RETHINKING HOW WE LIGHT AT NIGHT: CUTTING LIGHT POLLUTION FOR MORE SUSTAINABLE NIGHTS

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INTRODUCTION

Nighttime lighting is an essential part of modern society, yet all too often inefficient practices are employed that lead to poor visibility, energy waste, and light pollution. The use of dark-sky friendly lighting fixtures and techniques can improve the lit environment to be less harsh and more uniform, reduce many of the problems of light pollution, and lead to tremendous energy savings.

KEYWORDS

light pollution, dark sky, full cutoff, glare, light trespass, model lighting ordinance, sky glow, streetlights

The star-filled night sky once inspired every culture across the globe. With the advent of civilization we have sought to push back the night. First with gas, and then electric streetlights, we have been progressively cutting ourselves off from the night sky and turning our collective backs on the stars. For the first time in human history the majority of people live in cities where the stars are becoming progressively lost in the permanent glow of light pollution.

It is estimated that the United States wastes billions of dollars annually producing energy to power lamps with poorly directed lighting. Instead of illuminating roadways or paths, their photons shine directly upwards and contribute nothing toward increasing visibility, security, or safety.

For much of the 133-year history of the electric light, the solution to improving the outdoor nighttime environment has been simply to add more light—often without careful thought as to where it shines. Poorly conceived nighttime lighting creates glare, light trespass, threatens some species of wildlife, may impact human health, wastes energy, and unnecessarily brightens the night sky. It is important to realize the implications of lighting and to carefully consider exactly where, when, and how much to illuminate.

Technology is evolving at a rapid pace, making it increasingly easier to create higher levels of illumination using less energy. Simply keeping up with changes in technology will provide energy savings, but the incorporation of new tools will allow for smarter uses of our light, allowing us to control it in ways never before imagined that can lead to great improvements in the nighttime environment. If embraced, it will produce even greater savings, a diminished impact on the environment, and a night sky that feels less of the effects of light pollution.

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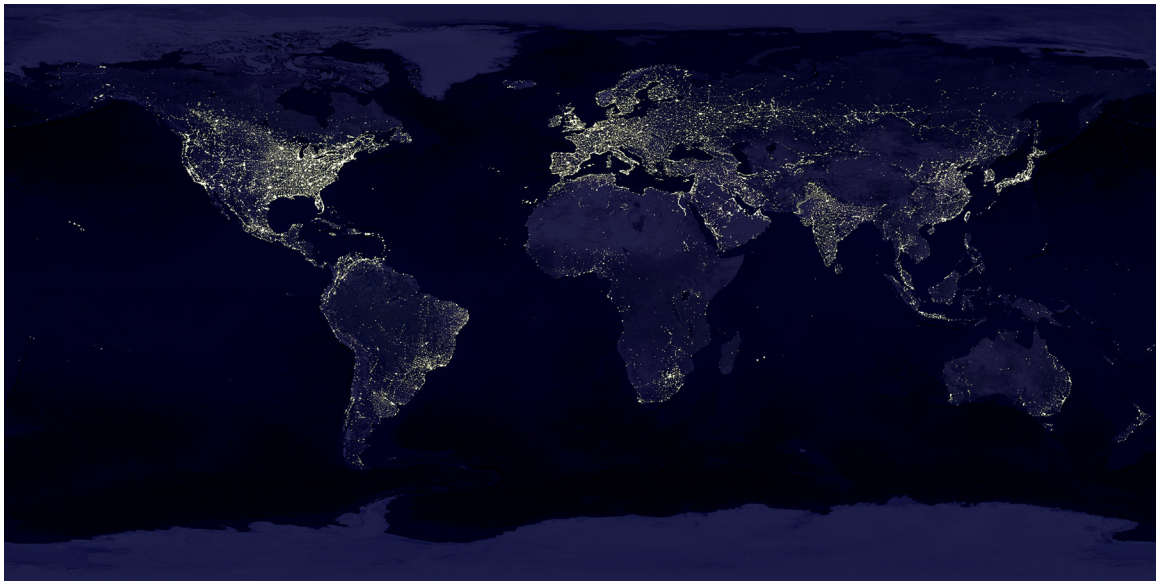
FIGURE 1. Earth at night from space. Untold billions of dollars of energy are wasted annually shining light into space. (credit: Data courtesy Marc Imhoff of NASA GSFC and Christopher Elvidge of NOAA NGDC. Image by Craig Mayhew and Robert Simmon, NASA GSFC, NASA Visible Earth http:visibleearth.nasa.gov/)



Light pollution comes as a result of excessive and inappropriate artificial light. The four main components of light pollution are often combined and overlapping. They include:

Glare—excessive brightness that causes visual discomfort. High levels of glare can decrease visibility.

Light intrusion—light falling where it is not intended, wanted, or needed. When light intrudes across property lines it is often called light trespass.

Clutter—bright, confusing, and excessive groupings of light sources, commonly found in over-lit urban areas. Clutter contributes to sky glow, intrusion, and glare.

Sky glow—the brightening of the night sky.

Outdoor lighting is used for a variety of purposes all over the world, from improving street and highway safety to illuminating billboards and building facades. Most of the applications are reasonable and many are considered essential. However, they are not all lit with the proper equipment and often there is an excessive amount of lighting.

The problems of light pollution would be greatly diminished with the use of fully-shielded (sometimes called full cut-off) luminaires. These are light fixtures that have been designed to direct light downward and emit no light past the 90-degree horizontal of the bottom of the fixture. This reduces glare and it lowers the cost of operating the fixture itself. Since the light is directed where it is needed and not skyward, it is possible to use a lamp with fewer lumens (lower wattage) within the fixture while still achieving the same or increased level of illumination on the ground.

Energy efficient outdoor-lighting luminaires are no more expensive in their initial cost than existing light fixtures. The advantage is that they are much more efficient to operate, they last longer, and their ability to direct light onto the ground is greatly improved. To maximize

efficiency, use only the proper level of illumination needed for the task, and only for the duration needed to complete the task.

There is an old school of thought that says fully-shielded luminaires are more expensive than traditional fixtures because they require more lights to cover the same area. This is old thinking about old technology. New luminaires are much better at controlling the directionality of the beam of light, allowing them to produce an even area of lighting without increasing the number of poles needed to achieve that coverage.

It is estimated that 30% of outdoor lighting is wasted light. Wasted light is defined as light that shines up into the sky where it does no good. Based on this number of 30% wasted outdoor lighting, if you translate the loss into watts per hour, it is estimated that we waste 22,000 gigawatt-hours a year. At a conservative average of $.10 per kilowatt-hour, the cost of that wasted energy is $2.2 billion a year. 3.6 tons of coal, or 12.9 million barrels of oil, are wasted every year to generate the energy for this lost light.

This very conservative estimate is only based on figures from the United States and it only applies to wasted lighting from streetlights. The lighting in parks, parking lots, residential areas, and light coming from office buildings, as well as the wasted light from other countries, is not considered in this statistic, meaning that the true amount of waste and its cost is much higher.

Light pollution does much more than just brighten the night sky and waste energy. It has a significant impact on wildlife, especially among migratory birds. Birds often fly directly into tall illuminated structures such as buildings and communication towers. It is estimated that in North America alone over 100 million birds die each year by colliding with lighted structures.

Light at night, even without a solid structure to collide into, can still pose a danger to birds. Birds are often drawn to bright beams of light. The light confuses them, causing them to become fixated and entrapped by the light. They fly around in the beam until they fall in exhaustion or death. Songbirds that sing in the dawn arise earlier and expend more of their energy because of sky glow.

Beyond birds, research points to many ways in which night lighting has an impact on wildlife. Hatching sea turtles, which evolved to find the reflection of starlight off of the ocean, are drawn to artificial lighting—and death—instead of the safety of the waves. Insects are attracted to lighting, which in turn attracts predators on up the food chain, causing changes in predator–prey relationships. Even humans feel the effects. Light at night, including in our homes, can lead to sleep disorders and disruption of our circadian rhythms.

FIGURE 2. Light pollution was once thought to be a problem only faced by astronomers, yet poorly-directed light at night has far-reaching impacts on wildlife, contributes to global warming, can reduce visibility, and wastes money.

Since 1988, the Tucson, Arizona-based International Dark-Sky Association (http://www.darksky.org/), an environmental, educational, nonprofit organization known as IDA, has been working to make a difference in the nighttime environment by calling attention to the problems of light pollution in an effort to conserve energy, safeguard ecosystems, and defend the view of the fading stars of the night sky. Dedicated to preserving humanity's view of the universe, IDA works to educate individuals, scientists, and communities around the world about the consequences of poor lighting practices and to offer solutions. IDA is a member-based organization with members in seventy countries worldwide. It has fifty-four volunteer chapters in sixteen countries, independently functioning groups that promote awareness and work to create regional legislation.

IDA's mission statement—"to preserve and protect the night-time environment and our heritage of dark skies through environmentally responsible outdoor lighting"—encompasses the organization's wide-reaching goals and attracts a broad range of interests. Light pollution is an intensely interdisciplinary topic, involving technology, astronomy, physics, biology, human health, ecology, energy and sustainability, politics, engineering, cultural history, and the arts.

IDA's two founders, amateur astronomer Tim Hunter and professional astronomer David Crawford, didn't realize at the time that IDA would develop such a far-reaching agenda. They knew that awareness about light pollution had to be raised or a beautiful, vital natural resource would continue to erode.

Crawford's experience with light pollution arose when he worked as an astronomer at the Kitt Peak National Observatory in Tucson. From the time he started working there in 1959, he had watched Tucson change from a sleepy outpost with Wild West roots to a burgeoning metropolis. As the population grew, so did sky glow. Crawford spent many years working on light pollution issues with local, national, and international organizations to address this growing problem on the largest scale possible.

Hunter was a serious amateur astronomer, even as a child living in the suburbs of Chicago. He bought his first telescope, a four-inch reflector, in 1956. In 1985, he made a slightly larger investment in buying a piece of land fifty miles southwest of Tucson to build the Grasslands Observatory. As the observatory developed, Hunter realized the amazingly dark sky of southeastern Arizona was a precious and fragile resource. He noticed what seemed like a lot of bad lights around Tucson, where he lived. He was aghast when the University Medical Center, where he worked, converted its old, dim, globe-style lights into unshielded orange low-pressure sodium lighting, and astounded when he was told that astronomers at Kitt Peak had recommended the lighting.

Hunter discovered that professional astronomers prefer such lighting because its somewhat monochromatic spectrum is easy to filter. But the unshielded bulbs created an unsightly light nuisance to amateur astronomers, and just about everyone else. Hunter knew that the Dark-Sky Office at Kitt Peak was headed by one David Crawford, internationally renowned as the project leader for the largest telescope at the observatory and for his work on stellar photometry. The two began to meet regularly to discuss how to address light quality and poor lighting design.

They realized that light pollution is a relatively easy environmental problem to solve, but it must first be recognized and addressed. Hunter had recently incorporated the Tucson Amateur Astronomy Association as a nonprofit in Arizona and recommended that he and Crawford found a nonprofit to combat light pollution specifically.

FIGURE 3. An example of the poor lighting environment created by an unshielded post-top lamp. In this case, harsh shadows exist directly under the light source. (credit: IDA)

Crawford expected IDA "to be an active international organization, wide in scope, breadth, and depth of topics. The nocturnal environment, implications on ecological and human health, and the role of energy and technology are all subjects related to dark skies, and we wanted to show how all these issues were relevant to each other." He combined the new IDA goals into his professional work, and for many years devoted most of his waking hours to developing IDA into the organization it is today.

IDA promotes one simple idea: light what you need, when you need it. It has worked with worldwide experts to shape this fundamental idea into a variety of tools that can be applied to achieve sound, lasting, lighting practices in remote villages and urban metropolises. IDA's network includes lighting engineers, astronomers, biologists, crime-prevention specialists, community planners, legislative bodies, land managers, conservation groups, and standards-making entities.

IDA also shares extensive partnerships with the Illuminating Engineering Society of North America (IES); International Astronomical Union; Astronomical League; United Nations Educational, Cultural, and Scientific Organization; and U.S. National Park Service.

IDA collects information to disseminate to the public and is active in forming standards and guiding legislation where possible. IDA initiatives play important roles in conservation, promotion of technology, and formation of state and local lighting ordinances. Materials such as brochures, posters, and presentations are free on the IDA website to help any interested citizen become a dark-sky leader in their community. Free information updates are available on the IDA's website, via email, and social media. Members receive a full-color quarterly newsletter that explores pervasive issues in the dark-sky community. IDA's first white paper, "Visibility, Environmental, and Astronomical Issues Associated with Blue-Rich White Outdoor Lighting," evaluates existing research on new lighting technology.

While light pollution continues to rise, its rate of spread has decreased dramatically as awareness of the benefits of good lighting has advanced. IDA and individual volunteer efforts are creating a philosophy that is reshaping the culture—a change from the idea that any lighting is good to an emphasis on the quality of light at night.

Many communities across the country are enacting lighting ordinances to help control energy usage and the adverse impacts to their nighttime environment. In cooperation with

the IES, the IDA has produced an outdoor Model Lighting Ordinance (MLO) to help their efforts. The MLO—freely available for download on the IDA's website—is a valuable guide for environmentally responsible outdoor lighting in North America. The MLO was designed to encourage broad adoption of comprehensive outdoor lighting ordinances without requiring municipalities to devote extensive staff time and resources to their development.

The MLO outdoor lighting template is designed to help cities develop outdoor lighting standards that reduce glare, light trespass, and sky glow, while still lighting to recommended safe levels. The MLO offers several innovations to outdoor lighting regulation, including the use of five lighting zones to classify land use with appropriate lighting levels for each. Zones range from LZ0, designed for pristine natural environments and limited outdoor lighting, to LZ4, for limited application in areas of extensive development in the largest cities. The second innovation limits the amount of light used for each property. Third, the MLO uses the IES's new TM-15-11 "BUG" (Backlight, Uplight, and Glare) classification of outdoor lighting fixtures to ensure that only well-shielded fixtures are used. No uplight for area and street lighting is allowed in any zone. The concept of lighting zones, also featured in the California Title 24 Energy code, recognizes that levels of illumination are not only governed by their use. The context of the surrounding area is just as important. This gives people proper transition from one lighting application to the next. Their use can help designers employ proper levels of illumination even in areas where the MLO is not in place.

IDA has been one of the champions of night-sky conservation. Its International Dark-Sky Places began over a decade ago and now the concept is growing around the world. In addition to IDA's conservation programs, Canada has its own dark-sky preserves, and UNESCO has formed the Starlight Initiative to protect observatory sites around the planet. In 2001, IDA recognized Flagstaff, Arizona, as the first ever International Dark-Sky Community after steps were taken there to reduce light pollution and educate the public. The International Dark-Sky Places program has spread across the globe and now includes a total of 4 communities, 10 parks, and 4 reserves. Aside from the U.S., Canada, England, Hungary, Namibia, New Zealand and Scotland have places that have been recognized by the IDA for their exceptional efforts at night sky conservation. Chile, France, Germany, and even China have expressed an interest in bringing new dark sky sites to their countries.

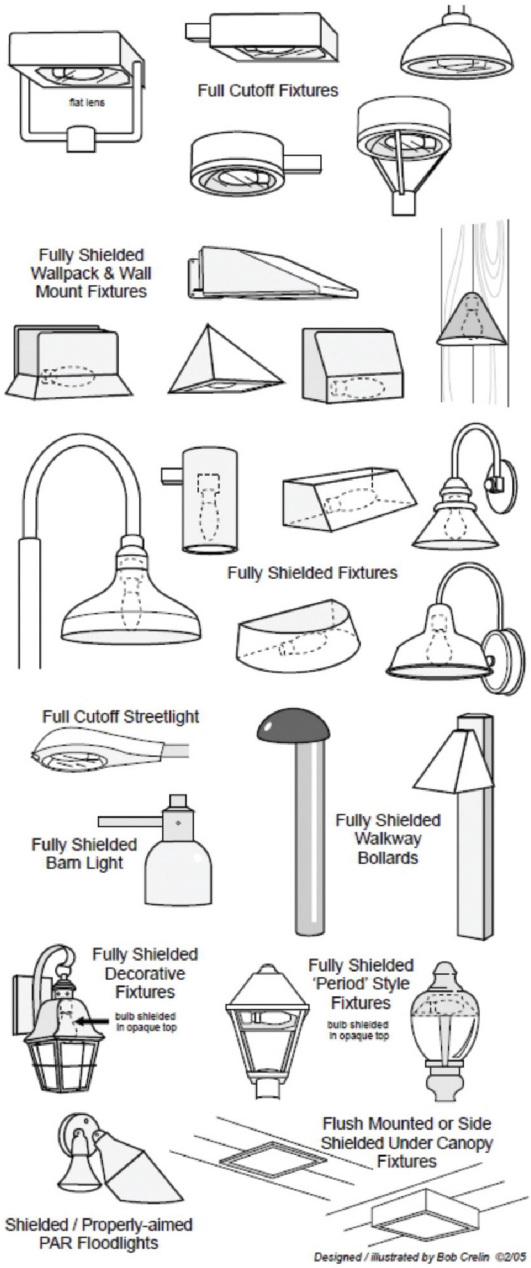
FIGURE 4. A deserted, but well illuminated public library seen hours after closure. Unneeded light spills out of the building creating light pollution. Simply turning off the lights when the building is not in use would cut down on energy waste and greenhouse gas emissions. (credit: Stephen Mosberg)

These conservation efforts need not only take place in lands that already have a natural night sky. There are many reasons to employ good lighting practices at home, wherever that happens to be. However, to do so one needs to have a wide-range of lighting tools available that, when used appropriately, will maximize light on the intended target and minimize wasteful light that is cast skyward.

Choice and availability of well-made lighting fixtures is crucial in improving the nighttime environment. Without them it is exceedingly difficult to design lighting systems with dark-sky principles in mind. In 1988, when IDA was founded, there were very few options on the commercial or residential market that could do the job. Since its inception, IDA has reached out to the lighting industry to encourage lighting manufacturers, distributors, and trade groups to produce and sell fixture lighting with appropriate shielding.

Eventually members of the lighting community were receptive to this message and have since worked to create quality products that minimize light pollution. As manufacturers began to develop luminaires that address the harms of uncontrolled light, the market began to expand. But the terminology involved with these luminaires was confusing to the layperson. Distinctions such as "full-cutoff" fixtures, which allow no light to shine above the ninety-degree angle, and "cutoff" fixtures, which allow as much as fifteen-percent uplight, were made, and the question of what qualified as a dark-sky-friendly fixture quickly arose. IDA sought to remedy this problem by offering third-party approval on fixtures that satisfy an established set of standards.

FIGURE 5. Examples of many styles of dark-sky friendly light fixtures that can be used in a wide range of applications. (credit: ©Bob Crelin/BobCrelin.com)



In 2005, IDA started the Fixture Seal of Approval (FSA) program to certify qualifying products as "dark sky-friendly fixtures." The program recognizes lighting manufacturers that integrate the concept of full shielding into their fixture design and to encourage market expansion of such designs. Manufacturers of these products create choice within the lighting industry: a choice to adopt smart lighting instead of misdirected light and energy efficiency instead of misdirected waste. This choice is vital in limiting the spread of light pollution and to its actual reduction.

To earn the seal of approval, manufacturers submit a luminaire's photometric data. An approved fixture must be fully shielded to emit no light above a ninety-degree angle. IDA analyzes the Upward Light Output Ratio of a luminaire (the amount of upward flux a fixture produces). If the criteria for full shielding are met, the fixture is approved, and the manufacturer receives a certificate and the Fixture Seal of Approval for use on their IDA-approved™ dark sky-friendly products. All approved fixtures are listed on the IDA website (http://www.darksky.org/fsa). The program is open for submissions from any manufacturers worldwide that produce luminaires believed to be dark-sky friendly.

The FSA program has been wildly successful for both IDA and the lighting manufacturers who join. The IDA seal is gaining worldwide recognition and becoming a selling point for manufacturers and vendors alike. The market for dark sky-friendly products is expanding as technology improves and companies work to design sleek, stylish, efficient fixtures. Over one hundred manufacturers have joined the FSA program, creating approximately three hundred approved fixture models. Lamp varieties that can be placed in the fixtures expand the choice of dark-sky-friendly outdoor lighting fixtures to more than a thousand.

FSA fixtures come in a wide-range of uses including landscape, residential, roadway, security, parking, pedestrian, and façade lighting. One of the original FSA-approved fixtures was the GlareBuster. In 2008, this lamp won the American Lighting Association's "Lighting for Tomorrow" competition. The GlareBuster (manufactured by Lighting by Branford and available at http://theglarebuster.com/) is a "green" alternative to the common household "security" floodlight or industrial wall pack lamp. It is a perfect example of a light that can illuminate the outdoors without producing unnecessary upward light, glare, light trespass, or the effects commonly associated with light pollution. Being both FSA and Energy Star® approved, the GlareBuster was a natural choice for a lighting fixture used to preserve the night skies over several U.S. dark sky sites, including Bryce Canyon National Park, Death Valley National Park, and the first International Dark Sky Park, Utah's Natural Bridges National Monument.

A lot of bad lighting choices come out of the fact that many people make their lighting choices based on how lighting fixtures look in the daytime and not how they perform at night. The so-called post top "acorn" lamp is a classic example of a grossly inefficient, but very popular, light source. People like the way that they look in spite of the fact that the vast majority of the light they produce—typically 70%—goes outward (making it a source of glare) and upward (making it a source of skyglow). Very little of the light leaving the fixture is actually useful. Some lighting manufactures have stepped up to the plate in order to produce luminaires with visual appeal that are also dark-sky compliant.

Visionaire Lighting has over 35 products in the IDA's FSA program. Their Dark Sky Bellagio is a solution to the standard acorn lamp. Unlike the standard acorn, the Dark Sky Bellagio features a hard cap that limits light that escapes upward. In addition, the light source is placed within that cap pointing downwards, making it a decorative acorn-style lamp that does not directly contribute to sky glow or glare. Other FSA-approved manufacturers such as Holophane and Phillips Lumec make lamps that preserve the old-style look of the acorn while providing modern, full-cutoff lighting.

Heading in the opposite direction of a decorative fixture is the WARP9 from Kim Lighting. According to the company: "Typical site lighting attempts to embellish, decorate, or adorn, often beyond the original architectural intent. WARP9 was designed to disappear from the site, camouflage itself within its surroundings, and avoid detection from daytime visual

FIGURE 6. A LEED Gold certified fire station in San Marcos, CA, where dark-sky friendly outdoor lighting was not taken into consideration. The station's flag lighting is a major source of glare. The light is bright enough that when low clouds blow in from the nearby Pacific Ocean, one can easily see the shadow of the flag in the sky.

perception." Incorporating what the manufacturer calls "visual stealth technology", this luminaire comes in several models, wattages, and can be pole or wall mounted, making it a good choice for parking, roadway, or pedestrian uses. It has full cut-off optics with a flat glass lens—standard fare for FSA-approved luminaires. Their WARP9 LED is available in 3500K and the very dark-friendly and wildlife-friendly 1700K amber CCT (more on CCT later), and contains what they call "MicroEmitter technology"—an optical system that provides unparalleled control over the light that gives uniform lighting on the ground with greatly reduced glare. MicroEmitter technology ensures that even when looking directly at the luminaire, only one-half of the LEDs can be viewed at any given time. This results in 50% less glare when compared to other LED sources.

The WARP9 and their FSA-approved Archetype LED, for parking and pedestrian lighting, may be some of the greenest commercial light fixtures on the market as the aluminum housing and reflector components for the fixtures are constructed from more than 90% recycled materials.

Architectural Area Lighting (AAL) has 16 FSA-approved fixtures. Like Kim Lighting, they are a Hubbell Lighting subsidiary and also make use of the MicroEmitter technology in many of their products.

Flag lighting is often excessively bright and typically shines upward, with most of its lighting missing the flag only to end up directly brightening the night sky. For applications where the U.S. or other flags must be illuminated at night, the Flagpole Beacon (http://www.flagpolewarehouse.com/) is an FSA-approved option that shines downward from the top of the flagpole. There is even a solar-powered version that will illuminate a flag, without directly contributing to light pollution, even from a location that is completely off the grid.

The seal of approval helps consumers gain access to products that will accomplish the goals of reducing stray light and creating better ambiance. Many of these products come with the added bonus of increased efficiency. People who install dark-sky-friendly fixtures outside a

home or business are making a conscious choice to respect neighbors, save energy, and balance backyard ecosystems. Because many residential fixtures use new technology that is only beginning to be developed for commercial use, these products can cost more than other choices. Despite the increased efficiency that usually offsets up-front costs over the life of the bulb, approved residential fixtures are not always found in neighborhood stores. Although these kinds of choices are starting to appear more often, dark sky advocates are encouraged to ask their local hardware and building supply stores to stock FSA dark sky-friendly fixtures.

On the other hand, the market for approved public and industrial lighting has grown exponentially. Manufacturers at industry trade shows display the FSA logo on many of their products. Builders, architects, and city planners who attend these shows can choose from a variety of dark sky-friendly products, including LEDs, induction lighting, and high-pressure sodium fixtures. The market now contains so many qualified products that there is virtually no difference in price between approved and unapproved fixtures.

Of course, fixture design is not the only component of good lighting practice. The amount of light used must be considered and dimmed where appropriate. The Installation Seal of Approval, a new aspect of the FSA program, is being designed to scrutinize the overall quality of an entire lighting system.

Creating alternatives to outdoor lighting applications offers quantum breakthroughs in night-sky protection. IDA created the Dark-Sky-Friendly Device designation to recognize devices and applications such as wireless dimming controls, timers, and even a radar system that can be used in place of continually running signal lights for aircraft. The latter system, the Obstacle Collision Avoidance System (OCAS), features sensors that use ground-based radar technology to detect aircraft. Upon detection, unlit light beacons begin to flash white during daytime and red at night. As a secondary warning, a radio system squawks "powerline, powerline." Use of such systems on towers, wind turbines and other structures avoids the use of constantly blinking lights, thus lowering energy use, while making less of an impact hazard for migratory birds. The FAA has approved use of the system for aircraft avoidance.

Scallop Imaging has another Dark-Sky-Friendly Device. Their M6-200 is a security camera system that operates at very low levels of light, proving that excessive illumination is not needed for security monitoring. The camera delivers panoramic HD video in bright sunlight and at light levels as low as 0.01 Lux. Other night security cameras make use of infrared illuminators to work in low levels of light. That option will not work for all applications and is not needed with this system.

These innovations employ creative technology to replace the need for lighting with a system of greater functionality and less light. They are revolutionizing the way the world looks at the necessity of lighting.

The availability of fully-shielded fixtures is changing the way cities are lit. In 2002, most of the sixty million luminaires used for public roadway and parking area lighting used drop-lens cobrahead fixtures. Less than ten years later, the majority of newly installed or retrofitted highway lighting products use flat-lens, fully shielded fixtures. These widespread changes are making a noticeable difference in municipal bills and dramatically decrease wasted light.

Between 2002 and 2005, Calgary, Canada, switched to lower wattage, shielded lighting as a part of their EnviroSmart Streetlight Retrofit program. This was done to save money on their streetlight electricity consumption, reduce their greenhouse gas emissions, reduce glare and curb light pollution—all while maintaining safe levels of illumination. The city has estimated that these changes were generating enough savings to fully pay for the conversion in

just a few years. Reduced energy consumption saved them an estimated $1.7 million per year, while energy savings are estimated at 25,000 MWh per year.

The high cost of energy and strapped municipal budgets, combined with sometimes mandated efforts to limit contributions of greenhouse gas emissions, has seen an increasing number of communities limit their use of street lighting, especially after midnight.

In 2009, the City of Santa Rosa, California, began an aggressive program for reducing the impact of their street lighting. Through their Street Light Reduction Program, the City is completely removing one third of their streetlights and dimming another third late in the night (between midnight and 5 a.m.). The City estimates that they will cut their energy costs by $400,000 per year and trim their greenhouse gas emissions by 1,000 tons annually.

Outdoor lighting has been shown to make people feel safer, but there is no conclusive research that demonstrates that it actually improves safety. Unfortunately, lighting levels have often been increased in the name of safety—often without careful thought as to where and when that light shines. It surprises many to learn that bright, glaring lights can actually decrease security. By creating a sharp contrast between light and darkness, this style of lighting makes it nearly impossible to see anything directly outside the area of direct illumination. This kind of bad lighting can even attract criminals by creating deep shadows for them to hide in.

Turning off streetlights after midnight is now a widespread practice in many parts of the United Kingdom—over half of the local governments are now using part night lighting or dimming for their streetlights. Programs were put into place for the same reasons Calgary and Santa Rosa addressed their street lighting, but they also suggest that in the United States

FIGURE 7. Dark-sky friendly lighting at a service station produces minimal glare, no up light, and uniform lighting with smooth transitions that the eye can easily adapt to.

we have something to learn about lighting and safety. In spite of some public fears about increased darkness leading to an increase in criminal activity, municipalities there are reporting that crime is dropping where there is less light.

Other cities are making conversions toward new sources of lighting. The City of San Diego, California, began a streetlight conversion in December 2009, moving away from high-pressure sodium lamps to new induction sources. During the testing phase of the program, according to a city report, it was determined there was no significant visual performance difference amongst the 250 watt high-pressure sodium and the lower wattage (150 to 190 watt induction) technologies. This reduction in wattage will save the city $100 a night per light fixture. In what might be the largest conversion in the country, the City of Los Angeles is changing some 140,000 of their existing streetlights to LED. This is being done in the name of energy savings and to limit the city's greenhouse gas emissions.

Induction and LED lighting are heading toward widespread adoptions for many uses beyond street and area lighting. LEDs produce light in a way that can be more effectively controlled. This increases efficiency of fixtures and allows light to be delivered precisely to the areas where and when it is needed. These technologies offer the potential for significant energy savings. Unlike the older lighting technologies often used for parking, streetlights, and other industrial uses, these new lamp sources can turn instantly on or off—no extended warm-up time is needed. This allows the use of dimming and "smart" controls that can turn the lights off when they are not needed late at night, but can also bring them back on when motion is detected. This technology, coupled with the inherent lower energy use of the new sources, offers greater potential for energy savings and overall lower levels of light pollution.

This move toward new lighting sources is also changing the color of outdoor lighting. One of the drawbacks about the nature of older high-pressure sodium sources has been their poor color rendering. Their orange illumination does not allow one to clearly distinguish a wide range of colors. LED and induction offer a low cost way to produce white light.

When interior lights began moving from incandescent to compact fluorescent blubs many people complained about the strong blue color of the new light sources. Over time, the industry responded to consumer comments and began offering warmer options. There is perhaps something similar taking place now in the switch towards LED and induction lighting applications in outdoor lighting.

So called "Warm white" sources, such as the perhaps more familiar incandescent bulbs, emit more strongly at the middle and longer (red) wavelengths, are often aesthetically preferred, and have a lower Correlated Color Temperature (CCT). "Cool white" sources are heavy on the bluer end of the spectrum and have a high CCT. Their light appears harsher and colder to many observers when used for artificial lighting. Many of the LEDs initially put into use had CCTs that were over 6000K. Looking at their light in great detail, many of these high color temperature sources have an excess of blue light, which disproportionally brightens the night sky—more so than any other color. For a variety of reasons, IDA recommends much lower color temperatures.

Though the perceived advantages of this shift toward white light (better color rendition, increased "visual effectiveness" and efficiency, decreased overall costs, better market acceptance) are commonly touted, there has been little discussion of documented or potential environmental impacts arising from the change in spectral energy distribution of such light sources compared to the high-pressure sodium technology currently used for most area lighting.

Many of these new white light options have never been applied on a broad scale and may have unexpected consequences if widely used for outdoor lighting. In particular, the stronger blue emission produced by white light sources, such as LEDs, has been shown to have increased negative effects on astronomy and sky glow, and has a greater impact on animal behavior and circadian rhythms than other types of light.

Widespread installation of white light sources rich in blue emission is among the largest concerns of the dark sky movement. This can be tempered by using warmer (lower CCT) light sources that reduce the amount of blue light emitted. That, combined with lower levels of illumination, directional lighting, and smart lighting controls offered by LED technology can make a significant difference on levels of energy used and light pollution produced.

IDA has been working directly with lighting manufacturers to develop new tools and techniques for a project with the National Park Service (NPS) to retrofit the lighting in nine National Parks. The focus for this project is to optimize efficient lighting design, reduce negative impacts on biologically sensitive habitats, eliminate wasteful light emissions that cause sky-glow, and apply the latest technology to provide effective illumination where it is needed. By employing these updates in the parks, the visitors' experiences will be drastically improved through the reduction of obtrusive glare, with no compromise on safety and security.

IDA approached leading experts to develop custom technology exclusively for this project and future retrofits for the NPS. Several of the lighting manufacturers have stepped up to the table to innovate new lighting technology to make this happen.

As an example, Hubbell Lighting modified their existing dark sky-friendly LED Lardeo LNC wall-pack to meet the unique requirements of the program. The light is being used to replace a variety of existing fixtures including twin Par floodlights, porch lights, and standard high-glare wall packs.

Many of the lighting solutions developed for the program utilize true amber, very low CCT, LED light sources—an innovative technology recently designed and previously unavailable. These light sources provide an ample amount of visibility without impeding the visitor's dark adaptation when traversing from a lighted environment to a dark environment (i.e., walking from a restroom back to a campground).

Many existing lights in the parks and elsewhere do not take visual adaption into account. Poor lighting, with unnecessarily bright lights, interrupts and delays the ability to adapt back to dark environs and can place visitors in danger, even along the easiest of paths. Amber light is also the most benign light source with regard to most wildlife and minimizes the potential for biological system disruption (i.e., predation, reproduction, migration, and disorientation). In addition to these benefits, LED light sources drastically reduce the amount of energy consumed by the park.

The lamp choices made today in our parks and cities will affect the nighttime environment for decades to come. It is imperative that decision makers understand the consequences—both positive and negative—of lighting choices. With proper controls of light direction, intensity, color temperature, motion detectors and the use of smart lighting to employ afterhours dimming, we can greatly lessen our impact on the environment and bring back the stars.