CITYLAB INSIGHTS

northeast group, llc

The Benefits of LED & Smart Street Lighting

A Performance Benchmark of US Cities

CIMCON Lighting

interact

Itron

SENSUS a xylem brand

verizon

About the Authors

CityLab Insights

Incubated at CityLab, CityLab Insights has the mission of helping urban decision-makers to make smart, informed decisions that benefit cities today and tomorrow. CityLab Insights' work is independent of any sponsor or funder and is independent of CityLab's journalism. Our work is solely the result of our internal research and analysis. Our goal is to help urban policymakers, private sector leaders, and community advocates navigate the quickly evolving world of the 21st century.

Northeast Group, LLC

Northeast Group is a market intelligence firm based in Washington, DC with expertise in the smart infrastructure sector. The firm analyzes and forecasts how smart infrastructure and the Internet of Things (IoT) will be deployed at utilities and in smart cities. Northeast Group publishes market research studies, datasets and offers custom research services.

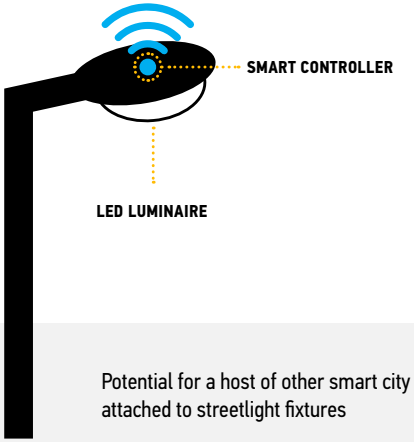
northeast-group.com

What's Inside

Quick read

Streetlights are the low hanging fruit for cities not sure where to start…

- Cities can save energy, reduce operational costs, and lay the foundation for smart city initiatives
- This is achieved by replacing legacy luminaires with more efficient LEDs and adding smart controllers with dimming and other capabilities

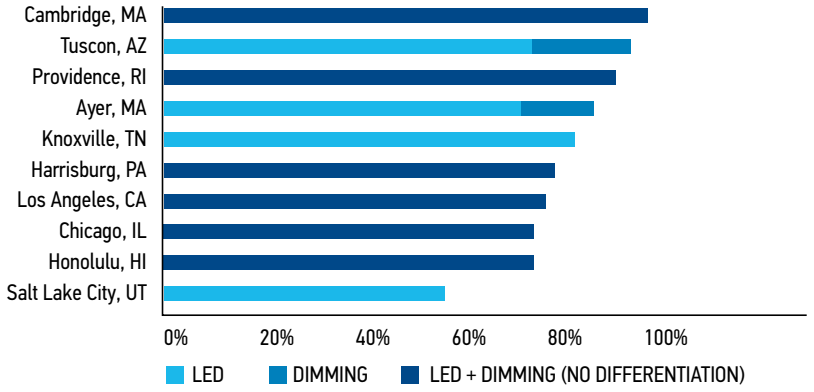


Potential for a host of other smart city sensors attached to streetlight fixtures

Energy savings of well more than half have been achieved…

- Among the participants in Northeast Group's benchmark, the average energy savings was 66%
- Savings ranged from 47% to 80%
- Street lighting alone typically accounts for a quarter or more of a city's electricity usage

ENERGY SAVING EXAMPLES



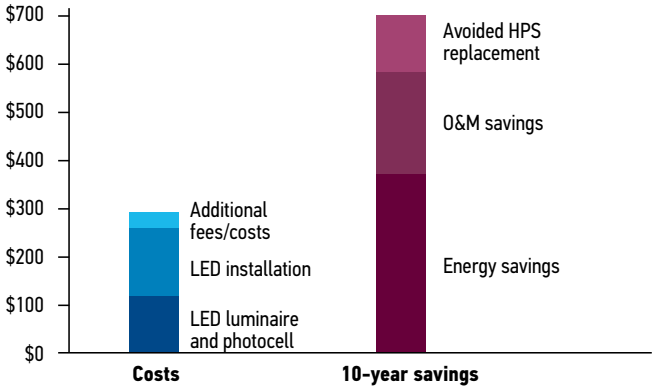
Source: Northeast Group

Quick read

Operational efficiencies add additional savings…

- LEDs have longer lifespans, reducing the frequency of replacing lights
- Smart controllers pinpoint outages and "day burners," streamlining maintenance
- With dimmable lights, cities hold fewer wattage types in inventory, further reducing costs

COST SAVING EXAMPLES



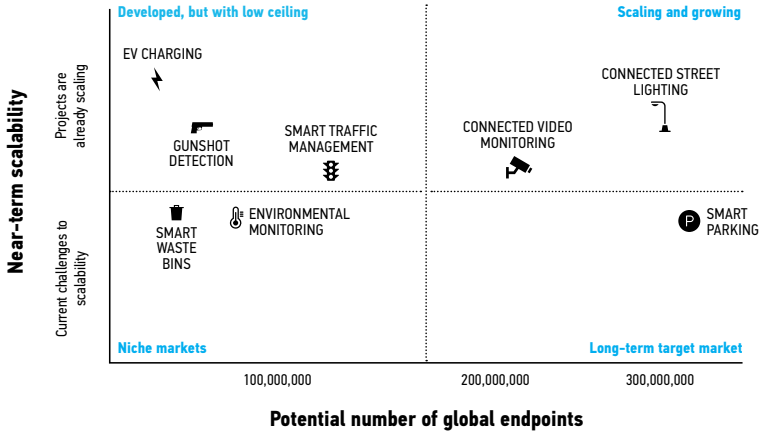
Source: Northeast Group

Foundation is laid for smart city applications and other benefits…

Communications and analytics infrastructure from smart street lighting lays the foundation for

- Traffic and pedestrian monitoring
- Smart parking
- Environmental sensors
- Utility smart metering
- A host of other applications

SMART CITY INFRASTRUCTURE POTENTIAL BY SEGMENT



Source: Northeast Group

Introduction

The potential of smart cities is compelling for policymakers, utilities, public works officials, residents and other city stakeholders. Smart infrastructure leveraging sensors with communications and analytics can generate energy savings, efficiency gains, improved public safety, and a host of other benefits for the community. However, a number of smart city applications remain unproven and their business cases too ambiguous when attempting to quantify costs and benefits.

The exception is street lighting. The business case for modernizing street lighting infrastructure with LED luminaires and "smart" controllers is a no-brainer. What was once a boring, nearly invisible element of cities' infrastructure has now become the linchpin for unlocking the smart city. Beyond the clear cut near-term benefit case for LED and smart street lighting projects, the same infrastructure also has the potential to enable a number of emerging smart city applications.

This study provides a performance benchmark of cities that have deployed LED and/or smart street lighting. It quantifies benefits from both LED conversions and the networking of streetlights with communications to make them smart. In all cases, these benefits have far outweighed the costs.

SIGNIFICANT BENEFITS

The benefits of LED and smart street lighting projects center on reduced energy usage and improved operational efficiency. Energy usage is reduced on two levels: first from more efficient LED luminaires and second, from dimming capability with smart controllers. Combined, these typically result in a 60% to 80% reduction in energy usage for a city or utility using smart streetlights, along with the corresponding reduction in carbon emissions. Just as importantly, operational efficiency is improved by both LED and smart streetlights. LEDs have longer lifespans and fewer failures, while smart streetlight systems immediately identify outages and "day burners," reducing truck rolls. This further reduces carbon emissions and O&M costs.

DECLINING COSTS

Paired with the significant benefits are costs that have declined rapidly and are now at the point of beginning to bottom out. The precipitous decline of LED luminaire costs over the past several years are well documented across the lighting sector. This holds true for streetlight luminaires as well. Costs have declined by over 65% since 2012 and are now effectively at cost parity with high-pressure sodium (HPS) and other legacy streetlight luminaires. Many industry insiders believe the bottom has been reached and further precipitous declines are unlikely.

Introduction

This study seeks to provide the reader with a clear view on both the quantitative and qualitative benefits of LED and smart street lighting projects. It can be used as support for city and utility stakeholders confronting the challenge of convincing decision-makers that these are projects with a clearly positive business case.

In addition to this introduction, there are six main sections to the study. Each section will walk the reader through an important element of the streetlight modernization process.

01 SURVEY RESULTS AND FINDINGS

In this section, the most important insights from the survey and benchmark are presented. These include the savings benefits from both LED and smart street lighting projects and unique benefits conveyed through interviews with city and utility leaders.

02 LED STREETLIGHT BENEFIT CASE

This will look solely at the benefits from converting legacy streetlights to LEDs. The key components of savings will be presented, including energy savings, O&M savings and avoided HPS replacement savings. Costs such as the LED luminaire and installation will be covered.

03 SMART STREETLIGHT BENEFIT CASE

This will add the "smart" component to LED conversions, where streetlights are paired with communications and smart controllers, enabling dimming for further savings and a host of other benefits. The various savings components of smart streetlights will be presented.

04 HOW TO OVERCOME CHALLENGES

Streetlight modernization projects are not without their challenges. This section will identify some of the key challenges and how they can be overcome.

05 TECHNOLOGY OPTIONS

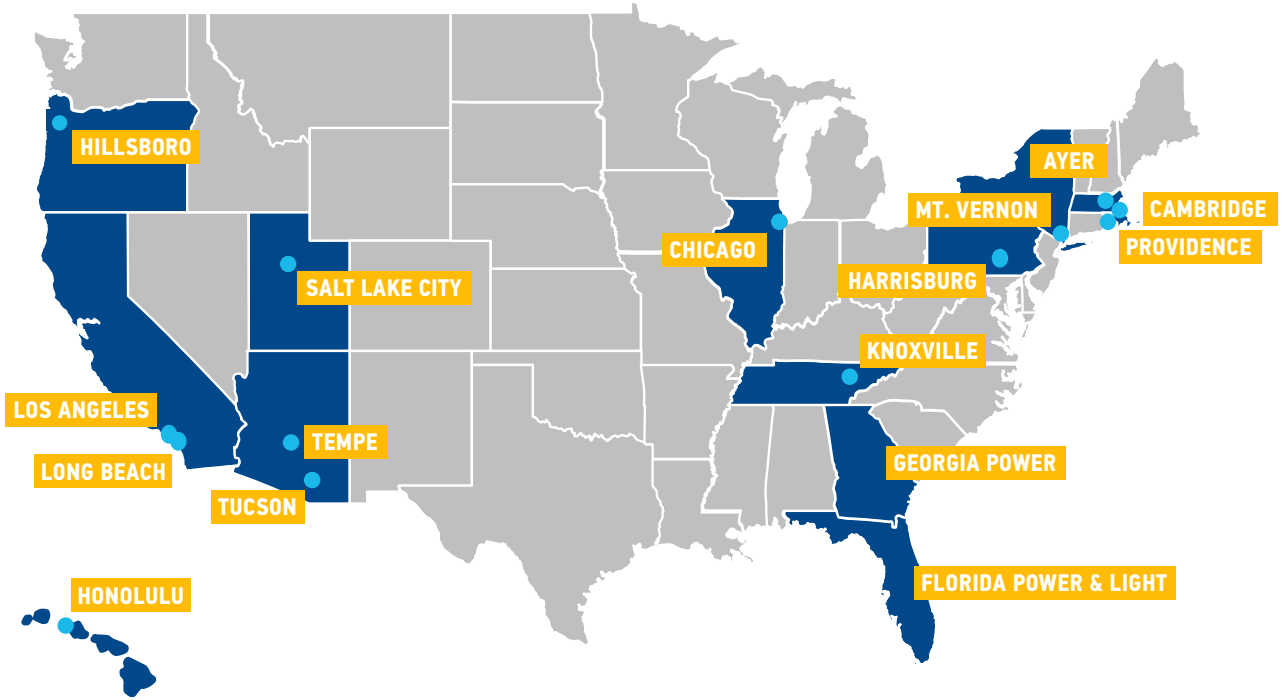
Decision-makers undertaking streetlight modernization projects will need to complete detailed assessments of different technologies to identify the best fit for their individual needs. Such an undertaking is outside the scope of this study. This section will identify at a high level some of the different types of communications technologies cities have used and define how they work. It will also introduce the software and analytics employed.

06 BROADER SMART CITIES OPPORTUNITIES

Smart street lighting is just one of many steps a city must take to realize the full potential of smart cities. This section will identify some of the other smart city applications cities are deploying and how they can coordinate with street lighting projects.

Survey results and findings

Northeast Group conducted primary research to assemble this performance benchmark. Cities and utilities were contacted to share the concrete energy, maintenance (O&M) and other savings they achieved through their street lighting projects. A diverse cross-section of cities and utilities was included in the benchmark to ensure different sizes and geographic locations were covered. Cities ranged from populations of just 8,000 to over 4 million (in addition to utilities that reach even larger populations).



Cities included in most cases have either completed or are in the latter stages of completing LED and/or smart streetlight conversions. Savings data come directly from the cities and utilities, either through interviews, publicly reported data, or both. In cases where deployments are not yet complete but the cities have done a detailed analysis (on a streetlight by streetlight basis) of the savings based on wattage levels, these savings have been reported. On average, cities report 66% savings in energy usage in addition to O&M savings and many other quantitative and qualitative benefits. This section highlights the findings, savings, and key takeaways from the benchmark.

Key findings from survey

- Energy savings averaged 66% across all cities and utilities
- O&M savings alone were sufficient in most cases to justify the costs of projects
- LED and dimmed streetlights are well received by residents
- City ownership of streetlights increases financial flexibility
- Cities want to be prepared for smart city applications, but few applications beyond street lighting have been deployed
- State-led initiatives are helping smaller cities develop these projects

BENCHMARK PARTICIPANTS

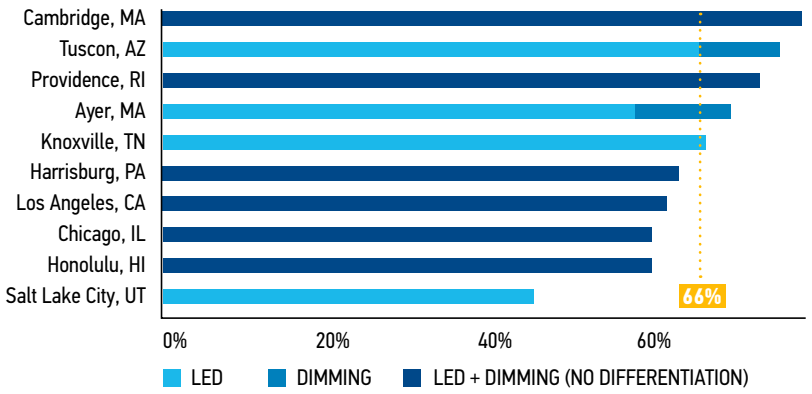
CITY/UTILITY	STREETLIGHTS	CONNECTED?*	DATE BEGUN
AYER, MA	563	YES	2018
CAMBRIDGE, MA	7,000	YES	2014
CHICAGO, IL	270,000	YES	2017
FLORIDA POWER & LIGHT	500,000	YES	2014
GEORGIA POWER	400,000	YES	2015
HARRISBURG, PA	6,127	YES	2016
HILLSBORO, OR	4,640	YES	2018
HONOLULU, HI	53,500	YES	2018
KNOXVILLE, TN	29,500	NO	2018
LONG BEACH, CA	26,000	NO	2018
LOS ANGELES, CA	165,000	YES	2013
MOUNT VERNON, NY	4,500	YES	2018
PROVIDENCE, RI	15.098	YES	2016
SALT LAKE CITY, UT	15,500	CONSIDERING	2012
TEMPE, AZ	8,000	NO	2016
TUCSON, AZ	18,330	YES	2016

*Cities that did not connect lights typically included 7-pin NEMA sockets to allow for future smart streetlight controls

Key findings from survey

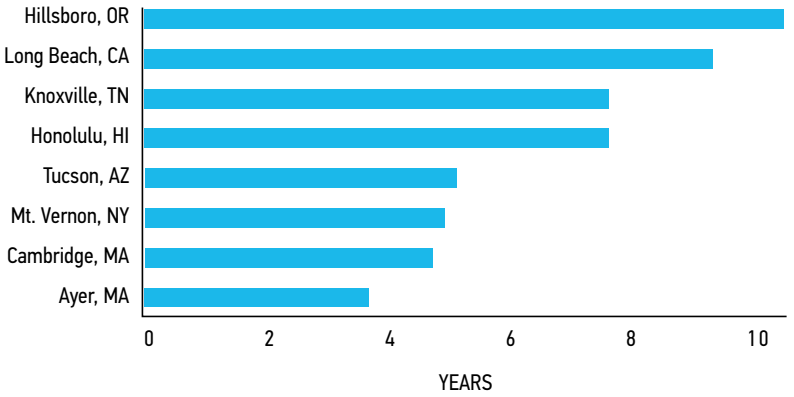
- All cities achieved at least 50% energy savings from LEDs, and typically a further 10-20% from dimming, depending on dimming schedule
- Costs varied significantly, which affects the payback period. Cities with longer payback periods typically had additional financing and overhead costs, or in some cases costs associated with purchasing their streetlights from utilities
- O&M savings in many cases exceeded energy savings. Cities with controls will likely see even further O&M savings in the coming years as cities can scale down replacement schedules and inventory

ENERGY SAVING EXAMPLES



Source: Northeast Group

PAYBACK PERIOD EXAMPLES



Source: Northeast Group

Streetlight controls and LEDs significantly reduce O&M costs

- Cities often think of energy savings as the sole benefit of modernized street lighting, but in many cases O&M reductions are the primary driver
- In cities where the local utility does not pass along savings from reduced energy usage (either from dimming or LED luminaires)[1], O&M savings alone have been used to justify the cost of streetlight conversions, often with short payback periods
- Streetlight controls help reduce inventory needs as cities can buy just a few models of luminaires and dim them accordingly to achieve the level of light desired, reducing the need to store as much inventory capacity

TEMPE, AZ

Failure rates have dropped from 10-15% to 1-2%. Tempe's local utilities have not developed LED tariffs, but the city's conversion project is paying for itself in reduced truck rolls alone.

SALT LAKE CITY, UT

Lighting controls are viewed as the equivalent of having another full-time employee. They reduce the number of customer service calls, streamline maintenance, and improve asset management.

[1] The issue of utility streetlight tariffs is a critical one; please see "How to overcome challenges" on page 19 for more information on this key sticking point.

LED and smart streetlights are well received by residents

- All of the cities reported positive feedback from residents and particularly from law enforcement officials
- Concern over LED brightness has decreased, but there is a strong preference for 3000K lights, which aren't as white or bright as 4000K lights
- LEDs help cities with dark sky initiatives, as light is more directed towards the ground
- Streetlight controls further improve customer satisfaction by allowing cities to dim lights in areas where they are deemed too bright

TUCSON, AZ

Meeting Dark Sky Association goals was a leading objective for Tucson, which has a large desert tourism industry. Tucson opted for streetlight controls and 3000K luminaires.

PROVIDENCE, RI

Providence has reported strong positive feedback from law enforcement. In the few cases where there were resident complaints over bright LED lights, Providence leveraged its control network to dim the lights according to resident demand.

Many cities are buying back their streetlights

- 4 of the 16 cities in our benchmark recently purchased their streetlights from their local utility. Costs ranged from $1 to $849 per streetlight
- 15 of the 300 largest US cities have either recently purchased their streetlights or are in the process of purchasing their streetlights
- Streetlight ownership helps guarantee O&M savings from streetlight conversions, but energy savings can still depend on tariff structures from the local utility

KNOXVILLE, TN

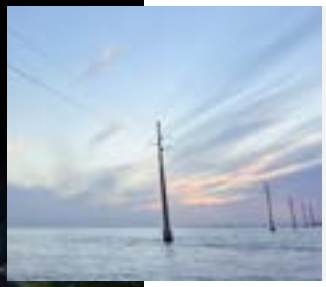
Facilities fees totaled over $2.3m per year before Knoxville bought its streetlights and are expected to fall below $1m per year upon project completion. The project's 7.5 year payback includes the costs of purchasing streetlights (approx. $176 per streetlight).

AYER, MA

Streetlights had a depreciated value of just $1. By buying its streetlights (at essentially no cost), Ayer was able to lock in the maintenance savings from its LED/smart conversion. Without a facilities charge and with 10-year warranties on its lighting system, maintenance costs have plummeted.

Municipalities and utilities want to be "smart city ready"

- Smart street lighting can form the backbone of larger smart city projects, providing a cost-effective entry point for smart city communications and software platforms
- Many cities are looking to use the same smart streetlight communications infrastructure for local utilities providing water, gas, and electricity metering
- The majority of cities in our benchmark that elected not to install streetlight controls opted for a standardized 7-pin NEMA socket that will allow for easy upgrades to smart city applications in the future. But cities that chose to wait will still have to pay additional labor costs that they would not have incurred if they had deployed controls at the same time as LEDs



FLORIDA POWER AND LIGHT

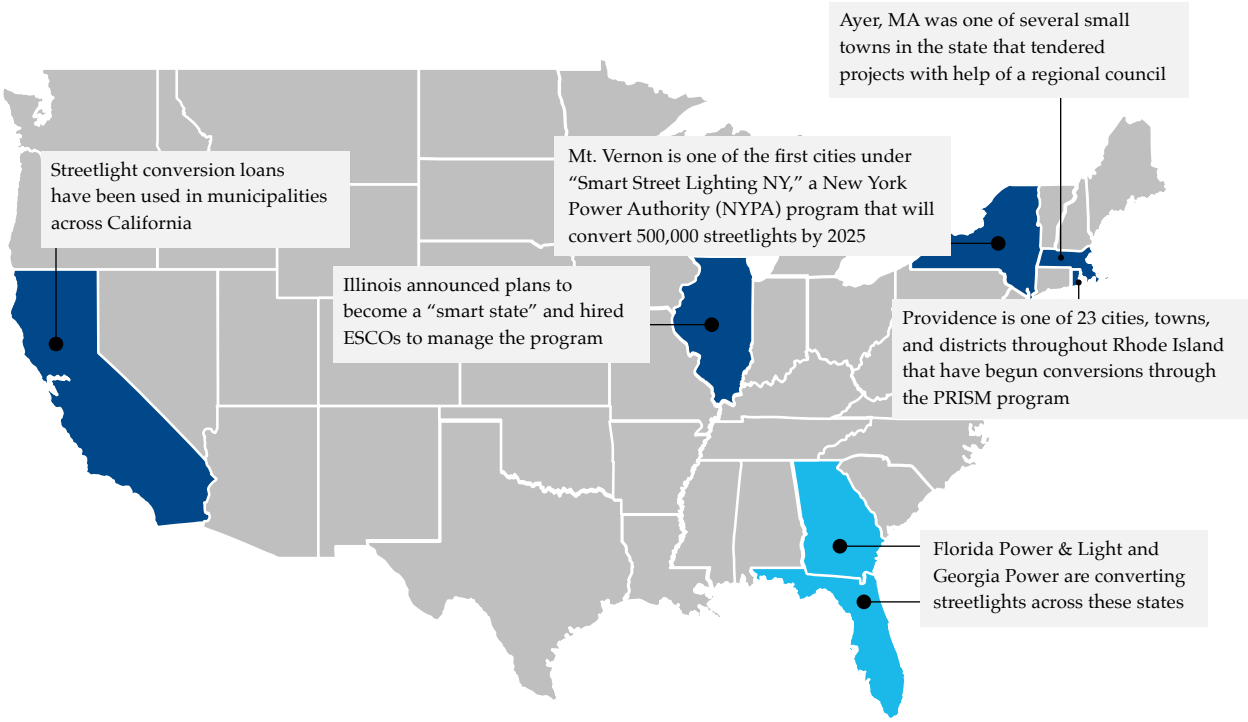
FPL's streetlight controls integrated with a communications infrastructure that also supports 5 million smart meters, 19,000 remote fault indicators, 1,300 capacitor banks, and 2,000 automated feeder switches.

GEORGIA POWER

Georgia Power has leveraged its smart streetlight network to sell video surveillance systems, lease telecom attachment rights, and more, greatly increasing its revenues per streetlight.

State initiatives will help move projects forward

- State-level programs are helping smaller cities develop knowhow and financing for streetlight conversions. New York and Illinois are setting up effectively state-run ESCOs[2] to develop energy-efficient lighting projects, while California is providing low-cost loans and tax-exempt bonds for conversions
- The Partnership for Rhode Island Streetlight Management (PRISM) is a non-profit entity that provides capacity and knowhow to municipalities wishing to buy back their streetlights from local utilities and also deploy LED and smart streetlights, in a model that could be exported across the US
- Some large investor-owned utilities are developing connected streetlight programs, bringing energy efficient lighting statewide



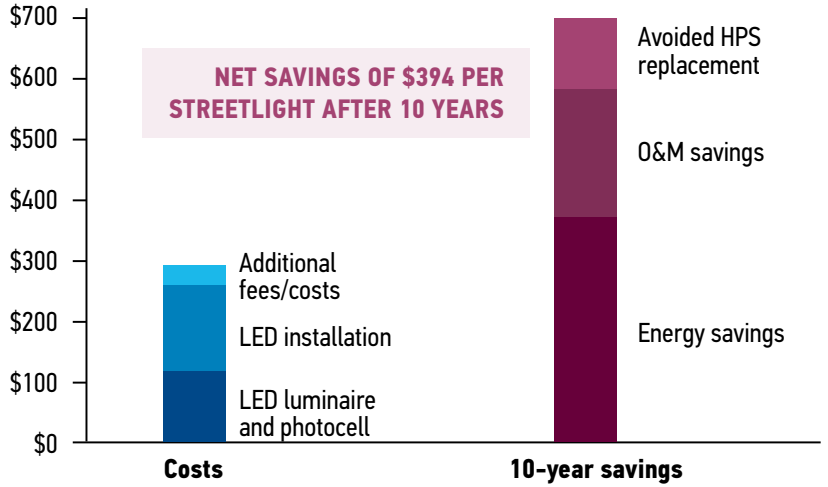
[2] An Energy Service Company (ESCO) is an entity that develops, designs, finances and implements projects that result in energy and other savings.

LED streetlight benefit case

LED streetlight conversions have a strong benefit case on their own – one that only increases when paired with smart controls. As shown in the chart below, these benefits far exceed the average cost of implementation, even without counting environmental, public safety, and other qualitative benefits. The primary benefits, further described on the following page, are:

- Energy savings
- O&M savings, including avoided equipment costs
- Environmental and qualitative benefits

EXAMPLE COSTS AND SAVINGS FOR 100W LED STREETLIGHT[3]



Source: Northeast Group

[3]This analysis of example costs and savings figures was completed by Northeast Group. It reflects a typical conversion deployment with average project, electricity and O&M costs and savings. Specific projects will vary in their results achieved, as shown on the following page with Knoxville.

LED streetlight benefit case

Energy savings

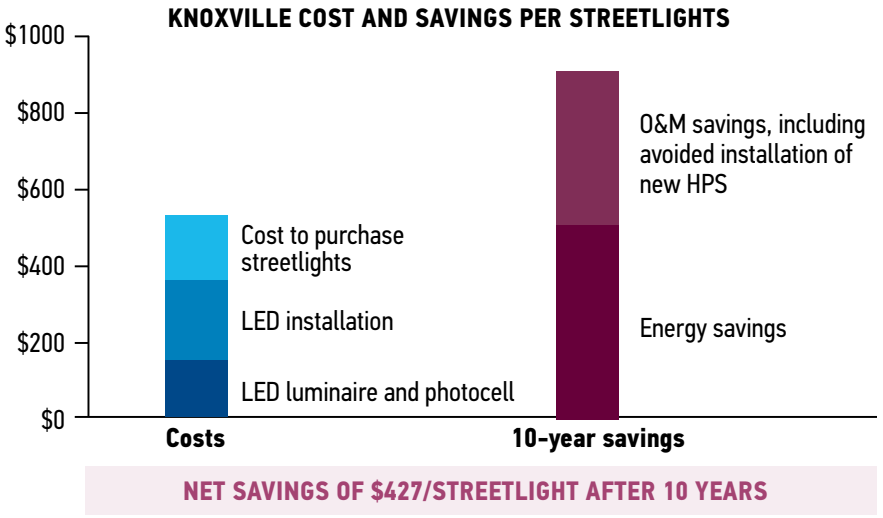
This is the most obvious and often the largest of the benefits from LED conversions. LED manufacturers typically claim about 50% energy savings compared with legacy HPS luminaires. In reality, many cities have found even greater savings, with the average LED-only city (those that did not implement controls with dimming capability) in our benchmark saving 57%. Most cities now have utilities that offer LED tariffs, meaning that they see concrete monetary savings from reduced energy usage, but this is not the case nationwide.

O&M savings

O&M savings are an often overlooked benefit of LED street lighting, but in many cases these savings pay for the cost of the projects on their own. LED streetlights have fewer failures and therefore require fewer truck rolls, helping to reduce costs. But perhaps even more importantly, LED luminaires last more than twice as long as legacy HPS bulbs. A significant portion of most cities' streetlight budget is for the regular replacement of streetlights, which has both capital and labor costs. With a 10-15 year lifespan, LEDs can reduce long-term O&M costs by more than half.

Additional benefits

For the reasons listed above, LED streetlights bring significant environmental benefits through lower energy usage and reduced carbon emissions from truck rolls. One city in our benchmark stated that its LED streetlight project alone was sufficient for it to meet its CO2 reduction goals. Additionally, LED streetlights are well received by law enforcement by improving visibility. Meanwhile, despite well-publicized reports about residents disliking the brighter lights, no cities in our benchmark encountered more than a small handful of minor complaints. Residents enjoy the more focused lights, and particularly for those using 3000K lights, glare was not a major issue.

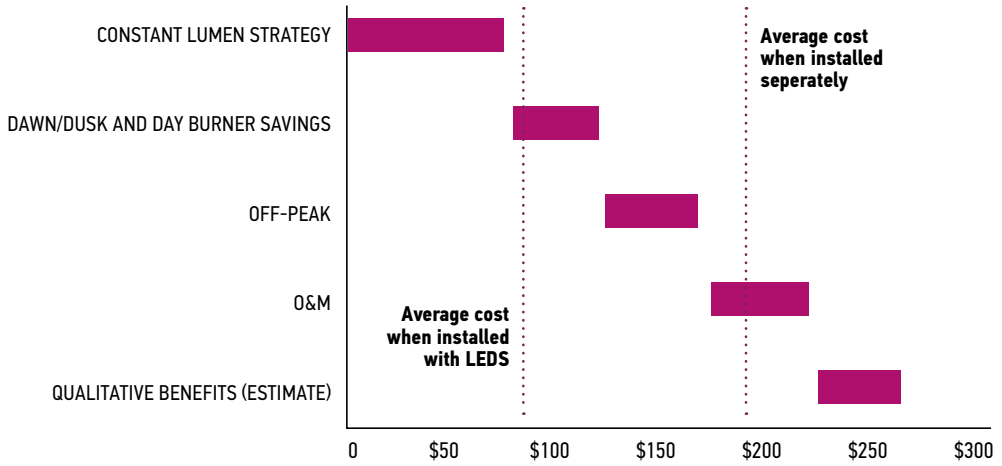


Smart streetlight benefit case

Smart streetlights add a new component to city lighting by allowing dimming and control. While smart nodes are more expensive than traditional photocells, they also bring a slew of new benefits. The most cost effective way for a city or utility to deploy a smart street lighting solution is to piggyback on the LED conversion project. This way both can be accomplished during the same truck roll. Crew costs for the incremental smart node are negligible.

The primary benefits of smart streetlights are reduced energy usage through dimming, reduced O&M costs through immediate identification of streetlight failures, and potential linkages to additional smart city applications, which are all described on the following pages. In addition to these savings benefits, smart nodes include revenue grade metering, which allows for more precise measurement of energy usage by a city's street lighting infrastructure. Traditionally, cities have paid a flat rate tariff for street lighting energy consumption based on estimated usage, and in most cities in our benchmark, this is still the case. Regulatory approval of smart node metering (which is currently limited in the US but expected to grow quickly) will further increase the benefits of smart street lighting.

SMART STREETLIGHT BENEFITS (10-YEAR SAVINGS)



*Does not include additional qualitative benefits such as reduced polution or future savings from smart city projects

Source: Northeast Group

Smart streetlight dimming strategies

CONSTANT LUMEN STRATEGY

The largest benefit from smart street lighting typically comes from employing a "constant lumen strategy." This involves deploying an LED that is stronger than necessary and then dimming it constantly to the level of light required. This prolongs the luminaire's life as the dimming level can be gradually reduced as the luminaire begins to lose strength. In many cases, luminaires are dimmed to just 70% of their potential and still provide the required lighting levels. Since many cities already deploy lights that are initially stronger than necessary (to avoid early replacement), early-life luminaires use excess energy and provide excess glare. This can be resolved through dimming.

DAWN/DUSK AND DAY BURNER SAVINGS

Most streetlights can also be dimmed during dawn and dusk when there is still sufficient light, reducing energy use. Smart streetlights also identify lights that are on during the day ("day burners"). These can be remotely shut off, further reducing energy usage.

OFF-PEAK DIMMING

Cities may also choose to dim their streetlights during off-peak hours, for example in the middle of the night when pedestrian and vehicle traffic is reduced. Each city can decide whether or not this option makes sense for them. In our benchmark, cities typically chose to dim between 30-50% from roughly 12am – 5am.

ADDITIONAL BENEFITS TO SMART STREETLIGHTS NOT FULLY CAPTURED IN QUANTITATIVE BENEFIT ANALYSIS

BENEFIT	DESCRIPTION
IMPROVED SAFETY AND SECURITY	Better quality lighting and fewer burned out streetlights lead to lower crime rates and fewer traffic accidents
FEWER CUSTOMER COMPLAINTS	Customers no longer need to call in to report burned out streetlights (or day burning streetlights) as these are automatically identified by the smart streetlight system
ENVIRONMENTAL BENEFITS	Fewer carbon and greenhouse gas emissions
NEW REVENUE STREAMS	Cities can lease network bandwidth to local companies and other possibilities
UTILITY BENEFITS	By adding nodes and communications to their rate base, utilities that own streetlights can earn a rate of return on the assets
GOVERNMENT REBATES	Some rebates and grants may be available for energy saving projects
ADDITIONAL SMART CITY APPLICATIONS	Implementing a network for smart streetlights can lay the groundwork for future smart city applications and reduce the cost of future applications

Additional Benefits

O&M

Reduced operations and maintenance (O&M) costs are another significant savings benefit from smart street lighting. By immediately identifying outages, smart streetlights both reduce customer service calls and the need for routine inspections. Smart streetlights also improve asset management by creating a database of lights and a snapshot of current maintenance needs. Few of the cities in our benchmark currently have tariffs that allow for cost savings based on dimming (although that is expected to change soon as regulations catch up to the technology), therefore, for now, O&M efficiencies are one of the primary cost benefits of smart streetlights.

LESS INVENTORY

Most cities have a variety of wattages in their streetlight infrastructure and are therefore required to carry inventory for each type of streetlight, which can raise costs considerably. With dimmable controlled lights, cities can carry just a few wattages and dim lights to the desired level, reducing inventory costs.

QUALITATIVE BENEFITS

In addition to the easily quantifiable benefits of smart street lighting, there are a number of additional benefits in which it is more difficult to put a concrete number. Dimmable lights give greater flexibility to law enforcement officials to either increase or decrease lighting during operations, while cities can dim lights in particular neighborhoods based on resident preferences. Controllable streetlights can also be flashed in emergency situations and have other capabilities. Additionally, all of the environmental benefits of LED lighting are even stronger in the case of smart streetlights.

Costs

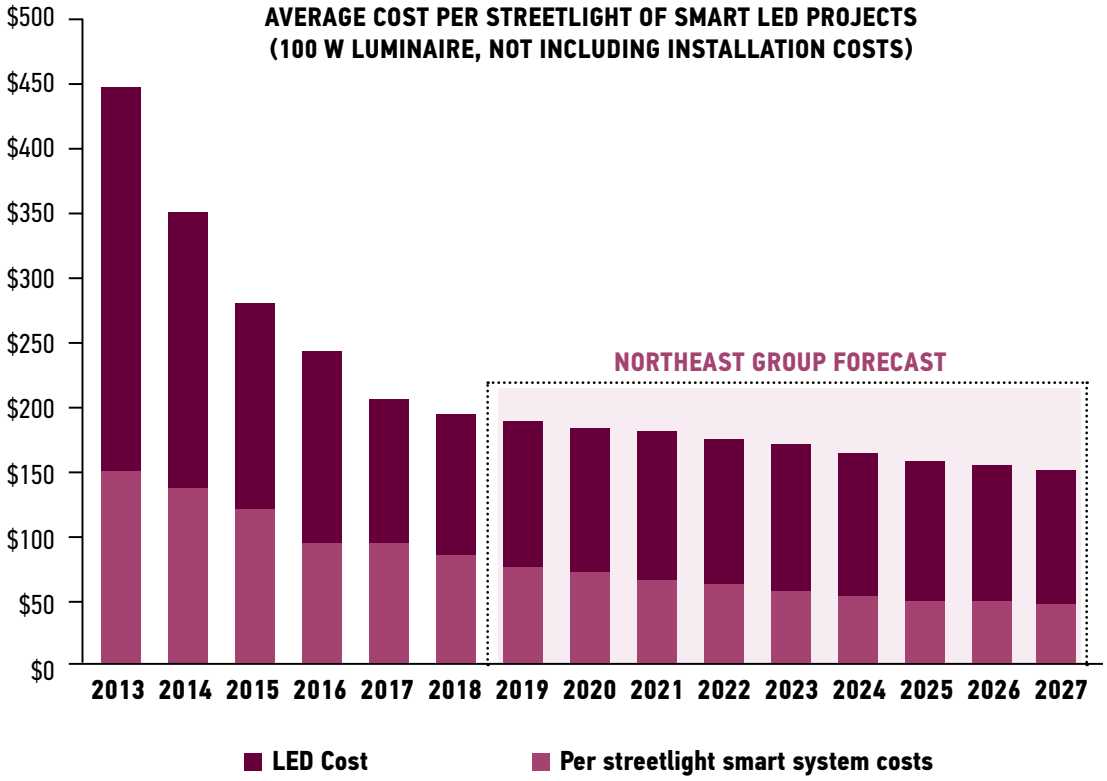
One of the driving factors of the LED streetlight market over the past decade has been the rapidly declining price of LED luminaires, which have now reached parity with HPS luminaires for many streetlight types. But until recently, the price of controllers and communications nodes for smart streetlights had declined only marginally, typically still averaging over $100 per streetlight (including controllers, gateways, and the Central Management System, or CMS). This has now begun to change. In several tenders at small cities in the US from 2017-18, winning bids averaged $67 – $83 per streetlight, including 10-year CMS software contracts. Other cities in our benchmark also quoted project costs of approximately $80 per streetlight for nodes and communications, although some projects still came in at higher prices.

Costs (cont.)

Overall, cities and vendors are now reporting that most projects come in well under $100 per endpoint, although it is not always easy to quantify recurring software-as-a-service and network-as-a-service costs on a one-time per-streetlight basis. On the low end, these costs are not expected to dramatically further decrease, but some of the more expensive prices are less likely to be seen in the years to come.

Additional costs, include financing costs, professional services costs, and overhead, are often covered by the ESCOs that often manage these projects. ESCOs were involved in many of the projects in our benchmark, including Chicago, Hillsboro, Knoxville, and Tucson.

When installed separately, smart streetlight projects also involve considerable installation costs, which is a major driver for choosing to install smart controls at the same time as LEDs.



Source: Northeast Group

How to overcome challenges

Most of the significant challenges to LED street lighting have been overcome over the past decade. Initially, the financing and logistical hurdles involved in switching to LED streetlights were the biggest hurdle. But a combination of lower costs, greater awareness, and active ESCOs (and public organizations that act similar to ESCOs) has mostly overcome these obstacles. Of the cities in this benchmark, a few received government rebates, but in all cases they stated that the rebates were nice to have but not necessary for the business case.

There have also been some past complaints about the brightness of LED luminaires, but recent studies have largely disproven the purported negative health effects of LEDs. The cities in this benchmark all cited relatively few complaints. Additionally, dimming from networked streetlights and new warmer colored LEDs can help address these concerns.

CHALLENGES TO IMPLEMENTING SMART AND LED STREETLIGHT PROJECTS

CHALLENGES	POSSIBLE SOLUTIONS
FINANCING: Municipalities either don't have funding for full change out, or funding is spread between different departments	• Lower costs and clearer benefits make financing easier to obtain • Vendors (performance contracting) and ESCOs can take on the risk • Government and other funding sometimes available
OWNERSHIP ISSUES: Cities don't always get savings benefits if utilities own streetlights or don't lower streetlight rates	• Controls can "meter" streetlights, ensuring cities don't pay for more energy than they use • Adding controls to rate base can help offset lost revenue from lower energy use for utilities
CONSUMER COMPLAINTS: Lights are too bright or too white	• Dimming is an easy solution if there are numerous complaints of lights being too bright • Newer LEDs come in "warmer" colors (e.g. 3000K)
LEGAL ISSUES: Lights are too bright or too dim	• Standards are helping reduce issue of dimming lights at night to unsafe levels • Dimming can address issues of brightness
LOGISTICAL CHALLENGES: Finding the right amount of light with LEDs and right network for larger smart city options	• ESCOs and project management vendors can take holistic approach to ensure street lighting fits into larger plans • Most communications vendors now have solutions that offer possibility for additional smart city applications, at a minimum through partners
CYBER SECURITY: Streetlights could be hacked	• Vendors with smart metering and other experience have knowhow in protecting networks. Small municipalities with limited IT knowhow will need to collaborate with vendors and project integrators to ensure robust cyber security

Streetlight ownership and electricity tariffs

One of the main hurdles to LED and smart streetlight adoption is the issue of city vs. utility ownership and the electricity tariffs charged for street lighting. In the past, utilities that owned streetlights were reluctant to install LEDs, while utilities that charged cities for streetlight usage were reluctant to establish LED streetlight tariffs. In both cases, investor-owned utilities feared lower energy usage leading to lower revenues. This has now begun to change and most major utilities offer LED tariffs. The reason for this is twofold. First, demand from cities and pressure from public utility commissions (PUCs) essentially required many utilities to adopt LED tariffs. But perhaps just as importantly, some utilities have been able to pass LED tariffs that are actually higher than existing tariffs – to account for the costs of LED installation – providing short-term benefits to utilities. Eventually, once the capital costs are accounted for, cities will save from lower energy usage, but utilities in some cases have managed to benefit in the near term. Additionally, in states where it is allowed, many cities are now buying back their streetlights from utilities. Four of the cities in this benchmark (Ayer, Hillsboro, Knoxville, and Providence) recently purchased their streetlights from their local utility.

The city-utility streetlight ownership issue has not slowed the growth of LED streetlights, but it is having an effect on smart street lighting. Currently, few utilities meter their streetlights, meaning cities have no way of proving how much they are dimming their lights and how much they should save. Most streetlight controls contain chips that can provide revenue grade metering, but these have mostly not been approved by PUCs and the regulatory approval process can be long and drawn out.

Currently, few of the cities in our benchmark are offered tariffs for actual (dimmed) energy usage, but multiple cities stated that they believe demonstrated energy reductions could pressure utilities and PUCs to offer electricity tariffs based on dimmed streetlights. Regulations still need to catch up to the technology.

The process for reaping the savings from smart streetlights will likely mirror what happened with LED streetlight tariffs over the past 5-6 years. In 2012, there were almost no LED tariffs available to cities, which depressed the LED growth potential at the time. But regulatory changes and declining prices reinforced each other over the course of several years, leading to the strong recent and expected LED streetlight conversion rates. The same pattern is now developing for smart streetlights, with progressive cities and utilities beginning to develop rates specifically for controlled streetlights, while improved technology is allowing streetlights to be effectively metered. Once the regulatory changes are made – which, admittedly, can take several years – one of the principal hurdles to smart street lighting will be overcome.

Technology options

Cities and utilities have a number of technology options, especially when it comes to communications for smart street lighting deployments. If there is existing communications infrastructure in place – for example from a previous utility smart metering deployment – this may influence the decision as smart street lighting may be able to piggyback on the existing communications, but this is not a prerequisite and many cities/utilities with existing smart metering infrastructure have selected new communications options.

It is outside the scope of this study to go into a detailed analysis of the specifics of each technology option, including the pros or cons of different options. The intent of this section is simply to provide a very high level overview of some of the different options with a brief description of each. These are found in the table on the following page, in alphabetical order.

In addition to selecting communications, cities and utilities also need to choose a software platform, typically known as a central management system (CMS) to operate the smart streetlights. Many of the leading communications and streetlight controller vendors offer their own CMS. Many CMS platforms are also expanding beyond streetlights to include a number of IoT sensors such as parking, waste bin, traffic, environmental and other smart city sensors. The CMS can serve as an effective data and analytics platform for a municipality's broader smart city applications covering a number of departments and functions.

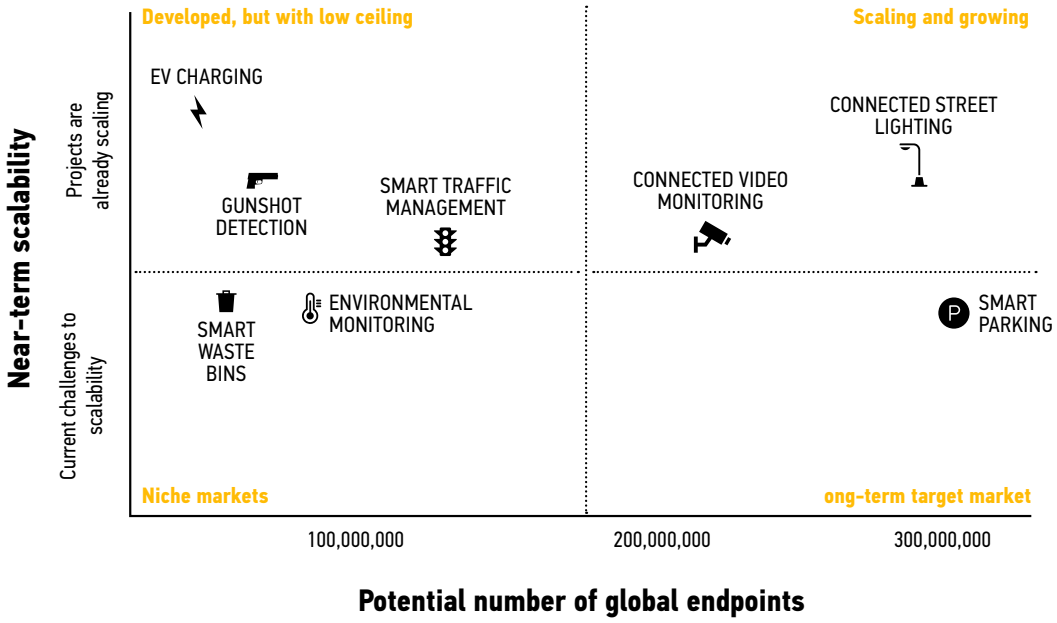
It is common for cities to have individual, siloed departments that are responsible for each of these different areas. This can present challenges when moving to one platform to handle all of the different IoT sensors deployed throughout a city. More innovative and forward-looking cities are beginning these discussions sooner rather than later and working to integrate different departments onto the same software and platform. This can create the need for complex process redesign but also offers the opportunity for streamlined operations and resulting efficiencies.

COMMUNICATIONS OPTIONS (IN ALPHABETICAL ORDER)	
COMMUNICATIONS TECHNOLOGY	**HOW IT WORKS**
CELLULAR (INCLUDING NB-IOT)	There are a number of licensed low power wide area network (LPWAN) communications options offered by cellular operators. These are public networks as opposed to many of the other options which are private networks. The emerging NB-IoT standard is perhaps the most well-known. NB-IoT is ideal for lower bitrate applications such as street lighting, with costs much lower than traditional cellular applications
LORA	LoRa is an open alliance of member companies and is another LPWAN communications option
POWERLINE COMMUNICATIONS (PLC)	PLC uses existing power cables to send data so it is a "wired" rather than a wireless communications option. PLC can be used for smart street lighting but has become much less common than the wireless options available and is more often found outside of the US
RADIO FREQUENCY (RF) •MESH •POINT-TO-MULTIPOINT •STAR	RF-Mesh networks have been used extensively by utilities and cities for smart metering and other IoT applications, including smart street lighting. The "mesh" configuration involves interconnectiveness between devices on the network to create a resilient, low cost network. The Wi-SUN Alliance is driving open standards and interoperability for RF-mesh devices and networks With RF Point-to-Multipoint, instead of the "mesh" configuration, each individual device communicates back to a central tower, without "hopping" to another device. Point-to-multipoint networks typically run over licensed frequency RF networks using Star topology use similar communications as mesh but with fewer connection points between the streetlights
ULTRA-NARROWBAND (UNB)	As its name suggests, UNB communications has a very narrow bandwidth. It is ideal for applications that generate small quantities of data, such as smart street lighting. There are a number of UNB offerings–including proprietary–such as Telensa and Sigfox

Broader Smart City Opportunities

Smart cities can mean many things, but the term typically refers to adding sensors, two-way communications, and analytics to city infrastructure to improve efficiency and provide added services to residents. Effectively, it is digitalizing infrastructure. While most of these applications are not yet well developed, many cities are deploying smart street lighting as the foundational layer for additional smart city initiatives. Using the communications and analytics infrastructure from cost-effective street lighting, utilities and cities can add on electric vehicle charging infrastructure, video monitoring, smart parking, environmental sensors, and other applications. Cities with municipal water, electricity, gas, and sewer divisions have also looked into sharing communications infrastructure across these segments. Cities in our benchmark expressed excitement over these potential applications, but also caution that they wanted to see more developed projects before moving forward. Most cities demonstrated interest in installing "smart city-ready" infrastructure, but reticence to committing to technology that might not yet be fully proven.

SMART CITY INFRASTRUCTURE POTENTIAL BY SEGMENT



This matrix describes the market opportunities for each segment:

- **Potential number of endpoints**: this is the total potential market, not the expected market in any particular year (e.g. there are currently 300 million street-lights globally, which is the theoretical potential market)
- **Near-term scalability**: related to penetration rate, but qualitatively scored on scalability. Top scoring segments are already scaling. Lower scoring segments face challenges of high prices, low customer demand, or techincal issues.

APPENDIX

Takeaways from all participants & study sponsors

APPENDIX: TAKEAWAYS FROM ALL PARTICIPANTS

AYER, MA
Purchased depreciated streetlights for just $1; reduced energy usage by 70%, including 50% off-peak dimming; service calls costing $1,000 per day have largely been eliminated

CAMBRIDGE, MA
50% sunset dimming and 30% off-peak dimming for combined energy savings of 80%; Total savings of $500,000 per year for 4.4 year payback

CHICAGO, IL
Will be largest single-city project in the US (will reach 270,000 lights); 60% energy savings and $1.8m saved as of end of 2018 (81,000 converted so far)

FLORIDA POWER & LIGHT
Largest current project in the US; linked with existing smart grid network to integrate with smart meters and distribution automation equipment; $46m in annual O&M savings, 25% improvement in reliability and accelerated restoration, 100,000 avoided field visits

GEORGIA POWER
2nd largest current project in the US (300,000 controls) and growing; reduced O&M costs and developed several new revenue streams (surveillance, 4G, etc.); includes metered, TOU rates; added costs associated with deploying some LEDs before controls

HARRISBURG, PA
$510,000 annual energy savings and $60,000 O&M savings (60-70% total cost reduction), 548 vehicles removed from road, 5.7m pounds CO2 removed

HILLSBORO, OR
Purchased streetlights for $849/light; 2m kWh per year saved once complete in 2019

HONOLULU, HI
Energy savings of $5m per year (16m kWh), 60% total savings; 90% of new lights will be 3000K, in part to meet Dark Sky Association recommendations

KNOXVILLE, TN
Purchased streetlights for $176/light; O&M reduced from $2.3m/year to less than $1m/year due to LEDs and streetlight ownership; 67% energy savings; meeting city's CO2 reduction goal with streetlight program alone; primarily 3000K luminaires

LONG BEACH, CA
$900,000/year energy savings and $275,000/year O&M savings once complete in 2019

LOS ANGELES, CA
165,000 converted to LED, 110,000 connected, and a few hundred include additional "smart pole" features including EV charging and 4G connectivity; 63% energy savings and 48,000 tons CO2 saved per year

MOUNT VERNON, NY
$776,000 in combined energy and O&M savings per year, reducing 2,500 tons CO2 per year; part of larger NYPA project that will eventually add smart city features

PROVIDENCE, RI
73% combined savings (65% including financing costs); avoided 383 truck rolls per year; largest in statewide PRISM project that included purchasing streetlights from utility

SALT LAKE CITY, UT
Created separate monthly fee to finance project; 47% energy savings so far (project not yet complete), with O&M savings reinvested into other city projects; want to add controls

TEMPE, AZ
No LED rates from utilities so can't determine energy savings; O&M savings alone have paid for project as failure rates have decreased from 10-15% to just 1-2%

TUCSON, AZ
67% savings from LED and 10% savings from controls (30% dimming offpeak in select neighborhoods) for 5-year payback; meeting Dark Sky Association recommendations

APPENDIX: STUDY SPONSORS

With over 25 years of experience in industrial controls and outdoor wireless applications, CIMCON Lighting has become the world's innovation leader for smart city solutions, including lighting management systems for traditional, LED, and solar-based streetlights. CIMCON's plug and play lighting controls offer the lowest "life cycle cost of ownership", reducing energy usage, maintenance, and repair costs while improving the quality of lighting services. They create a city-wide digital canopy that enables cities and utilities to remotely monitor, maintain and, in many cases, monetize their lighting assets and other devices on or near the light pole. In addition, CIMCON"s NearSky™ sensor integration platform provides cities a highly flexible and cost effective path for deploying additional smart city solutions such as public safety monitoring, traffic and pedestrian analytics, and air quality monitoring. CIMCON's lighting management solutions are appropriate for roadways, parking lots and parking garages, recreational areas, corporate and university campuses and a variety of industrial applications. For more information please visit www.cimconlighting.com.

interact

Interact is a portfolio of tailor-made software applications for the Internet of Things specifically designed to work with connected lighting systems and the data that those systems collect Grouped around key business areas, Interact software helps you save energy, improve operations, and gain the insight you need to address the biggest challenges facing your business or city today. With a common UI and UX, system-wide identity management and security features, and secure APIs, Interact is ready to become an integral part of your enterprise IT and innovation roadmap. Interact is a brand of Signify, formerly known as Philips Lighting, the world leader in connected LED lighting products, systems, and services.

Itron enables utilities and cities to safely, securely and reliably deliver critical infrastructure services to communities in more than 100 countries. Our portfolio of smart networks, software, services, meters and sensors helps our customers better manage electricity, gas and water resources for the people they serve. By working with our customers to ensure their success, we help improve the quality of life, ensure the safety and promote the well-being of millions of people around the globe. Itron is dedicated to creating a more resourceful world. Join us: www.itron.com.

Sensus, a Xylem brand, helps a wide range of public service providers—from utilities to cities to industrial complexes and campuses—do more with their infrastructure to improve quality of life in their communities. We enable our customers to reach farther through the application of technology and data-driven insights that deliver efficiency and responsiveness. We partner with them to anticipate and respond to evolving business needs with innovation in sensing and communications technologies, data analytics and services. Learn more at sensus.com and follow @SensusGlobal on Facebook, LinkedIn, Twitter and Instagram.

APPENDIX: STUDY SPONSORS

verizon

Verizon's Smart Communities team is dedicated to increasing efficiencies, reducing costs and improving the quality of life for people living in and around cities. We partner with each city to design infrastructure, systems and processes that enable cities to provide services like public safety, traffic management and energy solutions in new and cost-effective ways. Our Intelligent Lighting solutions provide a number of customized options including future-proofed lighting nodes that control energy usage while maximizing safety. These nodes are remotely controlled and managed via the Verizon-based, cloud-hosted platform, NetSense, which also provides extensive reporting capabilities to help troubleshoot and inform on future energy usage. When it comes to quality of life, there is immeasurable promise and unlimited potential in smart communities technology. At the heart of that promise are people. That's why improving the lives of people is a focus and a priority for us -- and why it will always be the core of our business.

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