deep shadows. List the security and other benefits of a properly lit terrestrial environment before you move on to the astronomical arguments. It is worth remembering that not everyone considers the night sky an important thing. Discuss money and energy savings.

'Broadsides' don't convince, carping criticism builds barriers, and baldly accusing someone of being a polluter is unwise. Have the facts to hand: published engineers' guidelines (www.theilp.org.uk), fact-sheets from CfDS and the International Dark-Sky Association (IDA, www.darksky.org), and other organisations which web searches may reveal.

*www.britastro.org/dark-skies/enquiries.php



Advice from the UK Government

The UK Government's environmental department, DEFRA, offers the following advice on its website for complaining about light pollution.

'When informal action is not possible or fails, you can resolve the problem by taking formal action. The most common route involves complaining to your local authority about the light problem. Local authorities have a duty to investigate complaints. Under sections 79 to 81 of the Environmental Protection Act 1990 local authorities have a duty to deal with light nuisance from premises which they consider to be a statutory nuisance.

If you want to make a complaint about light nuisance you should contact your local authority, usually the Environmental Health Department.

If they visit or witness the light problem and are satisfied that a statutory nuisance exists or is likely to occur or recur, they must act. If the light nuisance is intermittent, they may ask you to keep details of the problem in the form of a diary. Sometimes they may measure the light as part of their investigation into a complaint. There is no set level at which artificial light from premises becomes a statutory nuisance.' (www.gov.uk/government/publications/artificial-light-in-the-environment)

"When children and grandchildren stay, I have to hang blankets over the curtains as they are unused to sleeping with such intrusive light"
Interviewee, Campaign to Protect Rural England lighting survey 2010

8) Good and Bad Technologies

Although the night sky has all but disappeared over urban areas in the UK, there is still considerable public interest in stars and planets, as the continuing popularity of television programmes on astronomical subjects proves. We are encouraged by TV presenters to look for meteor displays, but soon realise that light-polluted skies prevent us from seeing all but the brightest, even on the clearest of nights. The Milky Way is a distant memory, erased by poor lighting practices.

Efficiency and economy are vital in good design, whatever the product. Wasteful globe lights and exterior domestic lights that cannot be pointed completely downwards are prime examples of 'how not to do it'.

Bad lighting is caused by:

- light beams pointing upward and sideways, creating useless skyglow and wasting energy (see chapter 2, The Disappearing Universe).
- too many lights, in inappropriate places (for example up trees!) and without real purpose.
- light intensity far beyond real needs.
- patchy and uneven light spread.
- lights being left on when not needed.
- colour tinted towards the unfriendly, cool-blue end of the spectrum (see chapter 6, The Cold Light of Night).
- lights that glare, dazzle and cast deep shadows, making it difficult for people, particularly the elderly, to see clearly, endangering road users and facilitating crime.

Technology has brought us enormous benefits, enabling higher living standards and opportunities unimaginable to our ancestors. But it has also introduced many unwanted side-effects, causing harm to environments - a huge and increasingly urgent issue.

With many technologies we have the choice whether to use them or not. We can choose to watch TV, use a mobile phone, switch on a bedside lamp and so on. These are personal devices within our own control. They may cause a little disturbance, but considerate use is acceptable.

Some forms of technology are provided for use in public spaces and are intended to improve the general good. Examples include most forms of public transport, automatic barriers, cash machines, outdoor lighting.... Individuals have little personal control over these devices. They are simply there, like it or not. We accept them as a price for living in advanced economies.

Organisations who build and run facilities like airports are given permission to do so by the community. Planning laws determine what constructions are allowed, and operating licences are granted by collectively controlled bodies. In many instances this works well, and people are happy with the system. However, individuals are seldom asked for explicit consent and some may be very unhappy and consider it an imposition. Remember Concorde? A beautiful machine, but it was noisy and smoky and annoyed many living under its flightpath. It worked well in some respects but was deeply flawed in others. How one views something depends if you are up there or down here.

Protect the Night

*Above the shrill cacophony of light
curtains of stars are hung against the sky.*

*Fold beyond fold, the galaxies recede
until our minds refuse to entertain
such depth, such time, such endless distances.
The well of heaven, deep and black and infinite.*

*And we, below our comfortable clouds,
baffled in light, forget to hear the stars,
whose high, rare harmonies, subtle as dreams,
stream through those nine imagined crystal spheres.*

*These curtains of stars, stubborn as time,
as fierce as fire, protect the night.*

David Robinson

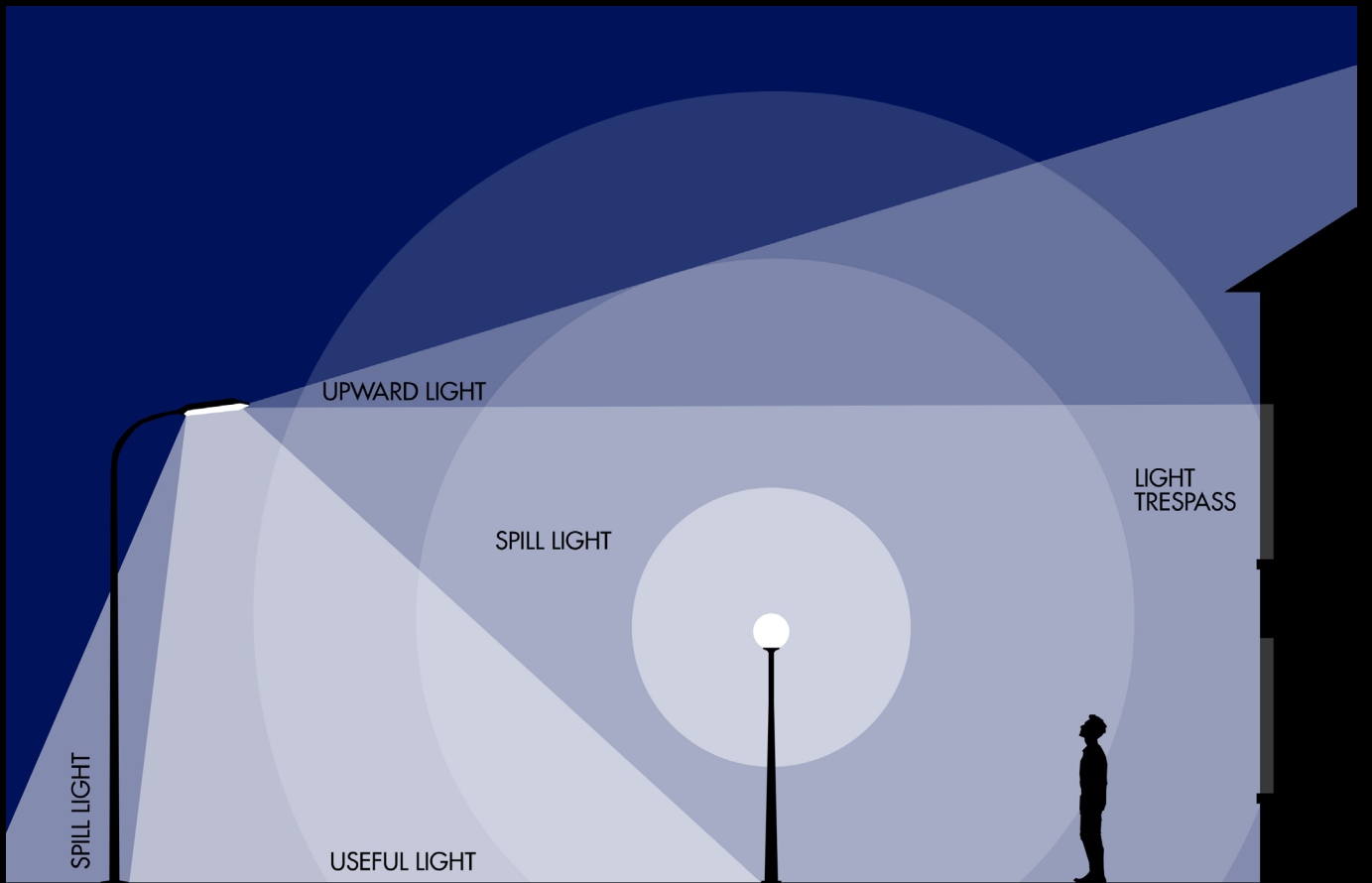
It is reasonable to protest when technology is simply not good enough. Standards for communally deployed technology should be most exacting. We now insist that planes are built to more stringent regulations, producing the least noise and air pollution that is technically workable. The higher the technology and the more intrusive it is then more stringent standards apply. A lit road sign needs greater care in deployment than an unlit one. Producers and implementers have a primary duty to strive for the best solutions available at any point of time. The public environment is not a space for maverick, arrogant or incompetent designers to practice.

Good lighting is a beneficial technology. The professional outdoor lighting industry has mostly accepted the problem of light pollution and taken many steps towards improvements. After all, it is no longer the 1970s. But problems remain. In the industrial, commercial and domestic sphere, lighting standards are rather poor. Are there valid reasons to light garden gnomes, point spotlights into neighbouring premises, leave shop window lights on overnight, angle car park lights to point skyward and so on?

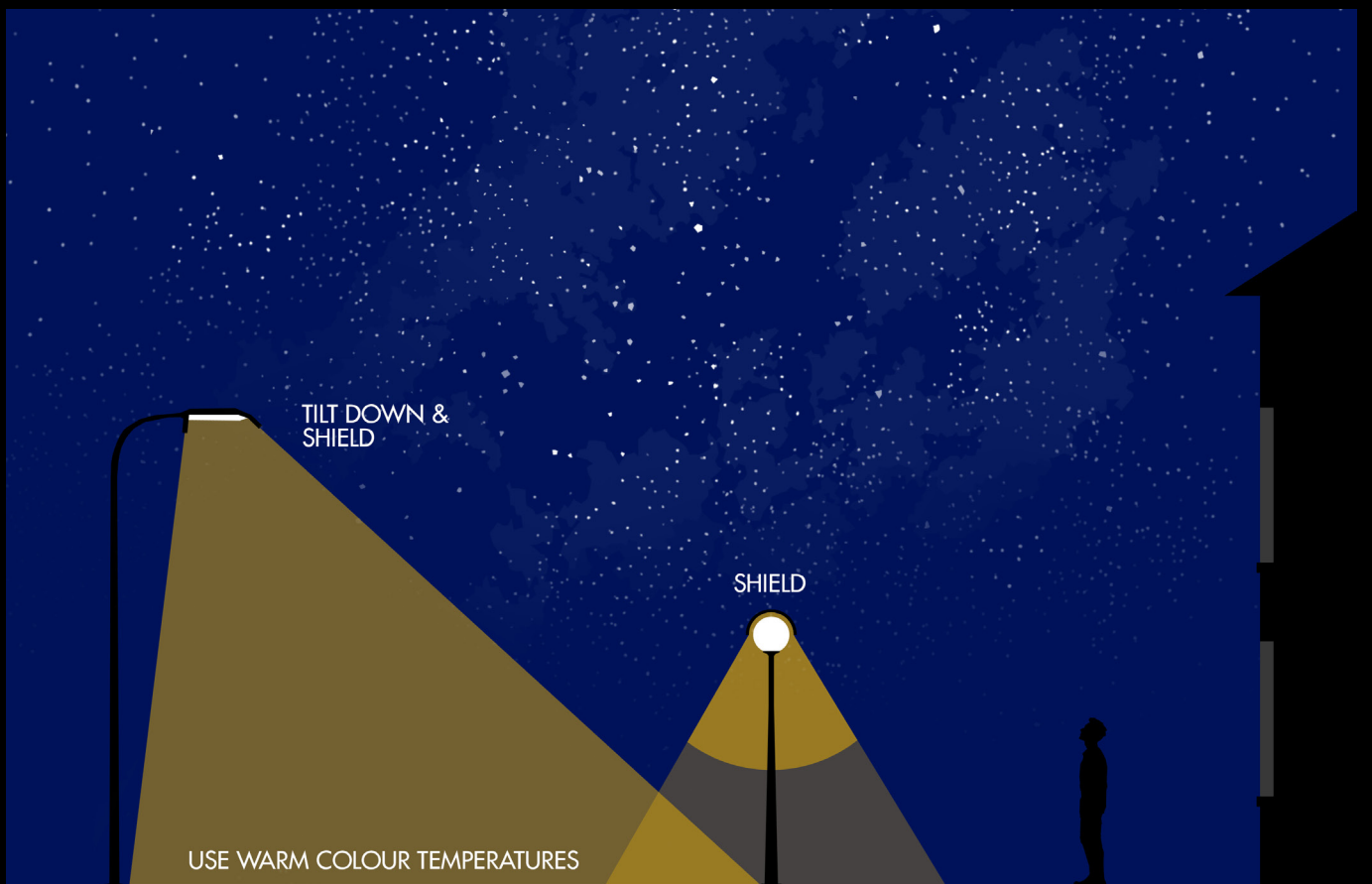
All outdoor lighting contributes to light pollution, which is particularly noticeable in sensitive rural areas. In the UK planning system much outdoor lighting comes under the heading of 'permitted development', but when planning consent is granted it is only day-time aesthetic considerations that are assessed. There are no anti-light pollution design constraints on lighting manufacturers and distributors. You can still buy globe-on-post lights to prettify your yard and dazzlingly bright, blue-rich so-called 'security' lights. Why is this allowed?

Lighting can bring us great benefits. Uncontrolled, unregulated lighting brings us problems that far outweigh those benefits.

"With good lighting, everybody wins"
Dr David Crawford, International Dark-Sky Association



Bad lighting example



Good lighting example

Appendix 1)

Lighting assessment principles

The natural night-time environment in the absence of artificial lighting is illuminated primarily by the Moon which, when full, produces an illuminance on the ground of approximately 0.5 lux. Moreover, under natural conditions, an overcast moonless night produces an illuminance on the ground of the order of 0.0001 lux. By contrast, public spaces tend to be illuminated to approximately 50 lux at night. Thus, artificial lighting increases the level of illumination above natural levels by a factor ranging from approximately 100 to 100,000.

Artificial light straying into the natural night-time environment constitutes a contaminant, in the sense that it is an impurity added to the natural illumination of the environment, and is undesirable. This contamination of the natural environment has the potential to be hazardous to species or ecological systems accustomed to that environment: in this sense the stray light may represent a pollutant. The following assessment principles are intended to provide a framework of guidance for those wishing to assess new lighting schemes or modifications to existing lighting schemes, with a view to minimising environmental and ecological impacts. The guidance is based on the reasonable notion that artificial lighting at night represents a contamination risk that is potentially hazardous to ecological systems. Other sections of this handbook provide arguments and evidence as to why this claim is believed to be true.

Formulated by the British Astronomical Association's Commission for Dark Skies, the following principles:

- provide a general framework to assist the public, councils or anyone else in their assessment of (or judgment on) a lighting scheme;
- offer a consistent and systematic approach to raising challenges against lighting schemes in a way which is not prescriptive, restrictive and unreasonable;
- act as a guide for the kinds of question which should be put to the originator or owner of a lighting scheme, or someone acting on their behalf;
- provide a means of obtaining pertinent information to better understand the justification for the lighting scheme and any shortfalls in that justification.

Assessment Principles

1) As a general principle, for a given lighting scheme, the number of light sources and the brightness of each light source should be minimised to be as low as reasonably practicable, consistent with intended site, function and task requirements.

Notes: The purpose of this principle is to guide the assessor to understanding why a further reduction in the number of lights or the brightness of the lights cannot be justified, including the option for switching off lights.

The term 'as low as is reasonably practicable' is to be interpreted in terms of weighing incremental benefits to the environment arising from a reduction to the number and brightness of luminaires against any dis-benefits of doing so, e.g. loss of function, detriment to the task etc. and may be viewed in the context of diminishing returns. Note also that lighting schemes can be both beneficial and detrimental to the general public.

2) The intended lighting target area or boundary and general lighting requirements should be defined, to which calculations and arguments underwriting the lighting scheme should relate.

Notes: This principle ensures that the boundary defining the location where the lighting scheme is to apply is defined, so that the environmental context beyond the boundary can also be defined. Consideration should be given to the function or task which the lighting scheme is intended to support, lighting objectives, horizontal and vertical parameters (including upward spill).



Area floodlighting causing stray light, some of which dazzles drivers on the road beside which it stands

3) All light sources having the potential to lead to light straying beyond the defined target boundary or contributing to skyglow should be identified.

Notes: A full schedule of luminaires should be obtained and reviewed. The description of light sources in the lighting scheme should be comprehensive: number, source type, luminous intensity, shielding, direction, spectra etc. Note that internally lit buildings with windows should also be considered.

4) The lighting scheme should be optimised to reduce stray light beyond the target area and reduce its contribution to skyglow to levels which are as low as reasonably practicable. Light sources should also be of a colour temperature which minimises any adverse effect upon the natural functioning of ecological systems.

Notes: The intention of this principle is to guide the assessor to understanding why a further reduction in stray light and contribution to skyglow cannot be justified. Consideration should be given to limiting the hours of use of the lighting, dimming strategies, the direction of light, shielding and other methods for reducing the quantity of stray light and contribution to skyglow. Ecological systems are also sensitive to the colour of light, with 'warmer' colours being generally less detrimental than 'cooler' colours.

Consideration should be given to understanding the surrounding night-time environment, critical viewpoints and sensitive receptors, light over-spill, obtrusive light and comparison with a baseline measurements or predictions (i.e. light levels in the absence of the intended lighting scheme).

5) A variety of hand calculation methods and computer codes are used in designing, assessing and substantiating lighting schemes. Assessors should consider the suitability and adequacy of these as appropriate.

Notes: The intention of this principle is to understand whether the right numerical tools for the job are being used when presenting results of lighting calculations. The soundness of calculational methods should be considered, including their validity for various weather conditions, such as clear conditions, fog, rain etc. which have different light-scattering characteristics and therefore lead to different effects upon the environment.

6) Calculations should include an analysis of modelling limitations, modelling approximations, systematic bias, tolerances, variations in source strength over time, and uncertainties in input data and outputs. Assumptions associated with input data should also be presented.

Notes: Calculational uncertainties and biases should be accounted for so that the worst-case impact of the lighting scheme can be assessed. Understanding whether calculation results are presented on a conservative basis or a best estimate basis with uncertainty, from the perspective of environmental protection, allows for a better understanding of the actual outcome following implementation of the lighting scheme. Additionally, evidence of verification of the calculations should ideally be presented by suitably qualified and competent persons or organisations. Input assumptions can include items such as weather conditions, surface conditions and reflectivity values.

7) Validation of hand calculations or computer calculations should be demonstrated by reference to benchmark data wherever possible. In cases where such data are not available, validation by comparison with an independent method may be acceptable.

Notes: This principle is intended to guide the assessor to understanding the validity of the calculational methods being used to underwrite the lighting scheme. Where possible, measured data for similar or identical lighting schemes should be sought for comparison against predicted lighting levels for those schemes. Consideration should be given to the latest research and development with respect to benchmarking calculations against measurements, and whether the conclusions drawn from the calculations account for this.

8) Lighting guidance notes may be used as an aid to judging whether lighting levels, directionality and colour are being adequately controlled or not, with due account being taken of their basis and limitations of use.

Notes: Submissions for lighting schemes usually reference various guidance notes produced by professional organisations. Assessors should be satisfied that the basis of such guidance and limitations inherent within it are understood by the lighting scheme designer; mere deferral to a professional body with no further consideration of basis and limitations should be regarded as not being good practice.

The following parameters are often mentioned in lighting guidance notes.

Environmental zones defined qualitatively in terms of lighting levels. These can have ambiguous demarcations, for example, between zones defined as being 'dark' and 'intrinsically dark'. Assessors should consider the extent to which such definitions are useful within the context of the proposed lighting scheme, its environment and whether a suitably conservative decision has been taken when allocating a lighting zone to a lighting scheme.

Illumination target values for horizontal and vertical planes. Assessors should consider the suitability of these target values and their consistency with the other assessment principles, regardless of whether the targets are expressed as minimum or maximum values.

Luminous intensity target values for the luminaire. These originate from considerations primarily to do with preventing glare rather than minimising skyglow. Assessors should therefore consider the suitability of specified luminous intensity targets, whether they relate to maximum values or not, and the direction to which they refer.

Luminance target values relate to the amount of light reflecting from structures, usually buildings, including light reflected upwards. As with the other quantified target values, the suitability of luminance targets should be reviewed for their consistency with the other assessment principles.

Upward light ratio (ULR) target values is the fraction of the total emitted light which is directed upwards. Target values are usually applied to the whole lighting scheme although assessors should also consider ULR values for individual luminaires. ULR values equal to zero imply that lights are of the full cut-off type. Values greater than zero should be avoided wherever possible, noting that light spillage of a mere few degrees above the horizontal can contribute significantly to skyglow. Legal requirements may also be relevant, such as The Management of Health and Safety at Work Act and the Clean Neighbourhoods and Environment Act. The Health and Safety Executive publishes guidance for the use of lighting at work, identifying risks to workers and recommendations for lighting levels, including for outdoor working environments.

9) Lighting levels should be optimised to be congruent with the least bright area of a zone or the least bright surrounding area beyond the defined boundary of the scheme, consistent with the objective of reducing stray light and contribution to skyglow to as low as reasonably practicable.

Notes: It should not be considered acceptable for a new scheme or modified scheme to regard existing or adjacent lighting levels as an acceptable benchmark. This principle is intended to avoid a runaway effect of introducing brighter and brighter illumination in or near to existing areas of illumination, or in dark areas adjacent to relatively bright ones. In some situations, credit may be taken for existing adjacent lighting schemes contributing light to the defined target area.

Appendix 2)

The cost argument

Below is a sample letter for complainants about poor quality lighting

It makes the point that not only is well-directed lighting more environmentally friendly, but any light that does not waste its emissions where they are not needed can potentially save money. Putting light in the right place means that the light source can be less bright.



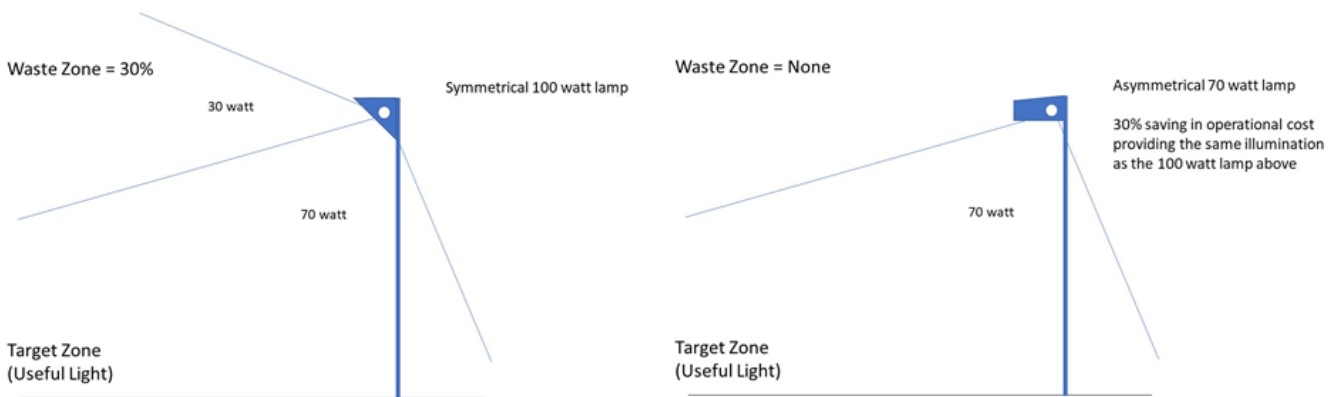
Shielded streetlight in residential context

Dear

I/we wonder if you'd like to consider a simple measure which can save you/your company money while improving night-time ecology and the environment. Householders/Companies illuminate premises at night using outdoor lights for various reasons. Often these lights are of the kind shown below.



The colour, intensity and direction of the light can have negative effects upon night-time ecology and environment. An obvious example of this is the distraction of moths by light from their usual night-time pollinating activities. Other creatures known to be adversely affected by external lighting include owls, bats and various insects. The use of 'warm white' light and a target correlated colour temperature (CCT) of 3000K or less, instead of blue-rich 'cold white' light, goes a long way to solving such problems.



The following 'before and after' diagrams show schematic views of how the use of asymmetrical flat-based lamps can reduce wasted light, energy and therefore running costs, while maintaining the desired level of illumination of the intended target area (figures are illustrative).

Please contact me/us for any discussion of these points.

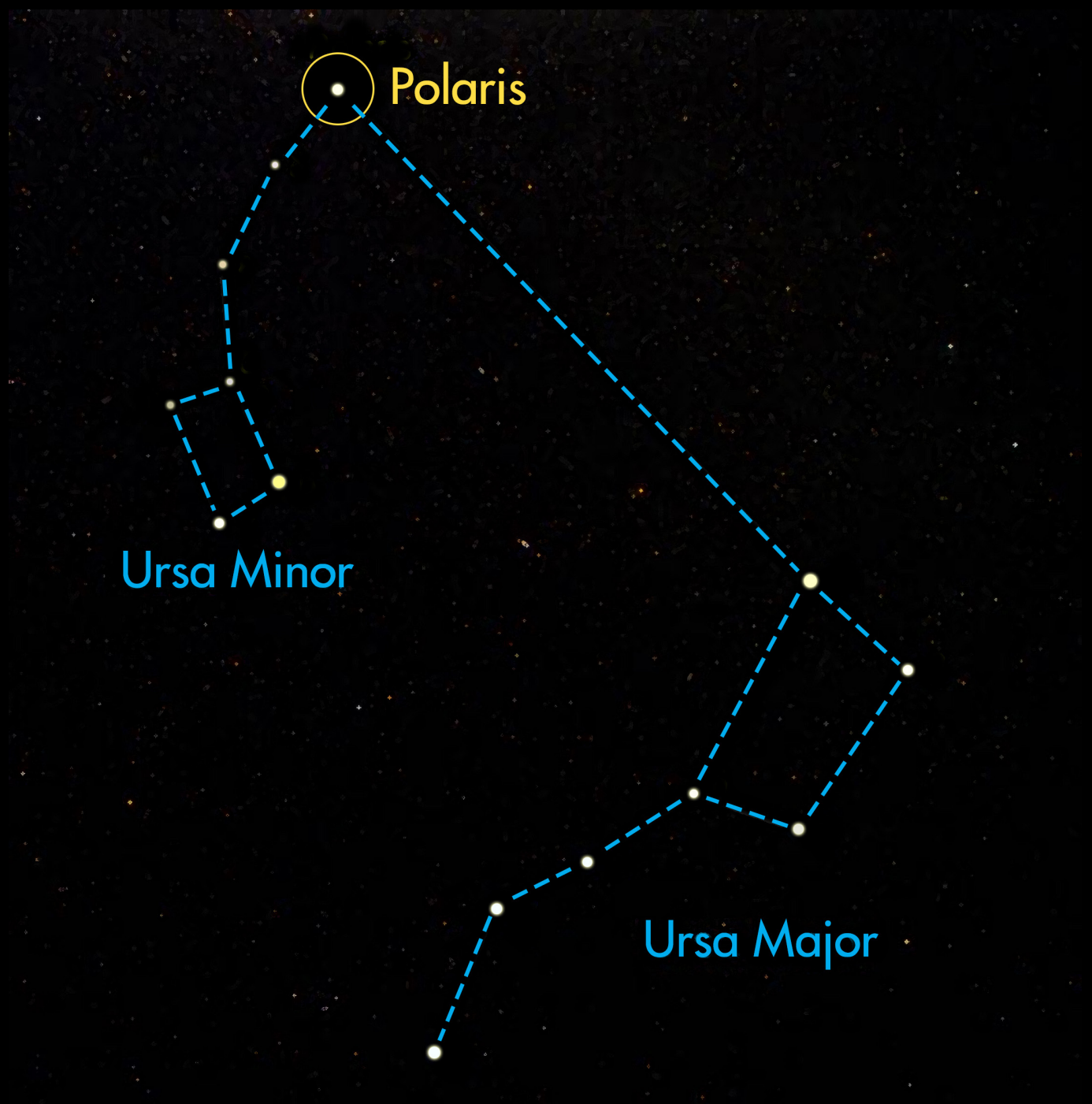
If you need further information, please refer to www.theilp.org.uk/documents/guidance-note-1-for-the-reduction-of-obtrusive-light-2020/

Appendix 3)

Method for Assessing the Quality of the Night Sky

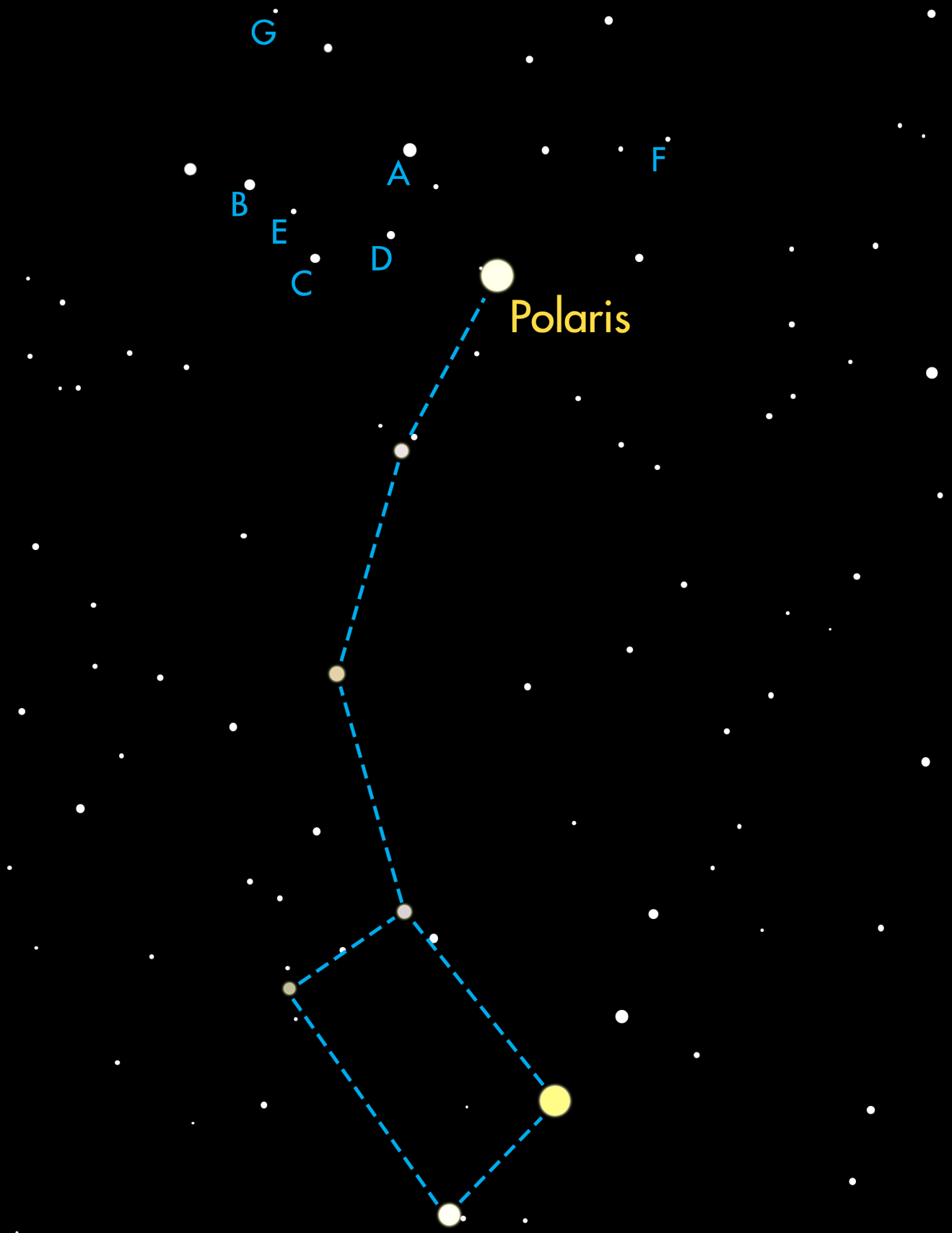
This appendix presents a simple method for assessing the quality of the night sky on a subjective but reasonably accurate basis. The method relies upon identifying stars of known brightness, in the vicinity of Polaris (the Pole Star), in order to determine the dimmest star that is visible in that direction of the sky. The method is as follows:

First, identify Polaris using the stars of The Plough, part of The Great Bear (Ursa Major) as a guide, as shown in the first picture.



Next, using the second picture, determine which of the marked stars in the vicinity of Polaris can be seen with the naked eye, taking particular note of the dimmest one that is visible. The marked stars have the following apparent visual magnitudes (brightnesses) based on data obtained from The British Astronomical Association Variable Star Section and The American Association of Variable Star Observers (A is brightest, G is dimmest):

A=4.2, B=4.7, C=5.3, D=5.6, E=5.9, F=6.1, G=6.4



In broad terms, if all of the stars are visible to the naked eye then the quality of the night sky may be considered to be very good in the vicinity of Polaris. By contrast, if only star A in the list is visible then the quality of the night sky may be considered to be poor.

Several points should be kept in mind when making the observations:

- Allow your eyes to adapt to the dark by waiting for at least 15 minutes before making the observations.
- Observe the listed stars in a consistent way with regards to using either direct or averted vision, taking notes accordingly.
- Avoid making the observations during twilight or when the Moon is visible. Observations during autumn, winter and spring are preferable.
- Make observations before and after midnight on any given night, if possible, with a minimum gap of one hour between observations.
- Repeat the observations throughout the year.
- Keep a record of the date, time (GMT), the naked eye limiting magnitude recorded and the weather conditions.

The above points will help to ensure that a reliable long-term record of the local sky quality is produced, with a view to identifying any changes in the quality of the sky over time whilst minimising any temporary biasing effects (e.g. biasing as a result of changes to atmospheric conditions).

Another simple method for assessing the quality of the night sky is to count the number of stars visible to the naked eye within the four main stars of the constellation of Orion when it is at maximum elevation above the southern horizon. The Campaign to Protect Rural England runs an annual national star-count of this kind to which the reader can submit results.

<https://www.cpre.org.uk/what-we-do/countryside/dark-skies/>

Objective results of the quality of the night sky can be obtained using a dedicated sky quality meter. These can be set up to provide frequent near-continuous monitoring of the limiting magnitude overhead, which can be fed to a computer for further processing. The CfDS is developing a network of sky quality meters and is able to provide further advice as to their use.

We hope the information in this booklet is of use to its readers and further advice may be requested from: www.britastro.org/dark-skies/enquiries.php

Thank you.

"The night sky is one part of our environment we have shared with all cultures in all periods of human history. It is very special."

Astronomer Royal Sir Martin Rees

**The British Astronomical Association's Commission for Dark Skies
Working towards star-quality lighting**

www.britastro.org/dark-skies



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