



Patricia Daukantas

# Light Pollution

## The Problem and the Possible Solutions

Over the past quarter-century, scientists have become increasingly aware of the problems that light pollution causes for astronomers, migrating birds and human health and safety. Finding effective means to reduce the effects will take the combined efforts of research scientists, lighting engineers, architects, city planners, businesspeople and homeowners.



**Earth's city lights imaged with data from the Defense Meteorological Satellite Program Operational Linescan System. Permanent lights and reflected light reveal the most urbanized areas on the planet.**

Data courtesy of Marc Imhoff of NASA Goddard Space Flight Center (GSFC) and Christopher Elvidge of the National Oceanic and Atmospheric Administration. Image by Craig Mayhew and Robert Simmon, NASA GSFC; <http://visibleearth.nasa.gov/>.

**W**hen was the last time you saw a really dark sky—one where no line separates the silhouettes of trees from the inky blackness of night? When did you last see thousands of dim stars spilling out of the Milky Way and filling in the gaps between familiar constellations?

If you live in any of the major cities or their suburbs on planet Earth, it's probably been quite a long time since you've seen a pristine night sky. Even on nights of low humidity and smog, a weird glow seems to pervade the space between the stars, washing out all but a few dozen of the brightest objects. On the horizon, the dark treeline is visible both day and night. This is light pollution.

By some estimates, 80 to 90 percent of all humans alive today live with some degree of light pollution, said Bob Parks, executive director of the International Dark-Sky Association (IDA). If you live in a city, you have little to no chance of seeing the Milky Way unless you travel a significant distance outside the urban core.

### Impact on astronomy

Astronomers were the first to sound the alarm on light pollution. In the 1960s and 1970s, Merle Walker of Lick Observatory and the University of California at Santa Cruz, U.S.A., studied sky glow empirically. In the 1980s and 1990s, Roy Henry Garstang of JILA and the University of Colorado, U.S.A.,

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developed more sophisticated models of light pollution, taking one of the most famous astronomical sites in America as a prime example.

The Mount Wilson Observatory in southern California is the poster child for the insidious effects of light pollution due to urbanization. Located just north of the greater Los Angeles sprawl, the facility houses the 100-in. (2.5-m) Hooker Telescope. When the observatory opened in 1904, the Los Angeles Basin had only 15 incorporated cities. By 1920, light pollution had made the background night sky at Mount Wilson about 13 percent brighter. By 1930, the sky was a noticeable 43 percent brighter. The brighter the sky, the longer astronomers need to observe to obtain a given signal-to-noise ratio.

The phrase "light pollution" goes back at least as far as 1970, when an anonymous correspondent for *Nature* described a pamphlet with that title, published by the directors of five major observatories in southern Arizona. As

a warning, the pamphlet contained photographs of the Los Angeles glare as viewed from Mount Wilson, and it asked Tucson officials to pass a municipal ordinance requiring shielded street lights and filtration of mercury-vapor lamps. The correspondent expressed optimism that Tucson residents would take pride in the local astronomy community and support the measure.

In the mid-1980s, shortly before forming the IDA, David Crawford and Tim Hunter worked with Tucson officials to get the city to adopt one of the first municipal lighting ordinances to try to control light pollution. The city continually updates the law to keep up with current technologies, according to Parks.

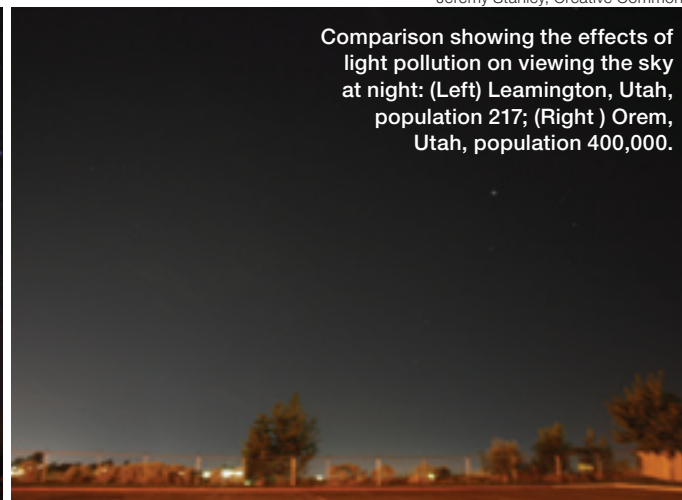
IDA attracted lighting manufacturers and professional lighting consultants, giving the organization more of an independent stance. "We listen to all sides: We talk to people in the industry; we talk to people in astronomy; and we try to come up with recommendations and insights that are not specifically tied to either group," Parks said.

### Impact on wildlife

"The introduction of a large quantity of light at night changes the environment," Parks said. The disruption of the normal diurnal cycle suddenly changes wild animals' predation and mating patterns that have existed for thousands of years.

Outdoor lighting has had a major impact on reducing the number of sea

Jeremy Stanley, Creative Commons



Comparison showing the effects of light pollution on viewing the sky at night: (Left) Leamington, Utah, population 217; (Right) Orem, Utah, population 400,000.

turtles in southeastern Florida. The Atlantic loggerhead lays its eggs on sandy beaches. When the eggs hatch at night, the baby turtles come up out of the sand, look for the brightest light source and crawl toward it. In the last few decades, the brightest spot visible from the beach at night may not be the open water (reflecting star and moonlight), but rather the apartment buildings and the hotels behind the beach. When the sea turtles hatch, they crawl onto the parking lots and roads, and either they are killed by moving vehicles or they die of dehydration.

Light pollution can affect wildlife in other, sometimes unexpected ways. Metal halide and mercury-vapor lamps emit visible and ultraviolet light. Many types of flying insects are attracted to them and are killed. Eventually, animals that eat these insects will have less food, Parks said. There's also significant evidence that some predatory creatures alter their behavior to adapt to newly installed artificial lighting; when they can see their prey better, they kill and eat more, thus tipping the balance of nature over time.

Ornithologists and amateur bird-watchers have found that artificial night lighting confuses some species of North American migrating birds. Atlantic puffins, which rely on the moon for navigation, have been thrown off their course by lights that appear brighter than the moon at night. In large cities, songbirds fly toward illuminated glass windows in office buildings and crash into them, resulting in injury or death. Records of this phenomenon extend as far back as 1935, when a Maryland birdwatcher began counting bird casualties at the base of the brightly lit Washington Monument in Washington, D.C.

### Effects on human health

People have evolved to experience bright white light in the daytime and dim light at night. Only in the last blink of an evolutionary eye have humans spent much time with comparatively dim indoor light during the day and bright light at night.

Several scientists have been investigating the possible interrelationship of nighttime lighting, hormones and cancer of the breast and prostate. Residents of industrialized nations are at much higher risk of these cancers than people in underdeveloped countries, and conventional risk factors, such as diet and genetics, fail to account for nearly 50 percent of breast cancers.

In 1987, Richard G. Stevens, an epidemiologist at the University of Connecticut Health Center, U.S.A., published a study suggesting that there was a link between light at night and breast cancer in humans. A few years earlier, Stevens got the idea for this line of inquiry when he lay awake in his apartment and realized that he could almost read a newspaper by the streetlight shining through his window at midnight—clearly a case of severe light trespass.

Stevens' study followed the 1980 discovery by Al Lewy and colleagues at the Oregon Health and Science University, U.S.A., that light suppresses the secretion of melatonin. Light on the retina—particularly bright blue light, 460 to 480 nm—inhibits the pineal gland, near the center of the brain, from giving off this hormone. Melatonin seems to help inhibit the growth of cancerous cells, in addition to its role in inducing sleep. However, scientists still say that the interplay among melatonin, sleep disturbances, night light and human cancer is speculative at best.

Other components of light pollution can create hazards for humans. Glare can be a safety hazard for drivers, particularly as they grow older. Reducing glare from streetlights makes it easier for senior citizens to drive their automobiles at night.

In 2010, two Brazilian biologists hypothesized that increased artificial light at night could give humans a higher infection rate from vector-borne diseases such as malaria, leishmaniasis and Chagas disease. They found some evidence to support the hypothesis, both because of the growing attraction of insect vectors to the lights and because people change their own behavior when night is brightly lit.

## What is light pollution?

Fernando Tomás



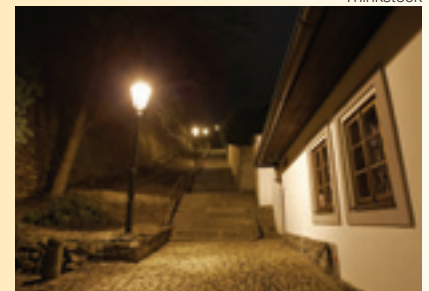
**SKY GLOW** is the increased brightness of the background sky that appears to surround the celestial bodies as seen from Earth. The night sky “between the stars” is not completely black; it always has a tiny bit of natural glow from sunlight scattered by solar-system dust and from excited oxygen atoms in our upper atmosphere.

Richard Murrin Campaign for Dark Skies

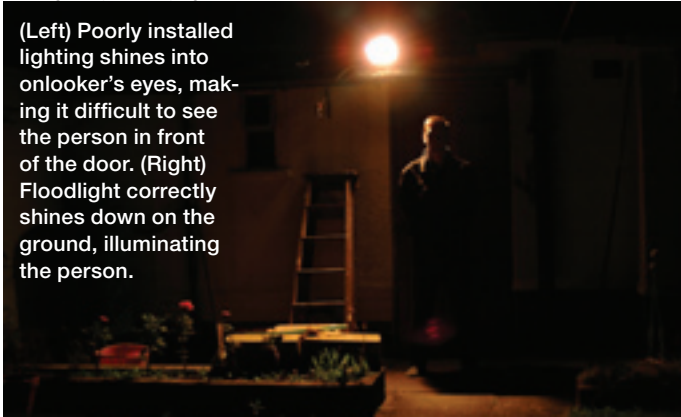


**GLARE** happens when unwanted light shines directly into a person's eyes. Poorly designed and poorly aimed fixtures are the major culprits.

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**LIGHT TRESPASS** occurs when glaring light fixtures spill their beams onto someone else's property. Glare and light trespass are localized phenomena, but they combine with reflected light from other sources to add to the general uplighting that creates sky glow.



(Left) Poorly installed lighting shines into onlooker's eyes, making it difficult to see the person in front of the door. (Right) Floodlight correctly shines down on the ground, illuminating the person.



### Energy considerations

A full-cutoff or fully shielded street light fixture can cast the same amount of light as an unshielded luminaire of higher wattage, but at a lower price. Many localities did not see lighting cost as a long-term issue until the last few years, when they started turning streetlights off because they couldn't pay the bills.

Since gas discharge lighting takes several minutes to come up to full brightness, such fixtures are traditionally left on all night. The newest LED streetlights are ideal for timed operation because they can be dimmed during periods of less traffic and turned up to full brightness an hour before sunrise to accommodate early commuters. "The eye doesn't even recognize a 20 percent dimming," Parks said. Cities that have implemented adaptive controls, such as San Jose, Calif., have realized significant energy savings, he added.

In many jurisdictions, the electric utility imposes a flat fee on each

streetlight pole per month or per year, instead of metering the actual energy use. Thus, municipalities have no financial incentive to turn many of the streetlights off when they are not needed. The state of Connecticut, however, has changed the utility regulations so that communities that choose to have their lights on for only half the night will be charged half the amount of money. "That kind of thing has to be done nationwide to encourage more localities to take advantage of it," Parks said.

### Strategies for reducing community light pollution

In June 2011, after seven years of study and consultation with urban planners, the IDA and the Illuminating Engineering Society of North America (IESNA) released a lengthy document called the Model Lighting Ordinance (MLO). It is a framework that local jurisdictions can adopt with little modification.

The MLO is a breakthrough in that it controls not only the shielding of the lights but also the quantity of light. Municipalities can customize the MLO by overlaying "lighting zones" (LZs) to various neighborhoods and regions within its borders. The zones range from LZ0, which corresponds to parkland and rural areas, to LZ4, which represents the most densely developed and lit downtown area.

Once city officials develop this overlay, they can assign the quantity of light allowed in each zone based on its population density. "Throughout it, the overriding concern is that there be little to no uplight," Parks said.

The MLO specifies the maximum lumens per square unit in each of the environmental zones. (Since the United States does not use the metric system exclusively, the document specifies lumens per acre or per square foot; other countries could convert that to lumens per hectare or per square meter.) The MLO goes by the lamp's output in lumens as specified by its manufacturer, regardless of the type of lamp technology. The ordinance also specifies how to adjust an area's total light output based on the percentage of pavement (or "hardscape area") in it.

The IDA is holding training sessions at planning and green-building conferences in the United States, and Parks expressed optimism that parts of the MLO may be integrated into green-building certification programs and even statewide regulations of outdoor lighting in the United States.

[ Lighting zones (LZs) in the Model Lighting Ordinance ]		
Zone	Light level	Suitability
LZ0	No ambient lighting	Parks, nature preserves, wilderness areas, undeveloped rural areas
LZ1	Low ambient lighting	Residential areas and small towns; single-family housing, community parks
LZ2	Moderate ambient lighting	Light commercial, high-density or mixed-use residential areas; churches, schools and neighborhood recreational facilities
LZ3	Moderately high ambient lighting	Commercial district of large cities; heavy industrial and manufacturing sites
LZ4	High ambient lighting	Not considered a "default" zone; describes the highest-density entertainment districts; special cases only

## Lighting for individual sites

Several years ago, the IESNA developed a new backlight-uplight-glare (BUG) rating for outdoor lighting fixtures, superseding the full- or semi-cutoff rating terminology that is deeply ingrained within the lighting-design industry.

Each B, U and G factor has a rating of 0 to 5. For example, a certain luminaire might be rated B1-U0-G2. Such a grade would inform potential purchasers that the fixture would have no uplight to add to sky glow, but it would cause a small amount of backlight, or light trespass, and it would cause a moderate amount of glare.

The MLO specifies the maximum BUG rating a light fixture can have in each of the five lighting zones. For example, that fixture rated B1-U0-G2 could be used in LZ2, but not in the more rural zones LZ0 or LZ1. Once a city has a lighting law based on the MLO, then just by looking at the numbers, lighting designers and city planners can see

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whether proposed lighting fixtures would be allowed in a given environmental zone.

The model ordinance also lays out two methods for determining whether a non-residential property complies with the law. Both methods limit the amount of light used on a property, but do not control how the light will be used to illuminate outside space. The prescriptive method simply specifies the “total site lumen limit” for a given area, based on its lighting zone and hardscape area. The performance method of compliance allows for more flexibility in decorative lighting, but it also requires the lighting designer to demonstrate whether the lighting will produce such off-site impacts as glare and light trespass.

Mark S. Rea, director of the Lighting Research Center at Rensselaer Polytechnic Institute (Troy, N.Y., U.S.A.), and his colleagues have developed a method called outdoor site-lighting performance (OSP) for predicting and measuring all three components of light pollution. Using commercially available software, a lighting designer draws a virtual box around a proposed outdoor lighting installation and then calculates how to minimize the amount of light leaving that box. “If you’re pumping a lot of lumens into your box, a lot are going to leave,” Rea said. “If you’re trying to prevent sky glow, it’s about light level—it’s not about optics.”

OSP provides the framework for a quantitative, not qualitative, discussion with a community about holding nighttime activities while minimizing light pollution and energy waste. “We’re not

there to tell you whether you should or you shouldn’t have high school football on Friday nights,” Rea said. Turning off the lights when they’re not being used for sporting events is one of the most important strategies for reducing a site’s contribution to light pollution.

## Prospects for the future


In the United States, light pollution is probably more prominent in the public eye than ever before. This spring, Arizona Governor Jan Brewer vetoed a proposed state law that would have permitted bright LED billboards. Independent filmmaker Ian Cheney recently released a documentary, *The City Dark*, which describes all aspects of modern-day light pollution, from stargazing to sea turtles; it has been making the round of this year’s film festivals. IDA is designating “dark sky” communities, parks and reserves in North America and Europe, and several entrepreneurs have set up their own amateur-astronomy resorts in the darkest corners of the American Southwest.

Still, Parks bemoans the deeply ingrained attitude that property owners in most places have more of a right to shine their security lights into their neighbors’ windows than to blast their stereos at 3 a.m. “Public nuisance law is the next frontier,” he said. ▲

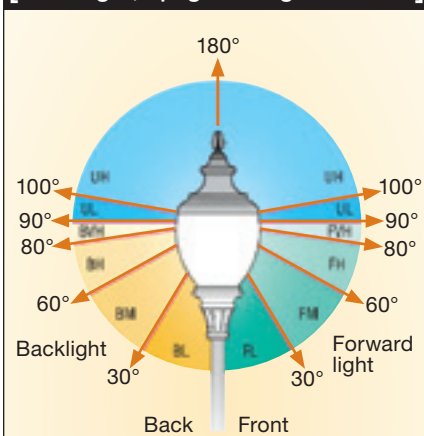
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 **ONLINE EXTRA:** For an expanded list of resources concerning light pollution, see the online version of this article at [www.osa-opn.org](http://www.osa-opn.org).

## [ Backlight, uplight and glare zones ]



Backlight, uplight and glare zones from a hypothetical luminaire. The B zones, which are opposite the area of intended use, create light trespass. The U zones create sky glow, especially the lower UL zone, which most degrades professional and amateur astronomy. The UH zone is mostly wasted energy. The G rating for glare takes into account the amount of lighting from the FH, FVH, BH and BVH zones.

Sternberg Lighting, U.S.A.