




# A Guide to LED Municipal Street Lighting Upgrades

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smart energy solutions. powerful savings.



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## Overview

Light-emitting diode (LED) technology offers the potential to help municipalities save substantially on their street lighting costs. Although some municipalities may be daunted by the volume of information regarding LEDs or may be challenged by high capital investment costs, upgrading older, less efficient lighting technologies in streets and public spaces with energy-efficient LED lighting is an excellent energy saving opportunity. Fortunately, the price of LED street lighting technology has dropped dramatically in recent years while performance has improved, making the prospect of converting to LEDs a more feasible endeavor.

Efficiency Smart is committed to educating participating utilities on the benefits and best practices of updating municipal street lighting and public lighting to energy-efficient technology. We present this guide, along with the supplemental information located in the appendices, to enhance your understanding of the critical considerations and steps involved with an LED street lighting project.

## Energy Savings Potential of LED Streetlights

Streetlights can account for 25 percent or more of a municipality's electric bill. According to the Municipal Solid-State Street Lighting Consortium, switching to LEDs can reduce energy use by up to 80 percent compared to existing streetlights, resulting in significantly lower energy costs and an improved nighttime environment in the community. The Department of Energy estimates that switching to LED technology has the potential to save communities as a whole \$1 billion annually in energy costs.



By upgrading to LEDs, Municipalities can reduce energy usage by up to 80 percent compared to existing lighting.

But energy savings are only part of the financial picture. Upgrading to LEDs require an initial investment, one that can be offset by energy and maintenance savings.

## Total Cost and Savings Assessments

Many municipalities view street lighting as a necessary and vital service that comes with two costs: the cost of electricity and the cost to maintain the lights. Often these costs are not separated from other operational expenses. A city's financial manager may pay the utility bills as a lump sum while employees responsible for public works may maintain street lighting in addition to many other civic maintenance projects. As a result, it may not be clear how much time and expense is involved in operating and maintaining this portfolio of assets.

Understanding the costs involved in operating and maintaining the current streetlight system is vital to any evaluation of a proposal to upgrade to LEDs. This evaluation starts with an inventory of current street lighting. A physical count is ideal but may not always be necessary. If the municipality is laid out on a grid, it may be possible to do a physical count of a representative sample of streets and extrapolate to the entire municipal area. If this is not practical, maintenance data can be used to estimate the total number of streetlights.

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Efficiency Smart has developed techniques for modeling current street lighting inventories that can be applied to your municipality. To help illustrate the cost and subsequent savings potential of street lighting, consider the street lighting scenario in Streetsville, USA<sup>1</sup>. Through inventory modeling, we determined that Streetsville has 13,689 250-watt high pressure sodium (HPS) fixtures. Streetsville replaces 1,500 fixtures each year as part of its maintenance requirements. If Streetsville:

- > Continues to maintain its HPS inventory, it will pay \$28,019,600 in energy and maintenance costs (assuming a fixed rate) over the next 20 years
- > Performs a one-time retrofit to 102-watt LED fixtures, it will pay \$15,515,531 over the same period (including the cost of upgrading), a savings of 45 percent
- > Simply replaces the 1,500 failed fixtures each year with 102-watt LED fixtures, it will still save 36 percent

The example Streetsville lighting project is outlined in more detail in Appendix A, including inventory, cost, and savings assessment methodology.

## Understanding LEDs as a System of Lighting

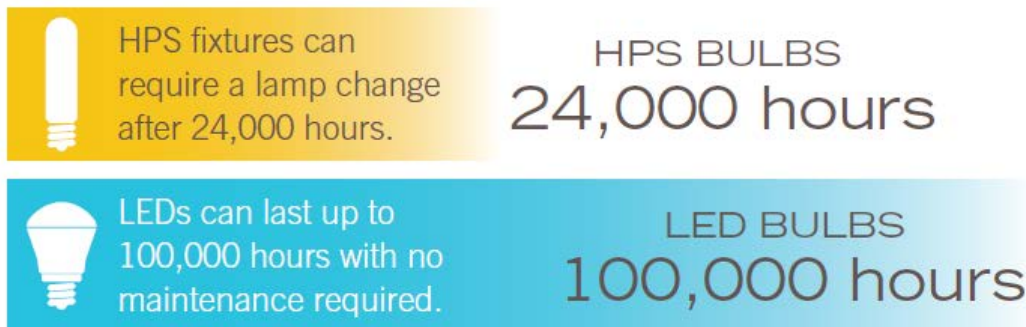
Installing LED streetlights requires more than just a replacement bulb or fixture upgrade. LEDs have a number of benefits that are interactive. Understanding these interactions will allow you to optimize your LED street lighting efficiency and performance.

### LEDs Provide Superior Lighting from Every Angle

LED technology offers several advantages over other streetlight forms. Specifically, LEDs produce more light output per unit of energy input than other forms of lighting. This measurement of efficiency is referred to by the lighting industry as lumens per watt (lm/w). Lumens are the measurement of light output from a light source and watts are the unit of energy. The average range of lm/w for a 100-watt high pressure sodium streetlight is 50 to 75. LEDs range from 78 to more than 100, resulting in more light for less energy.

LEDs also have a very long life. Typical LED streetlights are designed to last 60,000 to 100,000 hours (or 12-23 years) with no maintenance required. A typical HPS fixture will require a lamp change after 24,000 to 40,000 hours, and a ballast or entire fixture replacement after 48,000 to 60,000 hours.

## REDUCED MAINTENANCE COST



<sup>1</sup> Streetsville's calculations are based on data from a real municipality. The complete analysis of the inventory, costs, and savings opportunity for this example municipality are in Appendix A.

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LEDs are often recommended for general lighting applications based on energy and maintenance savings alone. Although these benefits are the easiest to quantify, LEDs also offer the following advantages:

**> Improved lighting quality:**

- Directional light sources make it easy to focus light output, which improves light efficiency and reduces unwanted light trespass<sup>2</sup>
- Even light distribution enhances the uniformity of light levels, resulting in fewer hotspots and dark areas and improved driver safety
- Instant illumination requires no warm up time, even when cycled off and immediately back on
- Efficient operation at all temperatures, including better performance and greater lifespan at colder temperatures

**> Highly durable:**

- Ability to withstand physical shocks that would shatter conventional lamps
- Capable of rapid switching or dimming without shortened life

**> Environmentally friendly:**

- Last for decades if properly managed, which reduces waste
- Are mercury and lead-free
- Reduce energy use and lower carbon footprint
- Offer silent operation with no hum or buzz
- Are dark-sky friendly<sup>3</sup>

**> Enhanced safety:**

- Have no ultraviolet (UV) or infrared (IR) radiation
- Use low-voltage power supplies, such as drivers, which provide a reduced risk of electrical shock

### Source vs. System Efficiency


High Intensity Discharge (HID) lamps, such as HPS and Metal Halide (MH), are typically evaluated based on their source efficiency. Source efficiency is measured as all light emitted from the lamp in all directions at room temperature. Some HID lamps appear very efficient (for example, 100 lm/w or higher) when evaluated solely on source efficiency. However, source efficiency does not accurately reflect how much light is actually delivered from the light source to the target area. Some of the light is lost in the fixture itself, some is directed away from the target area, and ambient and internal temperature can adversely affect light output.

System efficiency is measured with the lamp installed in a fixture. It is based on how many lumens actually reach the target area, not simply how many lumens are emitted from the lamp. System efficiency is always

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<sup>2</sup> Light trespass occurs when spill light is cast where it is not wanted. Light trespass is somewhat subjective, as it's difficult to define when, where, and how much light is unwanted. An example of light trespass is when spill light from a streetlight or floodlight enters a window and illuminates an indoor area.

<sup>3</sup> The directional light output of these fixtures reduces light pollution and glare. This effect is achieved by limiting upward and lateral light output.



lower than source efficiency due to the following four primary sources of light and power loss when a lamp is installed in a fixture:

- > **Trapped Light.** Traditional lamps, which emit light in all directions, require reflectors inside the fixtures to “bounce” as much light as possible away from the lamp and fixture components to the target area. However, not all light can be effectively redirected. According to Foresight Power, one of the leading providers of exterior LED products, 40 percent or more of the light emitted from a traditional lamp is typically trapped within the fixture and does not reach the target area.
- > **Protective Covers and Lenses.** Fixtures almost always use some sort of secondary optics (such as tempered glass or acrylic) to help focus or redirect light and to protect the traditional lamps or LEDs from the environment. These materials do not allow light to pass with 100 percent efficiency, effectively reducing system efficiency.
- > **Operating Temperature.** Many light sources become less effective as operating temperatures change. Because source efficiency is measured at a standard 25°C (or about 77°F), the actual operating efficiency under a range of outdoor temperatures may be significantly different.
- > **Power Supplies.** Most light sources require a ballast or driver to convert line power into a form which can be used by the lamp. These losses can vary from five to 25 percent, depending on the power supply used, resulting in lower system efficiency.

When considering all of the factors that affect system efficiency, LEDs provide a clear advantage over HID lamps. The following is a summary comparison:

- > **HID Lamps.** Initial source efficiency is typically 120 lm/w or higher. However, losses from trapped light, protective covers and lenses, inefficient ballasts, and unfavorable operating temperature typically result in a measured system efficiency of 60 lm/w or less.
- > **LEDs.** Initial source efficiency can be 100 lm/w or higher, depending on the type of the LED used. There are no losses from trapped light due to the focused output of the LED, and secondary optics and protective covers generally reduce output by 25 percent or less. LED power drivers are also more generally efficient than HID ballasts and reduce system efficiency by 10 to 15 percent. However, even when efficiency reductions due to high operating temperatures are included, LED system efficiency often exceeds 70 lm/w.

### Lumen Depreciation & Useful Life

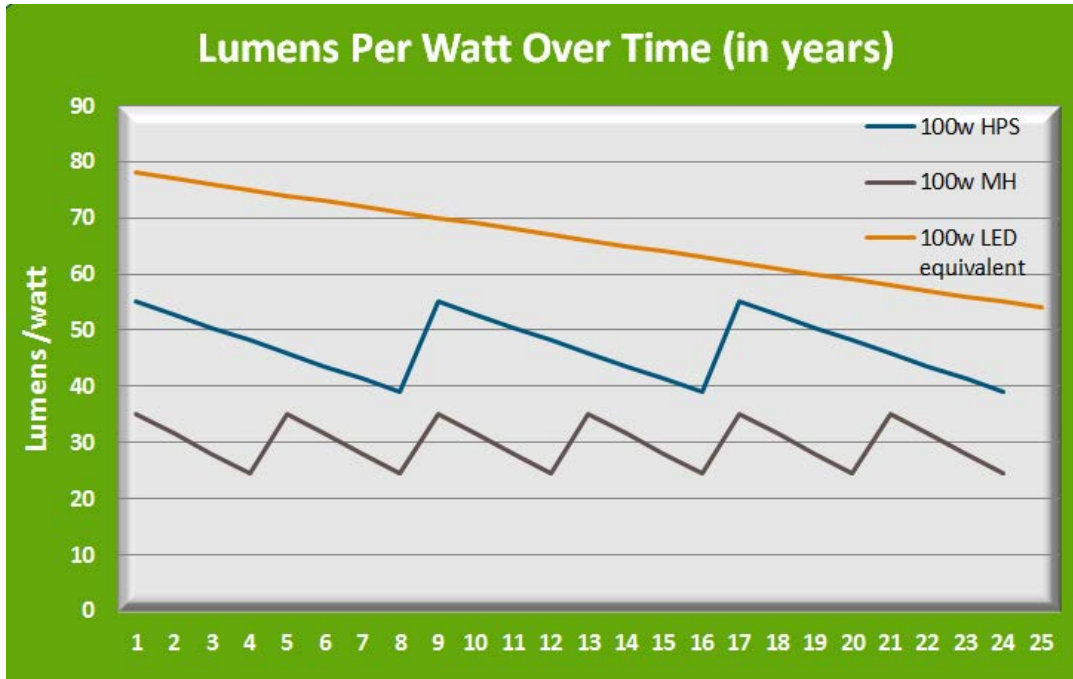
A second important factor involved in comparing the efficiency of LEDs to traditional lamp sources is accounting for the lumen depreciation of both sources. All types of electric light sources experience lumen depreciation, defined as the decrease in lumen output that occurs as a lamp is operated. Unlike incandescent lamps, which suffer a relatively small amount of lumen depreciation, HID sources—especially metal halide—suffer from substantial lumen depreciation over relatively short periods.

The useful life of all lamps (including LEDs) is typically defined as the operating time prior to 30 percent lumen depreciation, or 70 percent lumen maintenance (L70). This level of LED lumen depreciation has been widely adopted as the standard for useful life since a 30 percent decline in lumen levels is not easily detectable by most people. Although the time required to reach L70 lumen levels is directly related to typical operating temperatures, the life expectancy of LED streetlights can be 100,000 hours or more if operating temperatures remain inside established tolerances. This is significantly longer than any traditional HID light sources and relates directly to reduced maintenance costs over time.



## Aggregate Lifetime Efficiency: LED vs. HID

Higher system efficiency and slower lumen depreciation combine to provide substantially higher overall efficiency when LEDs are compared to HID sources. For example, the chart below compares the expected performance of a 100-watt MH streetlight and a 100-watt HPS streetlight versus a comparable LED. The chart depicts this performance in system lumens-per-watt.



Expected Performance of 100-watt MH and 100-watt HPS vs. LEDs

As shown in the chart above, the lumens-per-watt of the LED declines gradually over a long period, approximately 24 years. However, the lumen output of the equivalent MH lamp declines much more rapidly, requiring a lamp replacement at least five times over the same 24 years. And while the HPS lamp lasts much longer than the MH lamp, it too must be replaced twice over the 24 year period.

## All Light is not the Same

The color of the light, quality of the light, and its ability to illuminate the area or roadway in a manner that is conducive to driver safety also play key roles in why LEDs offer an advantage over HID light sources.

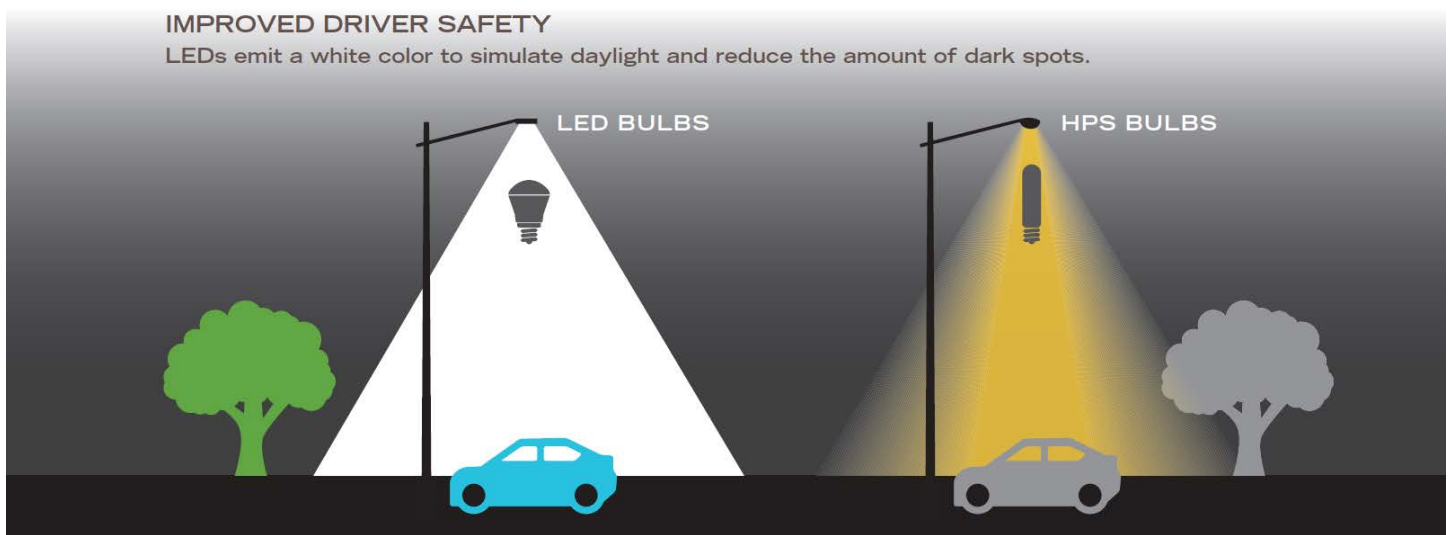
### Color Rendering Index

The color rendering index (CRI) is a scale of 1 to 100 that compares the relative “trueness” of the color of the object when lit by a particular light source. The higher the CRI, the more natural the objects look. Natural sunlight will render colors at a CRI of 100, incandescent light bulbs at 99, and high-performance T8 fluorescent light bulbs between 85 and 90. The CRI of a white LED is normally more than 75, while some well-encapsulated LEDs can reach more than 90, which makes the object look like it would in daylight even when placed in darkness. HPS is much lower, with a CRI of less than 23, resulting in the objects lit by HPS fixtures appearing yellow and gray.

## Color Temperature

Color temperature is a term used to describe the color of a given light, which relates to the quality of light from a light source. Color temperature is always measured in degrees Kelvin (K) and is a scale that allows for comparison of light sources with similar color temperature. For example, a 4100K fluorescent and a 4100K incandescent will produce a light with the same color.

The color temperature of HPS is approximately 2200K, which is illustrated by the yellowish light below. This yellowish light color generally makes people feel warm and sometimes sleepy—not a desirable quality on a roadway. Alternatively, the color temperature of LEDs can be customized and can range from 2600K to 10000K according to different functional illumination requirements. LEDs for street lighting applications are designed to produce cool white (4100K) or daylight white (5000K) colors which provide a daylight feeling. This effect is very desirable for street lighting.



## LED Street Lighting: A Sum Greater Than its Parts

Recent research conducted by CREE, one of the industry leaders in LED technology, suggests that drivers' safety is improved not only as a result of better night vision but also as a result of better light coverage. In fact, the research suggests that a driver's vision is improved dramatically simply because the driver is not forced to constantly adjust to high and low levels of light that are a natural result of traditional HID light sources—that is, the common "pool of light" effect from traditional streetlights. This is just one example of many benefits of LEDs that do not show up in a simple lumens-per-watt metric.

The true excellence of LEDs as an application for street lighting is not in the high lumens-per-watt or even the extra-long life of the LEDs. LEDs have a system of interactive benefits that allow them to be installed at wattage below nominal equivalency. For example, a common LED "equivalent" for a 250-watt HPS cobra head streetlight is a 140-watt fixture. This fixture is equivalent in lumen output to the 250-watt HPS fixture. But by combining high system efficiency, CRI, color temperature, and consistent light distribution, LEDs can reduce the nominal lumens required to properly light streets. This allows lighting experts to reduce the required LED wattage in the example above from 140 to 100.



## Getting Started with LED Street Lighting Projects

Following these steps will help to ensure the feasibility and technical and economic viability of your project:

- > Contact Efficiency Smart
- > Assemble a team of stakeholders to help garner community buy-in, which can be an essential part of implementing any new initiative. Use your team to educate rate-payers about the initiative.
- > Identify what your ultimate objective is and how you hope to achieve this. For example, is your goal to reduce energy consumption, cut maintenance costs, or reduce your carbon footprint?
- > Complete an inventory of existing lighting by identifying the type, quantity, placement, and age of current streetlights
- > Identify maintenance time and upkeep costs of current lighting
- > Retain the services of a qualified lighting designer to ensure your project meets your needs
- > Select LED products that meet industry performance standards
- > Obtain cost proposals from lighting contractors and/or suppliers and quantify the costs associated with completing your project
- > Perform a complete financial analysis of the project. If a community chooses to develop its own financial analysis, several tools have been developed specifically for street lighting upgrade projects. One of these calculators is the Department of Energy's Municipal Street Lighting Consortium Financial Retrofit Analysis Tool. Efficiency Smart has its own analysis tools to assist the communities it serves and provides this service at no additional cost.
- > Consider conducting a pilot as dictated by budget constraints. Install sample LED products to test performance. The pilot program should have specific and stated goals and a predetermined end-of-evaluation time. The team of stakeholders should collectively determine the evaluation criteria.

## How Efficiency Smart Can Help

More and more participating municipalities are taking advantage of Efficiency Smart's services to upgrade their streetlights due to the improved performance of LED street lighting, the reduced implementation costs, and the expanding guidance available from Efficiency Smart's technical experts. Efficiency Smart is able to provide technical assistance to help subscribing municipalities upgrade to LED streetlights, including:

- > Reviewing streetlight inventory
- > Identifying opportunities to eliminate unnecessary lighting
- > Preparing a scope of work for converting fixtures to LEDs
- > Performing a financial analysis of proposed projects
- > Evaluating the relative costs and benefits of purchasing versus leasing lighting
- > Verifying that installation is complete and lighting fixtures are working as intended
- > Providing financial incentives for eligible projects

Efficiency Smart can also assist subscribing municipalities in comparing lighting quality and cost savings analyses for communities of similar size that have already completed LED street lighting projects. These comparisons help municipalities pick the solution that best fulfills the community's specific circumstances and needs. Contact Efficiency Smart at 877-889-3777 or [info@efficiencysmart.org](mailto:info@efficiencysmart.org) to learn more.



## Appendix A: Streetsville Inventory, Cost, and Savings Assessments

Streetsville is presented as a model municipality, based on real data, challenges and conditions faced by many municipalities. Efficiency Smart began with known data and then modeled the inventory, costs, and savings opportunities available. We can provide a similar service to your municipality.

Streetsville is a community of 82,000 residents. Streetsville did not know how many streetlights it had in its municipality but wanted to explore replacing the existing streetlights<sup>4</sup> with LED equivalents in order to save energy and reduce maintenance costs. Streetsville was able to determine that it replaced an average of 1,500 streetlights each year as part of routine maintenance by reviewing purchase orders for streetlight replacement fixtures from three consecutive years.

Streetsville's practice has been to replace the entire fixture with a new fixture of the same size and type—typically, a 250-watt HPS cobra head fixture which represented the vast majority of fixtures in its inventory. It did this as both a labor savings strategy—it was faster than troubleshooting the problem and repairing the damaged components—and because the fixture cost is approximately equal to the cost of the lamp and ballast (the primary failed components). The cost of the new 250-watt HPS cobra-head was \$87 each.

### Assumptions Made to Model Inventory

- > Streetlights generally operate using photo cells and, therefore, we can assume that fixtures operate from dusk to dawn. The Illuminating Engineering Society (IES) has established that the deemed burn hours for this dusk to dawn cycle is an average of 12 hours per day or 4,383 hours annually. However, local conditions such as excessive cloud cover, numerous tunnels, or extensive shading could alter this deemed operating hour assumption significantly.
- > The majority of street lights in any municipality are cobra head fixtures using a specific lamp and wattage. In order to calculate the total number of fixtures, it is necessary to assume that all fixtures are of this type and wattage unless maintenance data exists for each fixture type.
- > The replacement of fixtures is done as a result of work order requests generated by calls that lights are not working. Most municipalities maintain streetlights in a purely reactive fashion, repairing lights either by replacing the lamp, replacing the ballast, or replacing the whole fixture only when it burns out and the outage is reported. We also assume that the replacement is made immediately after the burn out occurs, which may not be the case. The burned out light may go unreported for some period of time, affecting replacement rates.
- > Lamp, ballast, or fixture replacement frequency is highly predictable based on the known life of the lamp, ballast, or fixture—whichever is being replaced. If the municipality replaces the entire fixture each time a burn out is reported, we can assume that this burn out is due to lamp failure since the ballast and fixture are designed to last much longer than the lamp. And, therefore, we can predict that the “fixture life” is really only as long as the lamp life. For example, a typical 250-watt HPS ballast will last as long as 48,000 hours but the HPS lamp will last 40,000 hours on average.<sup>5</sup>

<sup>4</sup> This analysis does not include *decorative* streetlights. It focuses on cobra-head street lighting. The economics are different for decorative street lighting needs. Contact Efficiency Smart to learn more.

<sup>5</sup> HPS lamps are categorized by “rated life” in hours. This refers to the point when on average 50 percent of the lamps will have burned out based on laboratory testing. This rated life value is useful for comparing HPS lamps among various brands but does not reflect the true end of life average for HPS lamps in the field. Data logger testing shows that HPS streetlight lamps actually last much longer than the rated life (typical ratings are 12,000-24,000 hours) and that is why we use 40,000 hours in our calculations.

## Inventory Modeling Calculations

A typical 250-watt HPS lamp will last on average 40,000 hours or 9.126 years (40,000 hours / 4,383 hours per year) before it burns out. And since we know that the lamp is replaced every 9.126 years and that 1,500 lamps are replaced each year, total lamp inventory—and therefore fixture inventory—is 13,689 (1,500 X 9.126). That means that the failure rate on average for the entire inventory of HPS lamps is 10.96 percent (1,500 / 13,689).

Also, we can conclude that choosing a lamp or fixture with a longer life will result in fewer replacements per year and, therefore, reduced maintenance costs—at least as far as labor is concerned. For example, choosing an LED with a life of 100,000 hours would result in an average annual replacement of only 600 fixtures per year over 20 years for Streetsville: 13,689 fixtures / (100,000 hours / 4,383 hours per year) = 599.9 fixtures.

## Costs of Current inventory

Estimating the energy cost to operate these streetlights is calculated using the following assumptions:

- > A typical 250-watt HPS lamp and ballast fixture uses 295 watts of power or 0.295 kW (295 / 1000)
- > Municipalities generally pay a wholesale rate rather than a retail rate. The blended wholesale rate for the US Midwest region is assumed to be \$0.06 per kWh while retail rates are \$0.0965/kWh on average.
- > Kilo-watt demand charge is not included in electric charges for municipal street lighting since they are used during off-peak hours

Estimating the costs to maintain these streetlights can also be calculated using the following assumptions:

- > Streetlights are normally maintained by municipalities' employees earning prevailing wage. For safety reasons, a typical street lighting maintenance crew is two workers and a bucket truck.
- > Prevailing wage (including benefits) is \$75 per hour<sup>6</sup>. Each streetlight replacement takes on average 45 minutes including travel time. Total labor per fixture is \$112.50 (2 workers X \$75 per hour X 0.75 hours).
- > Streetsville is 50 square miles, making roundtrip travel an average of 50 miles. Using the General Services Administration (GSA) mileage reimbursement rate of \$0.53 per mile, truck cost is \$26.50 per fixture.
- > The average cost for a replacement 250-watt HPS cobra head is \$87 per fixture.

## Operating Costs

(Total number of fixtures) X (annual burn hours) X (kW per fixture) X (kWh rate) = operating cost in dollars annually. In Streetsville, this equates to: (13,689) X (4383) X (0.295) X (\$0.06) = \$1,061,980.

Using the same calculations as above, both the potential energy savings from an LED street lighting upgrade and any maintenance savings can be predicted and quantified. For example, replacing the 250-watt HPS fixture with a 102-watt LED equivalent will result in a new operating cost of \$367,193.19 or savings of \$694,787 annually. (Total number of fixtures) X (annual burn hours) X (kW of new fixture) X (kWh rate) = operating cost; or (13,689) X (4,383) X (0.102) X (\$0.06) = \$367,193.19.

## Maintenance Costs

(Labor cost per fixture + truck cost per fixture + cost of each replacement fixture) X 1,500 per year = maintenance cost in dollars annually. Using our example, (\$112.50 + \$26.50 + \$87), the total cost per fixture replacement is \$226. The total current annual street lighting maintenance cost is \$339,000 (\$226 / fixture X 1,500 fixtures).

<sup>6</sup> Prevailing wage is calculated based on a heavily urban district, using a labor rate of \$55/hour with a 36% allowance for benefits and incidentals.

## Evaluating Streetsville's Options

Using our example municipality, we can compare the 20-year costs of three scenarios: 1) No change to process or system, 2) using in-house staff to install 1,500 new LED fixtures each year until the entire portfolio is LED instead of replacing the 250-watt HPS fixtures, and 3) implementing a one-time upgrade to LED fixtures. For purposes of illustration, we are assuming that a new LED replacement is a 102-watt fixture and can be purchased for a material cost of \$150 plus our already established labor and mileage to install it.

### Cost of Scenario 1 (No Change)

If Streetsville does not implement a lighting upgrade to LED fixtures, the annual cost to operate the existing streetlights will continue to be \$1,061,980 and maintenance cost will continue to be \$339,000. Without adjusting for energy rate increases, labor increases, or changes in the other costs to replace the existing fixtures, after 20 years the municipality will have spent \$28,019,600 on the system.

Cumulative Costs by Doing Nothing						
Year	Energy Cost	Annual Energy Savings	Total Energy Savings	Installation and Maintenance Costs	Annual New LED Material Costs	Total Annual Costs
1	\$ 1,061,980	\$ -	\$ -	\$ 339,000	\$ -	\$ 1,400,980
2	\$ 1,061,980	\$ -	\$ -	\$ 339,000	\$ -	\$ 1,400,980
3	\$ 1,061,980	\$ -	\$ -	\$ 339,000	\$ -	\$ 1,400,980
4	\$ 1,061,980	\$ -	\$ -	\$ 339,000	\$ -	\$ 1,400,980
5	\$ 1,061,980	\$ -	\$ -	\$ 339,000	\$ -	\$ 1,400,980
6	\$ 1,061,980	\$ -	\$ -	\$ 339,000	\$ -	\$ 1,400,980
7	\$ 1,061,980	\$ -	\$ -	\$ 339,000	\$ -	\$ 1,400,980
8	\$ 1,061,980	\$ -	\$ -	\$ 339,000	\$ -	\$ 1,400,980
9	\$ 1,061,980	\$ -	\$ -	\$ 339,000	\$ -	\$ 1,400,980
10	\$ 1,061,980	\$ -	\$ -	\$ 339,000	\$ -	\$ 1,400,980
11	\$ 1,061,980	\$ -	\$ -	\$ 339,000	\$ -	\$ 1,400,980
12	\$ 1,061,980	\$ -	\$ -	\$ 339,000	\$ -	\$ 1,400,980
13	\$ 1,061,980	\$ -	\$ -	\$ 339,000	\$ -	\$ 1,400,980
14	\$ 1,061,980	\$ -	\$ -	\$ 339,000	\$ -	\$ 1,400,980
15	\$ 1,061,980	\$ -	\$ -	\$ 339,000	\$ -	\$ 1,400,980
16	\$ 1,061,980	\$ -	\$ -	\$ 339,000	\$ -	\$ 1,400,980
17	\$ 1,061,980	\$ -	\$ -	\$ 339,000	\$ -	\$ 1,400,980
18	\$ 1,061,980	\$ -	\$ -	\$ 339,000	\$ -	\$ 1,400,980
19	\$ 1,061,980	\$ -	\$ -	\$ 339,000	\$ -	\$ 1,400,980
20	\$ 1,061,980	\$ -	\$ -	\$ 339,000	\$ -	\$ 1,400,980
<b>Total Energy Costs =</b>	<b>\$ 21,239,600</b>		<b>Total Maintenance Costs =</b>	<b>\$ 6,780,000</b>	<b>Total Cost Over 20 years =</b>	<b>\$ 28,019,600</b>

### Cost of Scenario 2 (Phased Installation)

Municipalities may not have resources to implement a total lighting retrofit and it is common for some to perform a self-installed upgrade staged over several years. If Streetsville decided to implement an upgrade to LED fixtures as a phased approach, they could simply install the LED equivalent fixture as part of normal maintenance service—that is to say, 1,500 LED fixtures would be installed to replace the burned out fixtures until all of the fixtures in the inventory are LEDs.

We estimate that it would take nearly 12 years to complete this phased approach. It would take this long because as fixtures are installed there is also a moderate early failure rate. Therefore, we anticipate that some fixtures would be replaced twice before all HPS fixtures would be replaced. Some of these fixtures would also be outside the warranty period, so a total of 18,000 fixtures would be installed over the 12-year phased period.

The cost of 1,500 fixtures would be approximately \$225,000 per year.<sup>7</sup> Maintenance, labor, and truck costs remain unchanged from the first scenario through year 12, as 1,500 fixtures are still being replaced each year. Material costs increase slightly as the new LED fixture is estimated to be \$150 or \$63 more than the HPS fixture.

The energy savings are incrementally greater each year as more fixtures are installed until year 13 when the project is complete and the total energy savings potential is reached. We also discount the energy savings each year, years two through 12, by 10 percent to account for the failed fixtures that will require re-installation. This means that less than 1,500 fixtures replace the HPS fixtures each year until after year 12 when full energy savings are realized.

Maintenance costs decrease in year 13 as the retrofit is complete and only five percent of the LED fixtures are replaced when they fail each year thereafter. The total 20 year cost is slightly more than with the one-time upgrade scenario (\$17,794,159 vs. \$15,515,531) as a result of the delay in realizing the energy savings. This still represents a savings of \$10,225,441 after 20 years, or 36 percent over Scenario 1. It is also important to note with this scenario that cash flow is negative compared to Scenario 1 in years one and two. The total annual cost increase in year one is \$94,500—the incremental added costs of the 1,500 LED fixtures while claiming no energy savings—and in year two is \$25,980 over Scenario 1 before real total annual savings start to be realized.

Self-Install over 12 Years						
Year	Energy Cost	Annual Energy Savings	Total Energy Savings	Installation and Maintenance Costs	LED Material Costs	Total New Annual Costs
1	\$1,061,980	\$0	\$0	\$208,500	\$225,000	\$1,495,480
2	\$993,460	\$68,520	\$68,520	\$208,500	\$225,000	\$1,426,960
3	\$924,940	\$137,040	\$205,559	\$208,500	\$225,000	\$1,358,440
4	\$856,420	\$205,560	\$411,119	\$208,500	\$225,000	\$1,289,920
5	\$787,900	\$274,080	\$685,199	\$208,500	\$225,000	\$1,221,400
6	\$719,380	\$342,600	\$1,027,799	\$208,500	\$225,000	\$1,152,880
7	\$650,860	\$411,120	\$1,438,918	\$208,500	\$225,000	\$1,084,360
8	\$582,340	\$479,640	\$1,918,558	\$208,500	\$225,000	\$1,015,840
9	\$513,820	\$548,160	\$2,466,718	\$208,500	\$225,000	\$947,320
10	\$445,300	\$616,680	\$3,083,397	\$208,500	\$131,018	\$784,818
11	\$376,780	\$685,200	\$3,768,597	\$208,500	\$102,668	\$687,948
12	\$367,193	\$694,787	\$4,463,384	\$208,500	\$102,668	\$678,361
13	\$367,193	\$694,787	\$5,158,171	\$161,796	\$102,668	\$631,657
14	\$367,193	\$694,787	\$5,852,958	\$104,250	\$102,668	\$574,111
15	\$367,193	\$694,787	\$6,547,745	\$104,250	\$102,668	\$574,111
16	\$367,193	\$694,787	\$7,242,532	\$104,250	\$102,668	\$574,111
17	\$367,193	\$694,787	\$7,937,319	\$104,250	\$102,668	\$574,111
18	\$367,193	\$694,787	\$8,632,106	\$104,250	\$102,668	\$574,111
19	\$367,193	\$694,787	\$9,326,893	\$104,250	\$102,668	\$574,111
20	\$367,193	\$694,787	\$10,021,680	\$104,250	\$102,668	\$574,111
<b>Total Energy Costs =</b>	<b>\$11,217,920</b>		<b>Maintenance Costs =</b>	<b>\$3,393,546</b>	<b>Total Costs Over 20 years =</b>	<b>\$17,794,159</b>

<sup>7</sup> Efficiency Smart can provide financial incentives to participating municipalities for eligible street lighting projects. This incentive reduces the initial investment and makes the project economics even more favorable.



### Cost of Scenario 3 (One-time Upgrade)

The cost to implement the installation of 13,689 new fixtures is calculated to be \$3,956,121 based on an estimated \$150 material cost for each LED fixture and using the same installation cost per fixture (\$112.50 + \$26.50 = \$139) as used previously for HPS fixture replacement. Implementing a one-time LED lighting retrofit results in immediate energy savings (calculated starting after year one) and yields a 20-year energy cost of only \$8,038,647. Maintenance labor costs are cut significantly throughout the 20 years as we assume a conservative failure rate of five percent for the new fixtures (this includes early failure of fixtures).<sup>8</sup> A 5 percent failure rate results in a replacement of only 750 fixtures annually, a reduction from the 1,500 previously experienced. Additionally, we can assume that all fixture failures during the first five years are covered under manufacturer's warranty and cost Streetsville nothing. The total cost to implement the lighting upgrade and to operate and maintain this system for 20 years is \$15,515,531, a cumulative savings of 44.6 percent.<sup>9</sup>

One-Time Upgrade						
Year	Energy Cost	Annual Energy Savings	Total Energy Savings	Installation and Maintenance Costs	LED Material and Labor Costs	Total New Annual Costs
1	\$ 1,061,980		\$ -	\$ -	\$ 3,956,121	\$ 5,018,101
2	\$ 367,193	\$ 694,787	\$ 694,787	\$ 104,250		\$ 471,443
3	\$ 367,193	\$ 694,787	\$ 1,389,574	\$ 104,250		\$ 471,443
4	\$ 367,193	\$ 694,787	\$ 2,084,361	\$ 104,250		\$ 471,443
5	\$ 367,193	\$ 694,787	\$ 2,779,148	\$ 104,250		\$ 471,443
6	\$ 367,193	\$ 694,787	\$ 3,473,935	\$ 104,250	\$ 102,668	\$ 574,111
7	\$ 367,193	\$ 694,787	\$ 4,168,722	\$ 104,250	\$ 102,668	\$ 574,111
8	\$ 367,193	\$ 694,787	\$ 4,863,509	\$ 104,250	\$ 102,668	\$ 574,111
9	\$ 367,193	\$ 694,787	\$ 5,558,296	\$ 104,250	\$ 102,668	\$ 574,111
10	\$ 367,193	\$ 694,787	\$ 6,253,083	\$ 104,250	\$ 102,668	\$ 574,111
11	\$ 367,193	\$ 694,787	\$ 6,947,870	\$ 104,250	\$ 102,668	\$ 574,111
12	\$ 367,193	\$ 694,787	\$ 7,642,657	\$ 104,250	\$ 102,668	\$ 574,111
13	\$ 367,193	\$ 694,787	\$ 8,337,444	\$ 104,250	\$ 102,668	\$ 574,111
14	\$ 367,193	\$ 694,787	\$ 9,032,231	\$ 104,250	\$ 102,668	\$ 574,111
15	\$ 367,193	\$ 694,787	\$ 9,727,018	\$ 104,250	\$ 102,668	\$ 574,111
16	\$ 367,193	\$ 694,787	\$ 10,421,805	\$ 104,250	\$ 102,668	\$ 574,111
17	\$ 367,193	\$ 694,787	\$ 11,116,592	\$ 104,250	\$ 102,668	\$ 574,111
18	\$ 367,193	\$ 694,787	\$ 11,811,379	\$ 104,250	\$ 102,668	\$ 574,111
19	\$ 367,193	\$ 694,787	\$ 12,506,166	\$ 104,250	\$ 102,668	\$ 574,111
20	\$ 367,193	\$ 694,787	\$ 13,200,953	\$ 104,250	\$ 102,668	\$ 574,111
<b>Total Energy Costs =</b>	<b>\$ 8,038,647</b>		<b>Total Maintenance Costs =</b>	<b>\$ 1,980,750</b>	<b>Total Costs Over 20 Years =</b>	<b>\$ 15,515,531</b>

<sup>8</sup> LEDs are categorized by "rated life" in hours based on L70 testing. This refers to the estimated point when, on average, 30 percent of the lumen output of the fixture is gone. Like HPS lamps, this rated life value is useful for comparing LED lamps among various brands but does not reflect the true end of life of LEDs. We assume that the LED fixture will not be replaced until it is burned out, just like the HPS streetlight lamps, but LEDs have not been around long enough to have reliable data. In the absence of that data, we calculate that the LED will last 100,000 hours, yielding a failure rate of 4.36 percent. In our cash flow analysis, we use a more conservative five percent failure rate even for early failures.

<sup>9</sup> In both retrofit scenarios the majority of savings is in the reduced energy use, not in maintenance savings. The reduced maintenance labor is largely offset by the higher cost of the LED fixture, even though fewer fixtures need replaced.





## Appendix B: Street Lighting Funding Sources

The high cost of capital can be an obstacle to street lighting upgrade projects. In many cases, funds are available at the national, state, and local levels. To identify project funding early in the process, municipalities might consider the following resources:

- > **Federal Government.** Municipalities may find federal grants in the form of matching funds through the federal government. The DOE Municipal Solid-State Street Lighting Consortium (MSSLC) may be a good resource for identifying these opportunities.
- > **State Programs.** Many states have grants and low interest loan programs available for energy saving projects. A good example is the Ohio Energy Loan Fund.
- > **Self-funding.** Internal sources of capital coming out of the annual budget may represent the fastest and most cost-effective way to finance smaller street lighting projects. Internal capital can often be used without financing or transaction costs and extended waiting periods.
- > **Debt Financing.** With current relatively low interest rates, issuing bonds or arranging financing through private capital markets may be a good option. Municipalities typically have access to tax-exempt financing, which lowers the overall cost of borrowing. Sources of tax-exempt debt financing include:
  - Tax-exempt municipal lease
  - The issuance of bonds
- > **Manufacturers' Programs.** Large streetlight manufacturers might also help finance street lighting projects through payments over several years. Asking the manufacturers about these financing options and possibly including terms in the bid documents may help in identifying these opportunities.

**Energy Performance Contractors (ESCOs).** Performance contracting has been in existence for many years providing a turnkey approach to implementing energy efficiency upgrades. Most states allow municipalities to contract with ESCOs and use energy savings to repay the financing debt. Check with your state facilities commission for the availability of this option.