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EXECUTIVE SUMMARY

In response to a continual state of redevelopment, strong demand for safe and consistent lighting for all modes of transportation, and rapidly evolving lighting technology, Arlington County staff prepared this first comprehensive Streetlight Management Plan (SMP). The plan creates a practical decision roadmap for the Street Lighting Program as project and program decisions are made over time with both private and public redevelopment and infrastructure. The SMP lays out strategies for the County to provide quality and consistent street lighting over the long term. As the streetlight network continues to grow, it is crucial to keep the state of the street lighting program in good operating condition. The SMP also guides County staff on the selection of future streetlight technology, optimization of maintenance, defining design principles and policies, and the direction for future project prioritization and implementation. This plan establishes lighting standards that complement the Master Transportation Plan and is consistent with federal guidelines. The report was completed by researching new streetlight technology, investigating ways to enhance the appearance of streetscapes, updating lighting standards and improving outage reporting. The SMP identifies best practices and lessons learned based on interviews with other U.S. cities, including Seattle, Boston, Cambridge and Philadelphia. This plan makes recommendations applicable to Arlington County regarding its future needs and priorities and will guide optimal use of limited public resources.

This administrative document was prepared after a rigorous community engagement process. An Advisory Panel, comprised of different community groups, guided staff throughout the study, analysis, and recommendation development process. A two-month field demonstration of the technology was conducted within the County, such that County roadway users could see the performance of test lights for themselves and provide comments. The community was encouraged to provide feedback via hardcopies during the field demonstrations, and electronically via social media and Arlington County’s website. The County received more than 700 comments due to the high volume of people who participated. County staff crafted the recommendations in this document to reflect the feedback received from the public.

This document contains five chapters and seven Appendices (A-G). A summary of these chapters is provided below.

Chapter I provides a more detailed explanation of lighting by answering a list of frequently asked questions.

Chapter II provides a more in-depth background on lighting specific to Arlington County. Starting with the philosophy that drives the County's lighting program, this section highlights Arlington County’s commitment to safety and accessibility to all modes of transportation. It also details how the program was under-resourced to meet customer expectations of timely repairs and that service delivery performance immediately improved when the County Board approved additional resources. This section provides details regarding the existing lighting system both owned by the County and Dominion Energy (DE) and DE’s customer service. By providing a timeline of LED streetlight deployment, this section shows how electricity consumption and greenhouse gas generation is reduced by up to 80% compared to traditional light sources after the installation of LEDs.

Chapter III identifies vision and guiding principles of the street lighting program as safety and accessibility, sustainability, maintainability, intelligent system management, compatibility, and cost effectiveness. Recognizing inherent problems associated with the mixed ownership of streetlights within the same area, different ownership scenarios are evaluated and the districting concept of ownership is recommended where only DE or Arlington County own the streetlights in specific areas. Recommendations on implementing the district concept are also included. The section provides specifics on a maintenance plan, appropriate resource levels and how routine preventive maintenance will be carried out. The County’s street lighting vision framework for the Dominion-owned streetlights is governed by the Virginia Energy Purchasing Governmental Associations (VEPGA) and hence is detailed in this section. While light pollution is contributed by variety of light sources, light pollution by streetlights will be minimal by the use of cobra head luminaires or post-top lights with internal shields.

Chapter IV discusses different technologies in street lighting and the County’s approach to developing technologies. Even though the County is not recommending motion-sensing street lighting due to safety reasons at this time, adaptive lighting is a highly-discussed topic in recent years and basic criteria for such applications are discussed in this chapter should such technology mature in the future. There are very new technologies such as smart city applications, communication for streetlights, and small cell. The County is not implementing them yet but will be closely monitoring their development. Lighting technology and maintenance is evolving at a faster rate than in previous decades and the County’s needs also may evolve over time. Therefore, the County will be periodically updating this document to reflect such changes, via a system of clearly documented amendments, and when appropriate, more comprehensive updates.

Chapter V discusses different technologies in street lighting and the County’s approach to developing technologies. Even though the County is not recommending motion-sensing street lighting due to safety reasons at this time, adaptive lighting is a highly-discussed topic in recent years and basic criteria for such applications are discussed in this chapter should such technology mature in the future. There are very new technologies such as smart city applications, communication for streetlights, and small cell. The County is not implementing them yet but will be closely monitoring their development. Lighting technology and maintenance is evolving at a faster rate than in previous decades and the County’s needs also may evolve over time. Therefore, the County will be periodically updating this document to reflect such changes, via a system of clearly documented amendments, and when appropriate, more comprehensive updates.
INTRODUCTION

LED street lighting is a technology that continues to evolve and develop and the way we light roadways today could be very different than a decade from now. However, for those communities who invest now, there are many tools available to assure they select the appropriate fixture for their applications. These communities then have the ability to take the savings and invest in other services, such as police and fire.


Arlington County’s Streetlight Management Plan (SMP) creates a roadmap for the Street Lighting Program. It provides guidelines and standards based on the latest technology to enhance the safety and appearance of our streetscapes, update lighting standards, and improve Customer service. The SMP addresses Arlington County’s design principles and policies, recent best practices, advancements in lighting technology, and direction for future project prioritization and implementation. This document serves as a substantial update to the County’s Street Light Policy and Planning Guide published in 1995 and is also supplemented by the Arlington County Streetlight Specifications and Standards document which is available at: https://transportation.arlingtonva.us/streets/street-lights/. The County owns and maintains lighting along some of the trails. The technology, equipment, and lighting standard on trails are different from lights along “streets”. Trail lighting is managed through a different set of policies and technical guidelines, and therefore are not part of this document.

Arlington County has 1,059 lane miles of multi-modal roadways and 26 square miles of enclosed area. Residents and workers have a range of options for work and personal trips, and are served by 11 Metrorail stations, 17 ART bus routes, and 92 Capital Bikeshare stations. With almost 146,000* daily commuters from adjacent jurisdictions and over 3 million visitors per year to the Arlington National Cemetery, Arlington County is a very unique and active community that requires investing and planning for various lighting needs to accommodate a variety of different road types and transportation modes.

Effective street lighting reduces nighttime crash rates while enhancing community activities including business. Street lighting is a critical aesthetic element of roadways. It represents the significance and history of an area. It is important to follow certain standards for streetlights based on the needs and settings of an area. Historically, the lack of a county-wide policy has led to non-uniform lighting infrastructure and inconsistent illumination levels throughout Arlington County.

The SMP Community Advisory Panel was formed with 11 community members to provide a forum for key stakeholders to advise County staff on safety, sustainability (energy savings, health, environmental impacts), technology and streetscape priorities. Extensive public engagement was conducted to: educate the community about the Streetlight Management Plan; provide an overview of the technology and different products under consideration; and to listen to community feedback. Panel and community input helped inform the SMP.


<table>
<thead>
<tr>
<th>Name</th>
<th>Affiliation</th>
</tr>
</thead>
<tbody>
<tr>
<td>James Davenport</td>
<td>Transit Advisory Committee</td>
</tr>
<tr>
<td>Captain Pat Donahue</td>
<td>Arlington County Police Department</td>
</tr>
<tr>
<td>Bill Gearhart</td>
<td>Transportation Commission</td>
</tr>
<tr>
<td>Eric Goldstein</td>
<td>Pedestrian Advisory Committee</td>
</tr>
<tr>
<td>Frieda Kulish</td>
<td>Neighborhood Conservation Advisory Committee</td>
</tr>
<tr>
<td>Gregg Kurasz</td>
<td>At-large resident</td>
</tr>
<tr>
<td>Santya Lanman</td>
<td>Rosslyn BID</td>
</tr>
<tr>
<td>Tina Leone</td>
<td>Ballston BID</td>
</tr>
<tr>
<td>Rob Mandle</td>
<td>Crystal City BID</td>
</tr>
<tr>
<td>John Seymour (or Scott Dicke)</td>
<td>E2C2</td>
</tr>
<tr>
<td>Steve Offutt</td>
<td>Bicycle Advisory Committee</td>
</tr>
<tr>
<td>John Shoenecker</td>
<td>Fiscal Affairs Advisory Committee</td>
</tr>
</tbody>
</table>
CHAPTER I - STREET LIGHTING FUNDAMENTALS

Street Lighting Fundamentals and Definitions

A modern streetlight is more than a luminaire. A streetlight is a combination of the foundation, a light pole, and a luminaire(s). The luminaire, or fixture, may be installed on upright poles or suspended from the pole (pendant poles). While poles vary by color, style, material, and foundation structure, fixtures are even more diverse with differences in color, shape, wattage, and mounting style. The potential combinations of poles and fixtures therefore seems endless. The design of street lighting systems involves the provision of adequate lighting levels for a uniform pattern. It also requires consideration for sustainable maintenance costs.

This section presents definitions of key street lighting terminologies. It also discusses basic concepts related to lighting. For this section, and the rest of the document, “roadway” is a comprehensive term that includes travel lanes, sidewalks, crosswalks, and intersections, unless otherwise noted.

Average Initial Illuminance: This is the average horizontal illuminance level on a pavement surface of a traveled way at the time the lighting system is installed with new lamps and clean luminaires. It is measured in average footcandles or in lux.

Average Maintained Illuminance: The average level of horizontal illuminance on a pavement surface when the output of the lamp and luminaire is reduced by maintenance factors. It is measured in average footcandles or in lux.

Ballast: A coil of wire and/or related electronic components used to limit the amount of electric current flowing through a lamp. LED fixtures and incandescent lamps do not require ballasts.

Base: A lower part of a streetlight pole that supports the lamppost.

Breakaway Base: A base designed to yield when struck by a vehicle. It minimizes injury to the occupants of the vehicles and damage to the vehicle itself.

Backlight, Uplight, and Glare (BUG): The Model Lighting Ordinance, developed jointly by the International Dark Sky Association and the Illuminating Engineering Society, incorporates the BUG rating system for luminaires, which provides more effective control of unwanted light. BUG describes the types of stray light escaping from an outdoor lighting luminaire. BUG is the new standard criterion when describing the characteristics of lighting fixtures. “B” stands for backlight, or the light directed behind the mounting pole. “U” stands for uplight, or the light directed above the horizontal plane of the luminaire. “G” stands for glare, or the amount of light emitted from the luminaire at angles known to cause glare. BUG values are published by luminaire manufacturers so that lighting specifiers, designers, or purchasers can know how well a certain luminaire controls stray light or compares with other luminaires under consideration for an installation.

The BUG system makes comparing and evaluating outdoor luminaires fast, easy, and more comprehensive than older systems. As shown in Figure 1, this new system divides the sphere around a luminaire into zones assigning values according to an expected environmental impact. It offers the most complete evaluation of the total light emitted from luminaires. The values assigned by the new system may not always directly correlate to light pollution; this depends on the site, surrounding conditions, application, and how the luminaire is installed.

Figure 1: BUG Light Distribution
Glare: The sensation produced within the visual field by luminance that exceeds the eye’s ability to adapt. Glare can cause annoyance, discomfort, or loss of visual performance and visibility.

- Nuisance glare: Annoyance glare that causes complaints. IESNA defines nuisance glare as the “light shining in my window” phenomenon.
- Discomfort glare: The glare that causes physical/visual discomfort, but does not hinder the viewer from seeing an object.
- Disability glare: The effect of a bright light source that causes the stray light to scatter in the eye and causes loss in visual performance and visibility. The stray light obscures the primary image on the retina and restricts the viewer from seeing the object.

Candle: The unit of luminous intensity. The term “candle” was formerly used.

Candlepower: The luminous intensity in a specified direction.

Circadian Rhythm: Circadian rhythms are daily cycles that change our physical, mental, and behavioral state due to natural and internal systems. They respond primarily to light and darkness in the environment and regulate feelings of sleepiness and wakefulness over a 24-hour period. Circadian rhythms are found in most living organisms, including animals, plants, and many microbes. This complex timekeeper is controlled by an area of the brain that responds to light, which is why humans are most alert while the sun is shining and are ready to sleep when it’s dark outside.

Correlated Color Temperature (CCT): The absolute temperature of a blackbody whose chromaticity most nearly resembles that of the light source. It is a measure of the color appearance of the light emitted by a fixture in terms of “warmth” or “coolness.” CCT relates the color of the emitted light to the color of light from a reference source when heated to a certain temperature and is measured in degrees Kelvin (K). Fixtures with a CCT rating below 3200 K are typically considered “warm” in appearance, while those with a CCT above 4000 K are generally considered “cool”.

Color Rendering: A general expression used for the effect of a light source on the color appearance of objects when compared with their color appearance under a reference light source.

Color Rendering Index (CRI): A measure of the color shift the objects undergo when illuminated by the light source when compared with those same objects that are illuminated by a reference source of comparable color temperature.

Cutoff angle (of a luminaire): The angle that is measured up from the base, between the vertical axis and the first line of sight at which the bare source is not visible.

Dark Sky Compliance: The International Dark Sky Association’s (IDA) requirements for reducing waste of ambient light by using full shields. Dark Sky compliant fixtures minimize glare while reducing light trespass and skylight. Dark Sky requires the correlated color temperature configuration of 3000K or lower.

Footcandle: The uniform luminance of a surface emitting or reflecting light at the rate of one lumen per square foot. It is a unit of luminance or brightness.

Foot Lambert: The uniform luminance of a surface emitting or reflecting light at the rate of one lumen per square foot. It is a unit of luminance or brightness.

Glare: The sensation produced within the visual field by luminance that exceeds the eye’s ability to adapt. Glare can cause annoyance, discomfort, or loss of visual performance and visibility.

Nuisance glare: Annoyance glare that causes complaints. IESNA defines nuisance glare as the “light shining in my window” phenomenon.

Discomfort glare: The glare that causes physical/visual discomfort, but does not hinder the viewer from seeing an object.

Disability glare: The effect of a bright light source that causes the stray light to scatter in the eye and causes loss in visual performance and visibility. The stray light obscures the primary image on the retina and restricts the viewer from seeing the object.

Head: The part of the luminaire that holds the lamp or fixture socket and mounting hanger or collar. The assembly is referred to as either the head or the body, when the mounting collar is part of, or attached directly to, the reflector housing, in a “clamshell” style.

High-Mast Lighting: The illumination of a large area by means of a group of luminaires mounted on a fixed orientation at the top of a high mast, typically 65 feet or higher.

Illuminance: The time rate of flow of light is defined as luminous flux. Illuminance is the density of the luminous flux incident on a uniformly illuminated surface.

Lamppost: A standard support provided with the necessary internal attachments for wiring and the external attachments for the bracket and luminaire.

LED: Light Emitting Diode (LED) is a semiconductor light source with lower energy consumption and known for having a longer life than typical light sources.

Light Pollution: The haze or “glow” that limits the ability of a person to view the nighttime sky. It is the stray light from a luminaire that is directed into the skies. It is also referred to as “sky glow.”

Light Trespass: The light from a luminaire that falls onto neighboring space, outside the public right-of-way (ROW), or into windows of adjacent buildings. It is also referred to as “spill light.”

Louvers: A series of baffles used to shield a light source at certain angles, to either absorb or block unwanted light, or reflect or redirect light. They are usually arranged in a geometric pattern or as a grid.

Lumen: A unit to measure the quantity of light. A lumen is the amount of light that falls onto an area of one square foot, every point of which is one foot from the source (i.e., a sphere) of one candela (candle). A light source of one candela emits a total of 12.57 lumens.
CHAPTER I - STREET LIGHTING FUNDAMENTALS

Lumen Depreciation: The reduction in lamp lumen that occurs as a lamp is operated until failure.

Luminaire: A complete lighting unit consisting of a fixture or fixtures, together with the parts designed to distribute light, position and protect the lamps and ballast (where applicable), and connect the lamps to a power supply.

Luminaire Arm (Bracket): An attachment to a pole from which a luminaire is suspended.

Luminaire Dirt Depreciation: The dirt or dust that accumulates on luminaires decreasing the total output of light. It lowers the overall efficiency of the system.

Luminaire Efficiency: The ratio of luminous flux (lumens) emitted by a luminaire to that emitted by the corresponding fixture or fixtures used.

Luminance: The luminous intensity of a surface in each direction per unit of that surface as viewed from that direction.

Luminous Efficacy: The rate of converting electrical energy into visible energy, measured in lumens per watt.

Lux: The International System (SI) unit of illuminance, defined as the amount of light on a surface of one square meter, all points of which are one meter from a uniform source of one candela. One lux equals 0.0929 footcandle.

Photocontroller: A device that is typically cylindrical and the size of a tin can. It contains a light-sensitive element and other electromechanical or electronic components to turn the lights on at night and off during the day.

Reflector: Any polished or light-colored object used in optical control to change the direction of light rays as opposed to just blocking or absorbing them.

Refractor: A transparent panel or dish that serves as a lamp cover and has molded ridges to bend the light in desired directions.

Streetlight Pole: A pole used to support street luminaire(s). The luminaire(s) may be either installed on upright poles or suspended from the pole (pendant poles). Figure 2 shows the different components of poles. The upright poles include post-top (carlyle style) poles; and the pendant poles include cobrahead and teardrop.

Uniformity of Illuminance: The ratio of average footcandles (lux) of illuminance on the surface area to the footcandles (lux) at the point of minimum illuminance on the pavement area. It is also called the uniformity ratio.

Uniformity of Luminance: The Average-Level-To-Minimum Point method uses the average luminance on a roadway surface area between two adjacent luminaries, divided by the lowest value at any point in the area. The Maximum-To-Minimum Point method uses the maximum and minimum values between the same adjacent luminaries. The uniformity of luminance (avg/min and max/min) considers the traveled portion of the roadway, except for divided roadways that have distinctive designs on each side.

Veiling Luminance: A luminance superimposed on the retinal image that reduces its contrast. It results in reduced visual performance and visibility due to bright areas in the visual field.
CHAPTER I - STREET LIGHTING FUNDAMENTALS

Street Lighting Concepts

Light Sources

Light source is the principal element of illumination equipment. It determines visual quality, efficiency, energy conservation, and the economic aspects of the lighting system. There are several technologies of light sources currently being used in street lighting. They include Metal Halide (MH), High-Pressure Sodium (HPS), Light Emitting Diode (LED), Low-Pressure Sodium (LPS), Fluorescent, Incandescent, and Mercury Vapor (MV).

These light sources are generally compared based on four major characteristics:

- Luminous efficacy in terms of the number of lumens produced per watt of energy
- Color rendition in terms of color quality
- Lamp life in terms of number of operating hours
- Optical control

Among these light sources, LED is the most energy efficient option with a longer life span, and like Metal Halide, provide an excellent color rendition. Incandescent and Mercury Vapor are less common and are being phased out due to higher operating costs and inefficiencies. Existing incandescent and Mercury Vapor fixtures are being replaced with other fixtures. HPS are commonly used but gradually being replaced by LED. The comparison of various fixture types is shown in Table 2.

TABLE 2: COMPARISON OF FIXTURE TYPES

<table>
<thead>
<tr>
<th>Fixture Type</th>
<th>Features</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light Emitting Diode (LED)</td>
<td>Solid state fixture</td>
<td>Can be made retrofitted/interchangeable with other types of lamps</td>
<td>Higher initial cost</td>
</tr>
<tr>
<td></td>
<td>Uses Light Emitting Diodes (LED) as source of light</td>
<td>Longer service life (up to or more than 100,000 hours) and high energy efficiency</td>
<td>When not packaged properly with diffusers, pointed LED can cause glare</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High color rendition</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dimmable</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Environmentally friendly, mercury free product</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Resistant to vibration and impact</td>
<td></td>
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<tr>
<td>High Pressure Sodium (HPS) and Low</td>
<td>High intensity discharge arc tube in which light is produced by radiation</td>
<td>Relatively low cost</td>
<td>Short lifespan</td>
</tr>
<tr>
<td>Pressure Sodium (LPS)</td>
<td>from sodium vapor operating under intense pressure</td>
<td>LPS bulbs are efficient</td>
<td>May cycle on and off prior to complete failure</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hot restart can take several minutes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Poor color rendition, especially with LPS</td>
<td></td>
</tr>
<tr>
<td>Metal Halide (MH)</td>
<td>High intensity discharge arc tube in which light is produced by radiation</td>
<td>Great color rendition</td>
<td>Short lifespan</td>
</tr>
<tr>
<td></td>
<td>from excited Metal Halide</td>
<td>White light imitates daylight conditions</td>
<td>May cycle on and off prior to complete failure</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hot restart can take several minutes</td>
</tr>
<tr>
<td>Incandescent</td>
<td>Lamps produce light by using electricity to heat a filament</td>
<td>Powers on instantly</td>
<td>Short life (500-5,000 hrs)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low initial cost</td>
<td>Inefficient operations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Great color rendition</td>
<td>High heat output</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dimmable</td>
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<tr>
<td></td>
<td></td>
<td>Compact size</td>
<td></td>
</tr>
<tr>
<td>Fluorescent</td>
<td>Lamps that pass electricity through a gas enclosed tube</td>
<td>Twice the light and less than half the heat of an incandescent bulb of comparable wattage</td>
<td>Sensitive to temperature</td>
</tr>
<tr>
<td></td>
<td>Typically used indoors and for signage</td>
<td>Long life (10,000-15,000 hrs)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>More efficient than HPS or MH</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Good color rendition</td>
<td></td>
</tr>
<tr>
<td>Mercury Vapor</td>
<td>High-intensity discharge device that produces light by excitation of</td>
<td>Long life (16,000-24,000 hrs)</td>
<td>Inefficient to operate</td>
</tr>
<tr>
<td></td>
<td>mercury vapors</td>
<td>Low initial cost</td>
<td>Light output drops over life (2-3 yrs)</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>Delayed hot restart</td>
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Advances in HPS lamp technology have led to the development of a new color corrected HPS lamp. Color corrected HPS lamps are made by using optical coatings. However, the coating frequently gets burned out. Even with a greatly improved CRI of about 80, the color corrected HPS lamp delivers yellow light for lengthy periods of time when the bulb is switched on. It is not as white as the Metal Halide. It has also been reported that the color coating becomes ineffective about halfway through the life of the lamp.

LED technology offers a long life while using the least amount of power as compared to other conventional light sources and therefore has been increasingly favored by energy conscious communities. Additional advantages of LED-based lighting sources include high luminous efficacy and higher CRIs.
Poles

There are generally five types of pole materials used for luminaire support – Steel, Aluminum, Fiberglass, Concrete, and Wood. The advantages and disadvantages of each are discussed in Table 3. Arlington County typically uses aluminum and fiberglass poles.

<table>
<thead>
<tr>
<th>Pole Type</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel Pole</td>
<td>- High strength to accommodate several pieces of equipment</td>
<td>- Electrically conductive</td>
</tr>
<tr>
<td></td>
<td>- Electrically conductive</td>
<td>- Heavier to ship to job site than either aluminum or fiberglass poles</td>
</tr>
<tr>
<td>Aluminum Pole</td>
<td>- Good quality appearance. Fluting and other details are easy options to add</td>
<td>- Electrically conductive</td>
</tr>
<tr>
<td></td>
<td>- Lighter than steel poles</td>
<td>- More difficult to install than fiberglass due to anchor base</td>
</tr>
<tr>
<td></td>
<td>- With good-quality multi-stage paint finish in factory, corrosion is</td>
<td></td>
</tr>
<tr>
<td></td>
<td>minimal (especially when low-copper aluminum alloy is used)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Moderate cost</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Aluminum has scrap value at the end of its life</td>
<td></td>
</tr>
<tr>
<td>Fiberglass Pole</td>
<td>- Does not require waiting for concrete to cure.</td>
<td>- Needs to be painted about every 15 years due to color fading over time</td>
</tr>
<tr>
<td></td>
<td>- Some fiberglass poles are available to mount to an anchor base</td>
<td>- Base of fiberglass poles gets damaged by mowers etc</td>
</tr>
<tr>
<td></td>
<td>- Scratches are less noticeable if solid-core fiberglass materials are used</td>
<td>- If not stored carefully, heat can warp the pole</td>
</tr>
<tr>
<td></td>
<td>- Lower cost option than metal poles</td>
<td>- Cheaper and less durable in appearance than metal poles</td>
</tr>
<tr>
<td></td>
<td>- Electrically non-conductive</td>
<td>- Texture looks unmetallic if standard paint finish is applied</td>
</tr>
<tr>
<td></td>
<td>- Corrosion resistant</td>
<td>- Needs smooth paint finishes to get rid of turn marks</td>
</tr>
<tr>
<td></td>
<td>- Lighter, less expensive to ship to sites</td>
<td>- Improper installation may lead fiberglass direct-buried poles to lean</td>
</tr>
<tr>
<td></td>
<td>- Above ground hand hole or access door facilitates maintenance activities</td>
<td></td>
</tr>
<tr>
<td>Concrete Pole</td>
<td>- Durable, non-corroding</td>
<td>- Non-traditional (non metallic) appearance</td>
</tr>
<tr>
<td></td>
<td>- Electrically non-conductive</td>
<td>- Hard to add accessories such as banners or signs. Requires stainless steel</td>
</tr>
<tr>
<td></td>
<td>- Easy, direct burial installation</td>
<td>bands around the pole unless pole is predrilled for these attachments</td>
</tr>
<tr>
<td></td>
<td>- Color options available</td>
<td>- Limited number of appearance options (beyond color and aggregate type)</td>
</tr>
<tr>
<td></td>
<td>- Can function as a barrier against vehicular traffic for pedestrians,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>but will not breakaway if struck by vehicle</td>
<td></td>
</tr>
<tr>
<td>Wood Pole</td>
<td>- Lowest installed cost</td>
<td>- Appearance not appropriate for urban corridors</td>
</tr>
<tr>
<td></td>
<td>- Easy to install and maintain, flexible, resilient, strong</td>
<td>- Lower strength than other poles</td>
</tr>
<tr>
<td></td>
<td>- Natural, renewable materials</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Decades of good performance</td>
<td></td>
</tr>
</tbody>
</table>
Photosensor
A photosensor turns a streetlight on at low light levels, such as in the evening, and turns it off when it is exposed to a certain light level and above, such as in the morning. There are two types of photosensors - button-type and twist-lock. A button-type photosensor must be installed inside the luminaire and is mostly assembled in the factory since it is difficult and time-consuming to install in the field. A button-type photo sensor has a higher failure rate than twist-lock sensor. The County mostly uses twist-lock sensors. For cobras, twist-lock photosensors are installed on the luminaire itself, but for teardrops, it is installed on the bracket adapter.

Streetlight Central Management System (CMS)
Wireless devices report fixture status to a remote central monitoring system via gateway or mesh network field devices. With the availability of modern technologies, Arlington County is using CMS for efficient operation and maintenance of streetlights.

Light Distribution Patterns
The IESNA establishes a series of lateral distribution patterns, designated as Types I, II, III, IV, and V. Types I and V represent symmetric lighting distribution, and the light poles are typically mounted over the center of the roadway. Types II, III, and IV are asymmetric distribution patterns, and the light poles are generally mounted near the edge of the roadway.

Type I applies to rectangular patterns on very narrow streets; Type II to narrow streets; Type III to streets of medium width; Type IV to wide streets; and Type V to areas where light needs to be distributed evenly in all directions. These are illustrated in Figure 4.

Figure 4: Light Distribution Patterns
Pole Placement Configurations

Light pole placement is a vital part of an effective street lighting design. The luminaires are mounted at a given height above the roadway, depending on the fixture output, adjacent land use, and roadway characteristics. Roadways with no medians may have the light poles installed at a “house-side” location. This can be further described as a “one-side” system, a “staggered” system, or an “opposite” system, depending on how the light poles are placed with respect to each other. Roadways with wide medians and barriers may have the light poles installed on a “median lighting” system. This provides efficient lighting at a lower cost due to savings in luminaire supports and electrical conductors. Light poles can be placed in various configurations as shown in Figure 5.

Figure 5: Light Pole Placement Configurations
TABLE 4: COMPARISONS OF LUMINAIRE CUTOFF TYPES

<table>
<thead>
<tr>
<th>Cutoff Option</th>
<th>Features</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
</table>
| Full Cutoff   | - Light distribution with zero candela (intensity) at an angle of 90° or above | - Reduction in 'sky glow'  
- Best option for light control at ROW/property line  
- Restricts light spill  
- Reduces perceived glare | - Reduces pole spacing and increases number of poles  
- Least cost effective of all cutoff options  
- Concentrated down light component leads to maximum reflected uplight  
- Decreased uniformity due to higher lighting levels under the fixture |
| Cutoff        | - Light distribution where candela per 1000 lumens is ≤ 25 (2.5%) at an angle of 90° or more  
- Candela per 1000 lamp lumens does not exceed 100 (10%) at 80° vertical angle  
- 0% - 16% uplight | - Slight increase in high-angle light compared to full cutoff  
- Good light control at ROW/property line  
- Potential for increased pole spacing and lower overall power consumption as compared to full cutoff | - Potential for uplight  
- Less light control at ROW/property line than full cutoff  
- Higher amount of light reflected off pavement could lead to sky glow |
| Semi-Cutoff   | - Light distribution where candela per 1000 lumens is ≤ 50 (5%) at 90° angle or above  
- Candela per 1000 lamp lumens is ≤ 200 (20%) at 80° vertical angle  
- 1% - 32% uplight | - Potential for increased pole spacing and lower overall power consumption as compared to full cutoff  
- Used for high angle lighting for taller surfaces  
- Less light reflected off pavement than cutoff fixtures | - Greater potential for direct uplight and sky glow than cutoff  
- Potential light trespass concern near residential areas  
- Increased high angle light compared to cutoff |
| Non-Cutoff    | - Light distribution has no candela limitation at any angle  
- No restriction on uplight | - Potential for increased pole spacing and lowering overall power consumption as compared to cutoff  
- Used to accent taller surfaces  
- More vertical illumination  
- Leads to excellent uniformity  
- Least amount of light reflected off pavement  
- Better vertical surface visibility | - Greater potential for direct uplight component than cutoff  
- Least control of uplight - causes sky glow  
- Increased high angle light compared to cutoff |

Cutoff Fixtures
It is imperative to control the light flux emission distribution above the beam of maximum candela power. At higher vertical angles, light flux emission contributes considerably to increased pavement brightness, disability, and discomfort glare. The light flux emission above the beam of maximum candela power needs to be controlled to achieve balanced performance. Figure 6 compares a full cutoff fixture with a cutoff fixture. The categories of control are presented in Table 4 with facts, advantages, and disadvantages of each option.

Figure 6: Comparison of Full Cutoff Versus Cutoff
Frequently Asked Questions
Below are some frequently asked questions and answers based on technical and industry resources and recent community experiences:

Question: Why do we need street lighting?
Street lighting is an integral part of roadway infrastructure. Street lighting is used in urban settings, downtown areas, residential neighborhoods, mixed-use districts, industrial parks, highway interchanges, and rural intersections. Good street lighting illuminates the roadway for all users and contributes to the safe movement of all modes (vehicles, pedestrians, and cyclists). In simpler terms, lighting reduces the chance of personal injury by allowing roadway users to view their surroundings and be seen by others. It also enhances the aesthetics of an area and promotes business during evening and nighttime hours. According to the American National Standard Practice for Roadway Lighting, street lighting provides four primary functions:

- Reduction in night accidents, preventing personal injury and economic loss
- Aid to police protection and enhanced sense of personal security
- Increased facilitation of traffic flow
- Promotion of business and the use of public facilities during the night hours

Question: What are the applications of different light pole types?
Different areas of a community have distinct requirements for street lighting. Along a main street in a downtown area with businesses operating in the evening, major safety concerns may include sidewalks, crosswalks, on-street parking, and intersections. The area needs to be illuminated to provide safety for pedestrians and bicyclists, vehicles traveling down the street, and vehicles entering and exiting parking spaces. In the Rosslyn-Ballston or Crystal City corridors, characterized by multiple crosswalks and a high volume of vehicle and cycle traffic, a driver or pedestrian has multiple moving objects to navigate through. Research suggests that for these areas, identified by multi-modal traffic or conflicting modes, the best illumination sources are short light sources that illuminate objects horizontally. This feature is typically seen with post-top fixtures. A community can create a vibrant atmosphere in an area by using aesthetic lighting. Such an area may need to be illuminated to a higher level for safety, and decorative light poles may be a consideration. The main concern along major roadways through the community is safety for vehicles, pedestrians, and cyclists. Cobras are more suited to illuminate such wider cross-sections of roadways because they illuminate objects vertically. On local, low speed roads in residential areas, lower light levels may be sufficient for safety and security due to limited traffic and pedestrians at night.

Question: How does street lighting affect light pollution and dark skies?
There is a balance between improving safety through street lighting and providing a pristine dark environment in urban communities. The effect of lighting on the environment and health of humans and wildlife has been scrutinized in recent years. The Dark Sky movement calls for attention and countermeasures to light pollution. Arlington is conforming to this concept and seeks light pollution control through the SMP. Chapter 3 of this document specifically addresses light pollution through the lighting standards.

Satellite images of North America show significant amount of light directed or reflected upward at night. Populated areas are distinctly visible from outer space due to the glow of artificial lights. It is important to note that light pollution is typically unavoidable because, in addition to streetlights, the urban night environment is illuminated by lighting from various sources, including parking lots, buildings, and car headlights. However, uplight, which can contribute to light pollution, can be controlled by using luminaires, like cobras and post-tops, equipped with uplight shields.

Question: How will the County address glare issues from the streetlight luminaires?
In the past, some of the old streetlights used to have clear lens. Those luminaires were retrofitted with LEDs without changing the globe causing glare issue for post-top fixtures. Since then, the County has adopted the use of prismatic lens for post-top fixture which significantly reduces the glare. The LED industry has also evolved to provide better diffusion and less concentrated light distribution, which reduces glare.

Question: What is the County doing to improve customer service on streetlight outages?
Dominion Energy (DE) Streetlights: As discussed in the subsequent sections, customer service levels for DE owned streetlights are mainly governed by the Virginia Energy Purchasing Governmental Association (VEPGA) agreement. Since the agreement is periodically renewed, staff are constantly renegotiating terms and conditions for improved customer service that is optimally balanced with the new rate DE proposes to charge. The County intends to add clauses to the agreement to ensure that DE’s service level, with respect to streetlight repair issues, is more favorable to the County.

Arlington County Streetlights: The County street lighting program went through a period of inventory growth where maintenance staffing was not adequate to provide timely repairs. In the FY 2018 budget process, both additional funds and staffing were added to the program resulting in the improvement of the County’s response time. The County is also working to develop better tools so that customers can easily report outages and view work progress updates.

Question: How do light exposure levels from street lighting compare with those from other sources?
Light at night can disturb the circadian rhythm that the human body is designed to follow. Research is still underway to determine any links to negative health impacts. As discussed in Appendix A, exterior lights can also play a role if exposed to high intensity lights for long durations. Potential health concerns are primarily driven from indoor lights in homes and workplaces. Even though LED lights have been labeled as unique, a study by the Department of Energy shows that all light sources have some or very comparable levels of relative melanopic content (biological response to light). Therefore, trying to keep one’s daily routine as close as possible to day and night cycles is the best way to reduce negative impacts.
Arlington County Street Lighting Philosophy

Street lighting contributes to the quality of life of Arlington County residents by providing safer streets at night. Increased roadway lighting can prevent accidents and crime and improve nighttime driving conditions. Aesthetic features of street lighting also contribute to a vibrant neighborhood atmosphere.

Public street lighting is critical in urban areas like Arlington. The need can be classified into four major categories: traffic and pedestrian/cyclist safety; crime deterrence; promoting economic activities during night; and aging driver considerations. The purpose of street lighting is to provide improved visibility for the various street users and facilities along the roadway. Past research has found that street lighting, in general, can reduce night crashes by about 30 percent.

The objectives of providing street lighting is to:

- Improve visibility of roadway objects for all roadway users including pedestrians and cyclists.
- Increase road user comfort and reduce apprehension.
- Improve user safety and comfort.
- Reduction in nighttime crash rates.
- Provide socioeconomic gains in urban areas.

The primary street lighting philosophy questions for Arlington County are:

- Should Arlington County address street lighting goals beyond safety and security? Should Arlington County use street lighting to improve the County’s appearance and image?
- If yes to both questions, how can this philosophy best be accomplished when Arlington County has varied neighborhood needs and preferences, and limited resources?
- How do we accommodate lighting needs for different age groups with different visual capacities?

The night driving environment is complex due to limited visibility, different roadway types, a higher volume of pedestrians and traffic, and the diverse array of drivers. The human eye is hindered by the amount of information-gathering required during night driving. As any driver can attest, automobile headlights can never provide the full lighting needed at night. Fortunately, the night driving environment can be made safer with the latest energy efficient, sustainable technology.

Street lighting also plays a key role in urbanized settings where vehicles, pedestrians and cyclists interact in often conflicting movements (such as crossing the road), in a limited right-of-way. Proper consideration should be given to enhance pedestrian-cyclist safety during the streetlight design process.

Current research indicates that lighting strongly boosts crime deterrence and adds to the perception of citizen safety. A perceived safety threat is as powerful as a real one. If people fear venturing out at night, that decision impacts the overall well-being of the community. Arlington’s Transportation Engineering & Operations Bureau (TE&O) works in coordination with the Arlington County Police Department to focus on specific areas needing prioritized improved lighting. Such systems do not necessarily reduce overall crime, but can deter it, by contributing to a perception of neighborhood safety.

The pictures on this page show examples of current County streetlights.
State of Lighting in Arlington County

Arlington County has the lowest resident drive-alone commute rate in Virginia. Forty-six percent of residents use non-single occupancy vehicle as their primary commute mode. Over 200,000 jobs are clustered around transit in Arlington’s high-density corridors. Hence, Arlington is not auto-centric. The County promotes walking, biking, and alternative modes of transportation. As a result, street lighting in Arlington is unique in addressing the needs of multi-modal users in the County.

Arlington County’s 1,059 miles of roadway are illuminated by approximately 18,500 streetlights as shown in Figure 7. Of these, some 7,350 are owned and maintained by the County and approximately 600 lights are owned and maintained by Virginia Department of Transportation (VDOT). The remaining 10,550 are managed by Dominion Energy (DE) (formerly known as Dominion Virginia Power (DVP)). A majority of the streetlights managed by DE are currently non-LED.

Accuracy of field data and asset management is very critical to manage the program efficiently. In 2017, the County decided to conduct a field test on a representative sample for accuracy of streetlight data. Field data collection was completed on approximately 1,000 streetlights owned by both the County and DE. The data verification included comparison against the County asset management database for different attributes including ownership, pole numbers, location, wattage, and color. The limits were along Wilson Boulevard and Clarendon Boulevard between North Fort Myer Drive and North Glebe Road and from Arlington Boulevard to Columbia Pike between Washington Boulevard and South Walter Reed Drive. This dataset was analyzed to update the GIS files and quantify the extent to which the information in the County’s and DE’s GIS files are up-to-date. Findings of this field study are detailed in Appendix B.

Although trail lights have some commonalities to streetlights, the unique application and design needs are substantially different than roadways. Therefore, trail lights are not currently part of this document.

Street lighting systems installed within Arlington County in the last 20 years are underground and in conduit. Most of the street lighting along the mixed-use corridors use underground conduit as standard practice.

All the County-owned streetlights are maintained by Arlington TE&O Bureau within the Department of Environmental Services (DES). The TE&O Bureau is divided into four functional groups.

In addition to the street lighting portfolio, DES has recently added additional responsibility of trail light maintenance using existing streetlight resources.
Existing Street Lighting Systems

Arlington County currently has a variety of lights in its street network. The majority of the County-owned streetlights in commercial and mixed-use corridors are post-tops or ‘carlyle acorn’ style. Certain areas, such as the form-based code mandated Columbia Pike corridor and the Crystal City-Pentagon area, use a combination of teardrop and post-top lights. A few neighborhoods have cobra streetlights and bridge underpasses are illuminated by wallpacks.

Post-Top
- Decorative in nature and appropriate for areas where public right-of-way is used by both vehicles and pedestrians.
- 85% of County-owned Post-top lights are LED lights that use less energy, need less warm up time, and are dimmable. The rest are HPS lights.
- Smart feature compatible with potential use for emergency management.
- Color temperature: 5500 degrees Kelvin for LED and 2700 degrees Kelvin for HPS.
- Shields or eyebrows help block the light from shining towards/on property, and redirects it to sidewalks.

Cobra
- Regarded as more functional than decorative.
- Normally installed on taller poles (25’ – 30’).
- Luminaire offsets from the pole.
- Provides vertical lighting
- Mixed inventory of LED and HPS.
- Color temperature: 4000 degrees Kelvin.
- Some are installed at signalized intersections as part of traffic signal configuration.

Teardrop
- Mainly used at signalized intersection on traffic signal poles in the Pentagon City, Crystal City, and Columbia Pike corridors.
- Helps provide significant illumination at the intersections for better visibility of pedestrians, cyclists and vehicles.
- Regarded as both functional and decorative.
- Normally installed on taller poles (25’ – 30’).
- All teardrop lights owned by the County are LED lights that are more energy efficient, and need less of a warm up period.
- Color temperature: 4000-4500 degrees Kelvin.

Wallpack
- Typically used for underpass lighting.
- Mixed inventory of LED and HPS lights.
- Color temperature: 4000 degrees Kelvin.

Dominion Energy Streetlights in Arlington

Dominion Energy (DE) also has different styles of streetlights within the County boundaries.

- Higher percentage of cobra and colonial luminaires in DE portfolio.
- Various pole types from wooden (distribution poles) to concrete, aluminum, and fiberglass poles.
- Higher percentage of High-Pressure Sodium (HPS) and Mercury Vapor (MV) streetlights.
- Began offering LEDs in 2018 with limited streetlight fixtures.
- No existing dimming capability.
- Reactive based system; no reporting system due to lack of a Central Management System (CMS).

Table 5 shows examples of the most frequently used streetlight styles owned by either Arlington County or DE. Field deployment may slightly differ from the pictures.

Table 5: Arlington County and Dominion Energy Luminaires

<table>
<thead>
<tr>
<th>Arlington County Outdoor Lighting Fixtures</th>
<th>Dominion Energy Outdoor Lighting Fixtures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Carlyle (Acorn)</strong></td>
<td><strong>Carlyle (Acorn)</strong></td>
</tr>
<tr>
<td><strong>Cobra</strong></td>
<td><strong>Cobra</strong></td>
</tr>
<tr>
<td><strong>Teardrop</strong></td>
<td><strong>Cobra</strong></td>
</tr>
<tr>
<td><strong>Wallpack</strong></td>
<td><strong>Colonial</strong></td>
</tr>
</tbody>
</table>
Central Management System (CMS)
- Only applies at this time to ornamental carlyles (85% of County lights).
- Dedicated radio frequency based system.
- Includes a master antenna and a set of four repeaters.
- Provides fixture dimming, operational status, energy reporting, and alerts for proactive maintenance.
- Three zones for dimming levels: residential, mixed-use, and commercial.

CMS User Interface

CMS Logic Diagram

INETRANET

INTERNET

RF BASE STATION

USB

REPEATER ZONE 1

STREETLIGHTS

REPEATER ZONE 2

STREETLIGHTS

REPEATER ZONE 3

STREETLIGHTS

REPEATER ZONE 4

STREETLIGHTS
Street Lighting Funding

The County streetlight system is supported by the County’s general CIP funds for major and minor streetlight repairs. Figure 9 shows the County’s street lighting operating expenses from 2008 through 2018. In the past, the street lighting program was underfunded and understaffed. In recent years, the budgeted funding and actual expenditures have marginally increased year-to-year with a net increase of approximately 2,000 streetlights in the last six years.

Figure 10 shows the County’s street lighting inventory from 2011 through 2017. The street lighting inventory has increased year-to-year with a net increase of approximately 2,000 streetlights in the last six years. The increase was significant between 2011 and 2014 due to several CIP projects and site plan developments by developers. There was nominal increase after 2014 due to a reduction in major streetlight projects.
Street Lighting Maintenance

Arlington County receives public complaints through various sources such as PublicStuff (County’s Report A Problem application), social media, email, and phone calls. Figure 11 shows trouble calls by agency. It is based on calls from April 1, 2017 to April 1, 2018. DE may have many more trouble calls than recorded since not all are routed through the County call center or PublicStuff.

As a proactive measure, Arlington County’s ITS program performs a yearly streetlight survey. The survey is conducted annually around the last quarter of the calendar year. Every streetlight located within the public right-of-way throughout the County is surveyed regardless of streetlight ownership. Outages, damaged streetlight poles, and missing or damaged identification tags are recorded. The results from this survey enable the streetlight team to proactively perform the required repairs and upgrades to maintain Arlington County streetlights. In 2017, the streetlight team utilized the County’s existing problem reporting tool, also known as “PublicStuff” (PS), to record the results on-site. This team accomplished several important achievements:

- Recorded observations onsite (pictures, pole number, geolocation).
- Streamlined recording and tracking of issues.
- Reported progress and daily results.
- Recorded true location of the issue using GPS capabilities of the application.
- Identified, recorded, and reported streetlight poles with damaged and/or missing identification tags.
- Recorded geolocation of streetlights to compare to the County’s current GIS data base.
- Recorded data are available for setting accurate performance measures and expectations.
- Further analysis of recorded data overtime will directly influence the County’s ongoing asset management plans and decisions.

Preliminary data from the 2017 streetlight survey shows that by the end of year 2017 there were 972 streetlight related issues:

- 757 issues related to lights maintained by DE.
- 208 issues related to lights maintained by Arlington County.
- 7 issues related to lights maintained by VDOT.

Based on the survey results, 95% of the 18,000 streetlights that the Transportation Engineering and Operations Bureau is responsible for are in service, and free of physical damages. According to a 2016 analysis of all phone complaints received by the County within the prior three years, 97% of the trouble calls were made for outages or pole issues.

The County has significantly improved customer service after 2016 due to additional funding and an increase in staff resources. The Table 6 below shows the improvements in response times after the increase in resources. There is still room for improvement to meet community expectations.

TABLE 6: AVERAGE RESPONSE TIME FOR COUNTY STREETLIGHTS

<table>
<thead>
<tr>
<th>Measures</th>
<th>FY 2017 Actual</th>
<th>FY 2018 Actual</th>
<th>FY 2019 Estimate</th>
<th>FY 2020 Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Response Time (Days) for Major Repairs</td>
<td>120</td>
<td>45</td>
<td>60</td>
<td>45</td>
</tr>
<tr>
<td>Average Response Time (Days) for Minor Repairs</td>
<td>30</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
</tbody>
</table>

Dominion Energy (DE) Customer Service

DE owns approximately two-thirds (11,150) of total streetlight assets in the County and is, therefore, a key player in providing good customer service to streetlight outages. DE’s performance and service delivery arrangements are governed by the agreement between DE and Virginia Energy Purchasing Governmental Association (VEPGA). VEGPA consists of municipalities, school systems, sanitation districts, jails, and others throughout the Commonwealth of Virginia. Staff periodically negotiates for better service delivery terms with DE through VEGA negotiation teams. The County is one of the 15 members on the VEGA board.

The agreement between DE and VEGA is re-negotiated every three to four years. As of 2018, DE has a certain number of days to repair outages depending upon the problem: 11 days for overhead issues, 15 days for cable repair, and 45 days for cable replacement. After this period, DE is not allowed to bill the County until the reported streetlights are repaired.

The frequency of streetlight outages is higher due to the installation of direct buried cables. DE’s customer service has been satisfactory for minor repairs, but when it comes to major repairs, there is room for improvement. The County is pursuing to add a clause in the upcoming VEGPA contract to improve DE’s response time for prolonged streetlight outages related to underground cables.

Recently, DE and VEGA provided an attractive flat rate for the conversion of DE streetlights to LED. This was made possible by concerted efforts by local jurisdictions in Northern Virginia with the discussion led by Northern Virginia Regional Council (NVRC) and support from VEGA. Elected officials from the Northern Virginia Regional Council communicated with DE’s corporate leadership and staff from these jurisdictions engaged on technical details of DE’s streetlight products and terms and conditions. Arlington County was instrumental in engaging with DE to enhance their LED offerings. Due to persistent engagement, not only has Arlington invested in LEDs, but also generated support in the regional context to bring more LEDs to urban streetscapes. Arlington County has successfully negotiated with DE to lower the rate for LEDs, which has, and continues to lead to significant cost savings.
CHAPTER II – ARLINGTON COUNTY STREET LIGHTING BACKGROUND

Electrical Consumption
Arlington County uses approximately 90 million kWh of electricity per year on government activities, excluding school buildings. Out of the 90 million kWh total, streetlights alone use approximately 13.5 million kWh with the traditional (HPS and MV) light source for all the streetlights within the County regardless of ownership. This is approximately 15% of total government operations in electrical consumption by the streetlights.

Currently, the County pays a $1.5 million flat fee for DE owned streetlights (11,150) that includes electricity, maintenance and capital replacement. Similarly, the County pays $250,000 (for 7,350 streetlights) to DE for electrical consumption. Any expenses related to maintenance and capital replacement is part of the County’s general fund, pay-as-you-go (PAYG) capital, or general obligation bonds.

LED and Emission Reduction
In Virginia, a significant majority of electricity is still generated using fossil fuels. While the year-to-year change in distribution of energy sources has been changing gradually as DE changes its generating plants, the use of fossil fuels for 60% of electricity consumed should concern any entity that wants to reduce greenhouse gas emissions.

Greenhouse gases produced during the generation of electricity to power the County’s streetlight inventory was 6 million pounds. The number was reduced to 1.5 million pounds after the conversion of streetlights to LEDs. The County strongly believes in environmental stewardship and therefore has targeted aggressive carbon emission reduction targets. Adopted in 2013, County’s Community Energy Plan states:

Arlington County has set a carbon emissions target of 3.0 metric tons of carbon dioxide equivalent (CO2e) emissions per capita per year by 2050, to match current emissions world benchmark cities such as Copenhagen. CO2e emissions are used as a proxy for energy productivity. The Plan establishes the framework for reducing greenhouse gas (GHG) emissions in the County from 2007 carbon emissions level of 13.4 mt CO2e/capita/year, a reduction of over 70%.
LED Conversion of Streetlights

Arlington County started using intelligent LED streetlights in 2010. The County received federal grants under the American Recovery and Reinvestment Act (ARRA) to install LED streetlight technology. These streetlights were installed as a pilot project in the Courthouse area in 2010, and also implemented corridor-wide on Columbia Pike in 2014. Since then, 85 percent of County-owned streetlights have been converted to LEDs.

Figure 13 shows the timeline of the smart street lighting system in Arlington County. Arlington County's current central management system (CMS) provides programming of lights based on time of day and type of area (commercial or residential).

The County saw a reduction of approximately 75 percent in power consumption in comparison to traditional technology after the LED conversion.

Reduction in electric consumption was one of the main reasons that the lighting industry was pushed to develop LED in street lighting application. As shown in Figure 14 on the next page, after all County streetlights are converted to LEDs, the power consumption would be reduced from approximately 5 million kWh to 1.1 million kWh. Since the County has been one of the early adopters of dimming technology, savings in electrical consumption was further realized from dimming. Therefore, the total savings is more than 80% or total of 3.9 million kWh savings in electrical consumption per year. This is equivalent to the annual electrical consumption of more than 300 residential homes.

The overall cost to convert the old streetlight inventory from HPS or MV to LED technology was $4.5 million dollars. In 2010, a cost-benefit estimate of converting HPS streetlights to LED was made based on roughly 6,000 County-owned lights. If the program was fully resourced, the annual maintenance cost for HPS lights would be $1.2 million versus $500,000 for LED. This translates to a payback period of approximately 6.5 years for LED conversions.

In 2010, the LED lights were available only in the high color temperature range. The product used by the County was 5500° Kelvin. The installation of 5500° Kelvin LED streetlights were generally well accepted in mixed-use and commercial corridors. However, in the residential areas, the County received multiple complaints about the new LEDs. There was a trend of a higher number of complaints in areas where there were previously no streetlights or if the existing streetlights were obsolete and giving off minimal light. After receiving feedback from County residents, the County began use of shielding, using prismatic lenses to reduce glare, and initiated extensive public outreach, including mandatory field technology demonstrations, for all new lighting projects. This approach was very effective to significantly reduce the number of complaints. In a 2016 analysis of all phone complaints received within the prior three years by the County, only 2% of the calls were made regarding the LED technology.

Figure 13: Timeline of Smart Street Lighting Pilot Project
Metering of Streetlights

All streetlights owned by the County are metered. There are more than 400 meters and the County pays approximately $250,000 per year to DE for the electrical consumption. A few decades ago, streetlights installed by developers were powered from the inside of private buildings which created significant maintenance access issues for repairs. The County is gradually separating such meters from private buildings and installing them in the public right-of-way.

Due to the flat overhead fee charged by Dominion Energy per meter and the high installation cost, it is very desirable to use existing meters where practical. County staff are working on consolidating under-used meters and connecting any new proposed lights to nearby existing streetlight meters. This is possible due to very energy-efficient LED technology since the same meter can handle several more LED streetlights compared to their predecessor due to their low power consumption. All existing meters are populated in GIS as shown in Figure 15.

Streetlight Project Delivery

Currently, lighting installation projects are delivered through multiple channels. The County has Capital Improvement Projects (CIP) that mainly invest in highly-travelled corridors. These projects are generally of high dollar value and streetlights often are part of larger projects with multiple roadway improvement components. Under certain circumstances, standalone CIP projects would install new streetlights. In most mixed-use corridors, developers install streetlights as part of the development on the frontage of parcels being developed. VDOT, through its CIP projects, installs streetlights on VDOT maintained roadways. After completion of VDOT projects, these streetlights are handed over to the County for ownership and maintenance responsibility. Small scale residential area lighting improvement projects are also delivered through the Neighborhood Conservation (NC) Program.
As-Built Drawings

Historically, record keeping of the constructed lighting plans was not done for a majority of projects. This was an industry-wide problem. In recent years, an awareness around the importance of ‘as-built’ drawings have increased. Due to the lack of as-built drawings, there is little knowledge of where electrical circuits are routed, which impacts the staff’s ability to diagnose and repair any malfunctions. Recently, staff has been collecting old drawings and digitizing them to overlay in the County’s GIS system to better assist the County’s repair staff and the designer community. The County has also introduced mandatory as-built drawing submissions for all streetlight projects.

Maintenance Friendly Equipment

The County constantly updates its standards and practices in lighting installations to: help promote the safety of workers and the public; minimize operation costs; and improve maintenance costs. The Hand-Off-Auto switch is installed with meters so that technicians can manually turn the streetlights on, off, or to automatic. This is an example of how technology helps staff troubleshoot more efficiently. Instead of having to wait until dark (when lights are turned on by a photocell) to see if a light is working, this feature allows staff to check to see if there are any issues during the day. The current standard practice of installing electrical cables only in conduits will help to make repairs significantly easier. Furthermore, by ensuring the installation of junction boxes at each corner and every certain number of feet, maintenance will be easier.
The primary street lighting philosophy questions for Arlington County are:

- What are the guiding principles for the street lighting program?
- How can Arlington County further implement and sustain a well-planned street lighting system?
- What is the optimal balance of ownership of streetlights between the County and Dominion Energy (DE)?
- How will the streetlight management plan balance road user safety, construction cost, aesthetics, and operation and maintenance expenses?

**Vision, Goals, and Guiding Principles**

Arlington County's street lighting vision is to implement lasting and innovative street light technology with maintainable infrastructure to promote a safe and sustainable community for pedestrians, cyclists, and motorists.

The goals of Arlington County's street lighting program are to:

- Provide safety for nighttime traffic operations.
- Provide a safe and secure environment for pedestrians and cyclists.
- Provide a street lighting plan that is consistent with the Illumination Engineering Society and Federal guidelines.

Below are guiding principles that support the County’s vision and goals for street lighting.

**Safety and Accessibility**

The diversity of roadway users (pedestrians, cyclists, etc.) results in a complex roadway environment that is amplified by the limited lighting conditions at night. In addition to safety, accessibility is a particularly important aspect, as the County heavily promotes other non-vehicular modes of transportation that are not equipped with lighting. Street lighting must also address lighting requirements for pedestrians and cyclists for a given roadway.

There are several factors that impact public safety and accessibility at night. Lighting works as one of many contributors to a safe environment, which shall be the most critical program goal of street lighting.

**Intelligent System Management**

Innovative technology that offers more advanced features in operation and maintenance will continue to be one of the major criteria in the street lighting program. Arlington County has installed an intelligent, energy efficient LED lighting system. The smart central management system will be used to help remotely monitor streetlights, generate reports on energy and other system performance measures, trigger malfunction alerts for proactive maintenance, and facilitate emergency management. The smart streetlight system can also work as backbone infrastructure for smart cities initiatives in the future.

**Sustainability**

Sustainability will continue to be a priority in several aspects of the street lighting program. Characteristics that can be monitored to achieve the sustainability goals of the streetlight network include: electric consumption, products used, and the operation and maintenance process. Given the inventory as of 2018, all streetlights in Arlington County, including those owned by DE and VDOT, would have consumed 13.5 million kWh of electricity per year with the use of older technology. Appropriate lighting technologies are critical to minimize electricity consumption. This results in reduction of greenhouse gas emissions and carbon footprint. A careful consideration shall be given to uplight during the streetlight design and product specification.

**Compatibility**

Lighting systems shall be able to provide the lighting levels needed for the various roadway environments and for all modes of transportation on those roads. Additionally, the system must be compatible and consistent with the streetscape of the environment. This includes maintaining effective lighting levels when mature streets trees interfere with lighting. Lighting and street tree selection and placement should be done in an integrated manner to prevent future lighting challenges as tree canopies mature.

**Maintainability**

Efficient street lighting systems are easier to install with minimal maintenance and have longer life spans. Maintenance shall be a primary consideration during the selection of lighting products as the County storage space is limited for streetlight equipment. Maintenance also helps streamline repairs for streetlight technicians due to less variations in street lighting equipment. A consistent standard helps keep maintenance costs low. Streetlight installation will follow standard methods. For example, the installation of cables will be in conduits. Such methods will simplify repair efforts.

**Cost Effectiveness**

It is important for street lighting systems to have lower operational and lifecycle costs. Arlington County's payback of investment on the LED street lighting system is less than 6.5 years. A cost effective streetlight system will include a limited variety of products with the least life-cycle cost with environmental considerations that include the cost of production, operation, and disposal at the end of life. Additionally, proactive reporting of malfunctions and a well-established maintenance protocol will reduce the maintenance cost.
Street Lighting Ownership Approach

Streetlights in Arlington County are owned by the County, Dominion Energy (DE), and Virginia Department of Transportation (VDOT) respectively. This mix has resulted in multiple streetlights with different owners on the same roadway section causing major operational and maintenance challenges. This report explores options to streamline the ownership mix to alleviate the operational and budgetary challenges. Financial analyses were performed to evaluate the most cost-effective ownership model for the best customer service.

Three specific scenarios of ownership were considered. The first scenario involved full streetlight ownership by DE, the second involved full streetlight ownership by Arlington County. Both assumed a complete removal of the existing system because prior experience in a pilot project showed that a full takeover in an “as-is” condition is subsequently very costly during repairs. The costs exhibited are only for budgetary purposes to calculate the order of magnitude in both scenarios as mentioned in Appendix C. Costs are calculated based on current present value, not taking inflation and other economic factors into consideration.

Scenario 1 – 100% DE Ownership

This scenario includes the removal of all existing County streetlights and the installation of DE streetlights as per DE standards. As shown in Appendix C, this scenario is estimated to cost between $60 million to $80 million as of 2017. The total cost with annual escalation is not calculated due to the uncertainty of the implementation timeframe.

Benefits

Ownership: DE would be the single owner, simplifying the reporting of streetlight malfunctions.

Budgeting: The streetlight budget will be relatively predictable based on the flat fee (fixed price per pole) of the existing DE contract.

Capital maintenance funding: Reduction in County’s capital maintenance funding request as DE will be responsible for capital maintenance.

Staffing: County’s street lighting staff can be reallocated to other priority programs.

Drawbacks

Cost: The cost is very high compared to the current $2.5 million per year CIP budget for the street lighting program.

Decision making: The County would not have control of maintenance/priority projects.

Sustainability: No dimming capability and no proactive reporting available for DE streetlights at this time.

Scenario 2 – 100% County Ownership

Existing DE streetlights would be removed and County-owned streetlights would be installed. This scenario is estimated to cost between $100 million to $120 million as of 2017.

Benefits

Ownership: Total County ownership will simplify reporting streetlight malfunctions.

Maintenance: The County would have control of maintenance and could quickly adjust repair priorities as needed.

Drawbacks

Cost: The cost is very high compared to the current $2.5 million per year Capital Improvement Plan (CIP) budget for the street lighting program.

Staffing: The County would need to significantly increase staffing and the operational budget for the program.

Capital maintenance funding: A larger separate capital maintenance budget would be required, since capital maintenance will be the sole responsibility of the County.

Warehousing: Currently, storage of equipment is a major challenge in the County’s street lighting program. A total ownership by the County would require Arlington to significantly increase warehouse capacity.

Both scenarios involve investing tens of millions of dollars, which is cost prohibitive relative to the anticipated available budget for the foreseeable future. Additionally, total ownership by either party may not be a worthwhile investment from the customer benefit standpoint. Under Scenario 1 - total DE ownership, significant service level improvement is only possible after DE and VEPGA negotiate prices and service level agreements. In Scenario 2 - total County ownership - the County service level will not increase until a significant amount of resources are added to operations and maintenance. A preliminary budget calculation shows that Scenario 1 will take upward of 30 years to accomplish at the current CIP funding level. Likewise, Scenario 2 will take upward of 45 years to complete.
Scenario 3 – Blended Approach (Streetlight Districting)

Under this scenario, existing streetlights in the County would be divided into districts. This is the selected approach moving forward. The ownership district means that both DE and the County continue to own and maintain streetlights but in geographically demarcated areas referred to as “districts.” Figure 16 shows the proposed street lighting districts by ownership. All the streetlights in the shaded districts and highlighted corridors are to be owned and maintained by the County. These districts include Rosslyn-Ballston District, Columbia Pike District, Crystal City-Pentagon City Corridor and other selected roadway corridors.

Developed in close coordination with DE in multiple meetings, this concept was supported by DE. At the end of the ownership swap, the number of streetlights transferred between DE and the County is expected to be approximately equal.

Districting helps operations and maintenance efforts with clearly defined areas. The primary criteria for districting are:

- Streetlight footprint
- Land use and primary corridors
- Maintenance and operational needs

Benefits

Clear problem reporting: Staff can immediately identify ownership based on location and route work order requests to the appropriate owner, providing more staff time to actual repairs. With the help of public maps on districting, citizens themselves can make repair requests directly to the right entity, saving routing and administrative time, resulting in improved customer service.

Improved maintenance: An owner can repair its street lights without inadvertently damaging another entity’s streetlight infrastructure. This can be an issue with streetlights located in limited right-of-way areas.

Streamlined planning: Owner entities can plan and schedule routine repairs, technology upgrades, and independent testing without having to coordinate with the other entities.

Clear guidance to designers: For projects ranging from site plans to County roadways, project designers can look at the districting map and, based on the ownership of the streetlight, easily determine the type of light.

Visual aesthetics: A single owner on a given street or corridor will eventually result in a uniform streetlight type, providing a consistent, appealing look.

Drawbacks

Coordination: Extensive coordination will be needed, in many cases by a project-by-project basis, for the ownership transfer to be completed.

Planning and prioritizing: Because of the large number of mixed streetlights, planning and prioritizing will be a significant effort.

Cost: There is a cost associated with the ownership transfer.

Unknown factors: These include lack of information about pole ownership and how they are powered.

This option is expected to cost approximately $20 to $30 million over the next 10 to 20 years to complete should the CIP funding remain at the current level. This will be carried out in incremental fashion by fixing one area at a time as discussed in the Implementation of Districting section of this document. Since the proposed corridors for County ownership are in Site Plan districts, a major portion of rebuild is expected by developer contribution. Therefore, the time and funding obligation to the County could potentially be smaller depending on the timing of redevelopment.

Figure 16: Streetlight Districting Map
### Proposed Streetlight Districts and Selected Corridors

Arlington County’s Street Lighting Districting Map, shown in Figure 16, indicates a general boundary of the districting. Due to the technical complexity, the exact boundary of lighting between DE and the County will be determined through field investigations. Gradually, as findings are further refined, the map will be updated. Lighting types along some of the major corridors are:

- Dual arm black post-top lights along Rosslyn-Ballston Corridor arterial corridors and single post-tops on side streets.
- Cobra LEDs along Arlington Boulevard, Glebe Road, and George Mason Drive.
- Teardrop LEDs in the median and post-top on the sidewalk along Jefferson Davis Highway.
- Dual arm post-top lights along Columbia Pike and Lee Highway east of Glebe Road, and single post-tops on local streets.

The selected streetlight types for these corridors are for general guidance only. Any deviation from the default style shall be investigated and approved by a County Streetlight Engineer on a case-by-case basis. Factors to be considered in an exception could include roadway classification, width, and parking arrangement among others.

### Implementation of Districting

As discussed in the previous section, implementation of ownership by districting seems logical given the drawback of complete ownership by any single party. A gradual shift away from the existing disparate ownership system in an incremental fashion appears financially feasible. The County will maintain three districts. Other selected corridors are discussed below. Detailed calculations are shown in Appendix C. Ownership realignment will be done incrementally over the next several CIP cycles.

For upcoming new projects, any new installation or replacement of existing lights will be carried out following the concepts stipulated herein. Maintenance of each streetlight will be carried out by the current respective owner of the streetlight, regardless of district. Customers can continue to use the current Report-a-Problem tool to report any streetlight malfunction and County staff will direct requests to the appropriate entity.

Implementation of the districting concept will be carried out in two major ways. First, in County districts as shown in the bullets below, DE-owned lights will be replaced by County-owned lights. In DE districts, County-owned lights will be gradually converted to DE ownership.

- The selection of projects and specific implementation schedule shall follow engineering design, cost analysis and coordination with other capital and/or development projects.
- The entire streetlight conversion of the Columbia Pike corridor to County-owned is expected to cost approximately $1.6 million.
- The estimated cost to complete Crystal City-Pentagon City is approximately $600,000.
- Projects will also be created to transition County-owned lights to DE-owned lights in DE districts. The estimated cost is approximately $14 million to complete the ownership transfer.
- In DE’s streetlight district, the County’s priority is to manage new projects using the County’s lighting standards, but not introduce more mixed ownership. Generally, where the County owns lights in a DE district, such as carlyles installed via a Neighborhood Conservation project, no immediate changes are recommended. Ownership transfer is planned at the end of the useful life of the assets.

Additionally, DE-owned lights also will be converted to LEDs in two ways: first, DE is currently converting the existing older technology lights as part of their regular maintenance program as the luminaires fail. Second, the County will seek funding large scale conversions of older lighting technology to LED as funding allows. The second approach will be more systematic since the conversions will occur in a corridor based or neighborhood based approach.
Maintenance Plan

Proper maintenance of a street lighting system is crucial for reliability and performance. Best practices typically involve outage surveys, cable replacements, pole/fixture replacements, and proactive maintenance. A sound maintenance plan is crucial in sustaining the balance between growing inventory and life cycle of existing infrastructure. A continuous funding stream is needed to keep the system in good repair and meet community expectations.

While scheduling the replacement of 2.5% of the cable system each year is prudent from a planning perspective, some underground cable can remain in service for much longer than the 40 years of a full replacement cycle. However, delaying replacement of aging cable puts the utility at risk for sudden large-scale replacement needs in a period of time.

A best practice is to replace underground cable once an area of the circuit experiences more than two failures. Combining proactive replacement with a needs-based replacement program, Arlington County can keep its underground cable system in satisfactory condition and ensure reliable streetlight service for its residents. The 2.5% of the County’s inventory selected for replacement will be prioritized by age, unless replacement is needed due to damages as described above.

Arlington County should implement a program that visually inspect the entire street lighting system every 5 years, or 20% of the system annually. This inspection shall include the condition of poles, tree growth around the luminaires, junction boxes, and handholes to develop a list of repairs needed, if any. Maintenance actions are then programmed according to the findings. In cases where street lights are in conflict with tree canopies, selective tree trimming and modification of the luminaire may be appropriate to maintain safe lighting levels year-round.

Additionally, the County will also implement a policy to visually inspect during night hours for any malfunction of streetlights at least once a year. By default, the County will attend to all requests on a first-reported, first-repaired basis. However, priority will be given to high-activity areas such as schools, transit stations, commercial zones, or regions with multiple outages.

As part of Arlington County’s Street Lighting Management Plan, outdoor lighting managers from Boston, Cambridge (Mass.), Philadelphia and Seattle were interviewed regarding their maintenance practices. Detailed benchmarking data is provided in Appendix D of this report, including inventory, maintenance, staffing, and budget. The average statistics from these four cities are presented below:

- Maintenance staff = 0.8 per 1,000 streetlight poles
- Bucket trucks = 0.3 per 1,000 streetlight poles
- Trouble calls = 100 per 1,000 streetlight poles
- Response time = 1 day – 7 days (minor repairs); 7 days – 90 days (major repairs)
- Inventory stocks = 60 per 1,000 streetlight poles

Based on these averages, the following numbers are calculated for Arlington County’s 7,350-streetlight system for an average response time of 4.5 days. These minimum requirements are determined for the dedicated streetlight program.

TABLE 7: RECOMMENDED MINIMUM SUPPORT ENVIRONMENT FOR STREETLIGHTS

<table>
<thead>
<tr>
<th>Resource</th>
<th>Minimum Number Dedicated to Street Lighting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total maintenance staff</td>
<td>7</td>
</tr>
<tr>
<td>Manager</td>
<td>1</td>
</tr>
<tr>
<td>Engineer</td>
<td>1</td>
</tr>
<tr>
<td>Supervisor</td>
<td>1</td>
</tr>
<tr>
<td>Technicians</td>
<td>2</td>
</tr>
<tr>
<td>Inspector</td>
<td>1</td>
</tr>
<tr>
<td>Clerk</td>
<td>1</td>
</tr>
<tr>
<td>Bucket trucks</td>
<td>2</td>
</tr>
<tr>
<td>Inventory stocks</td>
<td>6%</td>
</tr>
</tbody>
</table>

It should be noted that the response time for streetlight maintenance depends on the type of repair to be made. Minor repairs, such as fixture replacements and pole knockdowns, can typically be addressed within two days after the problem is known by staff. However, issues associated with underground wiring, aging infrastructure of the electrical system, special orders for parts or poles, and inclement weather require longer response times. Typical industry response times for these are 14 days after knowledge of the outage.

As the County’s streetlight inventory grew, the program entered a period where operations and maintenance were under-resourced and thus the County’s response time was not up to community expectations. The County increased the staffing level and funding resources in the FY 18 budget process. Although the current lighting program resource level is below the industry recommended standards due to resource constraint, the County has made significant improvements on service level in comparison to historical performance. The annual performance level goal will be set based on the resource level and the asset volume for the long-term health of the system and service.

Per the Illuminating Engineering Society of North America (IESNA) Design Guide DG-4-14 - Design Guide for Roadway Lighting Maintenance, maintenance management systems for lighting assets should be considered. These systems would monitor critical functions of the luminaire and detect outages. They would plot the most effective route for maintenance crews, providing the specific maintenance action at each lamp. The IESNA Design Guide also states that personnel should be considered along with materials and equipment. Functions to be included are: program direction, operations supervisor, record keeping, inventory control, and service/troubleshooting. Additionally, all service vehicles should be equipped with sufficient tools, traffic safety devices, and cleaning equipment. Each vehicle should carry materials, ladders, lift platforms, and buckets appropriate for the luminaire mounting heights.

Record Management

A good record management system shall be in place with asset information. The asset information will be clearly maintained in geographical information system (GIS) with relevant attributes that are easily trackable both in the database and in the field. Maintenance staff will be provided access to the database so that they can update the system as they change attributes in the field.

A central work order management database will allow monitoring of real-time inventory while tracking costs for completed work orders. The system will also be capable of providing performance measurement data.
Virginia Energy Purchasing Governmental Associations (VEPGA) Role

As stated in Chapter II, street lighting services provided by Dominion Energy (DE) are defined in the agreement between DE and the VEPGA. The VEPGA consists of 169 jurisdictions including municipal governments, school systems, and sanitation districts. While other members of VEPGA may have different priorities and expectations, the Arlington community has a very high degree of service expectations due to the County’s unique urban and multi-modal transportation network.

Since the agreement is periodically negotiated every three to four years, it is critical that the County continues advocating for better service delivery terms. The County should continue to encourage VEPGA to include clauses that incentivize DE to improve its service level. Examples:

- As of 2018, DE has started offering a variety of LED streetlights as standard products. Further negotiations need to occur to ensure that the rates are feasible.
- As of 2018, DE does not share data regarding streetlight outages. A centralized web interface for all street light malfunctions for both the DE and County lights will be beneficial to promote transparency.
- DE does not currently have smart or control technology. It will be important for DE to add this as a standard product line to benefit from dimming and smart cities applications.
- Even though County-owned streetlights are capable to self-report malfunctions, DE streetlights do not have that capacity.

Light Pollution

Environmental stewardship is and will remain a priority for Arlington County. Similar to reducing electric consumption and thus reducing greenhouse gas emissions, minimizing light pollution is also very important for the County. Streetlight fixtures will meet specification to produce the least amount of uplight and perform optimally with respect to Backlight, Uplight, and Glare (BUG) ratings.

The County or Dominion Energy will install cobra luminaires for most residential streets and post-tops for mixed-use corridors. Cobra luminaires shine light downwards to the ground and have very minimal-to-no uplight. Post-top streetlights carry a historical value due to their aesthetical and inviting appearance but generally do have more uplight than cobra luminaires. A balance will be sought by installing internal light shields to prevent uplight. It is important to note that these uplight cutting treatments can only be applied at the luminaire level and do not account for surface reflectance. To prevent light pollution as a community, other significant measures may be warranted such as turning off or dimming sources of light installed in buildings, landscaping, parking lots, and elsewhere.

In all new installations, cobra and teardrop streetlights shall have less than 5% of uplight. Post-top streetlights shall be equipped with internal light shields to minimize uplight while keeping their aesthetic appearance as shown in Figure 17.

Recommendations

This management plan recommends the following regarding the street lighting vision:

- Implement the districting concept to reduce operational and maintenance challenges.
- Adopt a sustainable maintenance plan.
- Visually inspect at least 20% of all County-owned lights to include the condition of poles, tree growth around the luminaires, junction boxes, and handholes to develop a list of repairs needed, if any.
- Visually inspect all the lights during night hours for any malfunction at least annually.
- Schedule routine replacement of 2.5% of the underground cable system annually.
CHAPTER IV - STREET LIGHTING STANDARDS

The primary street lighting philosophy questions for Arlington County are:

- How can community groups, various County departments, and other agencies collaborate to promote consistent and satisfactory lighting and design practices?
- How should streetlight projects be selected?
- Do we define the County as an urban community, sub-urban community, or a combination of both?
- How should Arlington County maintain a balance between the County’s pole and luminaire inventory and the urban design goals for different land uses?

Streetlight Design Guidelines

These guidelines for street lighting can be used as a tool for engineering/design and the prioritization of street lighting projects. The Federal Highway Administration’s (FHWA) Roadway Lighting Handbook has a warranting system for highway and street lighting. The warrants include a major emphasis on the following geometric, operational, and environmental factors:

- Roadway Geometry
- Roadway Markings
- Channelization
- Intersection Location
- Driveway Access
- Pedestrian Activity
- Development and Adjacent Light Sources
- Elderly Drivers
- Tourism Attraction Proximity
- Average Daily Traffic

Roadway geometry refers to the physical characteristics of the roadway, including horizontal and vertical curves. Roadway markings, such as solid or dashed lines, delineate the paths for drivers and pedestrians. Roadway channelization includes raised medians or islands. They separate opposing traffic or divert traffic to a turning lane. Roadside objects and barriers such as utility poles, fire hydrants, and trees must be visible to the driver at night. In instances where a driver runs off the road, an illuminated section would lessen any damage that could occur. Roadway segments identified as safe routes to school and roadways leading to or near activity centers must be illuminated for safety reasons.

Additionally, when designing lighting plans, the effect of lighting on the driver’s vision must be evaluated. According to the FHWA’s Roadway Lighting Handbook or AASHTO Roadway Lighting Design Guide, a driver’s eye adjusts every time it experiences a lighting change. It takes longer for the eye to adjust from light to dark than conversely. The AASHTO Roadway Lighting Design Guide also specifies a transition lighting section when changing from one lighting level to another. Street lighting also plays a key role in urbanized settings where vehicles, pedestrians and cyclists interact in a limited right-of-way (ROW). Consideration shall be given to enhance pedestrian and cyclist safety during the streetlight design process.

IESNA TM-15-11 defines a classification system for outdoor luminaires. LED luminaires are classified with the Backlight-Uplight-Glare (BUG) system since LED luminaires do not have lamp lumen ratings. The traditional full cutoff, cutoff, and semi-cutoff classifications apply to high intensity discharge (HID) luminaires. Overly stringent BUG ratings can prevent uniform roadway lighting. For example, some amount of backlight is required to illuminate sidewalks. Post-top mounted luminaires typically have a certain level of uplight that provides additional lighting to the surrounding area.

Lighting zones reflect the base or ambient light levels desired by a community. The use of lighting zones (LZ) was originally developed by the International Commission on Illumination (CIE). It was introduced first in the US in the IESNA Recommended Practice for Exterior Environmental Lighting, RP-33-99. Per this definition, the mixed-use corridors in Arlington County, characterized by high vehicular and multimodal traffic, are considered to be LZ3 for moderately high ambient lighting. The residential streets are considered LZ2 for moderate ambient lighting.
CHAPTER IV - STREET LIGHTING STANDARDS

Lighting Levels

Arlington County streetlights will be properly designed following national guidelines and best practices for sound engineering. A systematic approach will establish a lighting system that best meets the needs of all modes of traffic, has a long life-cycle, and is easy to maintain. This policy document supports engineering specifications and standards developed and implemented by Arlington County (the most current version is available on the County website as Arlington County Streetlight Specifications and Standards). These standards are applicable to most projects on the public rights-of-way (ROW) and will exclude certain elements including transit stops, art structures, landscape lighting, and County parking lots. All other projects involving streetlights require photometric analysis, full engineering design, cost estimation, and County review/approval before project implementation. Situations may call for variation from the guidelines in this management plan, at the discretion of the Arlington County Streetlight Engineer. County inspection is required prior to the integration of new systems to Arlington’s asset management system.

Arlington County has adopted the guidelines of the American Association of State Highway and Transportation Officials (AASHTO) for lighting. AASHTO lighting criteria are backed by objective, national research-based photometrics of land use. Land use is defined based on zoning, site plans, and ordinances. AASHTO specifies illuminance level (lighting levels) on roadways depending upon the roadway classification and general land use.

Roadways are classified as arterials, collectors, and local roads as defined in the Arlington County Street Functional Classification map available on the County website. Land use is classified as commercial, mixed-use and residential. Roadway classification and general land use are related to pedestrian activity. For example, commercial areas typically have more pedestrian activity than most residential areas. The values for the various roadways and intersections are provided in the Arlington County Streetlight Specifications and Standards document. Intersection lighting levels are based on the functional classification of the crossing streets and the level of pedestrian activity at that intersection. Arterial roadways serve through traffic and have higher operational speeds and traffic volumes. They require the highest lighting levels among all roadway classifications. A collector street carries local traffic into the major arterial streets and does not serve as a through street. Local streets are typically in residential areas and are illuminated to the least stringent standard. Sidewalks along the roadway should follow the same lighting level requirement. There are no roadway tunnels in Arlington. However, certain road underpasses may function as a tunnel from the lighting standpoint and thus AASHTO Tunnel Lighting Guide shall be followed for lighting design.

These guidelines are not a substitute for engineering knowledge, experience, or judgment. All projects in Arlington County shall follow the guidelines provided in the Arlington County Streetlight Specifications and Standards for the design and installation of streetlights. The illuminance values adopted in 2018 are summarized in Table 8. The Arlington County Streetlight Specifications and Standards must be consulted for the most recent values.

The values in Table 8 are for continuous lighting at mid-block environments (non-intersections). Intersections where two continuously illuminated roadways meet are typically illuminated at the level equal to the sum of individual street lighting values, per AASHTO standards. For example, the intersection of arterials and local roadways both in commercial areas will have 2.2 fc (1.4 fc for arterial and 0.8 fc for local roadways). However, special considerations should be given to locations with significantly higher pedestrian activity which may result in a higher illumination level.

<table>
<thead>
<tr>
<th>Roadway Classification</th>
<th>General Land Use</th>
<th>Average Maintained Illuminance in fc</th>
<th>Uniformity Ratio Avg/Min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arterials</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commercial</td>
<td>1.4</td>
<td></td>
<td>4/1</td>
</tr>
<tr>
<td>Mixed-Use</td>
<td>1.0</td>
<td></td>
<td>4/1</td>
</tr>
<tr>
<td>Residential</td>
<td>0.7</td>
<td></td>
<td>4/1</td>
</tr>
<tr>
<td>Collectors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commercial</td>
<td>1.1</td>
<td></td>
<td>4/1</td>
</tr>
<tr>
<td>Mixed-Use</td>
<td>0.8</td>
<td></td>
<td>4/1</td>
</tr>
<tr>
<td>Residential</td>
<td>0.6</td>
<td></td>
<td>4/1</td>
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<td></td>
<td></td>
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<tr>
<td>Commercial</td>
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<td></td>
<td>6/1</td>
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<tr>
<td>Mixed-Use</td>
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<td>6/1</td>
</tr>
<tr>
<td>Residential</td>
<td>0.3</td>
<td></td>
<td>6/1</td>
</tr>
</tbody>
</table>
Typical Profile and Cross Section

Arlington County primarily uses post-top light poles and cobra light poles for street lighting. Post-top light poles are used in mixed-use, pedestrian areas. Cobra light poles are used along higher speed arterials to efficiently illuminate wider roadways. Poles with double luminaires are common in mixed-use corridors or at locations with median mounted light poles, where fewer poles are available to meet the generally higher lighting requirements. Single luminaires are more common in residential areas. Light pole spacing depends on the cross-section of the roadway, number of lanes, roadway width, sidewalk width, median width, etc. Light poles should be spaced to provide light overlap and minimize dark spots. Different pole arrangements and layouts are shown in the diagrams on this page.
CHAPTER IV - STREET LIGHTING STANDARDS

Equipment

In addition to the technical standards on photometrics, the County must follow certain standards in equipment and processes to maintain its streetlight inventory. Investing in standardized equipment improves warehouse organization and reduces a stocking burden. Warehousing space in County storage facilities is scarce. Managing this space effectively results in faster service deliveries, increased response time, and cost savings based on economies of scale. Therefore, the County recommends limited varieties of poles and luminaires that meet the guiding principle outlined in Chapter III. All products will be required to meet the minimum performance requirements stated in Arlington County Streetlight Specifications and Standards.

In residential areas there are a variety of existing post-top streetlights owned by Dominion Energy (DE), other than cobras, such as acorns and colonials. The County does not plan to replace them with cobra style streetlights before the end of the design life of post-tops.

As discussed in Chapter III, the default lighting style will be post-top in mixed-use areas. Roadways and the residential area outside of the mixed-use corridor will have cobra luminaires regardless of ownership. An Arlington County Streetlight Engineer must be consulted for any new streetlight project.

Due to the difficulty in maintaining poles with various colors, the County recommends that all ornamental post-top poles and octafline aluminum poles be black (Federal Standard 27038). Currently, the County has in some areas brown ornamental poles that will be incrementally replaced as part of streetlight projects or during any pole knockdowns.

All electrical cables feeding streetlights shall be in underground conduit to increase cable life and ease of repair. The rate tariff established for streetlight application can only be used for streetlights. The connection of other electrical applications will not be allowed at streetlight meters.
Correlated Color Temperature (CCT)

Arlington County was one of the early adopters of LED technology for street lighting. In 2010, LED lights were readily available only in the higher color temperature range. LED temperatures used by the County were 5500° Kelvin. While 5500° Kelvin LED streetlights were well accepted in mixed-use corridors, the acceptance level in residential neighborhoods was low. A 2018 survey has shown a similar trend regarding the use of lower CCT as shown in Appendix G. The graphics shown in Figure 18 show the comparative range of different color temperatures.

Regardless of the performance or impact of different light hues, color is one of the first phenomena people perceive in lighting. Society has generally adapted well when the technology of artificial lighting changed from gas light to incandescent to fluorescent to high-pressure sodium to LEDs. Higher CCT is associated with electrical efficiency and CCT around 4000° Kelvin is found to provide the best visual clarity for roadway users. This clarity is critical in mixed-use corridors where various roadway users co-exist in a limited right-of-way. Adaptation to change differs among individuals. The right balance of benefits and drawbacks must be maintained for community acceptance of CCTs.

Based on the County’s research, community feedback, and advancements in LED technology, this report recommends the use of 4000° Kelvin in mixed-use corridors and 3000° Kelvin in residential areas as a standard color temperature.

At the end of their life span, the current 5,500K LED lights shall be replaced in accordance with new standards. The County streetlight program may seek funding to support replacement at an expedited pace as needed.
**CHAPTER IV - STREET LIGHTING STANDARDS**

**Pole Identification**

There are streetlight-related equipment owned by Dominion Energy (DE) or the County within the rights-of-way. Therefore, there is a need to maintain a County pole numbering system distinguishable from that used for DE-owned poles.

County streetlight pole numbers are designed based on a combination of an abbreviated street name, block number, and pole number sequence. This is intended to help technicians immediately locate the pole for repair purposes, reducing response time. The methodology of County pole decal details is published on the County website. Figure 19 and Figure 20 show the different pole decals for DE-owned and County-owned streetlights.

**Street Light Dimming**

The County is committed to making street lighting adaptable to Arlington’s community life style as much as practicable by setting up brightness levels that support the street’s activity level. The County’s Central Management System (CMS) allows streetlights to be dimmed at different times of the night as activities on the streets are reduced.

Streetlights are grouped based on land use type. Categories are: residential, mixed-use, and commercial areas. Streetlights in these three zones are configured in different settings.

**Temporary Lighting**

Arlington County requires temporary lighting in mixed-use areas even if there is no existing lighting or there was insufficient lighting prior to construction. Temporary lighting is typically not required in residential areas, unless there are major activity centers nearby such as a school or community center. Temporary lighting should be designed to the same lighting levels as permanent lighting. Temporary lighting illuminates the project construction/work zone area and any lane or sidewalk configuration changes and should not impede a road user’s vision.

**Recommendations**

This management plan makes the following recommendations regarding street lighting standards:

- Arlington County’s street lighting standards and AASHTO street lighting guidelines shall be used for all projects.
- Post-top light poles shall be used for mixed-use areas and cobra light poles shall be used for residential areas, regardless of ownership.
- All post-top light poles shall be black.
- All cobra and teardrop streetlights shall have less than 5% of uplight and post-top streetlights shall be equipped with dome shields to reduce uplight.
- During street lighting installation, a CCT of 4000° Kelvin shall be used in mixed-use corridors and a CCT of 3000° Kelvin shall be used in residential areas.
- The number of dimming zones shall be maintained as residential, mixed-use, and commercial.
- Temporary lighting shall be provided for construction projects in mixed-use areas. Temporary lighting shall be designed to the same lighting levels as permanent lighting.

Figure 19: Streetlight Pole Labelling for Dominion Energy

Figure 20: Streetlight Pole Labelling for Arlington County
The primary street lighting philosophy questions for Arlington County are:

- How will street lighting play a key role in a connected and automated vehicle (CAV) environment?
- How will the streetlight management plan adapt to new technology?
- How will smart city applications take advantage of existing County infrastructure?
- What role will street lighting have on the latest network technology?

Street lighting technology is constantly evolving. There are newer installations of connected, smart streetlights that can be remotely monitored and dimmed. They can serve as platforms for ancillary uses, such as for mounting security cameras, Wi-Fi, vehicle or pedestrian detection while lighting smart corridors used by connected and automated vehicles.

Adaptive Lighting

FHWA’s Design Criteria for Adaptive Roadway Lighting states that, based on crash analysis and lighting performance, a series of criteria and associated design levels have been developed for light-level selection and the adjustability of the light-level based on the needs of the driving environment. It is recommended that each street be evaluated in terms of its lighting needs and residential areas be adapted to a single lighting level. For roadway facilities, each roadway should be assessed individually, but drivers should not experience greater than a two-level change in the lighting class.

Adaptive street lighting must evaluate areas of critical visibility, such as curves, short visibility distances, or locations where traffic and pedestrian volumes are consistent throughout the night. It also states that the optimal approach to selecting the timing of adaptive lighting is to continually monitor the roadway and the environment. For example, ITS devices can provide traffic and pedestrian counts as inputs to an algorithm that establishes the lighting level in real-time. The following criteria can also be used to establish times to implement adaptive lighting:

- Changes in vehicular traffic level
- Typical closing hours of surrounding businesses
- Changes in the transportation schedule
- Changes in parking regulations
- Sampled pedestrian activity level

It is important to make exceptions to adaptive lighting during special events and bad weather.
LED Lighting Pilot Project - 2018

Arlington County began implementing LED fixtures in 2010. Since then, street lighting technology has progressed and public opinion of the technology has evolved. The County has received feedback on various aspects of lighting such as color temperature and dark-sky compliance. The County needed a way to address these real-world concerns through actual field demonstrations.

In August 2017, a request for information (RFI) document was published by Arlington County to invite LED street lighting vendors to demonstrate their LED fixtures and poles on Arlington streets for a period of three months. The vendors were also given an RFI questionnaire on LED street lighting fixtures and poles. One requirement was for the fixtures to be dimmable and compatible with Arlington County’s Central Management System.

Vendors shortlisted based on meeting Arlington County’s RFI requirements were invited to demonstrate their products. Arlington selected the demonstration locations in residential and mixed-use areas as shown on the map below.

The light vendors were assigned identification: A, B, C, and D. The number after the letter refers to the color temperature in Kelvin. For example, “A 4.0” means Vendor A with fixture color temperature of 4000 Kelvin.

Figure 21: LED Lighting Pilot Project Demonstration Locations
Illuminance values (in foot-candles) were measured in the field at night, following IESNA LM-50-13 Photometric Measurement of Roadway and Street Lighting Installations. A test grid was established to measure the intensity of light on the street. Point numbers were collected along the test grid. These values were then analyzed and evaluated. Appendix E shows how each light fixture type compared with the others in terms of field illuminance and uniformity. Uniformity was calculated in terms of the ratio of average to minimum illuminance.

Some of the findings from the RFI are as follows:

- Light fixture D 4.0 rated the highest in terms of field illuminance and calculated uniformity ratio for residential post-top fixtures.
- Light fixture C 3.0 rated the highest in terms of field illuminance and calculated uniformity ratio for residential cobra fixtures.
- Light fixture A 5.0 rated the highest in terms of field illuminance and calculated uniformity ratio for mixed-use cobra fixtures.

Additional factors to be considered while evaluating light fixtures included efficiency, community acceptance, operational cost, and construction cost.

The County used consultants, third-party accredited laboratories, plus its own engineers and technicians to collect fixtures data including wattage, efficacy, BUG ratings and photometrics. The County also studied how well the fixtures were engineered and manufactured for their communication capabilities and ease of installation. A summary of those findings is in Appendix F.

Through extensive community outreach on Arlington County’s website and others read by the community, tours by bus and on foot, and a feedback form available online and as a hard copy, the County received significant input from the pilot from residents and local leaders. The feedback period lasted a month in Spring 2018. The County received 707 individual responses, the majority from single-family residents. A summary of the community feedback is presented in Appendix G and shown in Figure 22 and Figure 23.

As referenced in Chapter IV, the County is recommending color temperatures of 3000° Kelvin in residential areas and 4000° Kelvin in mixed-use areas. The County’s decision on color temperature was based on technical information and community feedback plus factors like cost differential and fixture efficiency.
Advancements in LED Technology

LED lighting has had a history of production inefficiency. Slight variations in manufacturing, particularly with lumens, color temperature and LED voltage, meant individual LEDs were extremely difficult to produce with identical results. Recent technology and market competitiveness have spurred manufacturers to pay closer attention to binning—a process that sorts the chips so that all the LEDs from one particular bin look the same and have similar light output—creating products with consistent color and high output lumen performance.

LEP vs LED

Light emitting plasma (LEPs), produce light differently from LEDs. After electricity is applied to an LEP, a radio-frequency is generated and then applied to a chamber filled completely with gas. The radiofrequency energy excites the gas and when the gas has enough energy at its disposal, it turns into a plasma and produces light. Essentially, LEPs are similar to fluorescent or metal halide but LEPs outperform them.

However, LEPs do not outperform LEDs environmentally or economically. LEPs use noble gases and additional materials such as mercury or sulfur, both of which are not environmentally friendly. LED technology is also constantly advancing, leading to lower manufacturing costs and higher efficiency rates.

OLED vs LED

Organic LEDs (OLEDs) are made of organic materials, mainly hydrocarbon chains, as opposed to the various metals that make up LEDs. OLEDs use layers to produce color and are lighter and thinner than LEDs. In fact, OLEDs are so thin as to be flexible, allowing for a wide variety of lighting designs. Additionally, by nature, OLEDs are environmentally friendly and recyclable.

OLEDs are not without their limitations. Currently OLEDs have a shorter lifespan than their LED counterparts and as OLEDs age, they require more power to maintain efficacy. Additionally, the OLED manufacturing process is very expensive. This, in addition to the current effectiveness problem, prevents OLEDs from becoming an effective tool for street lighting for now.

Solar Technology

Streetlights can also be powered by solar energy. This is done using photovoltaic (PV) panels mounted on the lighting structure or connected in the pole. PV panels have a rechargeable battery, providing power to the LED lamp during night hours.

The solar option is the greener solution but there are other benefits. Solar powered streetlights operate independently of the utility grid, which could lead to fewer operational costs. There are no exposed wires, thereby minimizing accidents to maintenance personnel. Certain solar street lighting systems can be relocated with ease to solve lighting problems in remote areas.

Solar powered streetlights also come with disadvantages. The initial investment is higher than traditional streetlights. Inclement weather such as snow, dust, and excess moisture can gather on the PV panel, reducing or even preventing energy production. Depending on geographical location, the size of the solar panels varies for the same power generation due to available solar insolation in the winter. With no sun at night, there is a need for a large battery bank to operate the lights. The batteries, while rechargeable, will eventually fail (usually multiple times) throughout the life of the fixture, which must be factored into overall maintenance costs. Cities like Richmond, Va that have invested in solar streetlights now find themselves scaling back due to reliability issues and maintenance costs associated with battery replacement.

While solar powered streetlights have potential, the County is not recommending the use of this technology at this time. The County will continue to monitor the technology for viability.

Motion Sensing Technology

One new trend in the industry is motion activated streetlights. In theory, as a person or car approaches, the movement is detected by the closest streetlight. The streetlight would then increase its output to 100 percent. If the lights in the area are wirelessly connected, the surrounding lights also power on. When no movement is detected, the streetlight output reduces, creating a “moving spotlight.” As of now, there is nothing to keep the lights from being activated by unwanted movements from stray animals or waving branches. Thus, the County has decided to not recommend the use of this technology.

For the safety of its residents, the County recommends maintaining control of its own dimming capabilities instead of what essentially amounts to placing the streetlights on autopilot.
Chapter V – Street Lighting Technology

Street Lighting and Smart Cities

Smart Cities are areas that use Internet of Things (IoT) technology to gather and supply information to manage assets within the area and improve the lives of residents.

Smart Cities can connect multiple aspects of a city, including waste receptacles, parking and traffic sensors, noise pollution sensors and streetlights, to collect data and support efforts to reduce resource consumption, waste and overall costs.

Streetlights are playing an important role in the development of Smart Cities. LED street lighting poles and fixtures can be embedded with sensors and controls to allow for remote control, reducing lighting at certain times to conserve energy or increasing lighting to improve pedestrian safety. They can also monitor more than just lighting levels. Smart streetlights can collect and transmit information to help with many non-lighting applications as well.

Smart City Applications

Street lighting is a foundation of any Smart City and support a wide range of non-lighting applications such as:

Emergency Response: Integration with the 911 system will allow dispatchers to rapidly determine locations for assistance by flashing streetlights in front of a house in need of assistance. Streetlights can be controlled to flash in specific patterns providing highlighted evacuation routes in case of emergency. Additionally, the higher bandwidth wireless networks used and supported by street lighting can provide better quality HD video for closed circuit mounted television cameras.

Traffic and Parking: Street lighting facilities can connect to sensors that will monitor real-time traffic patterns more quickly and potentially integrate into any parking infrastructure with sensors to determine if a space is occupied.

Air Quality: Sensors for air quality and noise can be connected to the street lighting network infrastructure for real-time monitoring.
Communication for Streetlights

There are many options for streetlight communication today: radio frequency (RF) mesh networking and cellular communication, Wi-Fi, hybrid, and others. The County currently uses two: mesh networking and cellular.

Mesh networking creates extended reach for a device network by letting data hop from device to device. Radios too far apart to hear each other directly can still communicate this way, however, there are limitations. Arlington County is currently using an RF mesh network for its street lighting and experiences some issues with Line-of-sight (i.e. when an obstruction physically blocks the path.) The County is exploring other options available on the market including cellular technology.

Cellular communication transmits data straight to the cloud, eliminating the need for gateways, servers, antennas or any IT infrastructure on the street. There is no need for advanced installation expertise, complex initial surveys, or ongoing network maintenance. As soon as the cellular node is turned on, it immediately connects with the secure, reliable cellular network that is already in place. Cellular communication provides reliable connectivity to support a wide range of public lighting applications. LED manufacturers and CMS providers can scale their solutions to support everything from light dimming or inventory management to more bandwidth-intensive applications like video surveillance and sensor monitoring. With cellular technology, LED manufacturers are building solutions based on global standards that will be supported for many years, instead of proprietary RF technologies that risk becoming obsolete.

Small Cell Technology

With technology advancing, telecom companies will soon begin to introduce fifth generation (5G) technology and infrastructure. One strategy for deployment is to install small cell communication technology on existing streetlight poles. Small cell communication can improve coverage and capacity in heavily populated areas that have high mobile data usage. Arlington County is ready to embrace this new technology, while also being conscious about safety, the public right-of-way, operation and maintenance costs, lighting levels, and aesthetics. As part of ongoing technological advancement, the County is developing modified streetlight pole standards and specifications to support the deployment of small wireless technology while maintaining safety requirements. Telecom companies must conform to Arlington County pole specifications and design equipment that will not only meet the County’s safety standards and technological needs, but also fit in well with the County’s streetlight aesthetics.

Future Updates

Street lighting technology will continue to evolve as will research to inform our understanding of the benefits. The County will be diligently reviewing advances and new technology will be tested when warranted. Decisions regarding the adoption and implementation of new street lighting technology should be guided by both thoroughly researched scientific findings and by the needs and requirements of Arlington County and its residents. This document will be amended and/or updated at the direction of the County Manager.

Recommendations

This management plan makes the following recommendations regarding street lighting technology:

- Develop specifications for new post-top and cobrahead lighting fixtures based on information gathered during the RFI process.
- Implement new, innovative streetlight technology to promote a safe and sustainable community.
- Use modern technology to track and reduce the environmental impact and meet national guidelines and industry standards.
- Use smart street lighting infrastructure for connected and automated vehicles.
APPENDIX A - DOE QUESTIONS
How do light-exposure levels from street lighting compare with those from other sources?

All light at night can potentially contribute to the biological responses and related health concerns described in these FAQs, to varying degrees. At least two journal articles, for example, note that the primary concern about the effects of light at night on human health is driven by interior light levels in homes and workplaces, \([1,2]\) although exterior sources can also play a role if people (or other living organisms) are exposed to high enough light levels for sufficiently long durations. If the intensity and duration are identical, white light sources with higher proportions of short wavelengths (typically characterized as higher melanopic content) are more of a concern in this respect than are orange or amber sources with lower proportions of short wavelengths. The exact wavelengths of concern depend on the specific action spectrum. Because research is still ongoing, melanopic content is presently used as a proxy for most health concerns related to light at night.

Table 1 lists a few relevant characteristics of various lighting products used in both interior and exterior applications, including some products that are available at different CCTs. The "% Blue" column in the table divides the radiant power delivered in the wavelengths between 405 and 530 nm (a range used for similar purposes in a number of published reports pertaining to sky glow [3]) by the total radiant power delivered from 380 to 780 nm (approximately the visible spectrum) for each light source. The melanopic content of
a light source, listed in the last column, is the source spectrum weighted by the spectral efficiency of the ipRGCs (see "What are the five types of photoreceptors in the human eye, and what is an action spectrum?"), and is an indicator of the source's potential to stimulate a melanopic response (i.e., a response by the ipRGCs).

Values in the table are normalized first to a uniform lumen output, to enable “apples to apples” comparisons among sources; and then, in the last two columns, the values are normalized relative to HPS to illustrate impact compared to the most common incumbent type of street lighting. The table lists values of % Blue, Relative Scotopic Content, and Relative Melanopic Content for a number of specific light sources. LED sources are shown with a range of values, because at any given CCT there are many LEDs with varying spectra. Conventional light sources are all listed with single values rather than a range, but they, too, would be most accurately characterized with some amount of variability.

Importantly, reducing the total luminous flux from a light source (e.g., by 50%, as is common when converting from HPS to LED streetlights) reduces the melanopic content by that same amount (i.e., by 50% in this example). Proper application of the values in Table 1, then, must also account for pre- and post-installation light output, in order to accurately compare pre- and post-melanopic content.

Table 1. Characteristics of Various Light Sources

<table>
<thead>
<tr>
<th>Row</th>
<th>Light source</th>
<th>Luminous Flux (lm)</th>
<th>CCT (K)</th>
<th>% Blue*</th>
<th>Relative Scotopic Content</th>
<th>Relative Melanopic Content**</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>PC White LED</td>
<td>1000</td>
<td>2700</td>
<td>17% - 20%</td>
<td>2.77 - 2.20</td>
<td>1.90 - 2.88</td>
</tr>
<tr>
<td>B</td>
<td>PC White LED</td>
<td>1000</td>
<td>3000</td>
<td>18% - 25%</td>
<td>1.89 - 2.39</td>
<td>2.00 - 2.99</td>
</tr>
<tr>
<td>C</td>
<td>PC White LED</td>
<td>1000</td>
<td>3500</td>
<td>22% - 27%</td>
<td>2.04 - 2.73</td>
<td>2.34 - 3.57</td>
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<tr>
<td>D</td>
<td>PC White LED</td>
<td>1000</td>
<td>4000</td>
<td>27% - 32%</td>
<td>2.10 - 2.65</td>
<td>2.35 - 3.40</td>
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<tr>
<td>E</td>
<td>PC White LED</td>
<td>1000</td>
<td>4500</td>
<td>31% - 35%</td>
<td>2.35 - 2.85</td>
<td>2.75 - 3.81</td>
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<tr>
<td>F</td>
<td>PC White LED</td>
<td>1000</td>
<td>5000</td>
<td>34% - 39%</td>
<td>2.56 - 2.89</td>
<td>3.18 - 3.74</td>
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<tr>
<td>G</td>
<td>PC White LED</td>
<td>1000</td>
<td>5700</td>
<td>39% - 43%</td>
<td>2.77 - 3.31</td>
<td>3.44 - 4.52</td>
</tr>
<tr>
<td>H</td>
<td>PC White LED</td>
<td>1000</td>
<td>6500</td>
<td>45% - 49%</td>
<td>3.27 - 3.96</td>
<td>4.38 - 5.64</td>
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<tr>
<td>I</td>
<td>Narrowband Amber LED</td>
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<td>1656</td>
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<td>0.36</td>
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<tr>
<td>J</td>
<td>Low Pressure Sodium</td>
<td>1000</td>
<td>1718</td>
<td>0%</td>
<td>0.34</td>
<td>0.10</td>
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<tr>
<td>K</td>
<td>PC Amber LED</td>
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<td>1872</td>
<td>1%</td>
<td>0.70</td>
<td>0.42</td>
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<tr>
<td>L</td>
<td>High Pressure Sodium</td>
<td>1000</td>
<td>1959</td>
<td>9%</td>
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<td>0.86</td>
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<tr>
<td>M</td>
<td>High Pressure Sodium</td>
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<td>2041</td>
<td>10%</td>
<td>1.00</td>
<td>1.00</td>
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<tr>
<td>N</td>
<td>Mercury Vapor</td>
<td>1000</td>
<td>6624</td>
<td>36%</td>
<td>2.33</td>
<td>2.47</td>
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<tr>
<td>O</td>
<td>Mercury Vapor</td>
<td>1000</td>
<td>3725</td>
<td>25%</td>
<td>1.82</td>
<td>1.95</td>
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<tr>
<td>P</td>
<td>Metal Halide</td>
<td>1000</td>
<td>3145</td>
<td>24%</td>
<td>2.16</td>
<td>2.56</td>
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<tr>
<td>Q</td>
<td>Metal Halide</td>
<td>1000</td>
<td>4002</td>
<td>33%</td>
<td>2.53</td>
<td>3.16</td>
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<tr>
<td>R</td>
<td>Metal Halide</td>
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<td>4041</td>
<td>35%</td>
<td>2.84</td>
<td>3.75</td>
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<tr>
<td>S</td>
<td>Moonlight</td>
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<td>4681</td>
<td>29%</td>
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<td>4.56</td>
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<td>T</td>
<td>Incandescent</td>
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<td>2836</td>
<td>12%</td>
<td>2.23</td>
<td>2.73</td>
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<td>U</td>
<td>Halogen</td>
<td>1000</td>
<td>2934</td>
<td>15%</td>
<td>2.28</td>
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<tr>
<td>V</td>
<td>F32T8/830 Fluorescent</td>
<td>1000</td>
<td>2940</td>
<td>20%</td>
<td>2.02</td>
<td>2.29</td>
</tr>
<tr>
<td>W</td>
<td>F32T8/835 Fluorescent</td>
<td>1000</td>
<td>3480</td>
<td>26%</td>
<td>2.37</td>
<td>2.87</td>
</tr>
<tr>
<td>X</td>
<td>F32T8/841 Fluorescent</td>
<td>1000</td>
<td>3969</td>
<td>30%</td>
<td>2.58</td>
<td>3.18</td>
</tr>
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</table>

* Percent blue calculated according to LSPFD: Light Spectral Power Distribution Database, http://galileographics.ccgesterbrook.co.ca/apps/es/home

** Melanopic content calculated according to CIE (Imandiance Toolbox), http://blac.ca.co.uk/181_1NO03_Tebox.xls, 2013
APPENDIX A - DOE QUESTIONS

† Moonlight CCT measured and provided by Telelumen, LLC.
Key: PC – Phosphor Converted; LED – Light Emitting Diode

APPENDIX B - STREET LIGHT POLE DATA COLLECTION
The following street light pole data was collected:

- Coordinates/location
- Technology
- Pole number
- Pole type
- Pole color
- Pole height (approximate)
- Globe type
- Zoning restrictions

The field collected data was then used to update the GIS files provided for county-owned street lights and Dominion-owned street lights.

The following tasks were performed to evaluate existing conditions based on collected data and the corresponding GIS analysis:

- New GIS layer for infrastructures gaps
  - Missing street light locations
  - Inadequate spacing or non-existent spacing
- New GIS layer for street lights not meeting current standards
  - Non-LED locations
  - Identify street segments with inadequate spacing
- New GIS layer for inconsistent streetscape
  - Pole number
  - Pole type
  - Pole color
  - Pole height
  - Globe type
  - Pole placement (i.e. median versus curbside location)
  - Interaction with street trees and street furniture

After selecting the light poles within the project limits, individual shape files were created to reflect the findings for each task. Each task was first broken down into poles owned by either the county or Dominion, then evaluated per the given criterion.
Findings

The tables below present the light pole criteria used to analyze the light poles. Deviations are listed with each table. A dash indicates data was not available for analysis of that criteria and for poles of that ownership.

<table>
<thead>
<tr>
<th>Light Pole Criteria: Infrastructure Gaps, Non-LED (Non-Standard)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRITERIA</td>
</tr>
<tr>
<td>Non-LED Lights</td>
</tr>
<tr>
<td>Inadequate Spacing</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Light Pole Criteria: Inconsistent Streetscape</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRITERIA</td>
</tr>
<tr>
<td>Pole Placement</td>
</tr>
<tr>
<td>Pole Color</td>
</tr>
<tr>
<td>Pole Distance</td>
</tr>
<tr>
<td>Pole Number</td>
</tr>
<tr>
<td>Tree Obstruction</td>
</tr>
<tr>
<td>Pole Type</td>
</tr>
<tr>
<td>Bulb Type</td>
</tr>
<tr>
<td>Pole Height</td>
</tr>
</tbody>
</table>

Survey Methodology

Infrastructure gaps were determined by selecting light poles that were more than 150 feet from any other surrounding light pole. In the figures below, the number correlating with the nearest light pole of that color represents the distance measured between that light pole to the nearest light pole.

Light poles identified as not meeting current standards were either non-LED or those with inadequate spacing. Inadequate spacing was determined as infrastructure gaps; Non-LED lights were determined by the field 'BULB_TYPE' for county-owned light poles. No Dominion-owned lights were found to be LED, therefore that criteria was not evaluated.

Inconsistent Streetscape identification was broken down by which fields were evaluated to match which attributes. Each criterion is described below.

**Pole Placement** was determined to be any light pole that was in a median. This was done visually based on the geospatial data for both county-owned and Dominion-owned light poles.

**Pole Color** was determined by the field 'COLOR' for county-owned light poles. Pole Color could not be identified as an attribute for Dominion-owned lights, therefore that criteria was not evaluated. Unique values were assigned for each iteration of pole colors in their respective fields (based on ownership) and visually inspected for anomalies based on the adjacent pole color patterns. Light poles were automatically selected as inconsistent if the field for that light pole was not available, whether it was null (not filled out) or invalid (listed as 0, N/A, etc.).
Pole Distance was determined to be any light pole more than 10 feet from the curb from the center of the point by geospatial analysis. All poles, both county-owned and Dominion-owned were applied a 10-foot buffer and then selected on a visual basis from the geospatial data.

Pole Number was determined by the field 'POLE_NUM' for county-owned poles and 'DECAL_NUMB' for Dominion-owned poles. Unique values were assigned for each iteration of pole numbers in their respective fields (based on ownership) and visual inspected for anomalies based on adjacent pole numbering patterns. Light poles were automatically selected as inconsistent if the field for that light pole was not available, whether it was null (not filled out) or invalid (listed as 0, N/A, etc.).

Tree Obstruction was determined by visually inspecting all Dominion-owned and County-owned poles to see if the light appeared to be obstructed by trees when mapped by geospatial data. This correlated to the inconsistent streetscape criteria of "interaction with street trees."

Pole Type was determined by the field 'MATERIAL' for county-owned poles and 'MATERIAL_C' for Dominion-owned poles. Unique values were assigned for each iteration of pole types in their respective fields (based on ownership) and visual inspected for anomalies based on adjacent pole type patterns. Light poles were automatically selected as inconsistent if the field for that light pole was not available, whether it was null (not filled out) or invalid (listed as 0, N/A, etc.).

Bulb Type was determined by the field 'BULB_TYPE' for county-owned poles and 'LAMP_CD' for Dominion-owned poles. Unique values were assigned for each iteration of bulb types in their respective fields (based on ownership) and visual inspected for anomalies based off surrounding bulb type patterns. Light poles were automatically selected as inconsistent if the field for that light pole was not available, whether it was null (not filled out) or invalid (listed as 0, N/A, etc.).

Pole Height was determined by the field 'HEIGHT' for county-owned light poles. Pole height could not be identified as an attribute for Dominion-owned lights, therefore that criteria was not evaluated. Unique values were assigned for each iteration of pole colors in their respective fields (based on ownership) and visually inspected for anomalies based off surrounding pole height patterns. Light poles were automatically selected as inconsistent if the field for that light pole was not available, whether it was null (not filled out) or invalid (listed as 0, N/A, etc.).
Figure 1A: Dominion Energy-Owned Poles

Legend
- Bulb Type Inconsistencies
- Pole Color Inconsistencies
- Pole Number Inconsistencies
- Pole Placement Inconsistencies
- Pole Type Inconsistencies
- Tree Obstruction Inconsistencies
- Pole Distance Inconsistencies
- Verification Boundary

Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community
Figure 3A: Ownership of Light Poles

Legend

- County-Owned Light Poles
- DVP-Owned Light Poles
- Verification Boundary

DE-Owned Poles
Figure 4A: Inadequate Spacing

Legend
- County-Owned Poles
- DE-Owned Poles
- Verification Boundary

Numbers near light poles represent distance to nearest pole (in feet).

Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community
### Table 1: Ownership Cost Comparison Summary

<table>
<thead>
<tr>
<th>Task</th>
<th>Final Inventory (Current:18550)</th>
<th>Future Capital Cost *</th>
<th>Future Annual Maintenance Cost</th>
<th>Current Annual Maintenance Cost</th>
<th>Service Level (Days)</th>
<th>Unit Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1: All lights owned by DE</td>
<td>16822</td>
<td>$61,213,811</td>
<td>$2,335,585</td>
<td>$1,560,000</td>
<td>15/90</td>
<td>$8,900</td>
</tr>
<tr>
<td>Scenario 2: All lights owned by the County</td>
<td>18550</td>
<td>$94,320,000</td>
<td>$2,099,835</td>
<td>$686,001</td>
<td>15/45</td>
<td>$7,100</td>
</tr>
</tbody>
</table>

Scenario 1: In residential areas existing carlyles will be replaced with fewer cobras.
Scenario 2: No change in inventory type

* - Include cost of removal of existing lights and installation of new lights

\(^1\) Cost based on 2018 dollars.
### Scenario 1: In residential areas existing carlyles will be replaced with fewer cobras.

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<th>Scenario</th>
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<th>Future Annual Maintenance Cost</th>
<th>Cost</th>
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- Include cost of removal of existing lights and installation of new lights

Scenario 2: No change in inventory type

\(^1\) Cost based on 2018 dollars.
Literature Review and Interviews
Kimley-Horn conducted research and interviewed four comparable jurisdictions. Kimley-Horn provided a summary of best practices employed by these jurisdictions on inventory, specifications, budget, operations and maintenance, asset management, and technology. This information provided guidance for recommending a maintenance plan for Arlington County. The findings are also summarized in the table at the end of this document.

The selected four U.S. cities included:
- Seattle
- Boston
- Cambridge
- Philadelphia

Seattle
The City of Seattle, Washington owns 86,000 street lights. Sixty percent of those lights are LED with the goal of transitioning to 100% LED by the year 2018. The city has a total of 51,600 LED fixtures. The City of Seattle has 23 employees on their lighting staff, including 12 crew members, nine technicians/engineers, one inspector, and one manager. The parks department maintains the park lights, but the street department maintains the trail lights. Seattle currently has $15 million dollars allocated annually for street lighting. The power bill is billed to the city’s general fund. The city carries an inventory of about two percent of each type of fixture they use. Eighty to 90 repair orders are open at any one time and most repairs are resolved in a few days. Since the transition to LED, trouble calls have lessened and now most calls stem from conduit/connector connections.

Seattle affixes an aluminum plate with a seven-digit plastic tag and bar code to each pole for its identification. Field workers use tablets or computers to send data to the city IT department in Excel format. A GIS database is maintained for light poles. The city is using Enterprise GIS to map all lights and components for survey, but looped radio is not mapped. The database is continually updated when as-built drawings are submitted.

The specifications for Seattle’s LED fixtures are as follows:
- Cree and Leotek brands
- 135 W for arterial, 197W for principal arterial
- Residential cobraheads feature
  - 72W 1st gen
  - 52W 2nd gen
  - 38W 3rd gen
- 4000K color temperature
- Thirty- to 35-foot light poles on arterials and 25 foot on residential
- Plan to incorporate remote monitoring
- Solar power not feasible due to cloudy days

The city has no standards for residential street lighting. They use the European standard for minimum light levels. Corridor standards depend on roadway conditions. The city material standards specify LEDs and will add shoebox replacement and decorative pedestrian fixture (King fixture) to those standards. The city is International Night Sky compliant with zero uplight for all fixtures, except for globes.

Three years ago, Seattle began implementing a lighting plan by preparing the city council and broadcasting public service announcements. As a result, complaint rates dropped from 20 percent to less than 2 percent. The integration of LED fixtures has saved energy consumption and the city benefits from it since they are the utility provider. Second generation LEDs with chip and driver efficiency caused a 42 percent drop in residential power consumption and a 62 percent drop in arterial power consumption.

Boston
The City of Boston, Massachusetts has a total of 63,000 total street lights. They purchased street lights from the power company in 2002 with a Federal Energy Department Initiative. In 2010, Boston began LED conversions and now 95 percent of street lights are LED. The city has 40 employees on their street lighting staff, including 20 technicians, five engineers, two clerks, three supervisors, nine inspectors, and one manager. The city has an annual budget of $21 million. Out of this, $9 million is for the power bill, $10 million for maintenance and capital improvement plans (CIP), and $3 million for staffing. They have eight bucket trucks. Boston carries an inventory of 10 percent of all lights and notes that shipping takes a long amount of time. The lighting department receives 10,000 trouble calls per year and the average response time is 10 days. The city-negotiated labor rate is less than the contractor’s rate ($45/hour savings). They use the National Electrical Code exempt where trained city workers (non-electricians) are allowed to repair street lights The Boston Parks and Recreation Department installs and maintains all off-street lighting.

Boston does not field-identify light poles, but Verizon tags wood poles for its distribution system. All lights are in Excel and GIS databases which should be updated every 6 to 12 months, though the last update was done 3 years ago.
The specifications for Boston’s LED fixtures are as follows:

- **BETA, Leotek, Arieta, Acorns, King Luminaire, 60-100W**
- **Pole heights:**
  - 24-feet arterials
  - 11-feet to21-feet decorative
- **4000K color temperature**
- **Testing dimming using 7 prong photo-control**
- **Testing remote monitoring from 2 AM – 7 AM**
- **Solar power not used since their 4’x2’ panel failed wind test. No other vendors were identified.**

Boston follows RP-8 standards and uses Arieta shoeboxes for residential, acorns for shopping and commercial, and cobraheads for arterials. The city is International Dark Sky compliant with zero uplight. Dimming features lead to a 30 percent cost savings. Another best practice is to stipulate a 10-year warranty in contracts for their lighting products.

At the beginning of the new lighting system the city experienced that technology was changing quickly. Products were constantly being reevaluated to balance quality and cost. The city used federal grant for mercury vapor removal.

Cambridge

The City of Cambridge, Massachusetts has a total of 7,000 city-owned light poles, of which 5,500 are LED. This quantity includes street lighting and decorative lighting. The city employs 13 full time people for street lighting. Their budget is $600,000 per year for street lighting maintenance and usage. The parks department maintains the trail lights separately. The city has four bucket trucks and carries an inventory of about 2 percent for the three types of fixtures they use. The transition to LED from mercury vapor has decreased the number of annual repairs by 75 percent. Utility repairs account for the majority of the 300 annual repairs.

Each light pole is identified in the field with a number on a reflective sticker that specifies whether it is flat rate, metered, or off-grid as well as location on the street. The city also maintains a database of street lighting identified by GPS coordinates and each light fixture is marked in Google Maps. The city has not completed a redesign of their system, but luminaire replacements are identified in the system as they happen.

The specifications for Cambridge’s LED fixtures are as follows:

- **Cree LEDway 40, 80, and 120 (45W-275W)**
- **4000K color temperature**
- **Uplight (U=0) for International Dark Sky Compliance**
- **Lumewave (Echelon) Dimmers**
- **No solar powered units**

Cambridge uses dimming as a cost saving strategy. Default dimming of 35 percent is used to save energy and increase longevity. Seventy percent dimming starts at 10 PM for residential and at midnight for commercial areas. Since Cambridge’s lighting control system has a node for each light pole, each node can be adapted to dimming.

The design criteria and standards for the city were based on pedestrian and vehicular volumes and roadway width. The City of Cambridge follows the latest RP-8-14. It is a luminance-based design criteria for the roadway and an illuminance criteria for the sidewalk areas. The city uses Type A and B residential cobraheads, Type C in parks and pedestrian areas, Type D teardrops on commercial arterials, and Type E acorns on commercial arterials with pedestrian traffic.

Philadelphia

The City of Philadelphia, Pennsylvania has a total of 128,000 street lights, of which 105,000 are cobraheads. There are 5,000 ornamental lights and 18,000 alley lights. The city has a total of 2,000 LED fixtures. The city has 17 employees on their street lighting staff, including 11 technicians, one engineer, three inspectors, and two managers. The parks department maintains the trail lights. Philadelphia has a $17 million-dollar budget for lighting, out of which $15 million is allocated for the power bill. The integration of LED fixtures has saved energy consumption but not money since 85 percent of the power bill is a fixed fee; only 15 percent of it is consumption. The city has six bucket trucks and carries an inventory of 10 percent of each type of fixtures they use. They receive 12,000 trouble calls per year. If notification of a needed repair is received before 3 PM, the department’s goal is to make the repair the same day. The city has a $1.2 million contract with a contractor that responds to 311 calls and completes nighttime inspection and repair. Philadelphia is currently testing remote monitoring. Though the technology has not been tested long enough to know for certain, initial results are positive.

Every street light is owned by the city, but the wooden poles are not. The lights are not identified in the field, only in the system. The city’s IT Department maintains a GIS database of all lighting and the system is updated with each change.

The specifications for Philadelphia’s LED fixtures are as follows:

- **GE ESR Series (123W) for cobraheads**
- **Spring City’s decorative fixtures**
- **4000K color temperature**
- **Testing dimming**
- **Testing remote monitoring**

The design criteria and standards for the city were based on RP-8 and they are 2-foot candle uniform throughout the city. Commercial districts use a 14-foot pedestrian-scale light and cobraheads are installed in residential areas.
<table>
<thead>
<tr>
<th>City</th>
<th>Technology</th>
<th>Best Practices</th>
<th>Maintenance Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>chip and driver efficiency with led – residential 42% drop in power; arterial 62% drop in power for 2nd generation</td>
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<tr>
<td>Seattle</td>
<td>Aluminum plate with barcode</td>
<td>changed standard 3 years ago; public service announcements; prepared city council; complaint rate dropped from 20% to less than 2%</td>
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</tr>
<tr>
<td>Boston</td>
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<tr>
<td>Cambridge</td>
<td>Reflective sticker</td>
<td>default dimming of 35% used to save energy and increase longevity; 70% dimming starts at 10 PM for residential and at midnight for commercial areas</td>
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<tr>
<td>Philadelphia</td>
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<td>leds save energy but not enough money since 85% of power bill is fixed fee and 15% consumption</td>
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</tr>
<tr>
<td>Arlington</td>
<td>Both in GIS and in field</td>
<td>convert all county lights to led, install cables in conduit, replace dominion lights with cost-effective products</td>
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**STREETLIGHTING PROGRAM BENCHMARKING**

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**STREETLIGHT MANAGEMENT PLAN**

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<td></td>
</tr>
<tr>
<td>City</td>
<td>Total # Light Poles</td>
<td>LED light poles</td>
<td>Pole types</td>
</tr>
<tr>
<td>------------</td>
<td>---------------------</td>
<td>----------------</td>
<td>-------------------------------------</td>
</tr>
<tr>
<td>Seattle</td>
<td>86,000</td>
<td>51,600</td>
<td>Residential - cobraheads; Commercial - Post-top pedestrian; Arterials - cobraheads</td>
</tr>
<tr>
<td>Boston</td>
<td>63,000</td>
<td>59,850</td>
<td>Residential - shoebox; Commercial - acorns; Arterials - cobraheads</td>
</tr>
<tr>
<td>Cambridge</td>
<td>7,000</td>
<td>5,500</td>
<td>Residential - cobraheads; Commercial - arterials - tear strips</td>
</tr>
<tr>
<td>Philadelphia</td>
<td>128,000</td>
<td>2,000</td>
<td>Residential - cobraheads; Commercial - 14' decorative lights; Arterials - cobraheads</td>
</tr>
<tr>
<td>Arlington</td>
<td>7350</td>
<td>6,000</td>
<td>Carlyle - County Owned; Cobra and Colonial - Dominion Owned</td>
</tr>
</tbody>
</table>
## Field Illuminance Comparisons of Light Fixtures

<table>
<thead>
<tr>
<th>Roadway Segment</th>
<th>Fixture Type</th>
<th>Average Illuminance (fc)</th>
<th>Minimum Illuminance (fc)</th>
<th>Uniformity Ratio</th>
<th>Ranking by Roadway</th>
<th>Ranking by Fixture Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irving St between 7th St S and 9th St S</td>
<td>C 3.0</td>
<td>0.54</td>
<td>0.04</td>
<td>13.39</td>
<td>1</td>
<td>6</td>
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<tr>
<td>Irving St between 7th St S and 9th St S</td>
<td>A 2.7</td>
<td>0.40</td>
<td>0.00</td>
<td>NA</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>Ivy St between 7th St S and 9th St S</td>
<td>A 3.9</td>
<td>0.71</td>
<td>0.10</td>
<td>7.15</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Ivy St between 7th St S and 9th St S</td>
<td>C 4.0</td>
<td>2.43</td>
<td>0.50</td>
<td>4.86</td>
<td>2</td>
<td>3</td>
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<tr>
<td>Ivy St between 7th St S and 9th St S</td>
<td>D 4.0</td>
<td>0.88</td>
<td>0.30</td>
<td>2.92</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Highland between 7th and 9th</td>
<td>A 3.1</td>
<td>1.58</td>
<td>0.30</td>
<td>5.27</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Highland between 7th and 9th</td>
<td>D 5.0</td>
<td>Not measured since middle LED light was out and there were other streetlights</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irving between 6th and 7th</td>
<td>D 3.0</td>
<td>0.76</td>
<td>0.10</td>
<td>7.60</td>
<td>1</td>
<td>5</td>
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</table>
### FIELD ILLUMINANCE COMPARISONS OF LIGHT FIXTURES

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<th>Fixture Type</th>
<th>Average Illuminance (fc)</th>
<th>Minimum Illuminance (fc)</th>
<th>Uniformity Ratio</th>
<th>Ranking by Roadway</th>
<th>Ranking by Fixture Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>6th St S between S Glebe Rd and S Quincy St</td>
<td>A 3.0</td>
<td>0.98</td>
<td>0.10</td>
<td>9.83</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>D 3.0</td>
<td>0.86</td>
<td>0.00</td>
<td>NA</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>C 3.0</td>
<td>0.95</td>
<td>0.10</td>
<td>9.55</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>7th St S between S Glebe Rd and S Quincy St</td>
<td>A 4.0</td>
<td>0.77</td>
<td>0.00</td>
<td>NA</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>C 4.0</td>
<td>0.78</td>
<td>0.00</td>
<td>NA</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>D 4.0</td>
<td>0.79</td>
<td>0.00</td>
<td>NA</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>8th St S between S Glebe Rd and S Quincy St</td>
<td>A 5.0</td>
<td>1.10</td>
<td>0.10</td>
<td>11.00</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>D 5.0</td>
<td>0.99</td>
<td>0.00</td>
<td>NA</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0.43</td>
<td>0.00</td>
<td>NA</td>
<td>3</td>
<td>9</td>
</tr>
</tbody>
</table>
## FIELD ILLUMINANCE COMPARISONS OF LIGHT FIXTURES

<table>
<thead>
<tr>
<th>Roadway Segment</th>
<th>Fixture Type</th>
<th>Average Illuminance (fc)</th>
<th>Minimum Illuminance (fc)</th>
<th>Uniformity Ratio</th>
<th>Ranking by Roadway</th>
<th>Ranking by Fixture Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Columbia Pike between S Oakland St and S Veitch St</td>
<td>Commercial Post Top</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C 4.0</td>
<td></td>
<td>0.92</td>
<td>0.10</td>
<td>9.20</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>George Mason Dr between Lee Hwy and Washington Blvd</td>
<td>Commercial Cobra</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A 5.0</td>
<td></td>
<td>2.85</td>
<td>1.60</td>
<td>1.78</td>
<td>1</td>
<td>1</td>
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<tr>
<td>D 5.0</td>
<td></td>
<td>2.13</td>
<td>0.60</td>
<td>3.54</td>
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<td>7</td>
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<tr>
<td>A 4.0</td>
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<td>1.81</td>
<td>0.80</td>
<td>2.27</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>D 4.0</td>
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<td>2.87</td>
<td>1.10</td>
<td>2.60</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>B 4.0</td>
<td></td>
<td>2.72</td>
<td>1.40</td>
<td>1.94</td>
<td>3</td>
<td>3</td>
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<tr>
<td>C 4.0</td>
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<td>1.93</td>
<td>0.30</td>
<td>6.45</td>
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<td>8</td>
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<tr>
<td>A 3.0</td>
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<td>2.26</td>
<td>1.20</td>
<td>1.88</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>C 3.0</td>
<td></td>
<td>2.03</td>
<td>0.30</td>
<td>6.77</td>
<td>9</td>
<td>9</td>
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<tr>
<td>D 3.0</td>
<td></td>
<td>4.09</td>
<td>1.20</td>
<td>3.41</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>
### Vendor A: Post-Top

<table>
<thead>
<tr>
<th>Key Specifications</th>
<th>Tier</th>
<th>I</th>
<th>II</th>
<th>III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wattage</td>
<td></td>
<td>52.1w</td>
<td>47.5w</td>
<td>52.3w</td>
</tr>
<tr>
<td>Lumens per Watt</td>
<td></td>
<td>89</td>
<td>95</td>
<td>104</td>
</tr>
<tr>
<td>Color Temperature</td>
<td></td>
<td>2700K</td>
<td>3500K</td>
<td>4000K</td>
</tr>
<tr>
<td>Uplight Percentage</td>
<td></td>
<td>23.9% (UL-5.3%, UH-18.6%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Photometrics</td>
<td></td>
<td>7</td>
<td>2, 4</td>
<td></td>
</tr>
<tr>
<td>RF Communication</td>
<td></td>
<td>Antenna location: Very bad, Only 33% success</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Technician’s comments:**
- Not easy to install
- Ballast connections confusing
- To replace LEDs, fixture needs to be brought to the ground and disassemble the whole head before putting hack again

### Vendor C: Post-Top

<table>
<thead>
<tr>
<th>Key Specifications</th>
<th>Tier</th>
<th>I</th>
<th>II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wattage</td>
<td></td>
<td>39.3w</td>
<td>39.3w</td>
</tr>
<tr>
<td>Lumens per Watt</td>
<td></td>
<td>117</td>
<td>132</td>
</tr>
<tr>
<td>Color Temperature</td>
<td></td>
<td>3000K</td>
<td>4000K</td>
</tr>
<tr>
<td>Uplight Percentage</td>
<td></td>
<td>31% (UL-5.9%, UH-25.9%)</td>
<td></td>
</tr>
<tr>
<td>Photometrics</td>
<td></td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>RF Communication</td>
<td></td>
<td>Antenna location: Very good, 66% Success</td>
<td></td>
</tr>
</tbody>
</table>

**Technician’s comments:**
- Easy to install
- All components sturdy to handle and clamp
- Globe in two pieces so installation in-air-replacement possible
### Vendor D: Post-Top

#### Key Specifications

<table>
<thead>
<tr>
<th>Tier</th>
<th>I</th>
<th>II</th>
<th>III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wattage</td>
<td>39w</td>
<td>39w</td>
<td>39w</td>
</tr>
<tr>
<td>Lumens per Watt</td>
<td>132</td>
<td>139</td>
<td>139</td>
</tr>
<tr>
<td>Color Temperature</td>
<td>3000K</td>
<td>4000K</td>
<td>5000K</td>
</tr>
<tr>
<td>Uplight Percentage</td>
<td>26.2% (UL- 6.8%, UH-19.4%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Photometrics</td>
<td>5</td>
<td>1</td>
<td>Not measured</td>
</tr>
<tr>
<td>RF Communication</td>
<td>Antenna location: Bad, 66% Success</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Technician’s comments:
- Too difficult to mount on pole top
- Not enough room to work, easy to lose connection
- Confusing globe optics, had to rotate before getting it right
- Control box on the access door, easy to pinch wires while closing
### Vendor A: Cobra

<table>
<thead>
<tr>
<th>Key Specifications</th>
<th>Tier</th>
<th>I</th>
<th>II</th>
<th>III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wattage</td>
<td>63w</td>
<td>63w</td>
<td>63w</td>
<td></td>
</tr>
<tr>
<td>Lumens per Watt</td>
<td>109</td>
<td>116</td>
<td>116</td>
<td></td>
</tr>
<tr>
<td>Color Temperature</td>
<td>3000K</td>
<td>4000K</td>
<td>5000K</td>
<td></td>
</tr>
<tr>
<td>Uplight Percentage</td>
<td>0%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Photometrics</td>
<td>2</td>
<td>5 (4 Comm)</td>
<td>3 (1 Comm)</td>
<td></td>
</tr>
</tbody>
</table>

**Technician’s comments:**
- Hinges too fragile easy to break
- Easy install due to ballast mounted on the access door & rubber gasket for arm mounting

### Vendor B: Cobra

<table>
<thead>
<tr>
<th>Key Specifications</th>
<th>Tier</th>
<th>II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wattage</td>
<td>55w</td>
<td></td>
</tr>
<tr>
<td>Lumens per Watt</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Color Temperature</td>
<td>4000K</td>
<td></td>
</tr>
<tr>
<td>Uplight Percentage</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Photometrics</td>
<td>9, 3-comm</td>
<td></td>
</tr>
</tbody>
</table>

**Technician’s comments:**
- Too small for commercial size
### Vendor C: Cobra

<table>
<thead>
<tr>
<th>Key Specifications</th>
<th>Tier I</th>
<th>Tier II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wattage</td>
<td>53.9w</td>
<td>53.9w</td>
</tr>
<tr>
<td>Lumens per Watt</td>
<td>118</td>
<td>125</td>
</tr>
<tr>
<td>Color Temperature</td>
<td>3000K</td>
<td>4000K</td>
</tr>
<tr>
<td>Uplight Percentage</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Photometrics</td>
<td>1, 9</td>
<td>6, 8</td>
</tr>
</tbody>
</table>

Technician's comments:
- Easy to install, modular design
- Roomy inside and connections are very easy to work with

### Vendor D: Cobra

<table>
<thead>
<tr>
<th>Key Specifications</th>
<th>Tier I</th>
<th>Tier II</th>
<th>Tier III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wattage</td>
<td>TBD</td>
<td>60w</td>
<td>TBD</td>
</tr>
<tr>
<td>Lumens per Watt</td>
<td>TBD</td>
<td>118</td>
<td>TBD</td>
</tr>
<tr>
<td>Color Temperature</td>
<td>3000K</td>
<td>4000K</td>
<td>5000K</td>
</tr>
<tr>
<td>Uplight Percentage</td>
<td>0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Photometrics</td>
<td>4, 6</td>
<td>7, 5</td>
<td>8, 7</td>
</tr>
</tbody>
</table>

Technician’s Comments:
- Only one LED on residential fixture
- Knock outs are too flimsy for arm installation
- Made a confusing multiple shadow of same object
APPENDIX G - PUBLIC FEEDBACK SUMMARY
1. On a typical evening, how do you travel around Arlington? (Select up to 2 options)

- Walk
- Bike
- Transit (Bus, Metro)
- Personal Vehicle
- Hired Ride (Lyft, Taxi, Uber)
- Carsharing (car2go, Enterprise, Zipcar)
- Carpool / Vanpool / Rideshare (uberPOOL, Lyft Line)
- Other (please specify)

2. The picture below depicts the color temperature, or hue, in Kelvin. Using the scale and image below to guide you, what is your ideal light color?

*Note: As you move right on the scale, the efficiency of the streetlight increases and the cost decreases. Whiter light also increases visual clarity.

---

Instructions: Using the scale/line above, draw X indicating your preference.

---

Result:
3. On a scale of 1-5, how important are the following topics in regards to streetlights?

<table>
<thead>
<tr>
<th>Topic</th>
<th>Not Important</th>
<th>Somewhat Important</th>
<th>Important</th>
<th>Very Important</th>
<th>Extremely Important</th>
<th>No Opinion/Not Sure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safe (Helps to enhance public safety and improve accessibility.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sustainable (Reduces energy consumption and carbon footprint. Minimizes uplight.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compatible (Helps to improve community environment through streetscape.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smart (Advanced technology features may include: LED lights, sensors that automatically adjust light brightness, wi-fi equipped street poles, emergency push to talk system, charging spot for electric cars/bikes.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintainable (Easy to maintain and improve reliability while limiting inventory space needs.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost effectiveness (Minimize operating and lifecycle costs)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Other (please specify)

![Bar Chart]

Result:

- Cost effectiveness: 3.65
- Maintainable: 3.52
- Smart: 3.03
- Compatible: 3.32
- Sustainable: 4.00
- Safe: 3.84
4. County-owned streetlights are on a dimming schedule that turn on at dusk and gradually dim throughout the evening. Do you find this feature helpful?

- Yes
- No
- Neutral
- Other (please specify)

Result:

5. Among the following items, what is your biggest concern about streetlighting (please select up to 3)

- Not enough streetlights on my street
- Streetlights are broken on my street
- Sidewalk lighting is not bright enough
- Unable to see pedestrians/bicyclists crossing street
- Too much light shining into my property
- I don’t feel safe walking/biking at night
- No concerns
- Other (please specify)

Result:
6. There are two main categories of streetlight styles: Cobra (pictured left) and Post-top (pictured right). Cobra lights are approximately 25 to 30 feet tall and Post-top light are approximately 12 to 16 feet tall. Which style do you find provide the best lighting on roads and sidewalks:

- Cobra
- Post-top
- Neutral
- Other (please specify)

![Example of Cobra](image1.png)  ![Example of Post-top](image2.png)

![Preference over Cobra Vs Post Top](image3.png)

7. Please provide your 5-digit home zip code (ex. 22201).
8. Which of the following types of housing best describes your home?

- Single-family, detached house
- Condominium or apartment
- Townhome, attached to other houses
- Other (please specify)

9. Please share any additional feedback or comments.

10. Please share any additional feedback or comments.

Name: 
Address: 

Result: Not Applicable