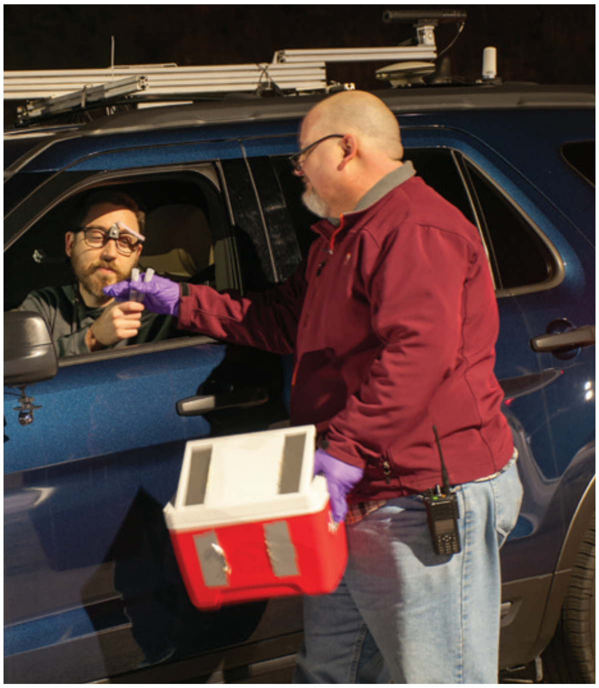
Rewriting the Rulebooks for Outdoor Lighting



To qualify health impacts, the Virginia Tech Transportation Institute collaborated with Thomas Jefferson University to document levels of melatonin in drivers, pedestrians, and sleepers. Researchers evaluated five different light sources, each with differing amounts of blue light content. Photo: Rajaram Bhagavathula, VTTI

Municipalities are taking action to replace high-pressure sodium outdoor and roadway lighting with light-emitting diode (LED) technology. They are motivated by compelling benefits, including reduced maintenance costs, energy savings, and mercury elimination. Despite this, many foundational questions remain unanswered, issues that stand in the way of cities' taking full advantage of LED lighting, particularly "smart" systems using connected and automated controls.

Morgan Pattison, PhD, Senior Technical Advisor, U.S. Department of Energy Lighting R&D Program

Advanced LED lighting systems that enable precise engineering of spectral power distribution (SPD), optical distribution, and dimming control are promising for their potential to enhance roadway safety and minimize light pollution while still achieving high efficacy and long life. For example, Chicago anticipates safety improvements and energy savings as outcomes of its ambitious smart lighting initiative. Chicago is in the process of installing 270,000 LED roadway lights, which should save the city $10 million in electricity costs annually.

Achieving the full benefits of LED roadway lighting will depend on an emerging scientific foundation. The challenge is to better understand how roadway lighting systems affect safety and how they affect human beings: drivers, pedestrians, and neighboring building occupants. LED technology allows users to control lighting levels, spectral power distribution, and optical distribution in ways that were not possible with previous technologies, so we need to establish what to do with these capabilities. Within the context of roadway lighting, scientists are exploring foundational questions about human vision, behavior, and physiology to determine:

- How much light is needed for optimal roadway illuminance and uniformity levels? What levels minimize traffic accidents and improve pedestrian and cyclist safety?
- How can improved optical control be used to eliminate or minimize glare for drivers?
- How can optical control be applied to minimize skyglow and light pollution associated with outdoor lighting? How are humans and animals affected by these reductions?
- What is the relationship between outdoor lighting and crash/crime statistics in residential areas?
- How should LED roadway lighting be dimmed when it is not necessary—and *when* is it necessary?

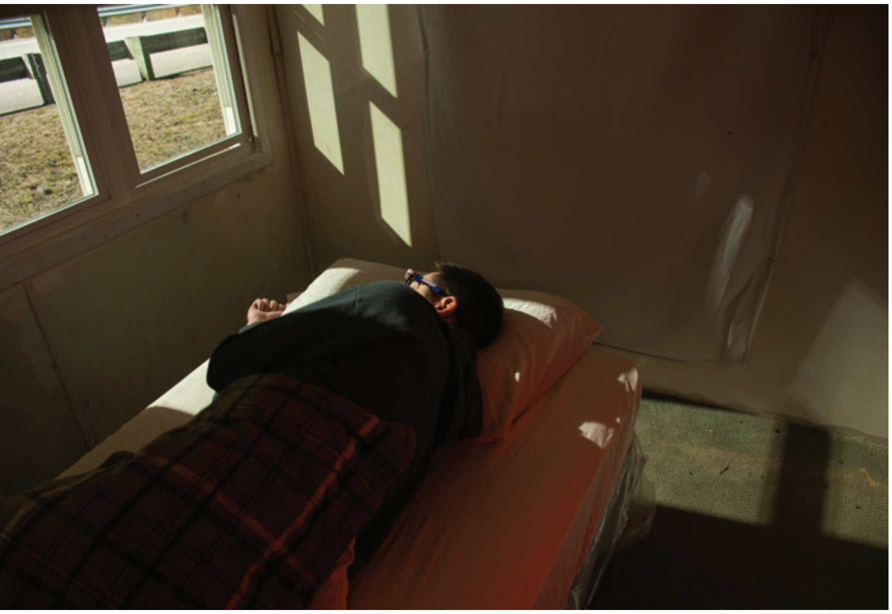


Photo: Rajaram Bhagavathula, VTTI

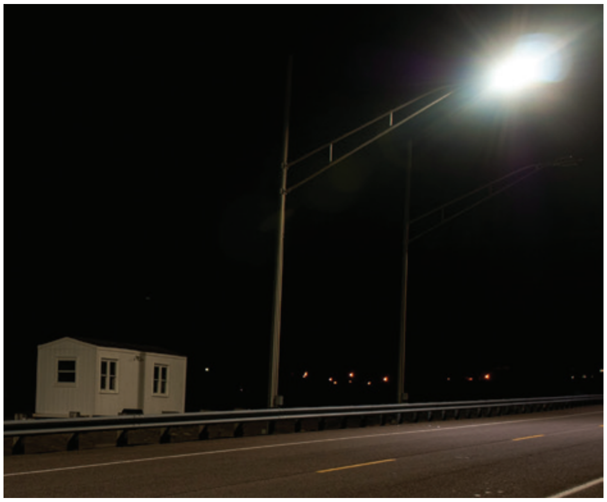


Photo: Rajaram Bhagavathula, VTTI

The U.S. Department of Energy (DOE) supports work to answer such questions and inform guidelines and specifications for deploying advanced LED roadway lighting. Two DOE-sponsored research studies by the Virginia Tech Transportation Institute (VTTI), for example, will increase understanding of the physiological and safety impacts of LED roadway lighting.

Quantifying Health Impacts in a Real-World Setting

In the first study, VTTI, in partnership with Thomas Jefferson University, has measured the impact of different types of roadway lighting on levels of melatonin in drivers, pedestrians, and sleepers with bedrooms facing the roadway. Using a realistic roadway environment that included a roadside cabin, researchers evaluated five different light sources, each with differing amounts of blue light content. Blood and saliva samples from 29 subjects were analyzed to see how the lighting affected their melatonin secretion; subjects wore a miniature dosimeter to estimate the lighting dosage. Statistical modeling was used to link the melatonin response to the lighting configuration. In addition, the subjects were evaluated on tasks specific to their category: object detection for drivers and gap acceptance of oncoming traffic for pedestrians.

The findings, which are awaiting publication in several peer-reviewed journals, can help answer such questions as which spectra of light are safest for roadway applications and how the various spectra can impact health. One preliminary finding is that LED roadway lights with a correlated color temperature

(CCT)[1] of 4,000 degrees Kelvin (K) provided increased visibility and increased stopping distances compared to warmer CCT LEDs. This finding might indicate that, for higher-speed roadways, a 4,000 K CCT SPD is beneficial, while a 3,000 K CCT might be suitable for more local, lower-speed roadways.

Evaluating Adaptive Roadway Lighting

The second VTTI study, which is ongoing, is analyzing the impacts of adaptive roadway lighting, in which instant-on and dimming capabilities are used to control lighting levels based on changing conditions. While dimming roadway lights can dramatically reduce light pollution and energy consumption, it must be accomplished without compromising roadway or pedestrian safety.

In this study, VTTI is examining adaptive roadway lighting in the city of Cambridge, Massachusetts, measuring light levels across the city and evaluating crash data and crime statistics to see if there is a relationship between the dimming of the lights and safety. VTTI also will be calculating energy savings with the dimming and the total reduction of light in the environment. As part of the project, VTTI will compare results with other cities that are deploying adaptive lighting—San Jose, California, and Tucson, Arizona—as well as with the neighboring city of Somerville, Massachusetts, which installed LED roadway lighting that did not include the dimming feature.

Based on the case study results, the impacts of adaptive lighting on established measures of roadway lighting will be better understood and objectively clarified, and these findings will be translated into guidelines and specifications for the application of adaptive lighting in streets and residential areas.

Efficient Light, Better Light

Much of the public is conditioned to think that energy savings come with significant tradeoffs. Yet good-quality LED lighting, intelligently applied, upends this belief. It proves that more energy-efficient light can be *better* light. By developing a robust lighting science foundation, and translating that foundation into practical guidance, we will rewrite what is possible in outdoor lighting (and all lighting applications). Future systems will dramatically reduce the light pollution footprint of society and deliver significant cost savings. They also will enhance public safety by ensuring that the right lighting is applied, when and where it is needed.

A second VTTI study is examining adaptive roadway lighting installed in Cambridge, MA. Photo: Paul Lutkevich, WSP.

Ultimately, urban planners and lighting engineers will need an entirely new set of guidelines and best practices that leverage the full potential of LED technology in lighting public spaces. The VTTI studies are important steps in translating the new capabilities of LED lighting technology into what is best for the application, informing decision-making related to lighting and control systems.

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1 CCT is not the best metric for relating the color of roadway light to the impact, but it is the current standard.