Outdoor Lighting Guide

Why care about Outdoor Lighting?

Outdoor lighting has become a vital part of our daily lives. Outdoor lighting makes it possible to expand our outdoor activity beyond the limits of natural light, making both nighttime work and recreation safer and more comfortable. However, as outdoor lighting has become more widely available, increasingly negative effects on the environment and human health have become apparent[1]. This phenomenon has become widely known as light pollution, and its effects include disrupting wildlife behavior, circadian rhythms, and limiting observation of the night sky[2].

Durham contains a multitude of important natural resources that could be affected by light pollution. These include wetlands, rivers, and estuaries[3], as well as forested areas and fields[4]. Excessive and poorly directed lighting can disrupt these ecosystems and alter natural patterns of migration[5], feeding[6], and even sleep among animals. The effects are not limited to wildlife, however. Humans are also vulnerable to light pollution, and negative effects have been observed on eye and sleep health. Light pollution also manifests as skyglow, which can limit observation of the stars at night and degrade the rural character of the town. As Durham is in an area experiencing high growth pressure, proactively addressing light pollution will allow for the preservation of valuable natural resources and rural character that makes the town an attractive place to live, work, learn, and play.

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[1] John Barentine, *Artificial Light at Night: State of the Science 2025* (Zenodo, 2025), https://doi.org/10.5281/ZENODO.15492393.
[2] Barentine, *Artificial Light at Night*.
[3] Martha J. Zapata et al., "Artificial Lighting at Night in Estuaries—Implications from Individuals to Ecosystems," *Estuaries and Coasts* 42, no. 2 (2019): 309–30, https://doi.org/10.1007/s12237-018-0479-3; Anirban Ganguly and Ulrika Candolin, "Impact of Light Pollution on Aquatic Invertebrates: Behavioral Responses and Ecological Consequences," *Behavioral Ecology and Sociobiology* 77, no. 9 (2023): 104, https://doi.org/10.1007/s00265-023-03381-z.
[4] Thomas W. Davies et al., "Multiple Night-Time Light-Emitting Diode Lighting Strategies Impact Grassland Invertebrate Assemblages," *Global Change Biology* 23, no. 7 (2017): 2641–48, https://doi.org/10.1111/gcb.13615; Emma Louise Stone et al., "Street Lighting Disturbs Commuting Bats," *Current Biology* 19, no. 13 (2009): 1123–27, https://doi.org/10.1016/j.cub.2009.05.058.
[5] Daniela Torres et al., "Artificial Skyglow Disrupts Celestial Migration at Night," *Current Biology: CB* 30, no. 12 (2020): R696–97, https://doi.org/10.1016/j.cub.2020.05.002.
[6] Emma Moyse et al., "Artificial Light at Night Alters Predation on Colour-Polymorphic Camouflaged Prey," *Basic and Applied Ecology* 73 (December 2023): 88–93, https://doi.org/10.1016/j.baae.2023.11.002.

Purpose and Scope of This Guide

This guide will serve as a reference for residents and businesses within the town that are interested in pursuing nature-friendly, cost-effective, and sustainable lighting solutions. It provides a compilation of best practices for application of existing lighting science to meet the unique needs of the residents and businesses of Durham.

Durham is unique for its makeup of important natural areas, a dense village center, and a seasonal student population. There are many variables to consider when choosing lighting solutions. By categorizing local environments into residential, commercial, and ecological sectors, the town can implement lighting standards that are efficient and satisfy the needs of each community.

This guide can be utilized by anyone in the Durham community choosing to light their property. The Durham Planning Board can then ensure the protection of wildlife during site plan and zoning reviews. If a resident or business intends to build near a wildlife-sensitive area such as a wetland, river, or woodline, this guide can recommend maximum lighting characteristics to minimize ecological disturbance. The Planning Board and developer can then be on the same page, view appropriate lighting fixtures, and adjust site plans accordingly.

Residential

The residential sector consists of communities of student housing to quieter, family neighborhoods like Faculty and Madbury Road. Light in these areas focuses on personal security and navigation, while limiting light trespass into neighboring windows or yards and the surrounding natural environment.

Figure 1: A streetlight in a residential area which is shielded to reduce light trespass into residential properties.

Commercial

Figure 2: Commercial ambient lighting in Downtown Durham, with cooler lighting shown on the right and warmer

Higher intensity lighting is required for public safety and visibility in commercial areas featuring businesses, restaurants, and shops primarily in Durham's "village district" located along Main Street and Jenkins Court. Modern design prioritizes fully shielded fixtures to maintain historic character while minimizing light pollution typically found in urban areas.

Ecological

Many parts of Durham, including the downtown region, contain sensitive riparian zones like the Oyster River waterfront and the Mill Pond Park that may be especially harmed by excessive lighting. These environments focus on nature friendly lighting strategies that utilize warmer color temperatures and strict shielding to preserve natural circadian rhythms and protect local aquatic and avian wildlife.

Figure 3: Mill Pond Park, an ecological feature that is more sensitive to disturbances from artificial light.

Recommendations within this guide seek to balance important trade-offs between human safety and nature sensitivity, along with changes that will benefit both variables simultaneously. Suggestions will be made for both residential and commercial properties within the town.

Understanding Light

There are three concepts that are important to understand when considering the design of lighting solutions that are both useful to humans and friendly for nature. A grasp of the basic science of lighting will help with the implementation of recommendations later in this guide.

Figure 4: A chart depicting four levels of shielding for outdoor lights, plus one light that is turned off. *DarkSky International*

- **Targeting** describes where most of the light emitted from a source is directed. In this guide, the concept of **flood** is used to generalize this property of light fixtures. A fixture with a large amount of flood spreads its light over a larger horizontal area. The amount of flood is controlled by how the light is shielded as well as the optics of the light source. As depicted in *Figure 4*, proper shielding helps avoid trespass into natural areas, saves energy by directing light where it is needed, and reduce skyglow.
- **Illuminance** describes the amount of light that is directed towards a certain object or area, measured in lumens per square meter (**lux**) or lumens per square foot (**footcandles**). This is a function of both the power of the light source and where it is targeted.
- **Color Temperature**
  The color appearance of white light using units of kelvin (K). Lower CCTs (1800K-2200K) appear very warm or amber. Medium CCTs (2700K-3000K) appear warm white, similar to standard incandescent bulbs. High CCTs (4000K and higher) appear cool white or daylight blue (*Figure 5*).

Figure 5: A temperature scale in degrees Kelvin corresponding to color of light.

Principles for Nature Friendliness

The implementation of artificial outdoor lighting needs to bridge the gap between necessary security needs and the reduction of ecological impacts.

In general, light should be:

Used only when needed.

The effects of continuous lighting have been shown to cause serious behavioral shifts in aquatic invertebrates[7] and alter the commuting behaviors of certain species such as bats[8]. To preserve the natural nocturnal state of the surrounding area, the implementation of timers or motion sensors ensures that human presence is needed for the light to be operational, which saves energy and the environment.

Figure 6: A motion sensor light highlighting the practical use of being off during the day and motion

Shaded towards warm colors.

Different wavelengths of light have an array of impacts on local wildlife making color temperature management crucial. Blue rich, short wavelength, "cool" white LED lighting has been found to significantly threaten the biodiversity of insect populations in past research studies[9]. Switching to orange or soft-white LED lighting with longer wavelengths and warmer colors will reduce risking ecological disruption and protect natural predator/prey balances.

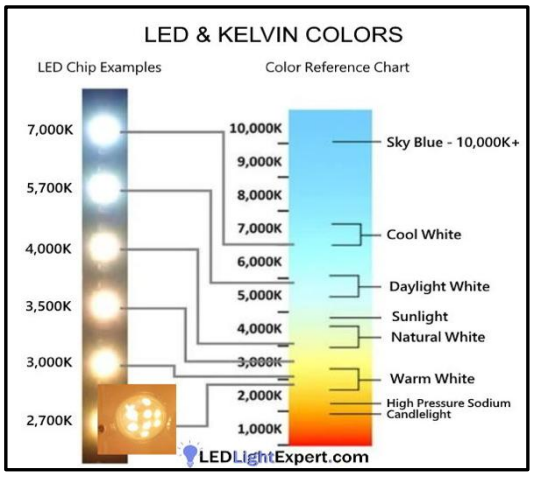

Figure 7: A temperature scale in degrees Kelvin corresponding to color of light. *LEDLightExpert*.

[7] Ganguly and Candolin, "Impact of Light Pollution on Aquatic Invertebrates."
[8] Stone et al., "Street Lighting Disturbs Commuting Bats."
[9] Davies et al., "Multiple Night-Time Light-Emitting Diode Lighting Strategies Impact Grassland Invertebrate Assemblages."

No brighter than necessary.

For safety and surveillance, the intensity of light frequencies should be kept to the minimum required. "Sky glow" is a phenomenon that disrupts the reception of celestial cues used by migratory species for navigation.[10] Ecosystem implications associated with high light intensity saturation can be avoided by limiting light output, which also reduces the footprint the lights leave on the environment.[11]

Figure 8: Cheonggyecheon Stream Park in Seoul at night, contrasting functional white light for urban use on the left and natural, warm light for the park on the right.

Directed whenever possible.

To prevent "light trespass" into neighboring habitats precision in light direction is critical. According to the state of the science regarding artificial outdoor lighting, unnecessary ecological disruptions are created when unshielded light spills beyond its practical target area.[12] To ensure that illumination is restricted to intended walkways and work zones without upward or outward spill, light fixtures should be shielded and directed downward. This exactness allows nocturnal species to move through dark corridors without disorientation caused by stray artificial light.

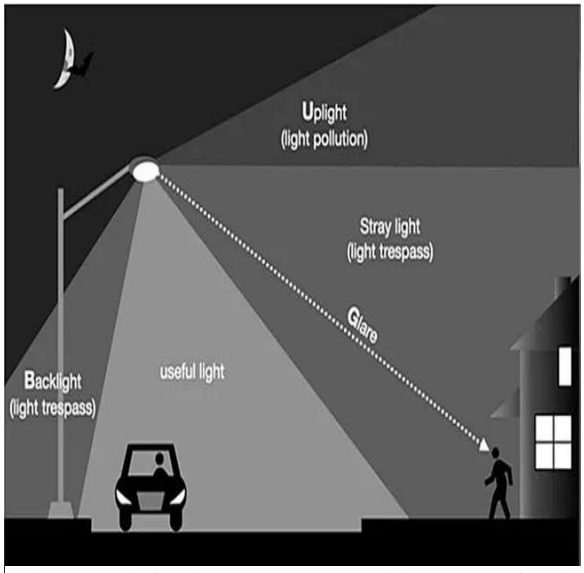

Figure 9: Distinction between beneficial "useful light" and harmful "uplight", "backlight", and "stray light"; which contribute to light trespass and pollution.

[10] Torres et al., "Artificial Skyglow Disrupts Celestial Migration at Night."
[11] Zapata et al., "Artificial Lighting at Night in Estuaries—Implications from Individuals to Ecosystems."
[12] Barentine, *Artificial Light at Night*.

Types of Lighting

There are three main types of light that can be generally inferred based on their purpose. When designing outdoor lighting for an area, start with **Ambient Lighting** to establish a baseline level of light that fills a target area with light. Then, use **Task Lighting** to illuminate areas with specific lighting needs or safety considerations. Finally, use **Accent Lighting** to highlight specific features and create a more welcoming environment.

1. **Ambient Lighting**

Ambient lighting provides a general illumination that fills an area with light, creating a comfortable and welcoming atmosphere. It is the foundation of any lighting plan and is crucial for safety and navigation.

Figure 10: A picture of a patio lit up using darksky-compliant area lights.

Examples of ambient lighting include string lights, wall-mounted fixtures, and pathway lights.

Illumination: 5-20 Lux (Medium)

Color Temperature: < 3000 K (Medium)

Flood (at a 20ft horizontal distance from light source): 0-6 Lux (Medium)

Cost: ~$150 🏠 ~$1500 🏘

2. Task Lighting

Task lighting focuses on brightening specific areas where activities occur, such as outdoor kitchens, seating spaces, or work zones. This lighting allows people to carry out specific tasks safely, clearly, and effectively.

Figure 11: A picture of angled, shielded spotlights, a common type of task lighting.

Examples of task lighting include spotlights, under-counter lights, and lighting directed at work areas.

Illumination: >20 Lux (Med-High)

Color Temperature: 3000K-4000K (High)

Flood: < 4 Lux 🏠 < 6 Lux 🏢

Cost: ~$100 🏠 ~$300 🏢

3. Accent Lighting

Accent lighting emphasizes specific features such as architectural details, landscaping, or decorative elements. This lighting creates visual depth and enhances the overall outdoor atmosphere.

Figure 12: A picture of a rock wall lit up using warm, low level lighting.

Examples of accent lighting include uplighting on the sides of buildings, cove lighting, and lighting of landscape features (such as trees and gardens). Christmas lighting also falls into this category.

Illumination: 0-5 Lux (Low)

Color Temperature: 2200K-3000K (Low-Medium)

Flood: < 4 Lux (Low)

Cost: ~$120 🏠 ~$400 🏢

Uses of Light

As a preface to the described uses of lighting below, many lit areas overlap or are adjacent to nature-sensitive areas such as a backyard wood line or a river next to a parking lot or sidewalk. It is important to first note if the desired light fixture will be placed near a wildlife habitat to limit the illuminance, color temperature, and flood. Try to shield light source from extending into nature-sensitive areas and only use light when necessary, by implementing timers/motion sensors.

Front and Back Yards

Outdoor yard spaces often serve both recreational and functional purposes. Lighting in these areas should prioritize comfort and safety while avoiding broad illumination of open areas as much as possible.

Ambient: Ambient lighting in yards should be kept at a low intensity and used sparingly. Instead of lighting an entire yard, consider lighting only areas that are commonly used at night, such as patios and other outdoor seating areas. Avoid broad floodlighting of entire yards, as this can cause light to spill over into adjacent properties and can disrupt nearby habitat. Warm-colored lights should be used to avoid disruptions to circadian rhythms and reduce effects on insects.

- Consider using warm-colored string lights and low-mounted fixtures to add stylish, cozy ambient lighting to outdoor areas. If possible, fixtures should be shielded from the top to direct light downward.
- In properties adjacent to wooded areas or wetlands, limit ambient lighting near the edge of the yard to preserve dark corridors for wildlife movement and reduce disruption to nocturnal species. Using yellow lights will attract less bugs than high color temperature white-blue lights.

Task: Task lighting in yards should be limited to areas where sensitive activities take place, such as cooking and outdoor work areas. While this lighting can be neutral white or cooler and moderately bright for accurate color perception, it should be tightly focused on the work area.

- For outdoor cooking, a spotlight aimed at a grill or other appliance coupled with low lights attached to countertops will clearly illuminate cooking areas while avoiding spilling light into natural areas.
- Outdoor work areas should be bright enough to provide safe navigation and conform to applicable regulations while minimizing light trespass.

Accent: Accent lighting can be used to highlight landscaping features such as trees, gardens, or architectural elements. However, it should be used minimally and with careful targeting. Low-luminance, warm-colored lights are preferred, and uplighting should be limited or avoided where possible to reduce skyglow. Seasonal or decorative lighting should also follow these principles to minimize cumulative impacts.

- Decorative lights such as Christmas lights can be hung under eves to reduce light scatter and timed so they shut off during late night hours.
- Lights illuminating signs should face downwards and can be dimmed or shut off when the business is closed to save energy and reduce light pollution.
- Avoid accent lighting near dense vegetation or garden beds that may serve as habitat, as even low levels of light can disrupt pollinators and other nighttime ecological activity.

Walkways and Sidewalks

Walkways and sidewalks are critical for pedestrian safety and navigation, particularly in a walkable community like Durham.

- An in-depth review of recommendations for minimum lighting of pedestrian facilities can be found in the FHWA Pedestrian Lighting Primer.

Ambient: Ambient lighting along walkways should provide consistent, low-level illumination that allows users to perceive their surroundings without creating glare. Even spacing of low-height fixtures can help achieve uniform lighting without excessive brightness.

- For walkways, small fixtures positioned near the ground can provide enough light for navigation while having minimal spill outside of the intended area.
- Sidewalks and walkways which carry large amounts of pedestrian traffic may benefit from a higher amount of flood to render faces clearly and increase safety. This can be done using fixtures that cast light horizontally while still preventing uplighting.

Task: Task lighting for walkways should focus on areas that pose hazards, such as stairways and crosswalks. Fixtures should be directed downward and designed to illuminate only the walking surface. Light levels should remain moderate, sufficient for safe navigation but not excessive. Shielding is especially important in these areas to prevent glare that can impair visibility.

- Stairway railings or risers present an opportunity for integrated lighting solutions that can illuminate the walking surface (to prevent tripping) while minimizing wasted light.

Accent: Accent lighting along walkways should be limited to subtle highlighting of adjacent landscaping or features and should not interfere with the primary goal of safe navigation. Any accent lighting should maintain low brightness and minimal flood. Low level, timed lighting of gardens and walls can provide a boost to ambiance without significantly impacting ecosystems.

- Avoid excessive lighting of gardens to promote nighttime pollinator activity. Aim light towards features such as rock walls and soil and away from the plants. Use lights that are red or warm-colored.

Driveways and Parking Areas

Driveways and parking areas require consistent, low-intensity lighting that supports vehicle movement and safety while limiting spill into adjacent properties.

- An in-depth review of recommendations for lighting of roadways can be found in the FHWA Lighting Handbook.

Ambient: Ambient lighting should be limited to high traffic areas and be warm-colored. Avoid lighting areas other than the driving surface and limit ambient lighting to times when the driving area is active using motion sensors or timers.

- Shielded, downward facing lighting mounted at the ends of driveways will often provide enough illumination for drivers to orient themselves.

- Evenly spaced, low intensity pole lights that are shielded will provide consistent illumination for parking lots.

Task: Task lighting is important for parking areas and areas where people will be maneuvering vehicles. This lighting should be consistent and be mounted high enough as to not generate shadows, as well as shielded to prevent glare and light trespass. Parking lots and turn-around areas are important areas for this type of lighting.

- Motion activated floodlighting that is carefully aimed can illuminate parking areas to provide safety and security.

- Focused spotlighting can provide enhanced safety for conflict areas such as intersections and pedestrian crossings.

Accent: Accent lighting around driveways and parking areas should be limited in brightness and shielded to prevent glare. Lighting of signs and architectural features should be located near the road to avoid creating distractions for drivers.

- / Lighting of trees along driveways can provide a welcoming aesthetic. Instead of uplighting trees, consider soft, warm string lights.

Entrances and Exits

Ambient: Whether for a house or business, ambient lighting should provide enough clarity for people to safely enter or exit through a doorway. Light should be low intensity to create a welcoming environment and reduce glare while entering a building.

- / In addition to being more nature-friendly, warmer colored (yellow) lights can also attract less bugs to the entrances of buildings. Ambient lighting around entrances should be turned off when the building is not in use or when people are not entering/exiting.

Task: Task lighting can be used to highlight important areas of an entrance/exit, such as a staircase, as well as provide security lighting. Often, fixtures with motion sensors can provide a whiter-colored light when activated to provide contrast and enhance facial recognition, especially for security cameras. However, these lights should be carefully calibrated so that they only activate when presence is detected near entrances.

- / A motion-activated light directed at the doorway and entry path can improve visibility and security while ensuring light is only used when needed.

Accent: Once again, accent lighting should maintain minimal light intensity and color temperature since its goal is to subtly emphasize landscape features rather than provide necessary light for humans to see. The light should also be directed towards building features without trespassing onto neighboring properties or entering the sky.

- Subtle, warm-colored lighting directed at architectural features such as door frames or nearby walls can enhance the appearance of an entrance without increasing overall brightness and skyglow.

How You Can Help:

I. If there are high color temperature lights greater than 3500K, meaning white-blue tone lights (refer to Figure 7 on page 6) on your property, **consider replacing them with yellower lights around 3000K or below, or using a color filter**.

Figure 13: High color temperature white light vs warmer color light below 3000K

Figure 14: Example of light intensity meter on a mobile phone app

II. Download a free phone app to measure lux around your property. This can allow you to **identify areas where the light intensity might be higher than what it recommended for nature friendliness** around your property, especially along woodlines, rivers, or wetlands

III. Determine whether outdoor lighting on property is necessary to be always on; **timers, motion sensors, or dimmers greatly support wildlife health and reduce energy use**

Figure 15: Outdoor lighting timer

Figure 16: Shield installed on outdoor lighting fixture

IV. Ensure light is properly directed only towards where it is needed. Investing in **downward facing light fixtures or supplemental shields can prevent light from trespassing outside of property lines while providing more concentrated illumination to the intended area**.