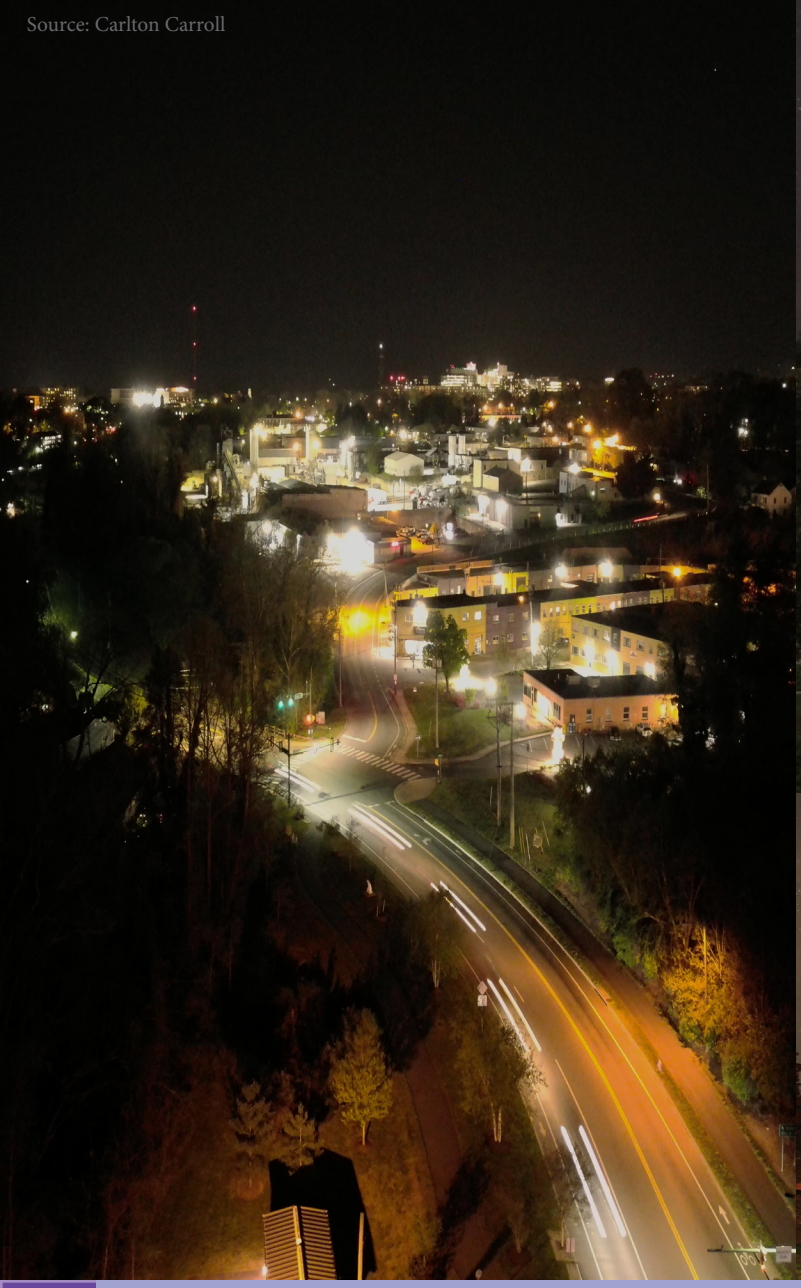
Source: Carlton Carroll


Source: Brennan Gilmore


Source: Andrew Shurtleff

Light Pollution in Charlottesville: Research, Partnerships, and Pathways Forward

PLAN 7993 Independent Study
May 2025

This report summarizes the work completed through an independent study on light pollution in Charlottesville, Virginia. Over the course of two semesters, the project involved measuring local light pollution levels, researching LED streetlight conversions, and engaging with stakeholders to support dark sky advocacy efforts. The findings highlight opportunities for improved lighting practices and outline steps for continued community and policy engagement.

By Pierce Harding, University of Virginia, Department of Urban + Environmental Planning

Acknowledgements

This project would not have been possible without the guidance and support of Dr. Tim Beatley and Dr. Barbara Wilson, who each supervised a semester of this year-long independent study. I am grateful to the Urban and Environmental Planning Department at the University of Virginia for providing funding for the sky quality meter used in this research. I would also like to thank the City of Charlottesville, the Virginia Responsible Streetlighting Coalition, and Dark Skies Piedmont for their time, collaboration, and ongoing advocacy. Special thanks go to Carlton Carroll for his assistance with drone photography and to Brennan Gilmore for his help capturing street-level lighting conditions.

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Introduction

Light pollution is an increasingly recognized environmental concern that affects not only our ability to view the night sky, but also public health, wildlife, and energy efficiency. Its consequences are far-reaching, contributing to sleep disruption, disorientation in migratory birds, disruption of insect populations, and even increased risks of glare-related accidents on roadways (DarkSky n.d). As cities across the country upgrade to LED streetlighting for cost and energy savings, there is an urgent need to ensure those upgrades align with principles of responsible lighting. While this report does not focus specifically on the full range of light pollution's impacts, a summary of the literature and resources for further information are included in Appendix A. For additional technical and scientific background, DarkSky International and the Illuminating Engineering Society remain the most comprehensive sources.

This independent study was undertaken to better understand Charlottesville's lighting landscape, support local advocacy efforts, and provide a foundation for long-term light pollution mitigation. Over the course of two semesters, the work involved researching the city's new LED streetlight conversion project, collecting baseline data on night sky brightness, participating in educational outreach, and contributing to regional advocacy through the Virginia Responsible Streetlighting Coalition (VRSC). The goal has been to assess current conditions and inform future conversations about responsible lighting, particularly as the city considers deeper environmental commitments like joining the Biophilic Cities Network and Dark Sky Community certification.

Charlottesville has a long-standing commitment to environmental stewardship, reflected in its climate action planning, green infrastructure investments, and growing interest in biophilic design. It is also home to a vibrant astronomy community, anchored by the historic McCormick Observatory at the University of Virginia. Opened in 1885, McCormick remains a valued educational and outreach institution, regularly hosting public nights that introduce residents to the wonder of the night sky (University of Virginia Department of Astronomy n.d.). These local traditions position the city well to take a leadership role in responsible lighting practices that both reduce pollution and reconnect people with the stars.

A key motivation behind this project was to bridge academic learning with real-world civic engagement. By participating in stakeholder meetings, working with local advocates, and giving public presentations, this study helped me strengthen connections between citizen science and policy. The project also aimed to make the process replicable and accessible to others, particularly through its work with Sky Quality Meter (SQM) data collection.

Charlottesville's LED Streetlights Upgrade

Charlottesville's LED Streetlight Upgrade Project is a major initiative aimed at reducing greenhouse gas emissions and improving lighting quality across the city. Streetlights account for approximately 7% of the city's municipal emissions, and most currently use outdated high-intensity discharge (HID) technology. By converting to energy-efficient LED fixtures, the city expects to significantly cut energy use while aligning with its Climate Action Plan goals of a 45% emissions reduction by 2030 and carbon neutrality by 2050. The project began late summer 2024 and will roll out in two phases over three years. Phase 1 will focus on major roadways, while Phase 2 will address remaining areas through a grid-based approach. The city has prioritized installing fixtures with a 3000K color temperature, the warmest option offered by Dominion Energy and zero uplight designs to minimize ecological disruption and light trespass (City of Charlottesville n.d.).

However, the project faces structural limitations due to the fact that approximately 95% of Charlottesville's 3,700 streetlights are leased from Dominion Energy. This arrangement requires the city to select from Dominion's limited LED inventory and work within their operational framework. Despite these constraints, Charlottesville is taking proactive steps to ensure the best possible outcomes. (City of Charlottesville n.d.).

These challenges are not unique to Charlottesville; many Virginia localities undergoing LED conversions with Dominion Energy encounter similar issues:

- **Limited fixture specifications:** Dominion does not provide comprehensive spec sheets, hindering the ability to design optimized lighting solutions.
- **Lack of adaptive controls:** Options for dimming or smart lighting technologies are not offered, limiting flexibility and efficiency.
- **Staffing constraints**: Dominion has a limited amount of staff with lighting design backgrounds.

While some jurisdictions, like Fairfax County, have negotiated expanded fixture options and reduced conversion costs, many others lack the administrative capacity or awareness to advocate for such improvements (Fairfax County 2018).


Market & 9th St Intersection


Gas Station Lights Trespassing onto Route 250


Common Halogen Fixture

Community Engagement & Advocacy

Stakeholder Interviews and Outreach

The first step of this study was to identify local stakeholders who are involved in dark sky advocacy or have the proper influence to make change at a systemic level. Below are summaries of the important connections made throughout the past two semesters. This section can also serve as a reference for who to remain in contact with for future advocacy efforts.

The City of Charlottesville
With the primary goal of my study being to research light pollution issues in Charlottesville, I set up an initial meeting with Kristel Riddervold, Director of the Office of Sustainability, and Kirk Vizzier, Energy Management Coordinator, to learn more about the city's efforts. They were receptive to my concerns about light pollution in Charlottesville and have since graciously been available to answer questions, provide feedback, and collaborate with other dark sky advocates in the city.

Throughout the study, I have maintained consistent email communication and participated in collaborative meetings with these individuals and local experts to discuss how the city can choose better lighting fixtures for its LED conversion project.

Dark Skies Piedmont Chapter (DSP)
The Piedmont Dark Skies group is a local advocacy organization in Virginia's Piedmont region dedicated to preserving the natural night sky by combating light pollution. Through community outreach and education, they promote responsible outdoor lighting practices to protect nocturnal environments.

Members of Piedmont Dark Skies engage in various initiatives, including hosting public talks on the ecological impacts of artificial lighting, such as its effects on native plants and pollinators. They also collaborate with local governments to support policies that minimize light pollution. For instance, in April 2025, Albemarle County recognized Dark Sky Week, highlighting the importance of preserving dark skies for both environmental and cultural reasons.

Throughout my study, I have worked closely with Christine Putnam, a member of the chapter, to give educational talks and organize advocacy efforts in the Charlottesville area.

Charlottesville Astronomical Society (CAS)
The Charlottesville Astronomical Society (CAS) is a nonprofit organization dedicated to promoting the enjoyment and understanding of astronomy for individuals of all ages and experience levels. Founded to foster public interest in celestial observation, CAS offers a variety of programs and events to engage both amateur astronomers and the general public.

In fall 2024, I spoke to Kevin Fitzpatrick, the current president of CAS. Through this conversation, I learned about their chapter's role in educating the public, encouraging the designation of Powhatan State Park as an Urban Night Sky Place, and how their chapter can support light pollution advocacy efforts moving forward.

Educational Presentations

Dark Skies Piedmont Chapter Meeting 2/12/25

This February, I was invited to give a short presentation during DSP's monthly meeting to help educate existing and new members. The presentation focused on the goals of my study, methodology, and summarized the current LED con project in Charlottesville. Overall, the presentation was well-received, and I was asked a few questions during and after. During the presentation, most questions were from new members seeking clarification on how ownership of public lights works and how the SQM readers function.

When explaining my data collection map (Figure 1), I received constructive feedback from long-time Charlottesville residents on what locations to add. In the end, I offered to take people out on my data collection days and explain the collection process in more detail. A few individuals showed interest in learning how to use SQM readers.

Charlottesville Astronomical Society Member Meeting 4/2/25

In March 2025, I partnered with members of the Dark Sky Piedmont Chapter to deliver an educational presentation during the Charlottesville Astronomical Society's monthly member meeting. The presentation aimed to raise awareness about the growing issue of light pollution in Virginia, with a focus on its ecological, health, and visibility impacts. Together, we provided an overview of the consequences of light pollution and discussed how LED streetlight conversion projects, while energy efficient, can worsen light pollution if not carefully designed.

We highlighted Charlottesville's ongoing LED retrofit project, noting both encouraging progress and areas that still need attention. I also presented findings from my independent study, which included sky quality measurements, insights from stakeholder conversations, and the advocacy work I have helped coordinate. The presentation concluded with practical ways community members can get involved through education, policy efforts, and local dark sky initiatives.

Zoom view of CAS Presentation

Collaboration with the Virginia Responsible Streetlighting Coalition (VRSC)

Upon starting this project and learning about Dominion Energy's role in Charlottesville's LED Streetlight Conversion Project, I discovered that similar conversions are taking place simultaneously across the state. As mentioned earlier in this report, many localities are not fully aware of the important issues related to light pollution or the limitations of Dominion's lighting inventory and technical assistance.

In response, a group of advocates from across Virginia came together in Fall 2024 to form the Virginia Responsible Streetlighting Coalition (VRSC), led by Laura Greenleaf, president of the DarkSky Virginia chapter. The group's primary goal is to coordinate statewide efforts to educate municipalities about the importance of reducing light pollution and to convince Dominion Energy to adopt better practices. Christine Putnam, Mark Schuyler (a local lighting designer and long-time advocate), and I have served as Charlottesville's representatives within the coalition.

Initiatives:

- In January 2025, we collaboratively crafted and forwarded a policy memo to Dominion. **The full memo can be found in Appendix A.**

- We have since participated in several calls with Dominion Energy's statewide outdoor lighting team. The purpose of these conversations has been to address their insufficient lighting inventory, the absence of comprehensive spec sheets, and to advocate for more transparency between them and their clients (localities).

- One of the key initiatives undertaken by the Virginia Responsible Streetlighting Coalition (VRSC) has been engaging directly with the Virginia Energy Purchasing Governmental Association (VEPGA), the regulatory body responsible for negotiating contracts and pricing with Dominion Energy. Recognizing that VEPGA's contract with Dominion is currently up for renewal, VRSC submitted a formal letter urging the board to require Dominion to offer streetlighting options that align with the lighting principles of the Illuminating Engineering Society and DarkSky International. The letter emphasized the urgency of the moment, noting that current LED conversions are happening statewide without adequate transparency or informed choice for localities. If not addressed, these conversions could lock communities into decades of increased light pollution, unnecessary costs, and public health impacts. VRSC's advocacy highlights the need for VEPGA to play a stronger, more visible role in guiding responsible lighting policy in Virginia.

The efforts of this coalition are ongoing, and membership continues to grow as awareness of the harmful impacts of light pollution spreads. With increased support from both technical experts and engaged citizen advocates, the coalition aims to drive meaningful change through continued dialogue with Dominion Energy and the local government leaders responsible for implementing safe, responsible lighting in their communities.

Light Pollution Data Collection

Sky Quality Meter Methodology

As part of this independent study, I collected light pollution data across Charlottesville using a Sky Quality Meter (SQM) to establish baseline conditions before the city's LED streetlight conversion project is completed. The goals of this data collection were threefold: to assess the current state of night sky brightness, to create a record that can be referenced in future assessments, and to help evaluate whether new lighting installations contribute to improved conditions. Additionally, this work serves as a model for community engagement. By documenting and sharing my process, I hope to educate and empower other citizen scientists to conduct their own measurements and contribute to a growing body of local data.

The SQM-L model (Sky Quality Meter – Lens) is a handheld device used to measure the brightness of the night sky in magnitudes per square arcsecond. This unit is inversely related to sky brightness, the higher the number, the darker the sky. The device uses a narrow field of view to minimize interference from nearby artificial light sources, making it suitable for targeted observations within urban or suburban settings. Measurements are typically taken while pointing the device straight up (at the zenith) and under consistent conditions to ensure accuracy. This method offers a simple yet effective way to quantify light pollution levels and track changes over time.

The Process:

- Only collect readings during the new moon phases to avoid interefence from moonlight.
- Only take readings under conditions of astronomical darkness
- Never take a measurement under directly underneath a light source or anything that might block the sky (trees, building facades, etc).
- Operating the device is remarkably straightforward:
    1. Turn on the device, hold over your head and press center button to take an initial reading. This calibrates the meter. Do not count this as an official reading.
    2. Once calibrated, take five total readings and record each one in a notebook.
    3. Take notes of variables such as cloud cover, temperature, and time. Too much cloud cover can distort light, invalidating your measurements.
    4. Refer to Dark Sky International's article on night quality surveys (DarkSky n.d.)

SQM-L Meter

Hikers taking SQM measurements (DarkSky International)

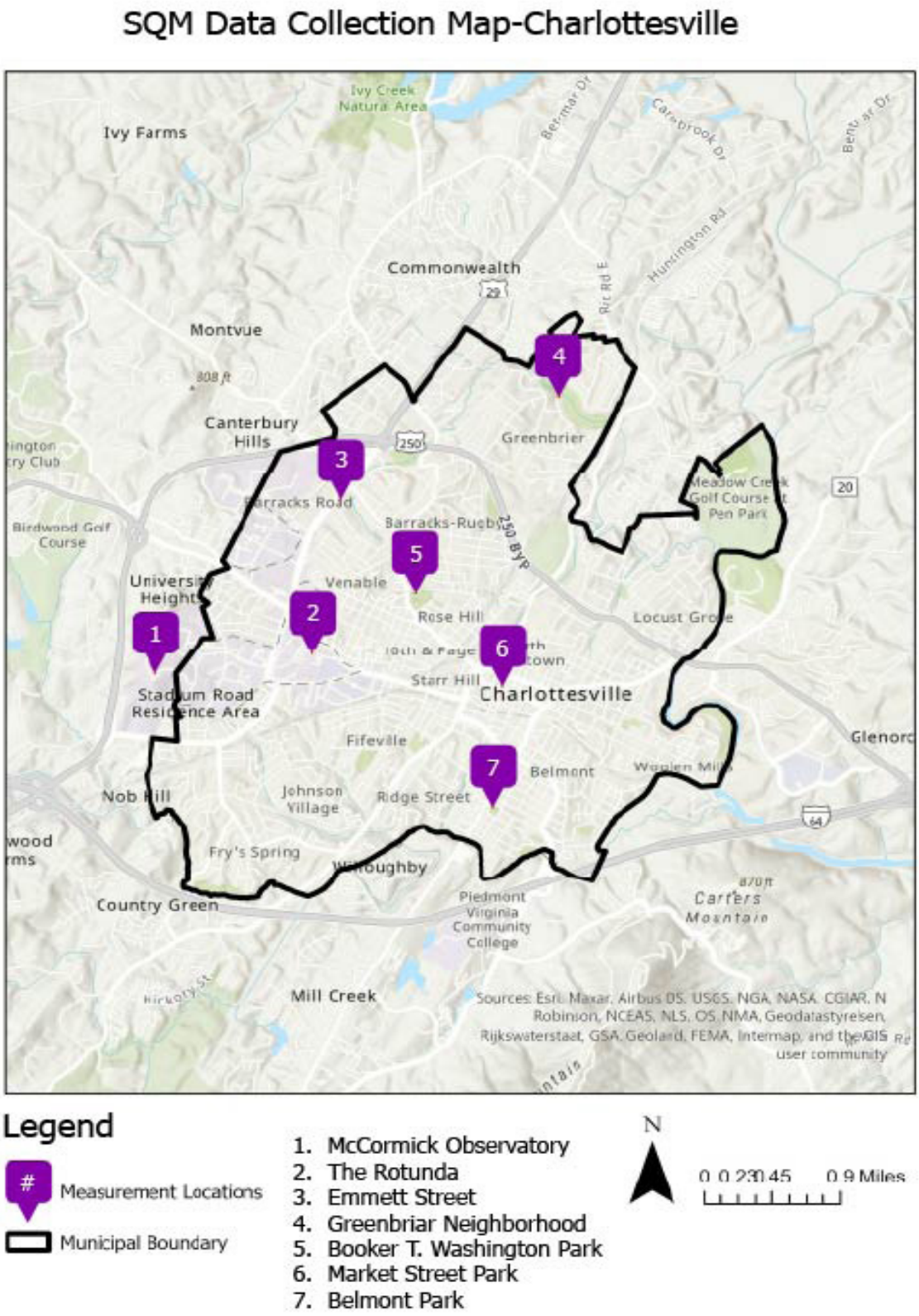

SQM Data Collection Map-Charlottesville
Ivy Farms
Ivy Creek Natural Area
Commonwealth
Montvue
Canterbury Hills
Greenbrier
Barracks Road
Barracks-Rugby
Birdwood Golf Course
University Heights
Venable
Rose Hill
Locust Grove
Starr Hill
Charlottesville
Stadium Road Residence Area
Fifeville
Belmont
Nob Hill
Johnson Village
Ridge Street
Fry's Spring
Willoughby
Country Green
Piedmont Virginia Community College
Carters Mountain
Mill Creek
Meadow Creek Golf Course
Pen Park
Sources: Esri, Maxar, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap, and the GIS user community
Legend
Measurement Locations
Municipal Boundary
1. McCormick Observatory
2. The Rotunda
3. Emmett Street
4. Greenbriar Neighborhood
5. Booker T. Washington Park
6. Market Street Park
7. Belmont Park
N
0 0.23 0.45 0.9 Miles

Figure 1.

Overview:

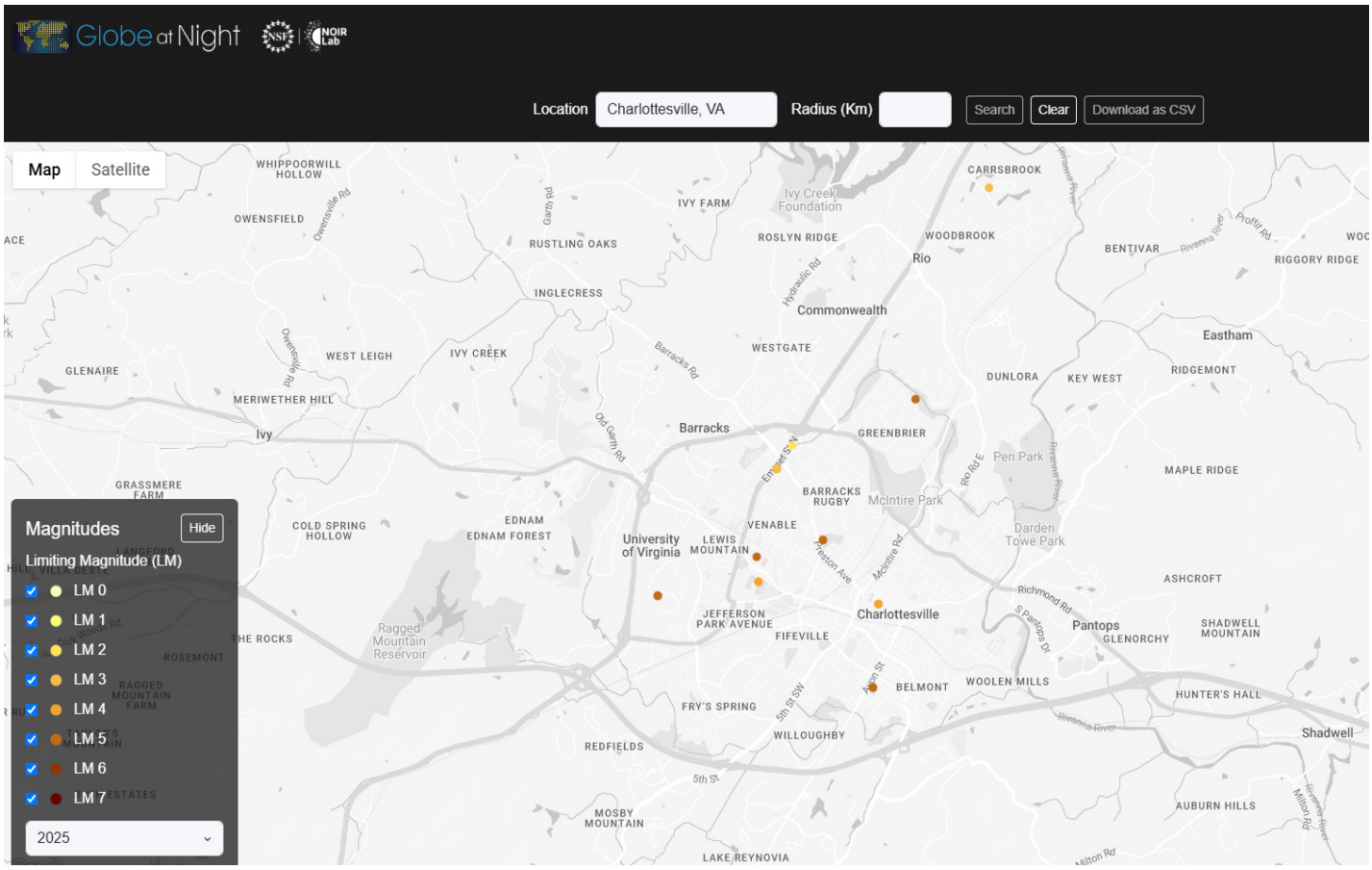
- Seven different locations with varying characteristics were selected to achieve comprehensive surveys
- Data was collected during four different new moon phases, but only two were counted since the others had higher than average cloud coverage, skewing results
- As shown below, the Observatory had the darkest average readings, closely followed by the Greenbriar Neighborhood
- **Reminder**: Higher values correspond to darker skies. As seen in the SQM image on pg. 6, the lower end of the scale is 16 (dense urban areas) and caps out at around 21 (wilderness areas/ preserves)
- Market Street Park had the brightest average, being in close proximity to the Downtown Mall
- Full data recording tables can be found in **Appendix B** for further context and use as a template

Location	SQM Average
McCormick Observatory	19.3
The Rotunda	18.45
Emmett Street-Caruthers Hall	18.4
Greenbriar Neighborhood	19.27
Booker T. Washington Park	18.97
Market Street Park	18.13
Belmont Park	19.12

Figure 2.

Globe at Night

After each round of data collection, measurements were uploaded to an open source tool called Globe at Night. **Globe at Night** is an international citizen science project that raises awareness about light pollution by inviting individuals to measure and submit night sky brightness observations. Participants use simple tools like SQM meters or even their eyes to compare visible stars with constellation charts, then upload their data to a global database. It's a valuable tool because it allows citizen scientists to contribute to a growing, publicly accessible dataset that helps researchers track light pollution trends over time and across the world. Submitting SQM data to Globe at Night not only supports scientific research but also strengthens community advocacy by making local conditions part of a global conversation (NOIRLab n.d.). The data from this study is visible on their interactive web map as shown below. The points can be interacted with to learn more about the specific details associated with each survey.



Globe at Night Interactive Web Map

Nighttime Drone Photography

As part of a broader effort to document and assess light pollution in Charlottesville, nighttime drone photography was used to capture patterns of light trespass and illumination from an aerial perspective. The images showcase a range of lighting conditions, including areas with significant light spill from commercial corridors, sites where the city has completed LED retrofit projects, and locations slated for retrofits in the near future.

Footage was collected in partnership with Carlton Carroll, a local drone pilot with a commercial license. All operations were conducted in compliance with local regulations, and the Charlottesville Police Department was notified prior to our flights. These images provide an overhead context to supplement street-level photos and Sky Quality Meter (SQM) readings, offering a more complete view of the city's lighting landscape.

Image 1: View down McIntire Rd, just south of 250

Image 2: Halogen/Cobra Head Fixture with uplight- John Warner Parkway Trailhead

Image 3: Intersection where McIntire Rd transitions into John Warner Parkway

Image 4: On-ramp from Emmett Street onto 250. Here the city installed new LED fixtures with 0 BUG ratings (no uplight), 3000K color temperature (lowest offered by Dominion at this time), and with 50-70% less lumens than the previous fixtures.

Image 5: Emmett Street

Image 6: View down Emmett Street with Barracks Shopping Center in the background

Image 7: Intersection of Market Street & 9th Street

Image 8: 9th Street SE

Image 9: Market Street & Downtown

Pursuing Dark Sky Community Certification

The International Dark Sky Community certification, administered by DarkSky International, recognizes towns and cities that demonstrate exceptional dedication to preserving the night sky through responsible lighting policies, public education, and community engagement (DarkSky n.d.). While this designation has gained popularity in the western United States, only one city on the East Coast has achieved this status: Groveland, Florida.

Groveland's journey to certification involved comprehensive steps, including adopting a robust outdoor lighting ordinance, conducting an inventory of city-owned lighting, and engaging residents through educational initiatives such as virtual workshops and community events. These efforts not only reduced light pollution but also fostered a sense of community pride and environmental stewardship (City of Groveland n.d.). Astro-tourism also boomed shortly after, bringing business to the city.

Charlottesville is well-positioned to pursue similar recognition. The city's ongoing LED streetlight upgrade aligns with DarkSky's principles by aiming to reduce excessive nighttime lighting. Additionally, Charlottesville is seeking membership in the Biophilic Cities Network, which reflects a broader commitment to integrating nature into urban planning (WHSV Newsroom 2025). Dark Sky Community certification would complement these efforts by strengthening the city's environmental goals and supporting public health, ecological preservation, and energy efficiency.

Eligibility Requirements

Eligibility Criteria	Analysis/General Recommendations
Management: The Community will coordinate with the local level of authority to write a lighting policy. For more information on benchmarks for such a policy, please review the IDA-IES Model Lighting Ordinance.	Charlottesville's current outdoor lighting regulations, outlined in its zoning ordinance, focus primarily on limiting light trespass and glare onto adjacent properties. The ordinance mandates that outdoor lighting be directed downward and shielded to minimize spillover, but it does not comprehensively address factors such as correlated color temperature (CCT), lumens per fixture, or curfews for non-essential lighting. In contrast, the International Dark Sky Community (IDSC) certification requires a more rigorous approach. Communities must adopt a comprehensive Lighting Management Plan (LMP) that enforces fully shielded fixtures, limits CCT to 3000K or lower, and sets strict controls on lumen output and operational hours for various lighting types.

	To align with IDSC standards, Charlottesville would need to update its lighting ordinance to incorporate these stricter requirements, ensuring that all outdoor lighting minimizes skyglow and preserves the natural night environment.
Nighttime Public Access: Planning and execution of at least two community dark sky awareness events per year. Educational matierals must be provided for residents and schools as well.	Local organizations such as Dark Skies Piedmont, the Rivanna Master Naturalists, and the Charlottesville Astronomical Society are well-positioned to lead the public education and outreach efforts required for Dark Sky Community certification. These groups already have a strong presence in the community and experience organizing events that promote environmental stewardship and scientific literacy. By hosting stargazing nights, presentations on responsible outdoor lighting, and educational programs in local schools, they can help fulfill the requirement of at least two community awareness events each year. Their existing networks and public trust make them valuable partners in advancing dark sky advocacy and cultivating long-term support for reducing light pollution.
Night Sky Quality: A sky brightness measurement program must be established and maintained either by the Community or by a public or private entity (e.g., university, research center, DarkSky Chapter, astronomy club) to follow the evolution of light pollution in the IDSC. Specific sky quality levels are not required. Applicants are encouraged, but not required, to submit their measurements to the citizen science projects such as My Sky At Night (myskyatnight.com) and Globe At Night (globeatnight.org).	The sky quality data collection program developed during this independent study can serve as a strong foundation if Charlottesville decides to pursue Dark Sky Community certification. The methodology, which involves using handheld Sky Quality Meters (SQMs) to gather readings at consistent locations over time, offers a reliable way to track changes in night sky brightness. Until formal certification is under consideration, local groups like Dark Skies Piedmont and the Charlottesville Astronomical Society are encouraged to continue and expand these data collection efforts. Doing so helps establish a valuable baseline and keeps public interest and momentum moving forward.

Resources: The Community demonstrates its commitment to dark skies and quality lighting by: - Retrofitting all publicly owned lighting within five years - Encouraging residents and businesses to participate in the dark sky movement with the use of, for example, flyers, events, informative websites, public service announcements, and funding of lighting upgrades - Providing examples of success in light pollution control with private lighting or new development - Presenting opportunities to learn about and engage with the night sky	Charlottesville is already well positioned to meet the resource commitment requirement for Dark Sky Community certification, as it is currently in the midst of a three-year citywide streetlight retrofit. This existing effort places the city ahead of the curve in demonstrating a commitment to dark sky principles through public lighting improvements. As the city refines its lighting policy, there are opportunities to partner with developers and private business owners to showcase examples of successful light pollution mitigation. These partnerships can help build community awareness, provide models for best practices, and reinforce the city's leadership in responsible outdoor lighting.

Figure 3.

*Please note that this table is not an exaustive list of all the minimum requirements for certification, but a general overview. Please refer to the References page for more information.

Proposed Timeline (Gantt Chart)

Tasks	Primary Leaders	Support	2025	2026	2027	2028	2029
LED Streetlight Conversion Project	City of Charlottesville	Consultant, VRSC					
Revising Outdoor Lighting Ordinance	City of Charlottesville	Consultant, UVA's UEP Department					
Hosting Dark Sky Outreach Events 2x a Year	Dark Skies Piedmont, Charlottesville Astronomical Society	UVA's Astronomy Department, City's Sustainability Department					
Establishing & Maintaining a Sky Brightness Measurement Program	Dark Skies Piedmont, Rivanna Master Naturalist Chapter, UVA	City's Sustainability Department, Other Advocacy Groups					
Crafting & Presenting Educational Content for Local Schools	Dark Skies Piedmont, Rivanna Master Naturalist Chapter	Teachers					
Collaborating with Local Businesses in Installing Responsible Lighting Fixtures as Demos/Examples	City's Sustainability Department	Dark Skies Piedmont, Charlottesville Astronomical Society					
Drafting & Submitting the Dark Sky Community Application by the end of 2029	TBD	Consultant, Dark Skies Piedmont, UVA's UEP Department, City's Sustainability Department					

Figure 4.

This 4.5-year timeline outlines key tasks and partnerships involved in pursuing Dark Sky Community certification. Charlottesville's LED streetlight conversion project, which began in late summer 2024, is expected to take approximately three years to complete. During that time, other organizations such as local advocacy groups and departments within UVA can begin laying the groundwork for additional requirements. For context, Groveland, Florida, a much smaller city, achieved certification in about two to three years. As the LED conversion wraps up and if the city expresses greater interest in certification, it will be important to designate a governmental coordinating body, such as the Office of Sustainability, to track progress and support communication among stakeholders and partners.

Conclusion

This independent study has demonstrated that while light pollution is a complex issue, there are clear and actionable steps Charlottesville can take to address it. With the LED Streetlight Upgrade Project already underway and a strong foundation of environmental stewardship and public interest, the city is well-positioned to further its commitment to responsible lighting. By collaborating with local advocacy groups, educational institutions, and community members, Charlottesville can continue building momentum toward reducing light pollution and improving public awareness.

Looking ahead, achieving Dark Sky Community certification would be a significant milestone, but the broader goal is to foster a lasting culture and understanding of thoughtful, responsible lighting practices. Continued community engagement, policy refinement, and data collection will be key to sustaining progress. The groundwork laid through this study offers a starting point for future efforts, and it is hoped that this report will serve as a useful resource for those committed to protecting and celebrating the night sky.

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Appendix

A. VRSC Policy Memo

TO: Tiffany Miller, Manager, Outdoor Lighting and Smart Cities
Leslie Downey and Susan Rivera, Outdoor Lighting Program Coordinators
CC: Local government elected officials, planners, and managers
FROM: Virginia Responsible Streetlighting Coalition
RE: Requested attention to LED streetlight conversions: best practices and standards to mitigate light pollution and support community well-being
DATE: January 22, 2025

INTRODUCTION

The advent of solid-state Light Emitting Diode (LED) technology promised dramatic gains in energy efficiency for municipal and commercial outdoor lighting applications. However, a narrow focus on efficiency and efficacy, a "cookie cutter" approach to applications that ignores unique features of LED technology, and the false assumption that "brighter is better" have led to ever-increasing light pollution. More than 99 percent of the U.S. population now lives beneath light polluted skies and in Virginia even the most remote, rural areas have degraded night sky quality.

Sky glow, high artificial light levels at night, glare, and light trespass are forms of environmental pollution that degrade ecosystems and habitat and pose harm to human health, safety, and well-being. Virginians are increasingly concerned about the effects of light pollution on their communities and neighborhoods; many are experiencing light pollution most directly through LED streetlight conversions.

Nationwide, streetlight conversions over the past fifteen years have brought attention to the challenges and missed opportunities of LED conversion. The transition to LED lighting too often has failed to address the unique attributes of technology that produces light with electroluminescence through a semiconductor device rather than with incandescence through a filament, in the form of a diode array rather than a bulb.

Increased glare, light trespass, and excessive brightness have generated community backlash while decision makers have neglected LED's great advantage of adaptive control to reduce both greenhouse gas emissions and light pollution. As "lessons learned" accumulate, some localities have changed course. Yet most LED lighting continues to fall short of the technology's capabilities to revolutionize outdoor lighting in beneficial ways.

In Virginia, Dominion Energy is uniquely positioned to show leadership in smart lighting. Light pollution is neither smart nor sustainable. A comprehensive approach prioritizes visibility, protects visual function, minimizes harm to quality of life and the environment,

and reduces greenhouse gas emissions through efficiency, appropriate light levels, and timing. By informing its practices with up-to-date science and design, Dominion can correct the most problematic aspects of LED conversion. Responsiveness to customers, alignment with responsible outdoor lighting standards, and use of technological advances would serve both economic efficiency and community needs while fulfilling the commitments in Dominion's own Environmental Policy Statement.

This memorandum concludes with specific recommendations for changes to Dominion's luminaire supply and streetlighting practices.

BACKGROUND: light pollution and its consequences

Measurable global light pollution has increased since the advent of LED technology.

- The night sky is artificially bright for eighty percent of the world's population. While the average increase in light pollution was estimated at two percent annually in the early 21st century, recent research using ground-based visual estimates indicates a global average increase of about ten percent annually.
- LED lighting, which now accounts for nearly 50 percent of lighting sales, has likely contributed to the increase. White LED emits a larger proportion of its energy in short-wavelength ("blue") light than other technologies; as early as 2010, the scientific community recognized that blue-rich light sources increase detectable sky glow by fifteen to twenty percent because it scatters farther in the atmosphere.
- LED lighting is most likely also contributing to expanded and amplified sky glow through overall increases in the use and brightness of lighting as a reaction to its cheaper operating costs.

Artificial light at night is a form of pollution that degrades ecosystems, harms wildlife, and is increasingly linked to adverse human health outcomes.

- All life on earth evolved over billions of years according to consistent, cyclical patterns of light and dark with the night illuminated only by starlight and moonlight. Natural light levels and photoperiod (seasonal changes in daylength) are the primary cues for the biology, behavior, and life cycle functions of all species.
- Research has found harmful effects from artificial light at night at both the individual and population levels for birds, fishes, amphibians, reptiles, mammals, insects and other invertebrates, and plants. For example, light pollution is implicated in the annual mortality rate of migratory birds and research increasingly identifies light pollution as a contributor to the decline in insect populations, including pollinators.

- Scientific evidence establishes a connection between artificial light at night and harm to human health through the biological role that light and dark play in the regulation of the circadian 'master clock' that in turn governs body organs and systems. The secretion of melatonin (suppressed by light, triggered by dark) features strongly in the possible link between exposure to artificial night at light and certain cancers. Sensitivity is greatest to short wavelengths; therefore "blue light" is most disruptive. While research design is challenging and results must be cautiously interpreted, frequent exposure to excessive light at night also may be a contributing factor to obesity, diabetes, cardiovascular disease, endocrine disorders, dementias, and developmental disorders.

fficiency alone does not fulfill promises of "sustainability." Wasted light is wasted energy.

- As lighting has become more efficient and less expensive, the world has consumed more of it. Using more and brighter lighting where and when it is not needed has eroded much of the potential for energy savings and emissions reductions.
- Unshielded fixtures, light directed horizontally and upward, unnecessarily intense illumination levels, and all-night lighting at full output when it does not serve a purpose all contribute to energy waste and climate change.

ublic health and safety are better served by less light pollution.

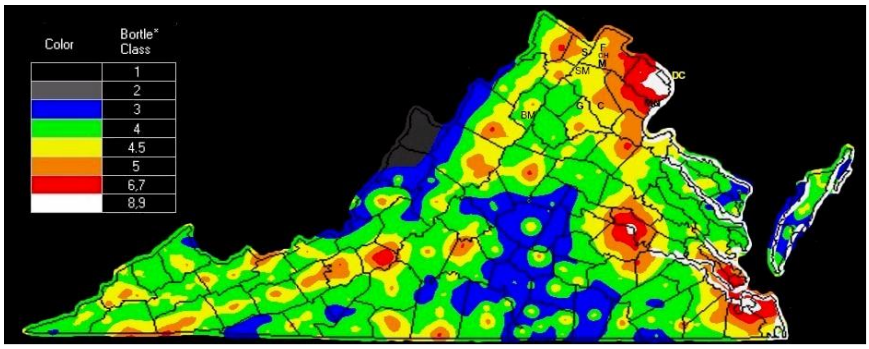
- Scientific evidence does not support the belief or practice that more lighting and brighter lighting universally increases safety and security.
- In a 1997 report to Congress, the National Institute of Justice noted that "We may speculate that lighting is effective in some places, ineffective in others, and counter-productive in still other circumstances. . . . offenders need lighting to detect potential targets and low-risk situations." In 2000, an increase in alley lighting in Chicago resulted in an increase in reported crimes in all categories. Reductions in streetlighting in the U.S. and the U.K. have not resulted in increases in crime and accidents.
- Poor lighting design that produces glare and reduces contrast degrades rather than enhances visibility and impairs vision. Short wavelength blue light produces more glare and negatively affects vision because it disproportionately constricts pupil size and hinders visual adaptation to changing light levels. The hazards of glare, particularly to older drivers, was a primary reason the American Medical Association began calling for action on light pollution in 2009.
- Clanton and Associates, a national leader in lighting research and design, had concluded by 2013 in a study with Virginia Tech Transportation Institute that lighting

level is "the worst predictor for visibility" and that "quality of light – good optical design" is essential to visibility.

- The organization Crime Prevention Through Environmental Design (CPTED) states that lighting systems should "minimize glare, shadow, light pollution, and light trespass." The U.S. CPTED Association and DarkSky International have developed shared goals that prioritize "lighting for safety and sustainability; environmental and community impact; and aesthetic and functional harmony."

Virginia suffers from polluted night skies even as its dark sky tourism sector seeks expansion and Virginians advocate for more responsible lighting and a reduction in light pollution. Generations of Virginians are growing up without experiencing a starry night sky.

The astronomical Bortle Scale ranks the most pristinely dark skies as a "1" and the most polluted as a "9". Virginia's darkest skies according to the most current data fall short of a "1" and most of the commonwealth ranks at or above a "4".



https://www.novac.com/wp/observing/bortle-scale/

- Virginia is home to five Dark Sky Parks designated by DarkSky International since 2015; that status depends on community commitment to reversing light pollution. Others are in an exploratory or early development phase.
- The Virginia Department of Conservation and Recreation's Virginia Outdoors Plan has since 2018 recognized night skies as a scenic resource to be conserved.
- Regional and local advocacy and organizing in Northern Virginia, the central Piedmont, Hampton Roads and Norfolk, the Shenandoah Valley and the Allegheny Highlands reflect Virginians' frustration with growing light pollution, particularly from LED streetlight conversions, and its detrimental impacts on their communities and Virginia's environment. This includes campaigns in northern Virginia and eastern Virginia to address light pollution's impact on the bird migration Atlantic Flyway.

EXPLANATIONS: A better future for LED lighting

The lighting industry supports and defines responsible outdoor lighting standards.

- The Illuminating Engineering Society (IES) jointly published with DarkSky International the Five Principles of Responsible Outdoor Lighting in 2020. The principles specify that lighting should be: 1) used only if it has a justified purpose; 2) shielded and aimed to contain illumination to its target; 3) no brighter than necessary; 4) used only when needed, through adaptive controls; and 5) 'warm' in color correlated temperature (CCT) with minimal blue spectrum wavelengths.

The Virginia Department of Transportation's Traffic Engineering Division 2019 memorandum on roadway lighting provides practical guidance. This memo has not been updated and does not reflect further advances in lighting technology.

- VDOT's default position is "no lighting" with a focus on "nodes, not roads." All lighting should be both "warranted and justified" and comply with IES minimum recommendations.
- VDOT policy supports dimming when traffic and activity are below certain thresholds on roadways and at parking facilities.
- VDOT specifies luminaires with "zero uplight" ratings and approves of 2700K luminaires when requested by localities or in historic districts.

The Federal Highway Administration's 2023 Lighting Handbook is an invaluable resource Dominion can use to inform and guide their streetlighting policies and practices.

- This handbook's chapters cover vision and physiology; principles and lighting metrics; lighting considerations; warranting; lighting planning and design process; lighting system selection; environmental impacts and mitigation; and adaptive lighting.
- The FHWA warns against over-lighting: "The benefits of increasing the lighting level reach a plateau beyond which there are diminishing returns."
- The FHWA also cautions that LED lighting is incompatible with one-to-one-replacement: "Luminaires vary greatly in optical efficiency and light distribution from product to product" and assuming that "all products meeting specifications will produce equal results can reduce the overall effectiveness of the lighting system".
- Dominion's luminaire supply and streetlight conversion practices run counter to FHWA expertise and standards.

LED streetlight conversions are evolving to correct for costly mistakes and to keep pace with rapid ongoing technological innovation.

- As early as 2011, the Pittsburgh *Remaking Cities Institute* "LED Streetlight Project" highlighted glare as a problematic feature of LED lighting, specified the discontinuing of acorn luminaires, incorporated adaptive controls, and recommended color range down to 2700K.
- In 2014 the city of Davis, CA halted an LED streetlight conversion following negative public reaction to glare, excessive brightness, and light trespass from 2800 lumen/4,000K luminaires. After a review with improved public participation, the project resumed with 1800 lumen/2700K luminaires with house-side shields. The upfront additional cost of the modifications was $325,000, but the revised installation used 30 percent less energy than the original plan.
- In 2016 Cambridge, MA completed a streetlight conversion that reduced lumens and illumination levels and employs two stages of dimming, down to 35 percent capacity.
- In 2018 the city of Tucson's LED streetlight conversion reduced total lumens by over 60 percent and blue light emissions by over 30 percent while adaptive controls dim streetlighting to 60 percent capacity after midnight.
- Recent streetlighting projects in Virginia reflect a preference for 'warm' lighting below 3,000K and for dimming. An installation in Washington, VA is using 2200K luminaires. A large-scale streetscaping and traffic calming project on State Route 9 in Hillsboro (Loudoun County) selected 2700K, ultimately using 3000K only for reasons of project timeline constraints; that installation dims to 50 percent capacity after 10:00 p.m.
- The Town of Vienna in Fairfax County has hired Clanton and Associates, a national leader in smart lighting design, to develop its new outdoor lighting ordinance, prioritizing a community friendly approach to lighting and a commitment to mitigating light pollution. Clanton and Associates' groundbreaking research with the Virginia Tech Transportation Institute led to new understanding of lighting and visibility ("less light . . . better sight").

REVIEW AND RECOMMENDATIONS

- Dominion needs to substantively address environmental and human health and safety harms of light pollution from poorly designed lighting and shift to standards that address all design aspects of community friendly lighting including smart controls, spectral content, and appropriate lighting levels.

- Dominion's luminaire product list is outdated; it has not kept up with advances in technology and does not reflect lighting design industry best practices.

The following changes are necessary:

- Eliminate the use of term "dark sky friendly" in its product list unless a luminaire is certified by DarkSky International or Community Friendly Lighting Program (Smart Outdoor Lighting Alliance). Over 180 manufacturers participate in DarkSky's approval program with thousands of approved luminaires.
- Follow current Recommended Practices of the Illuminating Engineering Society as they are updated.
- Limit blue spectral content to the greatest extent possible across CCT range.
- Include 2200K, 2400K, and 2700K options in product list with minimal short wavelength blue emissions spectral power distribution (SPD below 530nm of no more than 25 percent).
- Include phosphor-converted amber LED options (explainer attached).
- Utilize only luminaires with uplight ratings of zero and glare ratings of zero or one.
- Make available backlight shields for all residential installations and clearly state availability on Dominion website and in communications with municipality and residents.
- Equip all luminaires with adaptive control capability.
- Discontinue acorn fixtures, which waste approximately 40 percent of their illumination, causing glare, uplight, and trespass.
- Precede streetlight conversions with a public engagement process organized by a lighting consultant that includes surveying a broad cross section of stakeholders through a guided tour of a range of design options with adaptive control to demonstrate varied lighting levels. Residential installations need to include options at least as low as 2700K.

Note: *Spectral emission and lighting density (lumens per acre) are recognized as important factors in the overall effect of lighting. Industry standards to incorporate these characteristics into specifications are in development. For example, Scotopic/Photopic (S/P) ratios, which relate to a measure of short wavelength spectral power distribution, will be a more meaningful measure than Kelvins. We expect to follow up on these technical developments as research and industry standards evolve.*

CONCLUSION

Streetlighting's contribution to light pollution varies by location. However, streetlights disproportionately affect individuals and residential areas; they are the most typical source of light trespass into homes and have the most direct effect on visibility and visual comfort and adaptation for motorists. Streetlighting decisions and installations are in the hands of public utilities and governments, both of which have obligations to community residents.

As the energy provider for most of Virginia's population, Dominion Energy has an unrivalled influence and can set an example for truly smart outdoor lighting. Dominion's own "Environmental Policy Statement" aims "*to do what is right for the communities we serve*" and to meet or go "*beyond environmental requirements*." This statement makes a commitment to "*fostering innovation*" and pledges to "*implement sound environmental practices to protect wildlife, conserve habitats, and advance biodiversity.*"

Mitigating light pollution, respecting community character and the inviolability of private homes, and protecting the visual comfort of pedestrians and drivers are how to "do right" and "protect and conserve." "Fostering innovation" demands lighting that lands on the cutting edge rather than lagging far behind it. Dominion has an opportunity to show highly visible environmental leadership for the benefit of Virginia's towns, suburbs, and cities.

# # #

The Virginia Responsible Streetlighting Coalition includes advocates from Northern Virginia, Richmond, Norfolk, the central Piedmont region including Charlottesville, and the central Shenandoah Valley and Allegheny Highlands. Our collective professional experience and expertise includes urban and environmental planning; public policy, management and administration; law practice; education; health/medical practice and policy; military defense; engineering and contracting; lighting design; defense economics and consulting; social work; natural resource management; and public relations. Member organizations are Citizens for Responsible Lighting, Dark Skies Piedmont, DarkSky Virginia, DarkSky NOVA, and BirdSafe Hampton Roads.

Attachments

- VDOT 2019 memorandum on roadway lighting
- Federal Highway Administration 2023 lighting handbook
- Amber Phosphor LED explainer
- Dominion's Environmental Policy Statement

References and resources

- *State of the Science 2024 Report* https://darksky.org/app/uploads/2024/06/ALAN-State-of-the-Science-2024-EN-1.pdf
- *Science* special issue dedicated to light pollution, June 16, 2023 https://www.science.org/toc/science/380/6650
- *Reducing nighttime light exposure in the urban environment to benefit human health and society* https://www.science.org/doi/10.1126/science.adg5277
- *FHWA Lighting Handbook 2023*, Federal Highway Administration https://highways.dot.gov/safety/other/fhwa-lighting-handbook-2023
- Clanton and Associates Lighting Design and Engineering https://www.clantonassociates.com/
    - Presentation for Town of Vienna: https://us02web.zoom.us/rec/play/05vYm19FCsTdD74uafDyuyKEq0aoGgXZyMpENReZXoxTleLbiK2FpOmyg0pCyM2-koH2Q-kCUdoE4jZ4.RY4XRQkpBx7KlS_0
- *Preventing Crime: What Works, What Doesn't, What's Promising* https://www.ncjrs.gov/works/
- *Chicago Alley Lighting Project final report* https://www.ojp.gov/ncjrs/virtual-library/abstracts/chicago-alley-lighting-project-final-evaluation-report#:~:text=The%20Illinois%20Criminal%20Justice%20Information%20Authority%20undertook%20an,were%20most%20likely%20to%20have%20occurred%20in%20alleys
- *A Unified Approach to Safer, Sustainable Communities*, U.S. Crime Prevention Through Environmental Design and DarkSky International https://uscpted.com/dark-sky-international-us-cpted-association/
- *Crime Prevention Through Environmental Design as a Design Tool* https://www.dcjs.virginia.gov/sites/dcjs.virginia.gov/files/training-events/7596/l-1401-cpted-examples.pdf
- *Artificial Night Lighting and Protected Lands: Ecological Effects and Management Approaches* National Park Service https://irma.nps.gov/DataStore/DownloadFile/582058
- *Multi-Sector Campaign for Migratory Birds*, U.S. Fish and Wildlife Service https://www.fws.gov/story/2024-03/multi-sector-summit-address-light-pollution-and-bird-collisions

B. SQM Data Tables

SQM Model		Version	SQM-L				
		Total SQM Average	18.84171429				
Date	January 1-2, 2025	Total SQM Median	18.56				
	Location 1	Location 2	Location 3	Location 4	Location 5	Location 6	Location 7
Location Name	Booker T. Washington Park	Caruthers Hall Parking Lot	Greenbriar	Rotunda	McCormick Observatory	Market Street Park	Belmont Park
Latitude	38.04147	38.05101	38.0619	38.03514	38.03307	38.03172	38.01923
Longitude	-78.49113	-78.50018	-78.47379	-78.50367	-78.52267	-78.48061	-78.48174
Time	8:23 PM	8:30 PM	8:40 PM	8:56 PM	9:16 PM	9:53 PM	10:02 PM
SQM Reading #1	18.84	18.45	19.31	18.45	19.54	18.27	19.21
SQM Reading #2	18.9	18.46	19.27	18.4	19.55	18.26	19.17
SQM Reading #3	18.9	18.49	19.28	18.56	19.56	17.72	19.27
SQM Reading #4	18.89	18.48	19.31	18.51	19.46	18.15	19.09
SQM Reading #5	18.89	18.54	19.34	18.29	19.46	18.05	19.16
Location SQM Average	18.88	18.484	19.302	18.442	19.514	18.09	19.18
Location SQM Median	18.9	18.49	19.28	18.56	19.56	17.72	19.27
% Cloud Cover	0	0	0	0	0	0	0
% Moon Visibility	1	1	1	1	1	3	3
Air Temperature	41 F	41 F	40 F	40 F	39 F	35 F	34 F
Other Notes							There appeared to be less lights turned on in busy areas of town due to the holiday

SQM Model		Version	SQM-L				
		Total SQM Average	18.77028571				
Date	February 28-March 1st, 2025	Total SQM Median	18.56				
	Location 1	Location 2	Location 3	Location 4	Location 5	Location 6	Location 7
Location Name	Booker T. Washington Park	Caruthers Hall Parking Lot	Greenbriar	Rotunda	McCormick Observatory	Market Street Park	Belmont Park
Latitude	38.04147	38.05101	38.0619	38.03514	38.03307	38.03172	38.01923
Longitude	-78.49113	-78.50018	-78.47379	-78.50367	-78.52267	-78.48061	-78.48174
Time	10:30 PM	10:50 PM	10:40 PM	7:30 PM	7:45 PM	8:00 PM	8:10 PM
SQM Reading #1	18.92	18.38	19.23	18.35	19.14	18.22	18.97
SQM Reading #2	18.99	18.27	19.26	18.55	19.04	18.25	19.13
SQM Reading #3	19.39	18.27	19.25	18.47	19.07	18.18	19.08
SQM Reading #4	19	18.28	19.25	18.52	19.08	18.24	19.08
SQM Reading #5	19.02	18.25	19.21	18.47	19.07	17.99	19.09
Location SQM Average	19.064	18.29	19.24	18.472	19.08	18.176	19.07
Location SQM Median	19	18.27	19.25	18.47	19.07	18.22	19.08
% Cloud Cover	0	0	0	0	0	0	0
% Moon Visibility	2	2	2	8	8	8	8
Air Temperature	49 F	48 F	49 F	44 F	44 F	44 F	34 F
Other Notes							

SQM Model		Version	SQM-L				
		Total SQM Aver	17.949				
Date	March 30th	Total SQM Medi	18.56				
	Location 1	Location 2	Location 3	Location 4	Location 5	Location 6	Location 7
Location Name	Booker T. Washington Park	Caruthers Hall Parking Lot	Greenbriar	Rotunda	McCormick Observatory	Market Street Park	Belmont Park
Latitude	38.04147	38.05101	38.0619	38.03514	38.03307	38.03172	38.01923
Longitude	-78.49113	-78.50018	-78.47379	-78.50367	-78.52267	-78.48061	-78.48174
Time	-	9:45 PM	10:00 PM	9:37 PM	9:15 PM	-	-
SQM Reading #1	-	17.67	17.34	18.25	18.94	-	-
SQM Reading #2	-	17.65	17.04	18.25	18.99	-	-
SQM Reading #3	-	17.51	16.97	18.23	19.01	-	-
SQM Reading #4	-	17.49	16.89	18.21	19.01	-	-
SQM Reading #5	-	17.47	16.8	18.21	19.05	-	-
Location SQM Average	-	17.558	17.008	18.23	19	-	-
Location SQM Median	-	17.51	16.97	18.23	19.01	-	-
% Cloud Cover	-	10	10	10	10	-	-
% Moon Visibility	-	2	2	8	8	-	-
Air Temperature	-	73 F	72 F	73 F	72 F	-	-
Other Notes							Readings were significantly lower this month. My theory is that the higher cloud cover skewed the results.

*Survey not completed due to cloudy conditions persisiting over multiple days.