Starry Princeton

Gaspar Bakos, gbakos@astro.princeton.edu, 2025 Feb

Starry Princeton – Safe, Healthy, Sustainable, and World Leader

Namibian Red Desert, photo taken 2022 April. This is how the Milky Way looks like without light pollution. Majority of our students have not seen the Milky Way.

Flying in to Princeton

Princeton from above Route 1, 2023 March 28, 10:30pm. The central bright cluster of lights is Princeton. Glow on the left side is Philly. Glow on the right is New York. Barely any stars visible.

Flying in to Princeton

The reason for the bright sky and no stars:

Excessive, misdirected and blue lighting.

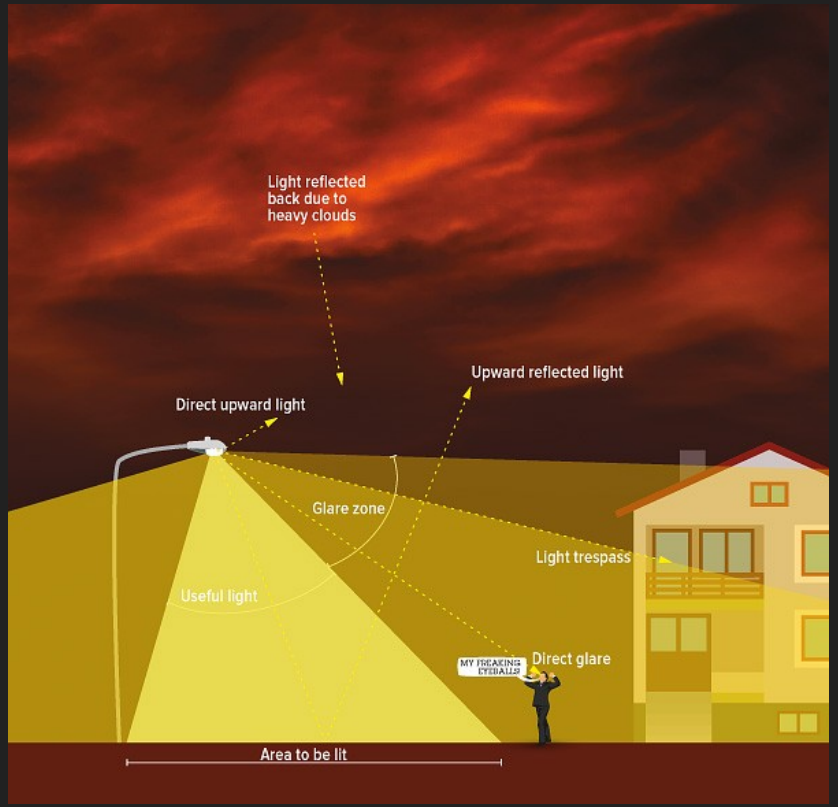
Photo: Princeton parking garage and Stadium, Lake Campus construction
2023 March 28, 10:30pm

Notice: lights are strong and “cold”, compared with sodium lights of Faculty Road (middle and right side of image), or “amber” LED lights of modern, eco-friendly solutions.

Light Pollution

Definition:

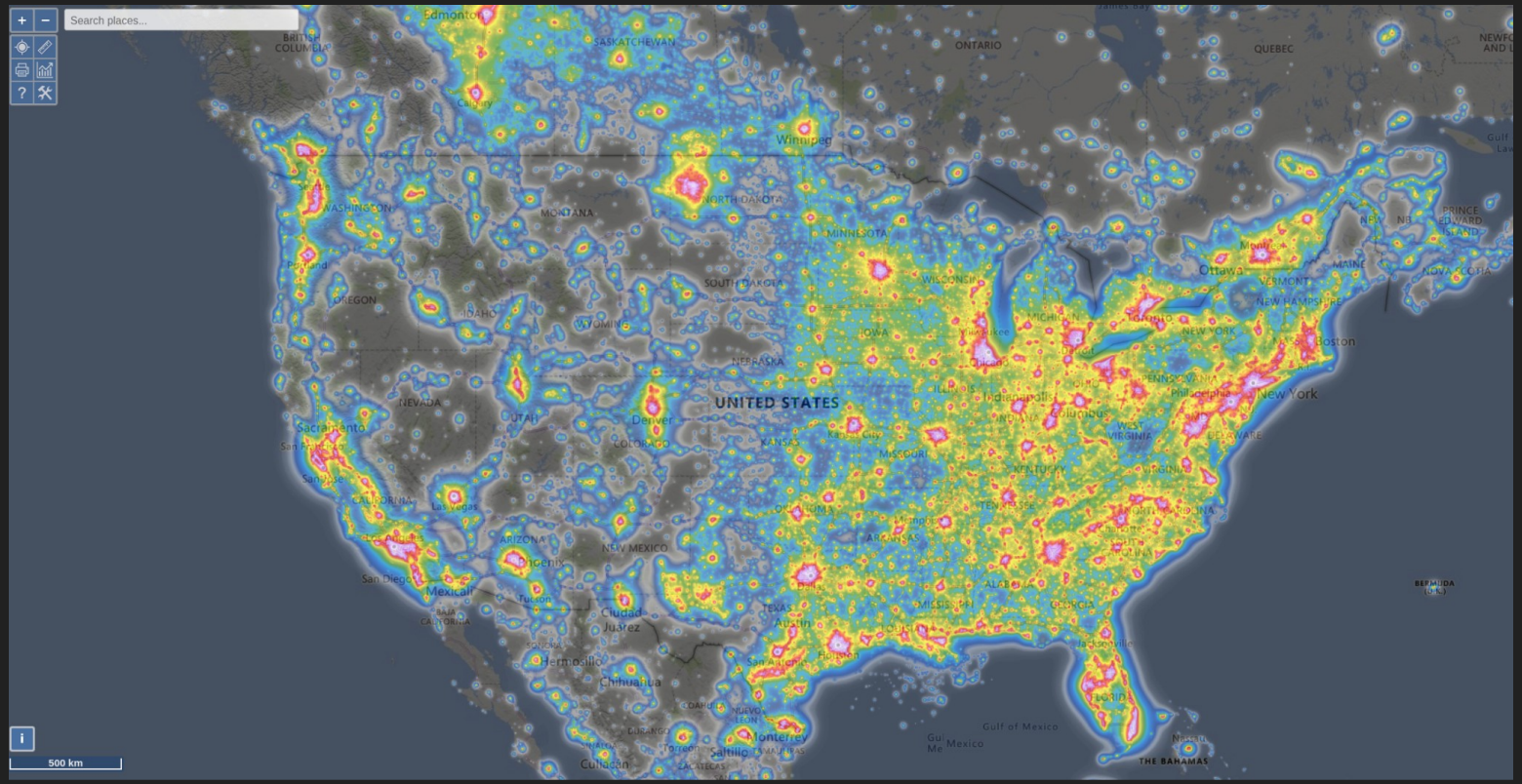
- Excessive,
- Misdirected or
- obtrusive artificial (usually outdoor) light



Light Pollution

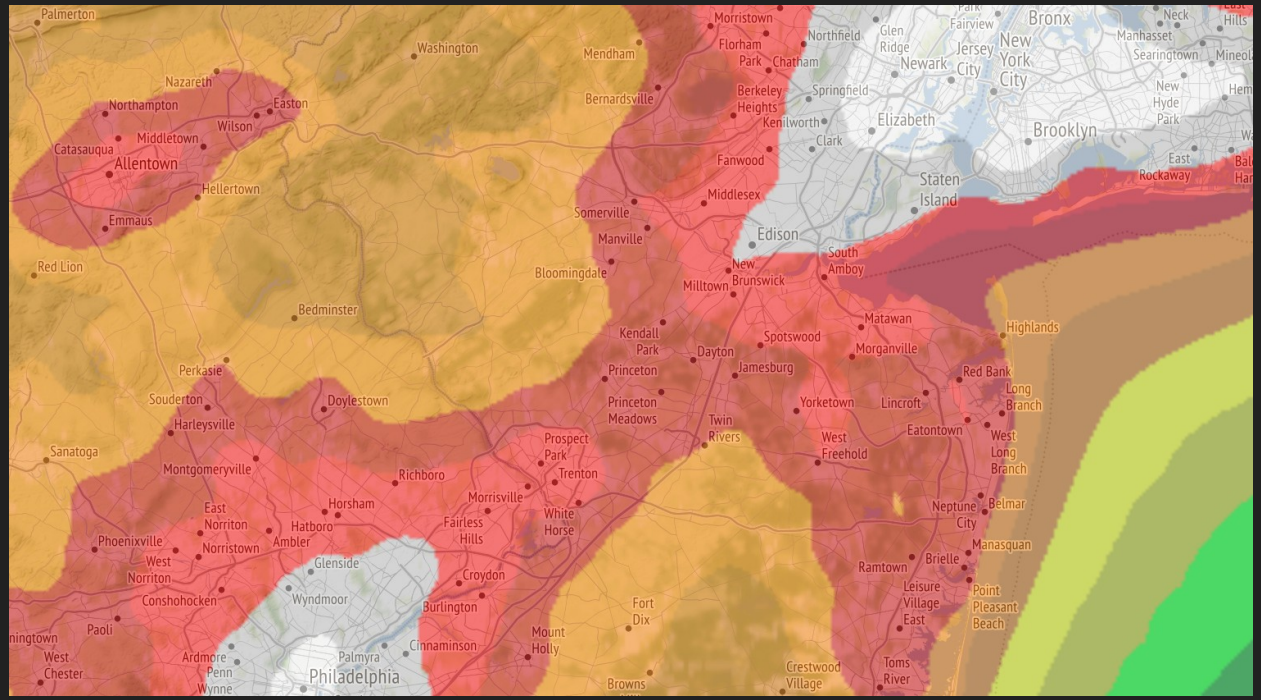
New parking garage across Lake Carnegie. This building is floodlit from underneath causing an unsightly glow in the night. This used to be a dark field just a year ago.

Light Pollution in the USA



VIIRS satellite data, 2021.
Sky brightness from direct emission

Light Pollution on the East Coast

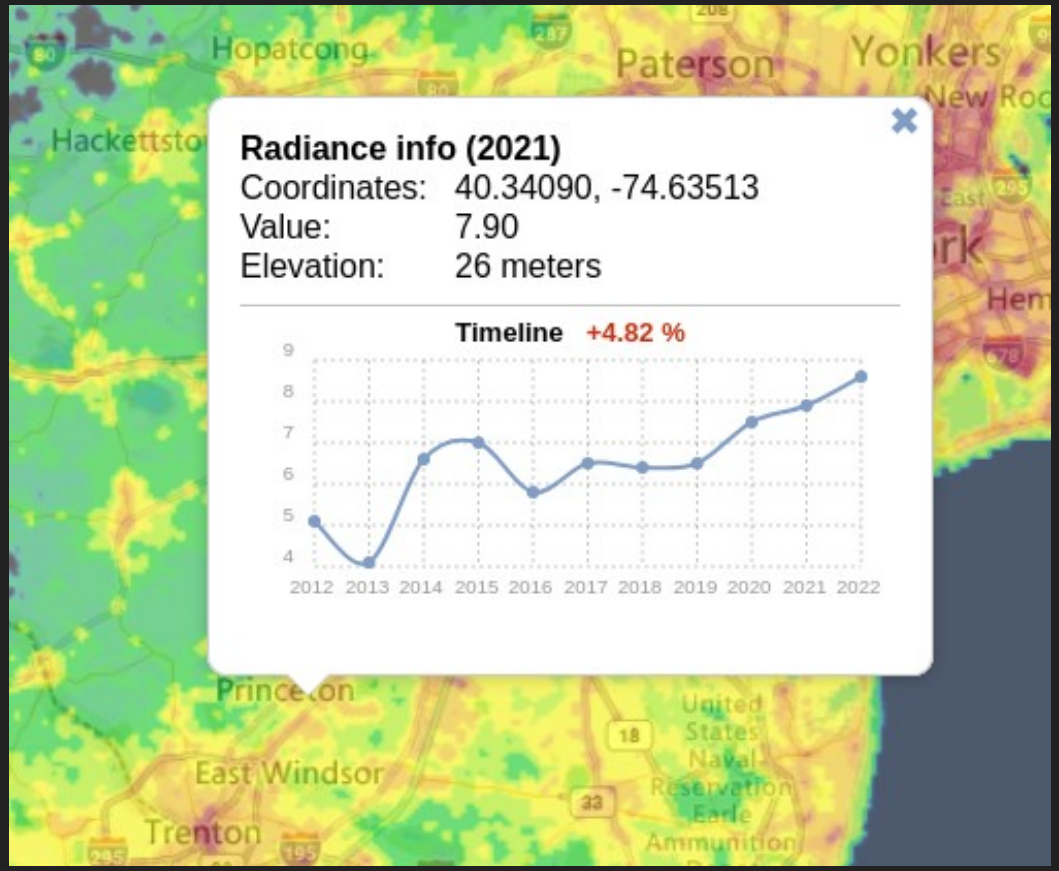


Darkskyfinder.com
Light pollution in the Princeton area.
Princeton is in the middle of a light corridor between Philly—Trenton--New Brunswick—NYC

There is an amazing opportunity here: keeping an Ivy League campus under starry skies.

Based on student polls, this is an important feature of Princeton.

Light Pollution in Princeton Increasing



Trend at Princeton over 10 years based on satellite data:

The pollution at least doubled.

The data are not fresh enough to reflect the recent Lake Campus and Stadium Drive Garage developments.

I estimate that the latter two result in a huge additional increase of light pollution for 2023, reaching at least 3x the 2012 value.

Light Pollution Before Stadium Garage

BEFORE. Stadium drive construction.

Light Pollution after Stadium Garage

BLINK this slide with the previous one to see the difference.

Note the bright and blue colors.

Faculty drive: sodium
Garage: 3000(?)K
Geothermal exchange: very blue, including area lights and bollards.

Princeton parking garage and Stadium, 2023 March 28, 10:30pm

SHORT TERM action item: permanently dim stadium drive lights to < 40% of current value, and to 10% (or 0%) after 11pm.
In addition, apply motion detectors.

Visual comparison of these two slides confirms the satellite measurements of a steeply increasing pollution.

Direct Sky Brightness Measurements

LIGHT POLLUTION AT PRINCETON UNIVERSITY

STEPHEN NICHOLAS BARTON

A JUNIOR PAPER

PRESENTED TO THE FACULTY

OF PRINCETON UNIVERSITY

IN CANDIDACY FOR THE DEGREE

OF BACHELOR OF THE ARTS

Where C is the surface brightness in terms of cd/m^2. Plugging in my calculated value, this conversion yields a night sky brightness of 20.94 $mag/arcsec^2$ on Princeton's campus due to nearby cities.

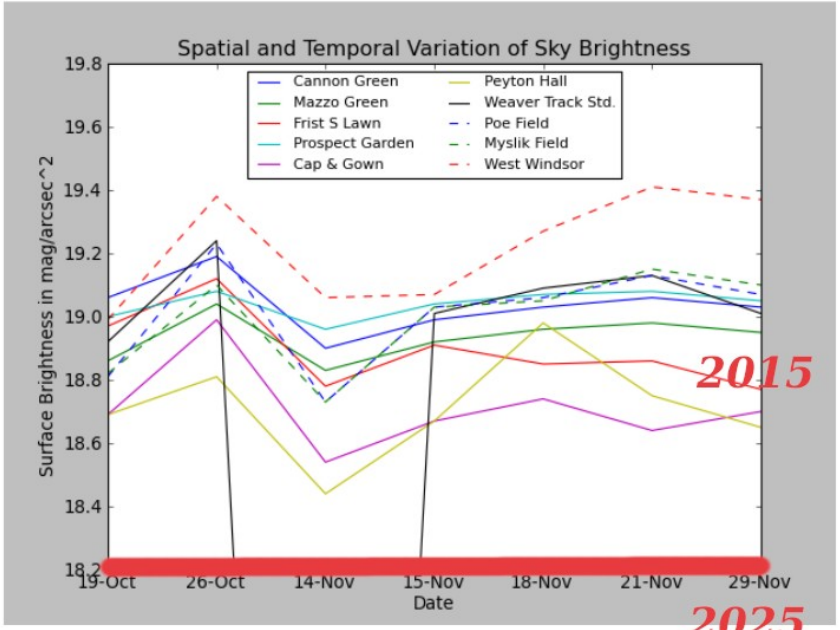


Figure 4.1: The spatial and temporal variation in sky brightness around Princeton University. A higher value of surface brightness in these units implies darker skies.

Junior Thesis of Nick Barton (later Rhodes Scholar)

RED line: recent measurements. Smaller numbers mean higher brightness (data in magnitudes)

Sky brightness increased by approx 1 mag/sqarcsec (2.5x) in 10 years. Princeton's sky is 2.5 times brighter in 2024 than in 2012. There is no good reason for this, and the trend can be turned back. >90% of this pollution comes from our campus.

(measurements done in zenith, see relevant papers for the mathematical connection between upward emitted light and local sky background. The asymptotic value, if Princeton was fully turned off, would be 20.94 mag/arcsec^2)

Sky Brightness above Princeton

In summary, based on:

- Satellite data
- Photographic evidence
- Sky background measurements with a photometer:

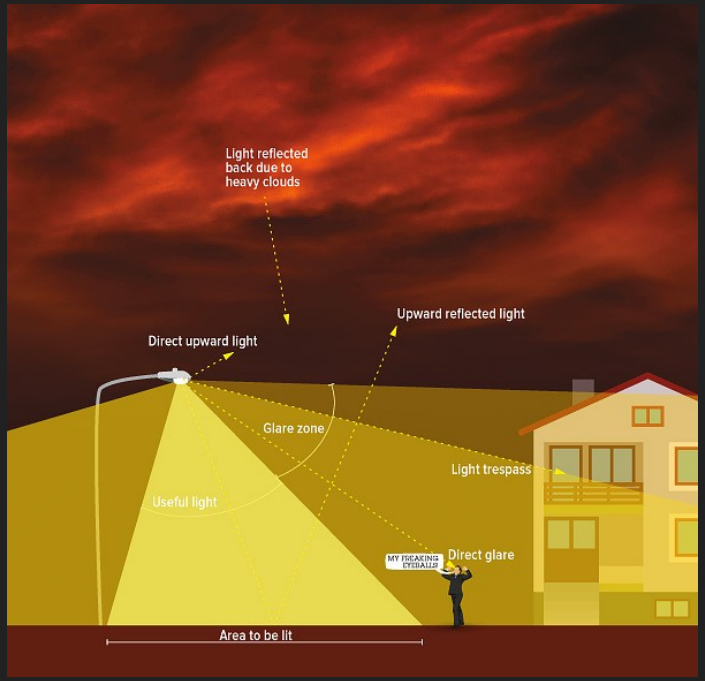
Sky brightness increased by approx 1 mag/sqarcsec (2.5x) in 10 years. Princeton's sky is 2.5 times brighter in 2024 than in 2012. There is no good reason for this, and the trend can be turned back.

(We don't have 2.5x more students , we are not 2.5x "safer", there is no 2.5x more traffic, etc.)

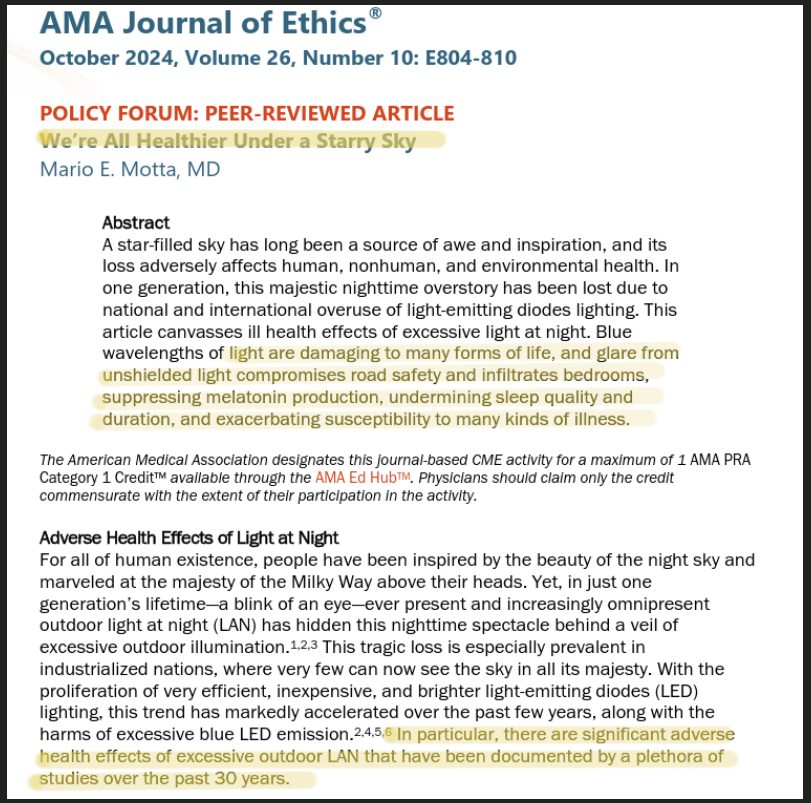
Light Pollution

Effects of light pollution

1. Adverse health effects, disrupts the circadian rhythm of humans and wildlife
2. Safety (glare and overlighting are not safe)
3. Waste of energy
4. Disrupts ecosystems (insects, turtles, any nocturnal wildlife)
5. Losing the night sky, our important cultural heritage.
6. Harming education and research in astronomy



1. Effects of Light Pollution – Health



AMA Journal of Ethics®
October 2024, Volume 26, Number 10: E804-810

POLICY FORUM: PEER-REVIEWED ARTICLE

We're All Healthier Under a Starry Sky

Mario E. Motta, MD

Abstract

A star-filled sky has long been a source of awe and inspiration, and its loss adversely affects human, nonhuman, and environmental health. In one generation, this majestic nighttime overstory has been lost due to national and international overuse of light-emitting diodes lighting. This article canvasses ill health effects of excessive light at night. Blue wavelengths of light are damaging to many forms of life, and glare from unshielded light compromises road safety and infiltrates bedrooms, suppressing melatonin production, undermining sleep quality and duration, and exacerbating susceptibility to many kinds of illness.

The American Medical Association designates this journal-based CME activity for a maximum of 1 AMA PRA Category 1 Credit™ *available through the* AMA Ed Hub™. *Physicians should claim only the credit commensurate with the extent of their participation in the activity.*

Adverse Health Effects of Light at Night

For all of human existence, people have been inspired by the beauty of the night sky and marveled at the majesty of the Milky Way above their heads. Yet, in just one generation's lifetime—a blink of an eye—ever present and increasingly omnipresent outdoor light at night (LAN) has hidden this nighttime spectacle behind a veil of excessive outdoor illumination.[1,2,3] This tragic loss is especially prevalent in industrialized nations, where very few can now see the sky in all its majesty. With the proliferation of very efficient, inexpensive, and brighter light-emitting diodes (LED) lighting, this trend has markedly accelerated over the past few years, along with the harms of excessive blue LED emission.[2,4,5,6] In particular, there are significant adverse health effects of excessive outdoor LAN that have been documented by a plethora of studies over the past 30 years.

Effects include: depression, diabetes, obesity, cancer

Please see recent compilation (Motta, Starry Sky):
https://journalofethics.ama-assn.org/podcast/author-interview-were-all-healthier-under-starry-sky

https://journalofethics.ama-assn.org/sites/joedb/files/2024-09/pfor1-peer-2410_0.pdf

1. Effects of Light Pollution – Health

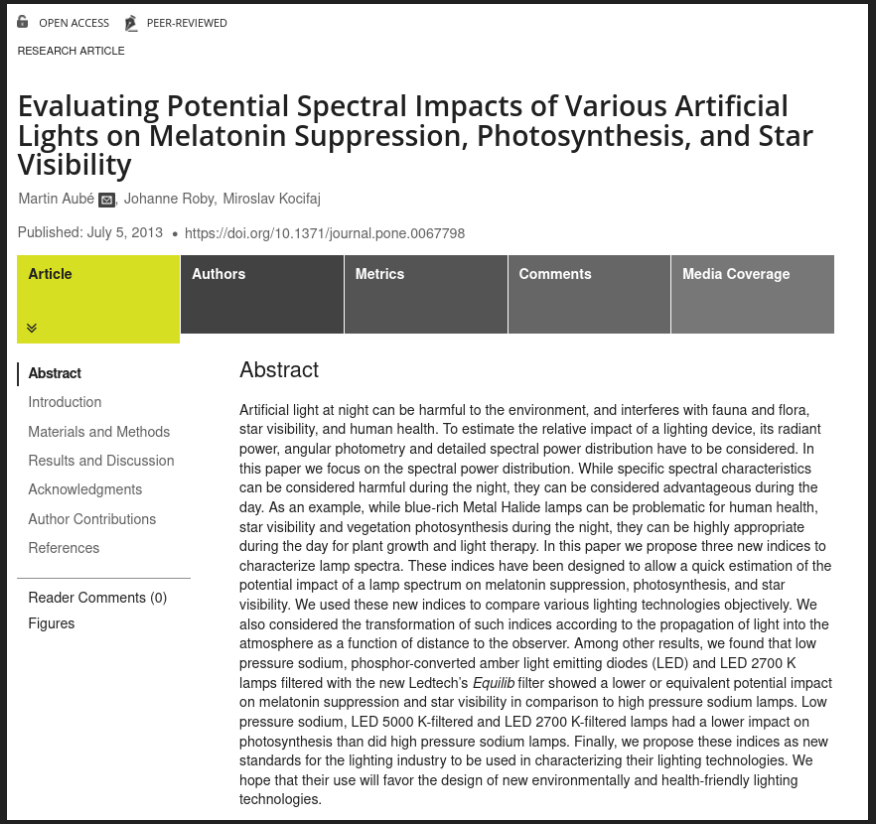
The American Medical Association (AMA) led the way by alerting the world to the dangers of excess LAN back in 2012 with a report titled "Light Pollution: Adverse Health Effects of Nighttime Lighting" and a second report in 2016 titled "Human and Environmental Effects of Light Emitting Diode (LED) Community Lighting."[11,12,13] Since then, 16 states and many cities and towns across the United States and in Europe have adopted the AMA recommendation to keep outdoor lighting below 3000 K.[14,15] Some companies, such as Apple, have even incorporated this recommendation in its products; the iPhone and iPad night shift setting limits blue light from screens after sunset.[16] However, implementation of the AMA recommendation to date has been sporadic in other companies and products.

https://journalofethics.ama-assn.org/article
messaging/2023-11

Cancer. There are now voluminous peer-reviewed articles showing a higher risk of hormonally linked cancers, such as breast and prostate cancers, with melatonin suppression.[4,21,22,23,24,25,26,27,28,29] Higher risk of thyroid and pancreatic carcinoma associated with LAN has also been reported in the literature.[30,31,32] The root problem lies in the disruption of circadian rhythmicity through suppression of melatonin production by the pineal gland. We evolved to have melatonin rise at sunset, but, in the modern world, melatonin production is delayed until bedtime and lights are out. Perniciously, however, even at bedtime, light penetrates into bedrooms in urban and suburban areas, further suppressing melatonin production. Melatonin has been shown to be an

disability glare.[5,19]

1. Effects of Light Pollution – Health



OPEN ACCESS PEER-REVIEWED

RESEARCH ARTICLE

Evaluating Potential Spectral Impacts of Various Artificial Lights on Melatonin Suppression, Photosynthesis, and Star Visibility

Martin Aubé, Johanne Roby, Miroslav Kocifaj

Published: July 5, 2013 • https://doi.org/10.1371/journal.pone.0067798

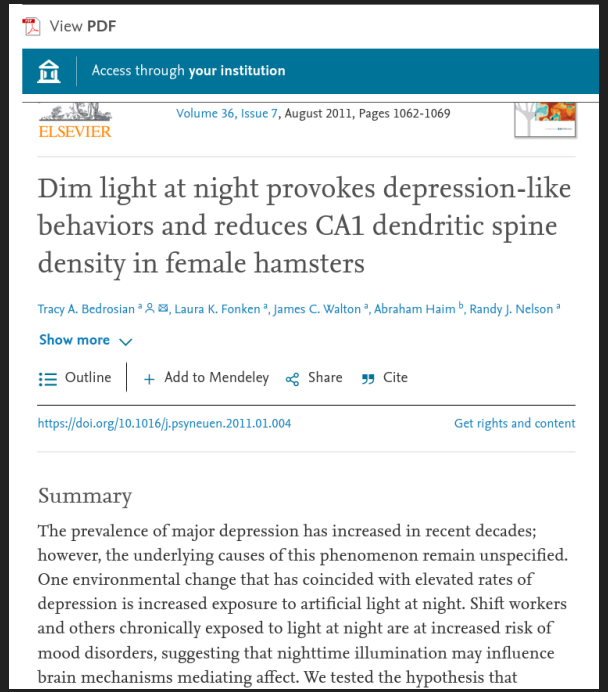
Article | Authors | Metrics | Comments | Media Coverage

Abstract
Introduction
Materials and Methods
Results and Discussion
Acknowledgments
Author Contributions
References

Reader Comments (0)
Figures

Abstract

Artificial light at night can be harmful to the environment, and interferes with fauna and flora, star visibility, and human health. To estimate the relative impact of a lighting device, its radiant power, angular photometry and detailed spectral power distribution have to be considered. In this paper we focus on the spectral power distribution. While specific spectral characteristics can be considered harmful during the night, they can be considered advantageous during the day. As an example, while blue-rich Metal Halide lamps can be problematic for human health, star visibility and vegetation photosynthesis during the night, they can be highly appropriate during the day for plant growth and light therapy. In this paper we propose three new indices to characterize lamp spectra. These indices have been designed to allow a quick estimation of the potential impact of a lamp spectrum on melatonin suppression, photosynthesis, and star visibility. We used these new indices to compare various lighting technologies objectively. We also considered the transformation of such indices according to the propagation of light into the atmosphere as a function of distance to the observer. Among other results, we found that low pressure sodium, phosphor-converted amber light emitting diodes (LED) and LED 2700 K lamps filtered with the new Ledtech's *Equilib* filter showed a lower or equivalent potential impact on melatonin suppression and star visibility in comparison to high pressure sodium lamps. Low pressure sodium, LED 5000 K-filtered and LED 2700 K-filtered lamps had a lower impact on photosynthesis than did high pressure sodium lamps. Finally, we propose these indices as new standards for the lighting industry to be used in characterizing their lighting technologies. We hope that their use will favor the design of new environmentally and health-friendly lighting technologies.



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ELSEVIER

Volume 36, Issue 7, August 2011, Pages 1062-1069

Dim light at night provokes depression-like behaviors and reduces CA1 dendritic spine density in female hamsters

Tracy A. Bedrosian [a], Laura K. Fonken [a], James C. Walton [a], Abraham Haim [b], Randy J. Nelson [a]

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https://doi.org/10.1016/j.psyneuen.2011.01.004 Get rights and content

Summary

The prevalence of major depression has increased in recent decades; however, the underlying causes of this phenomenon remain unspecified. One environmental change that has coincided with elevated rates of depression is increased exposure to artificial light at night. Shift workers and others chronically exposed to light at night are at increased risk of mood disorders, suggesting that nighttime illumination may influence brain mechanisms mediating affect. We tested the hypothesis that

Even dim ambient night time light is harmful. Note that typical light trespass is much brighter than the light of the full moon. Also note that the light of the full moon is only present for a couple of nights during the month.
Student testimonies indicate that light trespass is a significant issue at Princeton.

2. Light Pollution – Safety

The American Medical Association (AMA) led the way by alerting the world to the dangers of excess LAN back in 2012 with a report titled "Light Pollution: Adverse Health Effects of Nighttime Lighting" and a second report in 2016 titled "Human and Environmental Effects of Light Emitting Diode (LED) Community Lighting."[11,12,13] Since then, 16 states and many cities and towns across the United States and in Europe have adopted the AMA recommendation to keep outdoor lighting below 3000 K.[14,15] Some companies, such as Apple, have even incorporated this recommendation in its products; the iPhone and iPad night shift setting limits blue light from screens after sunset.[16] However, implementation of the AMA recommendation to date has been sporadic in other companies and products.

https://journalofethics.ama-assn.org/article
messaging/2023-11

Glare. In addition to suppressing melatonin production, improperly designed and poorly shielded light fixtures can result in glare and create a road hazard condition. Indeed, "glare is the most common health safety problem resulting from poorly designed outdoor lighting,"[17] as intense blue LED lighting leads to discomfort and disability glare. As I have noted elsewhere:

> Over time, calcifications build up in the lenses of our eyes, which eventually develop into a cataract. These calcifications and other lens and eye imperfections scatter light in a similar fashion to a dirty windshield. This effect grows more severe with age, and is the primary reason why the elderly have a difficult time driving at night under poorly designed street lights.[17]

Recognizing that our streets could be safer places at night, the AMA adopted a policy in 2009 that urges full shielding for all public street lighting.[18]

Glare can be greatly mitigated by proper design, shielding, and installation so that no light shines above 80 degrees from the horizontal. The visual hazard posed by these very intense point sources is further magnified by cooler CCT LEDs, because blue light scatters more in the human eye than warmer wavelengths, leading to increased disability glare.[8,19]

The concern is glare.

- Loss of contrast
- Glare hugely increases with age above ~50, with the calcification of lenses in our eyes

-
- (See: https://www.ajo.com/article/S0002-9394(07)00520-X/abstract
  Van Den Berg TJTP, Van Rijn LJ, Michael R, et al.. Straylight effects with aging and lens extraction. Am J Ophthalmol.2007; 144: 358–363.e351

Light Pollution – Safety and Glare

This poor example for glare is on Ivy Lane, next to the EAS construction. The “temporary” lights have been up for a year.

They shine mostly upward and blind the pedestrians.

Light Pollution – Safety and Glare

The new geo-exchange building at Stadium Drive.

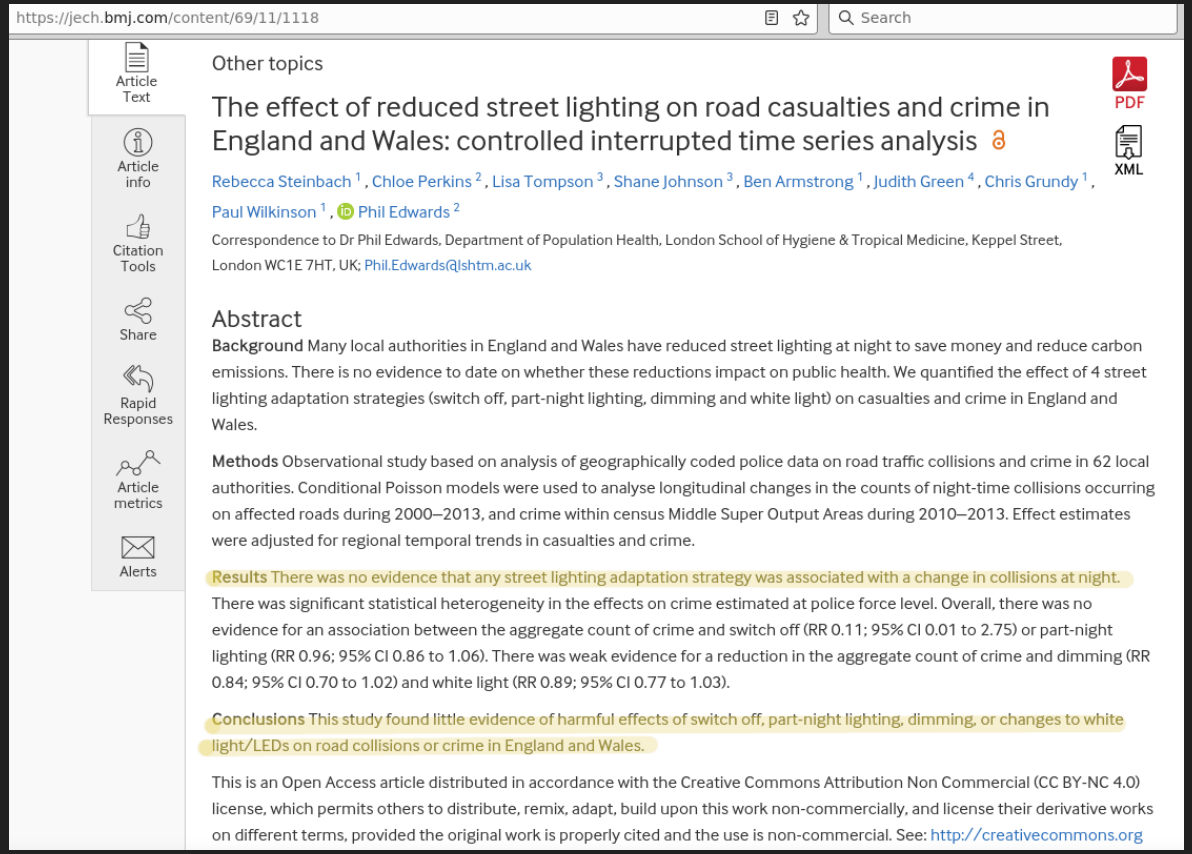
Problems are:
Interior lights are way too bright

They are ON full time.

Light leakage through the windows.

Bollards in front cause glare; they are useless.

Light Pollution – Safety



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The effect of reduced street lighting on road casualties and crime in England and Wales: controlled interrupted time series analysis

Rebecca Steinbach [1], Chloe Perkins [2], Lisa Tompson [3], Shane Johnson [3], Ben Armstrong [1], Judith Green [4], Chris Grundy [1], Paul Wilkinson [1], Phil Edwards [2]

Correspondence to Dr Phil Edwards, Department of Population Health, London School of Hygiene & Tropical Medicine, Keppel Street, London WC1E 7HT, UK; Phil.Edwards@lshtm.ac.uk

Abstract

Background Many local authorities in England and Wales have reduced street lighting at night to save money and reduce carbon emissions. There is no evidence to date on whether these reductions impact on public health. We quantified the effect of 4 street lighting adaptation strategies (switch off, part-night lighting, dimming and white light) on casualties and crime in England and Wales.

Methods Observational study based on analysis of geographically coded police data on road traffic collisions and crime in 62 local authorities. Conditional Poisson models were used to analyse longitudinal changes in the counts of night-time collisions occurring on affected roads during 2000–2013, and crime within census Middle Super Output Areas during 2010–2013. Effect estimates were adjusted for regional temporal trends in casualties and crime.

Results There was no evidence that any street lighting adaptation strategy was associated with a change in collisions at night. There was significant statistical heterogeneity in the effects on crime estimated at police force level. Overall, there was no evidence for an association between the aggregate count of crime and switch off (RR 0.11; 95% CI 0.01 to 2.75) or part-night lighting (RR 0.96; 95% CI 0.86 to 1.06). There was weak evidence for a reduction in the aggregate count of crime and dimming (RR 0.84; 95% CI 0.70 to 1.02) and white light (RR 0.89; 95% CI 0.77 to 1.03).

Conclusions This study found little evidence of harmful effects of switch off, part-night lighting, dimming, or changes to white light/LEDs on road collisions or crime in England and Wales.

No correlation between road casualties and street lighting (or between crime and street lighting).

Light Pollution – Safety

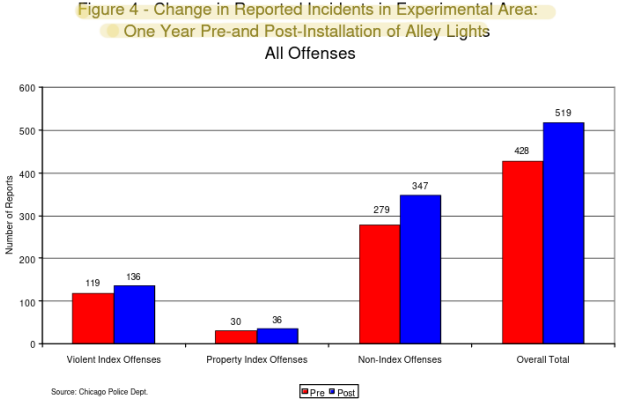
Figure 4 - Change in Reported Incidents in Experimental Area:
One Year Pre-and Post-Installation of Alley Lights
All Offenses

When the raw counts for this one-year analysis of the experimental area were examined, the data indicate that there were 428 total incidents reported in the pre-installation period and 519 total incidents in the post-installation period - an increase of 21 percent in reported offenses between the pre- and post-period test.

Chicago Alley Experiment: lighting was increased by a factor of 4. Thorough tracking of incidents. Night time crime went up by 20%.

The London experiment: upgraded lighting, no change in crime rate or “perceptions of security”.

Perceived safety does not mean safety. Perceived (but false) safety is dangerous.

https://www.ncjrs.gov/works/chapter7.ht

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festival with the restrictions, without control area comparisons.

Lighting

Lighting campaigns seek to enhance the ability of people to provide protection for each other. In 1979, the predecessor agency of NIJ, the National Institute of Law Enforcement and Criminal Justice, reported on a review of 60 lighting evaluations. The authors of this review concluded:

"*Is street lighting an effective approach in the reduction and deterrence of crime?* The answer is inconclusive. The paucity of reliable and uniform data and the inadequacy of available evaluation studies preclude a definitive statement regarding the relationship between street lighting and crime." (Tien, et. al. 1979, page 93, emphasis in the original)

Almost twenty years later, we know little more about the effectiveness of lighting.

In the 1980's, a borough in London upgraded all of its street lighting. Atkins, Husain and Storey (1991) compared reported crimes the year before the relighting to the year following for 39 sections of the borough. No control areas were used, so background trends in crime cannot be assessed. No systematic changes in crime were detected. Surveys of residents of one area found no changes in perceptions of security.

3. Effects of Light Pollution – Energy

USA alone: $3 billion / yr directly in the sky.

(= 1/3rd of the annual budget of the NSF, or 1/10th of NASA's budget)

Based on a survey of existing light fixtures on campus, their light levels and their shielding, and the fact that they are on at all times during night (even when not needed), we estimate that the relevant electric bill of Princeton University could be reduced by 75%.

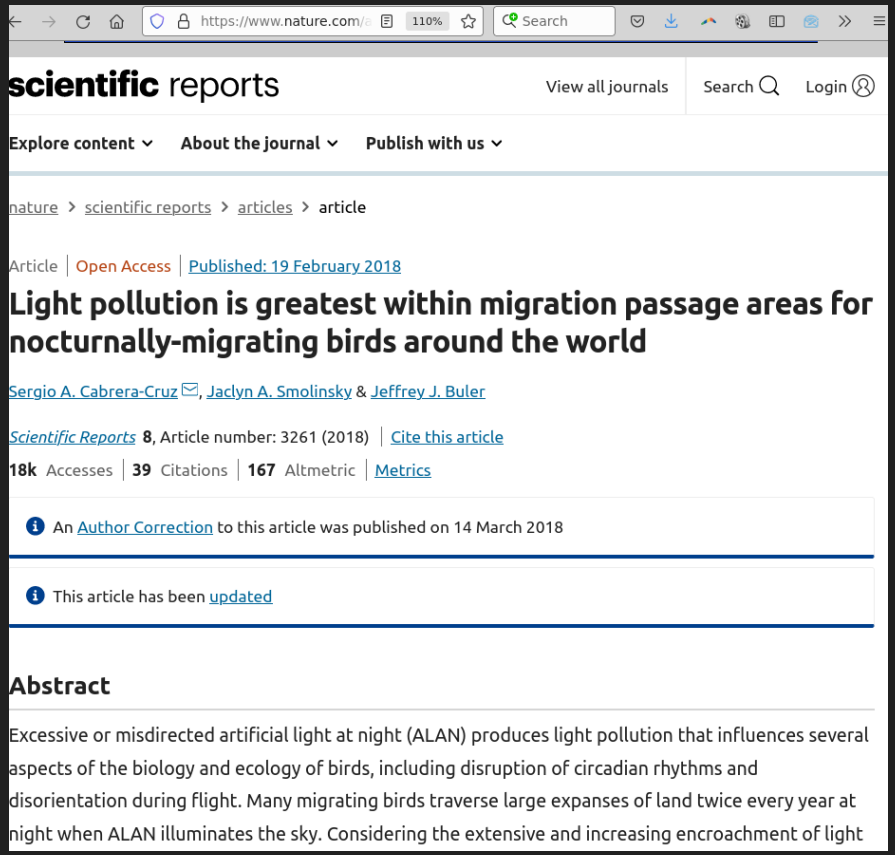
Sustainable Princeton

04: A Sustainability Framework

- Sustainability Objectives
  - Embedded Sustainability Strategies
  - A Shift Toward Broad Impacts Across Complex Systems
  - Aligning Campus Planning, Sustainability and Princeton's Educational Mission
- Components of the Sustainability Framework
  - Impact Priorities
  - Impact Indicators, Proposed Targets and Planning Strategies
    - Reduced Greenhouse Gas Emissions
    - Compact Campus Footprint
    - Transportation
    - Storm Water Management
    - Water Conservation
    - Habitat Integrity
    - Waste Reduction
    - Reliability

Sustainability is one of Princeton's top priority
Light Pollution is missing from the list.

4. Effects of Light Pollution – Ecosystems



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Article | Open Access | Published: 19 February 2018

Light pollution is greatest within migration passage areas for nocturnally-migrating birds around the world

Sergio A. Cabrera-Cruz, Jaclyn A. Smolinsky & Jeffrey J. Buler

Scientific Reports **8**, Article number: 3261 (2018) | Cite this article

18k Accesses | **39** Citations | **167** Altmetric | Metrics

An Author Correction to this article was published on 14 March 2018

This article has been updated

Abstract

Excessive or misdirected artificial light at night (ALAN) produces light pollution that influences several aspects of the biology and ecology of birds, including disruption of circadian rhythms and disorientation during flight. Many migrating birds traverse large expanses of land twice every year at night when ALAN illuminates the sky. Considering the extensive and increasing encroachment of light

Disruption of ecosystems spans a wide range, huge number of species affected (in)directly.

Examples:

- Insects
- Birds (see flap.org)
- Beavers (“the ghost of predators past”)

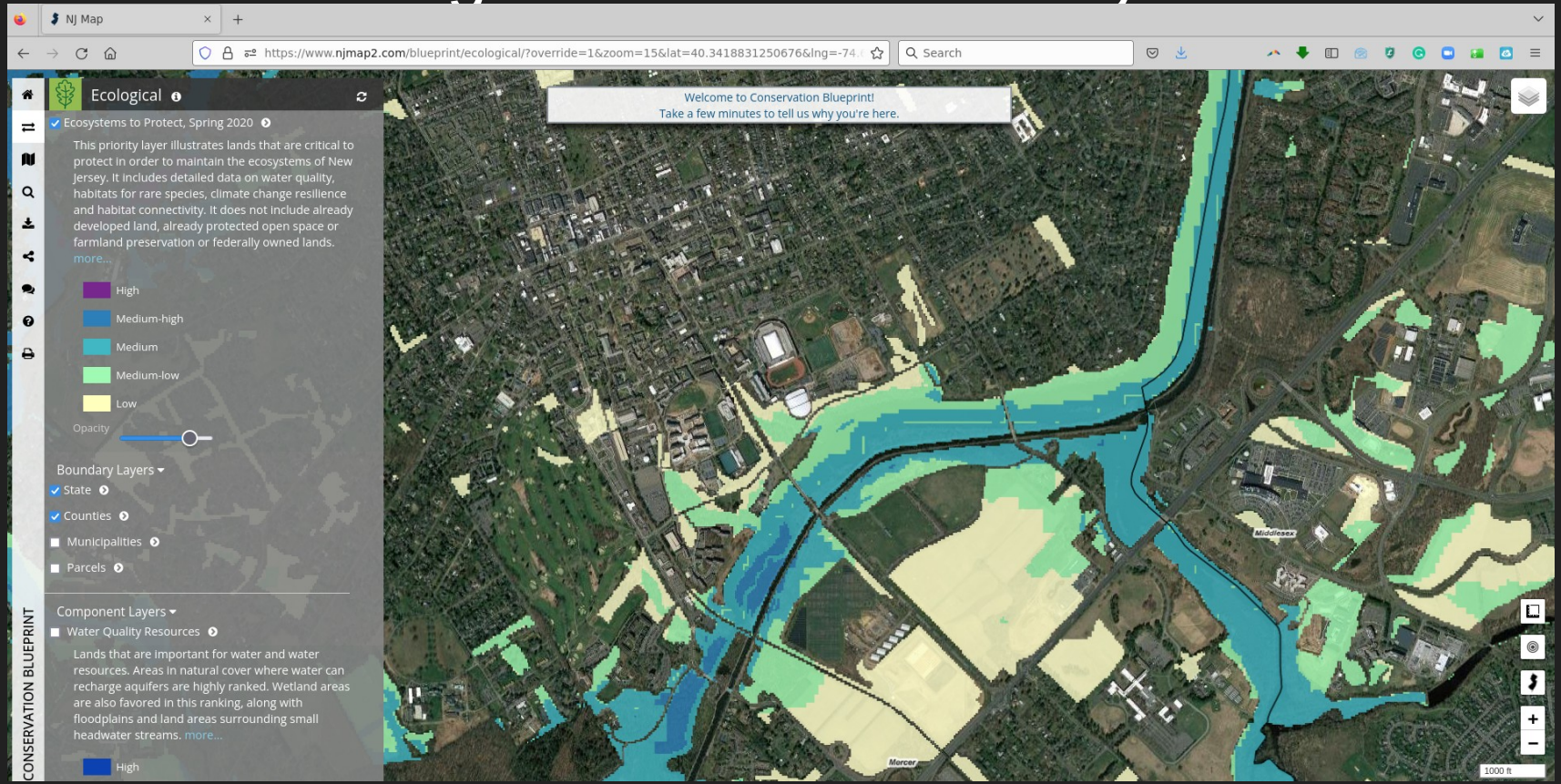
Insect apocalypse under way: population dropped to 45% due to light pollution.

Princeton is surrounded by fragile ecosystems: D&R canal park, Stony Brook, Millstone, Lake Carnegie, Wildlife corridors.

Can scientists help insects survive their fatal attraction to light at night?

Scientists test differently colored lights on bridges and in parks to help stem the 'insect apocalypse'

Effect of Light Pollution – Ecosystems



Princeton is surrounded by fragile ecosystems: D&R canal park, Stony Brook, Millstone, Lake Carnegie, Wildlife corridors.

Effect of Light Pollution – Ecosystems

Some of this fragile ecosystem was just recently lit up by unshielded “area” lights. The entire field across the lake is now constantly illuminated. ((Faculty road)

Education and Research

AST205 “Planets in the Universe”: 2012 – 2024

Altogether ~1000 students involved

Strong observational component with telescopes and cameras. About 40 observing sessions per year.

Alumni return after a decade to our observing sessions (aka star parties). One such event every month.

Strong degradation of sky conditions over a decade. Sky is getting very bright, and very few places remain with no direct glare from fixtures.

Peyton rooftop observing almost impossible.

Steeply increasing light pollution of Princeton is paralyzing the teaching activities.

Note: sky background is going up AND direct light exposure is increasing. Both are harmful.

Education and Research

AST205 “Planets in the Universe”: 2012 – 2023

Altogether ~1000 students involved

Strong observational component with telescopes and cameras. About 40 observing sessions per semester.

Alumni return after a decade to our observing sessions (aka star parties). One such event every month.

Strong degradation of sky conditions over a decade. Sky is getting very bright, and very few places remain with no direct glare from fixtures.

Photo: star observing from the golf course, graduate college.

Steeply increasing light pollution of Princeton is paralyzing the teaching activities.

Education, Research and Public Relations

Princeton's sky is valued by many other "layers" of our population: alumni, famous visitors, Nobel prize winners, musicians.

Photo: The Berlin Philharmonics and Maestro Dudamel on Peyton's Observing Rooftop Terrace

Light Pollution – What do we lose?

Visibility impacted both by direct lights blinding the observer, and indirect lights increasing the sky background.

An extreme example is the daytime sky, when due to the very high sky brightness, we only see one star ...

The following slides illustrate the
effect of sky background increase on the visibility of the night sky.

This slide shows an unpolluted dark sky with the Winter Milky Wa4y.
You can recognize the Big Dipper (slightly to the right) and Cassiopeia (in the Milky Way).

Simulations by G.Bakos, using stellarium

BLINK the next 9 slides.

Light Pollution – What do we lose?

The effect of sky background increase on the visibility of the night sky.

Increasing the sky background brightness...

Increasing sky background

The effect of sky background increase on the visibility of the night sky.

The effect of sky background increase on the visibility of the night sky.

The effect of sky background increase on the visibility of the night sky.

The effect of sky background increase on the visibility of the night sky.

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The effect of sky background increase on the visibility of the night sky.

Light Pollution – What do we lose?

The effect of sky background increase on the visibility of the night sky.

This is about equivalent to the night sky above Princeton.

With a bright sky background we barely see anything, due to the lack of contrast.

Light Pollution – What do we lose?

The effect of sky background increase on the visibility of the night sky.

BLINK this slide with the previous one.

Light Pollution – What do we lose?

Comet Atlas above the Graduate College, slightly to the right.

Light Pollution – What do we lose?

Comet Atlas above Graduate College

With a facade illuminated, this “heavenly” view would be lost.

In this photo, the facade is softly lit by the rising Moon.

Light Pollution – What do we lose?

Lunar Eclipse and Northern Lights

With facades illuminated, the “heavenly” sights would be lost.

Most students did not see the Northern Lights from Princeton due to direct glare of street lights.

Light Pollution – What do we lose?

Parking garage across Lake Carnegie. Image taken in foggy conditions to indirectly measure the excess glow caused by the floodlighting of the building. These lights have been on for a year, and they are in stark contrast with the principles laid out in the Lighting Master Plan of 2015.

Useful Observing Areas in Princeton with Starry Skies: 2012

Blue areas indicate places where night time observations were possible in 2014 (from most places, up till 2022).

Useful Observing Areas with Starry Skies: 2025

Red areas indicate places from where seeing the night sky has become impossible. Very few areas remain.

Student Responses

Q: Do you see a value in Princeton having a starry sky?
(Selection from about ~80 responses from alumni). See: https://www.astro.princeton.edu/~gbakos/AST205/testimonials.html

- "*Apart from the obvious educational value provided by having access to the night sky, the ability to gaze upon the stars has been defining for my Princeton experience. Walking back to my dorm or to a study spot at night and looking up at the sky instills students with a sense of wonder and curiosity. Moreover, the night sky is a key part of Princeton's famously beautiful campus in my eyes*." – Wyndham Freeman, 2026'
- "*As a student of philosophy, I took seriously Aristotle's exhortation to contemplate the celestial bodies as a part of the good life. So I took astronomy with Professor Bakos, and enjoyed it tremendously. Considering the universe, its stars (and their planets!), is awesome in the most literal sense: it provokes awe, wonderment, and a sublime sense, a humbling perspective, for how small we are. It's a tremendously valuable experience, and one that should be preserved for future generations of Princeton students*." – Thomas Horton, 2015'
- "*Princeton having a starry sky allows me to take a mental break after long, exhausting days of studying, classes, and meetings. Coming from New York City and coming to Princeton, observing the starry night sky was an unexpected joy I've discovered. I've really appreciated being able to view and learn about the stars and feel a greater sense of perspective and curiosity of the world." – Kate Alvarez, 2027'*
- *"Since my time in AST, I've continued attending a few star observation parties with the AST department and it's one of the activities that keeps me closer to the U as an alum.* " – Rodrigo Moretti, 2019'
- "*Princeton having a starry sky holds immense value, as it creates opportunities to connect deeply with the universe in ways that are both intellectually and personally transformative. During my senior year, I took AST 205 with Prof. Bakos, which was a highlight of my Princeton experience. The course made me realize how beautiful the night sky is, and to this day, I am captivated by its wonders.* " – Antek Hasiura, 2024'
- "*When my father asked me right before college what I'd miss about being home, the first thing I thought of was "stars." I was really pleasantly surprised that we can see a fair scattering here, and it's wonderful. Not being able to see stars feels like blindness. Or being able to see the aurora last semester, which was so cool.* " – Katrin Brinkman

Student Responses

Did you experience light pollution on campus, and how did it disturb you? [Selection from ~80 responses from alumni]
See: https://www.astro.princeton.edu/~gbakos/AST205/testimonials.html

- "*The Poe Field lights are also very bright as someone who lives right next to the field. Light is good in dark walking places for safety; however, excessive light in unused areas at night ruins the ambiance and becomes a distraction for learning in classes that conduct outside research or for simple studying. The signs outside of the McGraw Center are also very bright and startling at night.* " – Elisa Gonzalez, 2027'
- "*Yes, I find it hard to sleep in my room because of all the light that shines in*" – Luke Trowbridge, 2026'
- "*I grew up in a dark place with few sources of artificial light, so attending Princeton was a significant change. I have found my sleep being disrupted by harsh unshielded artificial lighting nearby my dorm room (Forbes College) despite my room shades being fully drawn. As someone who is sensitive to light changes (I wake with a sunrise clock for this reason) this is very challenging, requiring sleep aids such as melatonin and eye masks. While walking around campus at night, I have also found the artificial lighting to often be unnecessary and disruptive, with unused offices, classrooms, and construction sites shining brightly, floodlights lighting up the sides of locked buildings, or casting light directly up into the sky. The sky brightness from artificial lighting has even created a noteworthy haze on some occasions, visible as a purple hue. This is not only a tremendous waste of energy, it is disruptive to the environment (such as to migrating birds) and to student's circadian rhythms, adding to the stresses of a challenging campus.* " – Calvin Grover, 2027'
- "*Pollution sullies natural beauty. Light pollution is no exception to this rule. Needless light at night prevents us from gazing at the natural beauty of the cosmos. I remember even ten years ago having some difficulty getting away from the lights of campus. And returning to Princeton since, I've noticed more needless light at night---parking garages floodlit near once-barren spaces we used to go to observe other worlds. Now those worlds are shut off from view, veiled from our eyes of our own doing. This saddens me. I worry that current and future Princeton students won't be able to have the wonderful experiences that I had.*" – Thomas Horton 2015'
- "*Yes. There are too many unnecessary lights. It makes it tough to go asleep for certain dorm rooms, and it makes nighttime less relaxing and peaceful* " – John Volker, 2025'
- "*Yes, and it has disturbed me greatly as someone who has lived in Princeton since elementary school-- I find it very agitating that there is so much light and light pollution on campus since it not only messes with my circadian rhythm but also with my actual sleep.*" – Devan Morey 2026'
- "*Light pollution has taken away a magical starry sky. Inefficient street lighting often causes glare that actually makes it harder to see when walking at night, the glare of each lamp jarring to the human eye attempting to adjust to a darker environment. The lights by every construction sight pointed inexplicably towards my eyes rather than towards the ground they're actually supposed to illuminate — as well as the ridiculously bright new screen in front of Frist Campus Center — are some of many examples of light pollution on campus.*" – Kristen Tan, 2026'

Princeton University Master Lighting Plan 2015 – Relevant Excerpts

1.1 EXECUTIVE SUMMARY

This document is an update to the Princeton University Outdoor Lighting Master Plan issued by Fisher Marantz Stone (FMS) on February 2010. This report has been prepared for integration into the Princeton Design Standards Manual to assist lighting designers in designing the Princeton campus exterior lighting.

This report aims to expand the 2010 report by providing specific guidelines for implementation and standardization of the overall campus exterior lighting while adhering to the original goal to *"address personal safety requirements for the University community without damaging the campus nighttime aesthetic, and do so in a manner consistent with the University's goals for energy conservation."*

Some important and relevant points are highlighted in the following slides.

- **Campus nighttime aesthetic**
- **Energy conservation**
- **Sustainability efforts**

1.3 GOALS

a. Define a set of guidelines for the overall exterior campus lighting.

b. Adopt new advances in lighting, particularly LED technology which has matured in recent years.

c. Create a checklist of luminaire requirements to assist in selecting the appropriate luminaire.

d. Update recommended illuminance levels based on Princeton University's park-like theme.

e. Provide solutions in response to the university's sustainability efforts to reduce carbon dioxide emissions.

f. Apply new recommendations based on newly published lighting reference materials.

Princeton University Master Lighting Plan 2015

2.2.1 Campus Standard Light Pole

The Princeton Campus Standard poles are undergoing a retrofit program from HID to QL induction lamps which was the most viable solution at the time the program was implemented. In general, the lamp technology switch has yielded positive results. A few of the newer poles however had lamps peering below the top cover which caused unwanted glare. Other poles were lamped with cooler lamp color temperatures. Both these errors are very noticeable and should be rectified.

2.2.3 Lot 16, 20, 23 and 32

The parking lots were previously unevenly illuminated with HID lamps that left large patches of dark areas particularly at the lot perimeters. They have recently undergone an upgrade to LED luminaires mounted on high masts to cover wide areas in the middle of the lot supplemented with shorter poles at the perimeter. The lights are controlled by motion sensor which works well with Princeton's energy conservation goals.

- Cooler colors preferred
- motion sensors,
- energy conservation

Princeton University Master Lighting Plan 2015

2.4. EXTERIOR LIGHTING GUIDELINES

This section outlines the typical conditions for various exterior areas and lists recommendations and important characteristics that should be considered when designing the lighting. It also incorporates light level recommendations based on IESNA (Illuminating Engineering Society of North America) standards, which, depending on project specifics, may be subject to deviations and resolved by professional judgment.

Below is an excerpt relevant to the Princeton University campus desired nighttime environment taken from the Illuminating Engineering Society (IES) website which cites a study conducted by the U.S. Department of Energy on Pedestrian Friendly Outdoor Lighting.

The study found that not every neighborhood is suited for pedestrian-friendly approaches, but where communities are receptive, the following may be helpful:

- If luminaire brightness can be controlled, neighborhoods may find lower-lumen-output luminaires and illuminances at the lower end of IES recommendations to be acceptable and even preferred.
- Luminaires with less optical punch and less sharp angular variation in candlepower may provide a softer, more visually comfortable lighted environment.
- Luminaires delivering warmer-color light, usually lower than 4,000K and often below 3,000K, may be appropriate for older, more traditional-looking neighborhoods, especially if residents have been used to high-pressure sodium or incandescent outdoor lighting.

2.4.1 PEDESTRIAN WALKWAYS

The illumination level for walkway lighting is based on the volume of pedestrian traffic and surrounding conditions. Areas like Princeton where there is minimal nighttime pedestrian traffic and low nighttime activity surroundings, do not require continuous uninterrupted lighting. Only hazards along the walkways require specific illumination levels.

Lighting Guidelines

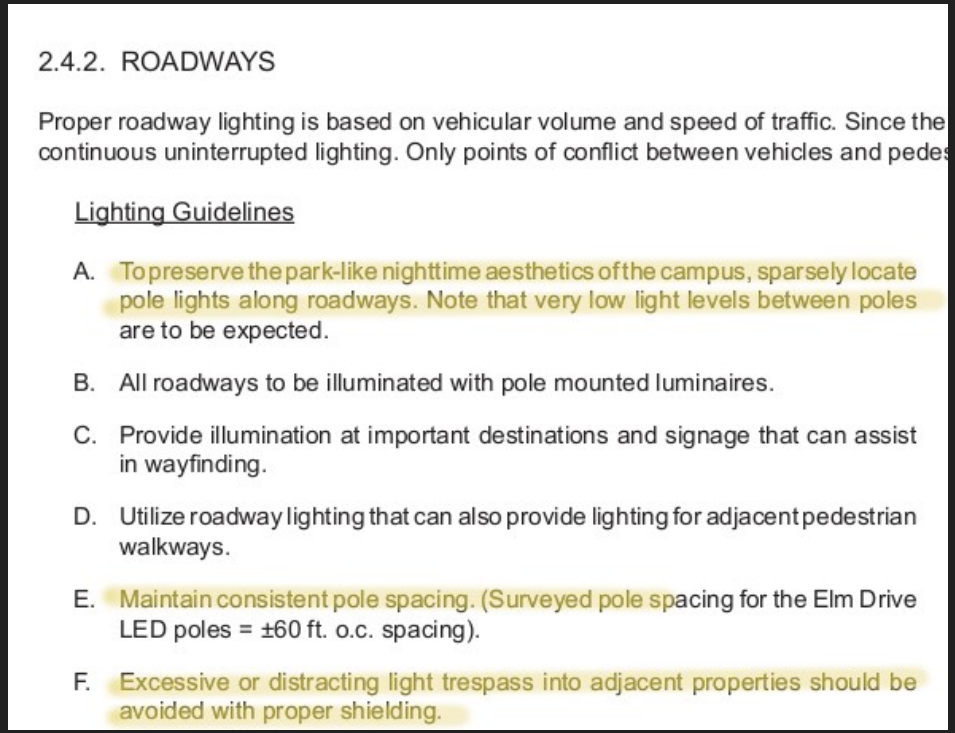
A. To preserve the park-like nighttime aesthetics of the campus, sparsely locate pole lights along walkways. This applies to walkways that are adjacent to and distant from roadways. Note that very low light levels between poles are to be expected.

Improvement Report.

H. Pedestrian walkway target illumination levels should follow recommended levels listed in Table 2: Recommended Pedestrian Walkway Illuminance

- Lower lumens are often preferred
- Warmer colors
- Park-like nighttime aesthetics, as a principle

Princeton University Master Lighting Plan 2015



2.4.2. ROADWAYS

Proper roadway lighting is based on vehicular volume and speed of traffic. Since the
continuous uninterrupted lighting. Only points of conflict between vehicles and pedes

Lighting Guidelines

A. To preserve the park-like nighttime aesthetics of the campus, sparsely locate pole lights along roadways. Note that very low light levels between poles are to be expected.

B. All roadways to be illuminated with pole mounted luminaires.

C. Provide illumination at important destinations and signage that can assist in wayfinding.

D. Utilize roadway lighting that can also provide lighting for adjacent pedestrian walkways.

E. Maintain consistent pole spacing. (Surveyed pole spacing for the Elm Drive LED poles = ±60 ft. o.c. spacing).

F. Excessive or distracting light trespass into adjacent properties should be avoided with proper shielding.

Park-like nighttime aesthetics.

Sparsely located poles and low light level between poles.

Avoid excessive lighting.

(Note on parks and night time aesthetics. There are plenty of parks open at night time in New Jersey and elsewhere. Examples are:

- Lake Carnegie Park,
- Community Park North,
- Herrontown Woods,
- Sourlands,
- Marquand Park,
- Mountain View Park Hillsborough,
- Delaware and Raritan Park,
- Grover Park
- … and hundreds of others

Princeton University Master Lighting Plan 2015

2.4.3 OUTDOOR PARKING

The primary purpose of parking lot lighting is to benefit the pedestrian. Key to safely illuminating a parking lot is enabling both driver and pedestrian to detect objects at both the bright and dark areas within the field of view.

Lighting Guidelines

A. Pole mounted luminaire selection will be limited to (2) types of lighting based on the parking space layout conditions.

   1. Use Type 1: University Campus Standard light pole for:
      a. single bank of parking spaces. Locate light pole on curb(s) as required. (see Figure 2.4-3)
      b. two banks of parking spaces sharing a common line between car ends. Locate light pole on common line and curb(s) as required. (see Figure 2.4-4)
   2. Use Type 2: Pole Mounted LED Luminaire for:
      a. Banks of parking spaces sharing a common driveway. Locate pole light on common line and curb(s) as required. (see Figure 2.4-5)

B. Avoid or minimize nuisance glare by providing low-glare or cutoff-type luminaires.

C. Tree growth or seasonal resurgence of tree foliage should be considered when locating parking pole lights adjacent to trees to avoid blockage of light. Tree foliage must be maintained periodically.

D. Parking lots adjacent to structures may be illuminated with structure mounted luminaires.

E. Maintain consistent pole spacing.

F. Avoid or minimize spill light into the night sky.

G. Consider dimmable luminaires wired to motion sensors to allow for multi-level lighting operation.

H. Visual clues about important destinations such as entrances and exits should be highlighted for wayfinding.

I. Stairs and abrupt changes in elevation to be illuminated to a specific illuminance level typically higher than straight and level paths.

J. Outdoor parking target illumination levels should follow recommended levels listed in Table 5: Recommended Typical Area Illuminance Levels.

K. Luminaire selection should conform with Section 3: Luminaire Guidelines.

Outdoor parking guidelines:
Avoid or minimize spill light into the night sky. NOTE: the Lake Campus Garage is in stark contrast with this principle.
Consider dimmable luminaires. NOTE: all new BEGA lights are missing such dimming, while they would all be capable of having such an option.

Princeton University Master Lighting Plan 2015

2.4.5 ARCHITECTURAL FEATURES (BUILDING FACADES, MONUMENTS)

The effective way of highlighting architectural features is to make them appear enchanting at night. Electric lighting, with its intensity, color, and controllable direction, can bring out elements that enhance the architectural characteristics of a structure.

Lighting Guidelines

A. Luminaires should have properly controlled light beams by means of shielding to minimize glare and stray light. Floodlights should be aimed to avoid direct light trespass into windows.

B. Account for surface texture and reflectance to avoid reflected glare.

C. Avoid unsightly light scalloping when attempting to wash flat surfaces.

D. Luminaires should be easily accessible for maintenance and aiming.

E. Avoid or minimize spill light into the night sky.

F. Select luminaire color finishes that will blend with the surrounding mounting locations so as not to call attention to their presence.

G. Carefully locate luminaires to prevent them from being pedestrian hazards or open to contact with vehicular movement.

H. Conceal luminaires to minimize direct view whenever possible.

I. Architectural feature target illumination levels should follow recommended levels listed in Table 5: Recommended Typical Area Illuminance Levels.

J. Luminaire selection should conform with Section 3: Luminaire Guidelines.

Architectural features. Similar principles:
- Avoid spill in the night sky
- Shielding to minimize glare and stray light

Princeton University Master Lighting Plan 2015

Table 5: Recommended Typical Area Illuminance Levels

Classification	Average Target Horizontal Illuminance (FC)	Minimum Target Vertical Illuminance (FC) (4.9 feet above grade)	Uniformity (avg to min)	
			(H)	(V)
Outdoor Parking	0.2 (Minimum)	0.1 (Minimum)	20:1 (max to min)	-
Building Entries (canopied, non-covered, immediate exterior)	1	0.6	-	-
Architectural Features (Buildings Facade, Monuments)	Vertical Average Target Illuminance (fc) Dark Surroundings and Medium Light Surfaces = 3 Dark Surroundings and Medium Dark Surfaces = 4 Dark Surroundings and Dark Surfaces = 5			
Plaza and Courtyards	0.2	0.2	4:1	-
Landscape Lighting	Luminance ratios between the focal points and surround should fall between 5:1 and 10:1		-	-

Recommended illumination levels adapted from IES 10th Edition Table 22.2 / 34.2, RP-20-98 Table 1, RP-33-99 Table 2 / Section 11.3

0.2 FC = 2 lux target illuminance

Stadium Drive Garage, top floor

Stadium drive parking garage top floor at midnight on a winter night.

Illumination levels are > 10x the 2015 master lighting plan values.

Princeton University Master Lighting Plan 2015

2015 target: 2 lux

Measured illuminance varies between 30 to 90 lux, i.e. 15 to 45x overlit.

No dimming, no motion sensors (as of early 2023).

Princeton University Master Lighting Plan 2015

3.1. OVERVIEW AND INTENT

To offer measures to avoid probable luminaire issues associated with installation, maintenance and performance. This section aims to provide a checklist for luminaire selection based on practicality, serviceability, industry practice and new technology.

Luminaire Guidelines

A. All lamps should have a Correlated Color Temperature of 3000 Kelvin.

B. All lamps to have low mercury content.

C. All new pole luminaires should be Dark Sky compliant.

D. All in-grade luminaires to follow manufacturer's recommended proper drainage and maintenance.

E. All LED packages in all luminaires to follow LM-80 standards.

F. All structure mounted luminaires mounted below 6'-8" shall be ADA compliant.

G. All mounting methods should be coordinated and approved by the university's facilities office.

H. All luminaires to follow manufacturer's recommended mounting method.

I. All luminaires to have a rating no lower than IP62.

J. All luminaires should be provided with weep holes or similar means of drainage to avoid any pooling of water.

K. All exiting non-LED source luminaires should be considered for LED source upgrade or complete replacement to an LED luminaire equivalent.

L. All luminaires should have the appropriate cut-off and shielding for glare control based on the application.

M. Adjustable fixtures to have sturdy locking mechanisms to prevent vibrations and unwanted shifting of aim.

N. All luminaires to have tamper-proof hardware.

O. All luminaires to be controlled by any of the following: photosensors / time clock motion sensors, bilevel dimming.

P. All underwater luminaire wiring to follow the local electrical code.

Q. Refer to Princeton University Outdoor Lighting Master Plan Issued for Final Presentation (2010) for additional.

Overview and intent of 2015 plan.

- Dark Sky compliance is one component of the guidelines
- Cut-off, shielding, glare
- Photosensors, time clock motion sensors, bilevel dimming.

Specific Examples at Princeton

Stadium garage under construction

Specific Examples at Princeton

Princeton parking garage and Stadium, 2023 March 28, 10:30pm

Question: why are the light levels not decreased? This should be a tunable parameter, just like it was for the parking lot in front of Peyton Hall.

Examples from Princeton University's Outdoor Lighting – archway lights in stadium

Examples from Princeton University's Outdoor Lighting – archway lights and glare. Direct uplight.

Examples from Princeton University's Outdoor Lighting – center of campus

Campus during the Winter. Note the Orion constellation. Princeton's unique night-time landscape: constellations and stars can be seen behind the foreground facades.

Examples from Princeton University's Outdoor Lighting – Peyton Hall in intensive glare

Examples from Princeton University's Outdoor Lighting – unshielded area light shining into the Peyton dome

Examples from Princeton University's Outdoor Lighting – glare from bollards

Examples from Princeton University's Outdoor Lighting – Peyton's roof
These are the area and archway lights that are permanently on.

Examples from Princeton University’s Outdoor Lighting – Peyton’s roof
Construction lights are unshielded with no consideration of light pollution.

Examples from Princeton University's Outdoor Lighting – Peyton's roof
The telescope dome "sunbathing" in daytime brightness. This has been on for a year.

Examples from Princeton University's Outdoor Lighting – Washington Road and Faculty Road
Light trespass into the wooded areas.

Examples from Princeton University’s Outdoor Lighting – Soccer Field
This is a good example, showing mostly shielded lights.

Review of Lake Campus Development (2020)

D The Lighting Plan of the Lake Campus

I have reviewed the following documents to understand the current lighting plan:

- 'AX01 Ligman Steamer USE-90002.pdf'
- 'AX11 84121_BEGA_Photometric.pdf'
- 'AX11 84121_BEGA_Spec.pdf'
- 'AX12 84148_BEGA_Photometric.pdf'
- 'AX12 84148_BEGA_Spec.pdf'
- 'Lake Campus Lighting Plan - 85 CD 20201217.pdf'
- 'Lake Campus Site Development 85\% CD Drawings - Appendix A fixture spec and alternates.pdf'
- 'Lake Campus Site Development 85\% CD Drawings - Site Lighting Drawings.pdf'
- 'Lake Campus Site Plan & Faculty Research Discussion_May_19_2020.pdf'
- 'LCSD Site Lighting_LT-100 OVERALL+isoline_210216.pdf'
- 'LCSD Site Lighting_Luminaire Schedule_A10_210105.pdf'

My general impression is that the design makes an effort to address light pollution, for example through the use of mostly darksky compatible fixtures (albeit with suboptimal versions). For this, I wish to compliment the architects.

Fig. 23: The lighting plan that I received and used to establish the level of light pollution, and to make specific recommendations

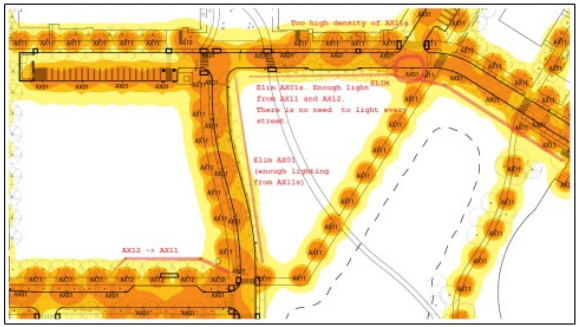


Fig. 28: Suggested changes to the current lighting plan. No need for the larger Bega fixtures, suggest to change all sidewalk luminaires to a single model (see text for suggestions). Other areas of overlighting are marked up.

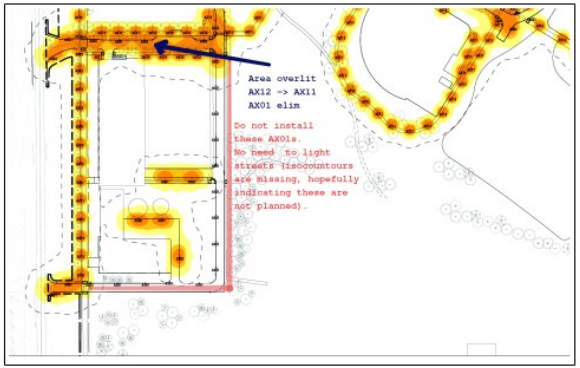


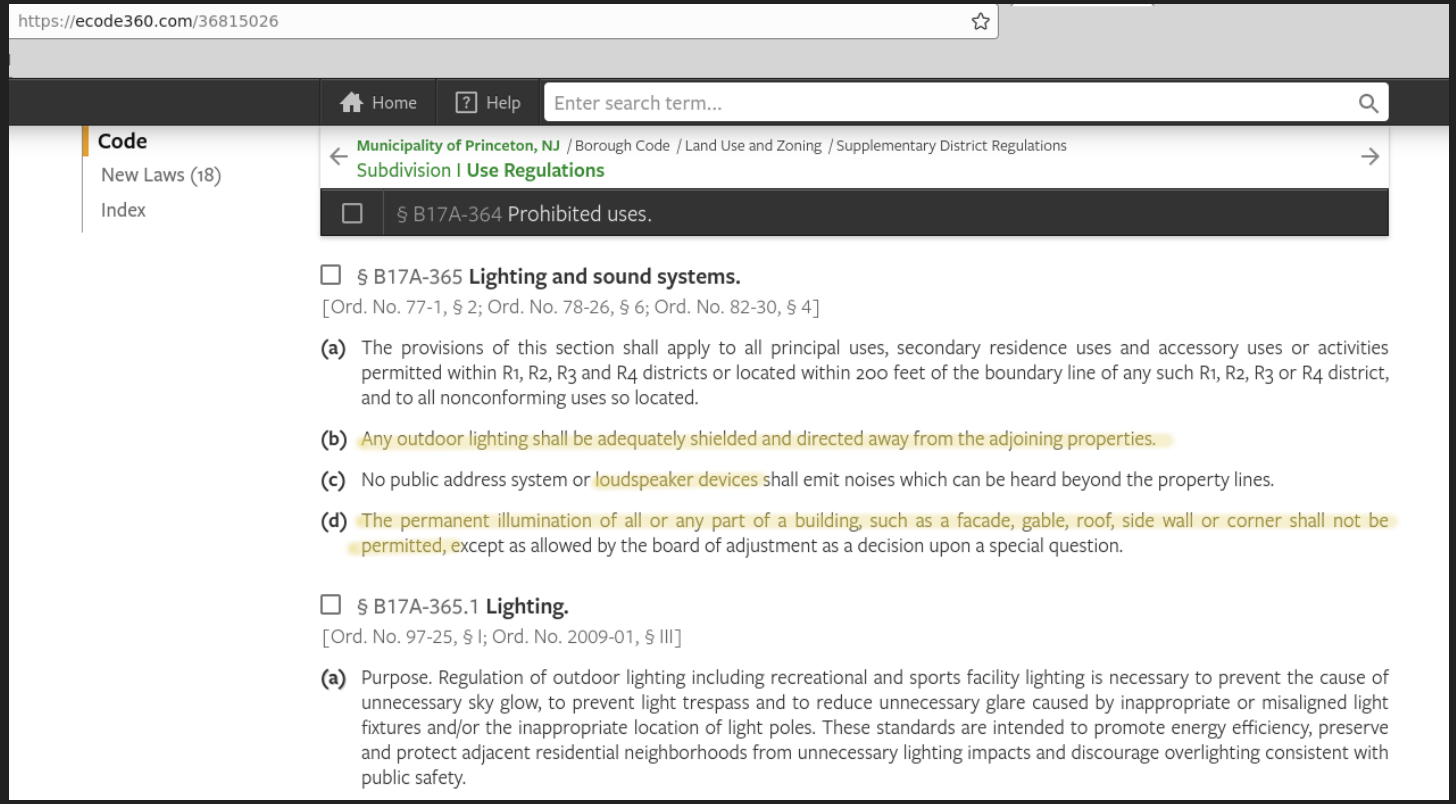
Fig. 29: Suggested changes to the current lighting plan. I assume all AX01 fixtures with no light contour would not be installed. The suggestion is to eliminate all AX01 fixtures except those 5 in the bottom right corner that may be around parking areas.

Real light levels are in excess of the levels shown in the plans. Action item: dimmers on all lights. Floodlit garage was not shown in plans.

Examples from Princeton University's Outdoor Lighting

Floodlighting the new garage is in stark contrast with the general sustainability principles of Princeton, and explicitly contradict the 2015 master plan. ACTION ITEM: turn these lights off. Also, dimming of top floor (terrace) to 40% of current, and 20% after 11pm (or turn off).

Light Pollution



https://ecode360.com/36815026

Home | Help | Enter search term...

Code
New Laws (18)
Index

Municipality of Princeton, NJ / Borough Code / Land Use and Zoning / Supplementary District Regulations
Subdivision I Use Regulations

§ B17A-364 Prohibited uses.

§ B17A-365 **Lighting and sound systems.**

[Ord. No. 77-1, § 2; Ord. No. 78-26, § 6; Ord. No. 82-30, § 4]

(a) The provisions of this section shall apply to all principal uses, secondary residence uses and accessory uses or activities permitted within R1, R2, R3 and R4 districts or located within 200 feet of the boundary line of any such R1, R2, R3 or R4 district, and to all nonconforming uses so located.

(b) Any outdoor lighting shall be adequately shielded and directed away from the adjoining properties.

(c) No public address system or loudspeaker devices shall emit noises which can be heard beyond the property lines.

(d) The permanent illumination of all or any part of a building, such as a facade, gable, roof, side wall or corner shall not be permitted, except as allowed by the board of adjustment as a decision upon a special question.

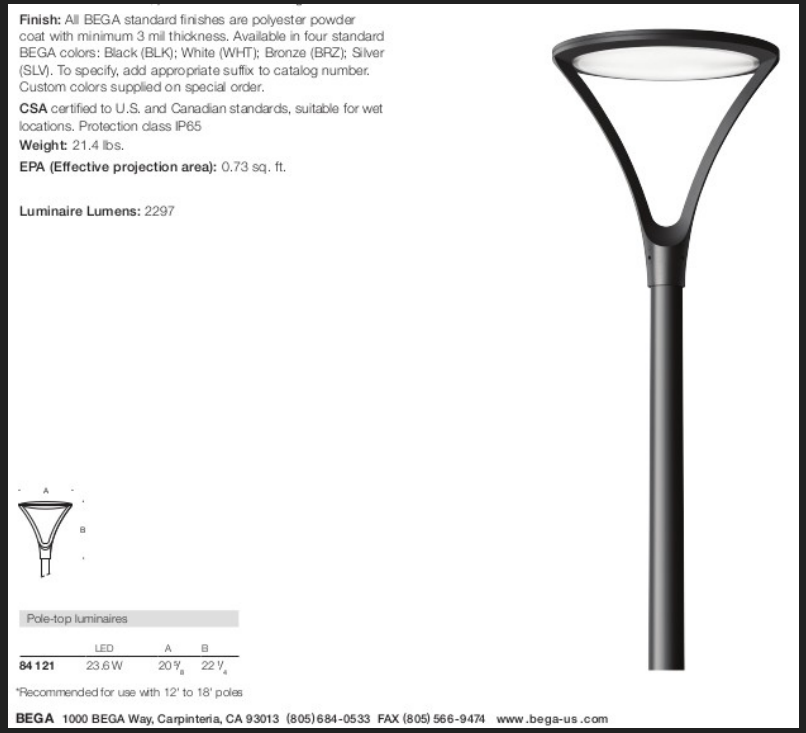
§ B17A-365.1 **Lighting.**

[Ord. No. 97-25, § I; Ord. No. 2009-01, § III]

(a) Purpose. Regulation of outdoor lighting including recreational and sports facility lighting is necessary to prevent the cause of unnecessary sky glow, to prevent light trespass and to reduce unnecessary glare caused by inappropriate or misaligned light fixtures and/or the inappropriate location of light poles. These standards are intended to promote energy efficiency, preserve and protect adjacent residential neighborhoods from unnecessary lighting impacts and discourage overlighting consistent with public safety.

Princeton Municipality Code for Lighting

Examples from Princeton University's Outdoor Lighting



Finish: All BEGA standard finishes are polyester powder coat with minimum 3 mil thickness. Available in four standard BEGA colors: Black (BLK); White (WHT); Bronze (BRZ); Silver (SLV). To specify, add appropriate suffix to catalog number. Custom colors supplied on special order.

CSA certified to U.S. and Canadian standards, suitable for wet locations. Protection class IP65

Weight: 21.4 lbs.

EPA (Effective projection area): 0.73 sq. ft.

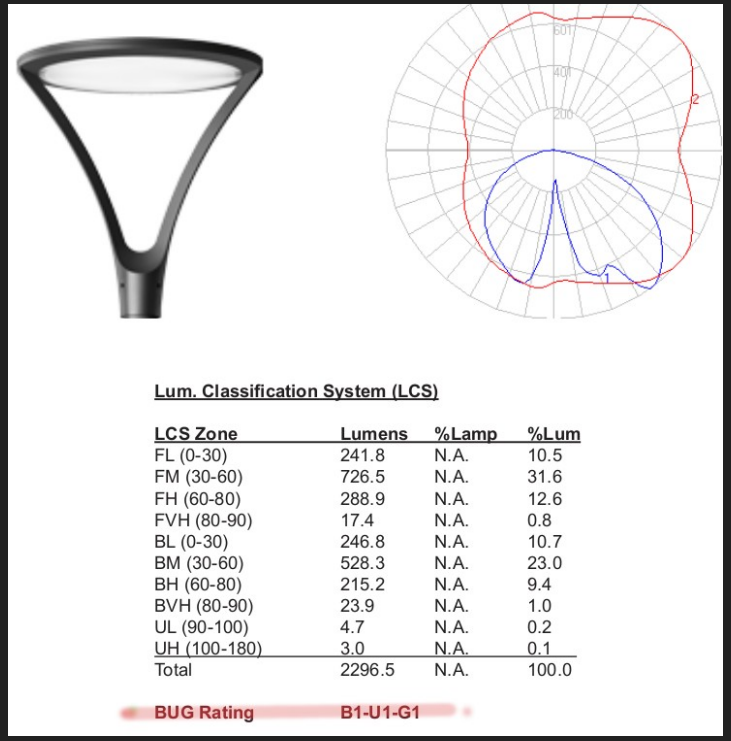
Luminaire Lumens: 2297

Pole-top luminaires

	LED	A	B
84121	23.6 W	20 9/16	22 1/4

*Recommended for use with 12' to 18' poles

BEGA 1000 BEGA Way, Carpinteria, CA 93013 (805) 684-0533 FAX (805) 566-9474 www.bega-us.com



Lum. Classification System (LCS)

LCS Zone	Lumens	%Lamp	%Lum
FL (0-30)	241.8	N.A.	10.5
FM (30-60)	726.5	N.A.	31.6
FH (60-80)	288.9	N.A.	12.6
FVH (80-90)	17.4	N.A.	0.8
BL (0-30)	246.8	N.A.	10.7
BM (30-60)	528.3	N.A.	23.0
BH (60-80)	215.2	N.A.	9.4
BVH (80-90)	23.9	N.A.	1.0
UL (90-100)	4.7	N.A.	0.2
UH (100-180)	3.0	N.A.	0.1
Total	2296.5	N.A.	100.0

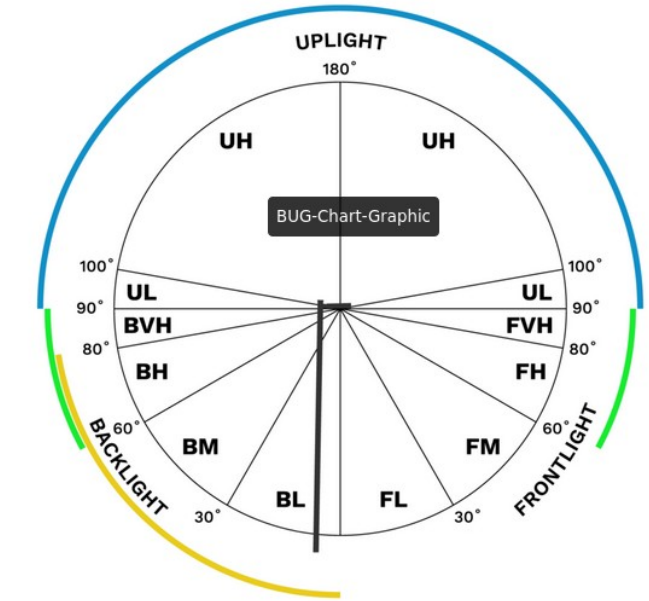
BUG Rating **B1-U1-G1**

"*Every pole is sensor-ready with a provision for a field-installable occupancy sensor.*" – lighting engineer from Synergy

BEGA 84121. University installation is missing the photosensors and dimming/wireless control altogether.
Cost of pole + fixture: approx $4000.
Cost of dimmer unit: $200 = 5%. ACTION ITEM: retrofit all

Examples from Princeton University's Outdoor Lighting

A BUG Rating gives a simple way to quantify where the light goes in a light. In most cases, **you want lower numbers as an indicator that light goes where it's supposed to versus unintended areas.** When you don't control the light well you get into situations where there may be consequences – such as in sensitive wildlife areas or residential neighbourhoods.



BUG rating

Examples from Princeton University's Outdoor Lighting

LED color temperature

☐ 4000K - Product number + **K4**
☐ 3500K - Product number + **K35**
☐ 3000K - Product number + **K3**
☐ 2700K - Product number + **K27**
☐ Amber - Product number + **AMB**

would be available in amber

Wildlife friendly amber LED - Optional
Luminaire is optionally available with a narrow bandwidth, amber LED source (585-600nm) approved by the FWC. This light output is suggested for use within close proximity to sea turtle nesting and hatching habitats. Electrical and control information may vary from standard luminaire.

LED module wattage	35.2 W (Amber)
System wattage	41.1 W (Amber)
Luminaire lumens	1,285 lumens (Amber)

BEGA can supply you with suitable LED replacement modules for up to 20 years after the purchase of LED luminaires - see website for details

Finish
All BEGA standard finishes are matte, textured polyester powder coat with minimum 3 mil thickness.

Available colors ☐ Black (BLK) ☐ White (WHT) ☐ RAL:
☐ Bronze (BRZ) ☐ Silver (SLV) ☐ CUS:

BEGA 99556

Light Pollution – Global Statistics

○ ALL COUNTRIES ◉ OECD ○ EEA +UK +CH ○ G20

Country	Population	Area (sq. km)	Avg. Sum	Trend	Rad./1k pop	Avg. Mean
Germany	83,019,200	360,625.87	1,888,756	+0.02 %	22.8	1.127
Switzerland	8,555,541	41,244.59	216,338	-2.14 %	25.3	1.128
Denmark *	5,811,413	48,270.28	159,165	+1.66 %	27.4	0.709
Austria	8,869,537	83,859.51	255,643	+0.73 %	28.8	0.656
United Kingdom *	66,435,600	258,026.39	1,974,604	-3.44 %	29.7	1.646
Ireland	4,857,000	74,321.77	200,745	-1.84 %	41.3	0.581
Turkey	82,003,882	787,146.28	3,878,446	+5.98 %	47.3	1.060
France	67,009,000	554,494.12	3,453,697	-3.18 %	51.5	1.340
Netherlands	17,332,500	38,586.10	919,682	-1.99 %	53.1	5.128
Belgium	11,473,875	30,790.18	673,733	-0.44 %	58.7	4.709
Sweden *	10,272,518	459,853.46	673,095	+1.27 %	65.5	0.496
Canada *	37,553,100	10,133,038.69	2,611,881	-0.99 %	69.6	0.226
Luxembourg	613,894	2,581.40	44,012	+0.83 %	71.7	3.669
Greece	10,741,165	144,280.45	774,802	+0.84 %	72.1	1.155
Italy	60,359,546	307,441.81	4,554,193	-0.07 %	75.5	3.187
Spain	46,934,632	511,569.46	3,591,390	-1.36 %	76.5	1.510
Norway *	5,334,762	351,481.18	452,967	+0.41 %	84.9	0.495
United States *	329,572,000	9,555,291.61	32,147,660	-0.32 %	97.5	0.899
Portugal	10,276,617	93,928.59	1,039,112	-1.76 %	101.1	2.380

Light emission per capita per country – OECD

USA emits about 5x more light per person as Germany, Switzerland, Denmark or Austria.

These are all highly developed countries with a high standard of living.

Light Pollution – Trends

Even the Eiffel tower can do it.

Light Pollution – Trends

Light Pollution – Trends

By ALEXANDER MACDOUGALL
Staff Writer

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NORTHAMPTON — In an attempt to both reduce light pollution and allow for greater safety at night, the city is looking to update its outdoor lighting policy, something it hopes to bring to a vote before the end of the year and the subsequent formation of a new City Council.

Members of the council's Committee on Legislative Matters and the Planning Board held a joint meeting on Nov. 13 to discuss a proposed ordinance that would establish new standards for outdoor lighting in the city. The standards would ensure that any new lighting installed covers the lightbulb entirely, ban incandescent lights, and limit the total amount of lumens, or measure of visible light, by street lighting to be "the lowest levels of lumens necessary," according to the current text of the ordinance.

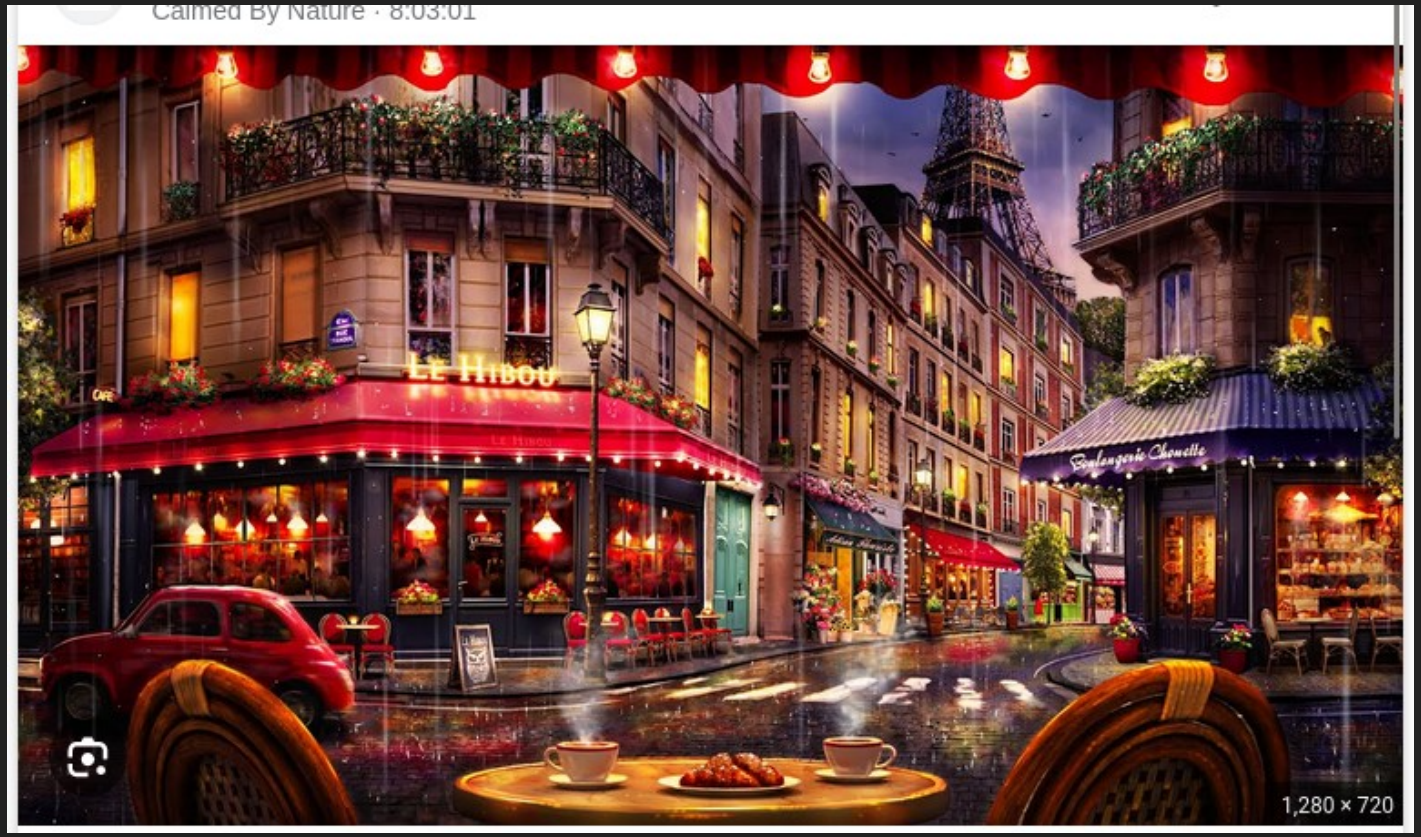
Light Pollution – Trends

A new low for bright lights

The 2200K luminaire the town chose is Cooper Lighting Solutions' Archeon Nano, which represents some of the latest LED technology to hit the streetlighting market. The smallest and most cost friendly of the Archeon series boasts an efficacy of 164 lm/W, output packages ranging from 2,000 to 7,800 lumens, and a cobra head style.

Ultimately, Pepperell town management set the fixtures to run at 50% capacity during evening hours and at 30% capacity between midnight and dawn. The lower light level saves more energy and money, reduces light emissions, and also gives the luminaires room to grow. All types of lighting decrease in output over time, Barentine said. Operating the luminaires at lower capacity will allow the town to increase brightness to make up for aging lights later on.

Light Pollution – Trends

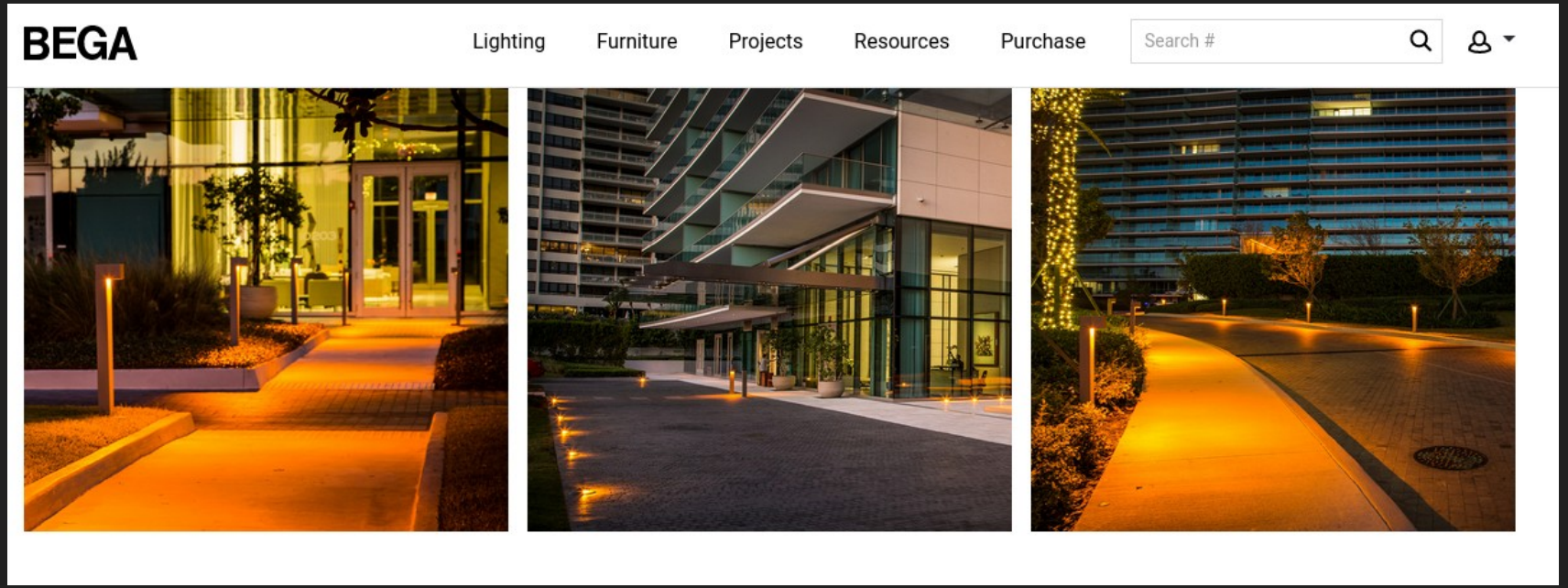


Dim and orange lights: good vibe
This is how we feel about Princeton.

Light Pollution – Trends

Harsh and blue lights: “industrial park” atmosphere
This is what we don’t want in Princeton

Examples from Princeton University's Outdoor Lighting



Princeton's lighting could be with fully shielded, dimmed, motion-sensored, AMBER LEDs

See renderings and photos of such installations from BEGA.

General Recommendations for “Starry Princeton”

- Use **fully shielded fixtures**. Fully shielded means 100% of light goes 10deg below horizon. BUG rating of 0-0-0.
- Use warm color temperature lights, amber LEDs, **2200K or even less around dark sky areas**.
  Note: high pressure sodium is approx ~2200K.
  Also note, all these LED spectra are non-planck curves; color temperature association is very loose.
- Do not overlight. (Note: many standards are obsolete (IESNA recommendations)
- Use modern technology: dimming and motion sensors.

- Establish task force or committee on light pollution in Princeton.
- Replace and phase out light polluting fixtures at high priority.
- Stick to the plan, e.g. the 2015 master lighting plan or its upcoming 2025 version.
- Review all new constructions, apply strong standards on accepted lighting before installation
- Educate campus population on light pollution and proper practices.
- Establish dark sky “starview” areas with zero stray light.
- Monitor direct light pollution (glare, uplight) and sky background.

Recommendations for “Starry Princeton”

Princeton should adopt the 5 principles of responsible lighting

Short-term action items

- Dim all new BEGA 84* and 99* fixtures to 40% of current light level, and 20% of current level from 23:00 to 06:00.
- Retrofit all new BEGA 84* and 99* fixtures with dimming, motion-sensing.
- Fund the design of retrofitting the BEGA 84121 with a rim to provide full shielding and make it BUG-0-0-0.
- Turn off the lights of the new lake campus garage top floor.
- Eliminate the archway lights of the stadium.
- Turn off lights in the top floor of the stadium (Schrödinger’s offices).
- Eliminate area lights with no shielding.

Medium-term

- Commit ourselves to IDA’s five lighting principles
- Create task force or committee on light pollution with representatives from the faculty of Astro, Bio*, and students.
- Fund research on light pollution, including development, aerial monitoring.

Long-term

- Establish dark sky park on campus. E.g. Broadmead or the Butler (former) graduate housing area.
- Establish a small observatory on campus
- Lead the way in becoming the first fully dark sky compliant campus.
- Influence Princeton Township and near-by communities.

References

- International Dark Sky Association: https://www.darksky.org/
- Contact me if you have a “bright” idea: gbakos@astro.princeton.edu
- Links: https://www.astro.princeton.edu/~gbakos/lp/
- Video on youtube (please glance at it and share): https://www.youtube.com/watch?v=FW0WZX75Nmo (Dark Sacred Night).
- Student feedback: https://www.astro.princeton.edu/~gbakos/AST205/testimonials.html