DECEMBER 2015

THE CLIMATE GROUP

PHILIPS

PRINCE ALBERT II OF MONACO FOUNDATION

NO NEED TO WAIT: ACCELERATING ADOPTION OF LED STREET LIGHTING

CONSULTATION PROCESS TO IDENTIFY AND ADDRESS REMAINING BARRIERS FOR ADOPTION OF ENERGY EFFICIENT LED LIGHTING IN CITIES AROUND THE GLOBE

NEW YORK CITY'S 250,000 STREET LIGHTS WILL BE LED BY 2017. THE CITY WILL BE SAVING US$14MILLION IN ENERGY AND MAINTENANCE COSTS[1]

This document supports The Climate Group's ongoing LED (light emitting diode)* consultation process, which is designed to identify key remaining issues around LED adoption, and support leaders and decision-makers in accelerating the transition to LED street lighting in cities and municipalities around the world.

"A FULL SWITCH TO THE LATEST ENERGY-EFFICIENT LED LIGHTING SOLUTIONS PROVIDES SIGNIFICANT ENERGY SAVINGS, A REDUCTION IN CO_2 EMISSIONS, AND WILL TRANSFORM URBAN ENVIRONMENTS [...] WE BELIEVE THAT BY DRIVING THIS LIGHTING MARKET TRANSITION, OUR LED LIGHTING SOLUTIONS WILL CREATE LIVEABLE CITIES FOR THE BENEFIT OF RESIDENTS AND VISITORS."[3]

Many regions have aging lighting infrastructure which in most cases is based on technology that may be over 30 years old and in urgent need of replacement. Prompted by the unprecedented opportunity for energy savings of up to 50-70% from LED solutions there is a need to not only schedule scale up of LED adoption but to increase the rate of city renovation.

LED TRIALS AROUND THE GLOBE[2]
Kolkata, Toronto, New York, London, Hong Kong, Sydney, Adelaide, Guiyang, Haldia, Mumbai, Tianjin

INTRODUCTION

In 2011 The Climate Group's LightSavers[4] street lighting project undertook LED trials in 10 cities around the globe. These trial results, supported by many other initiatives, demonstrate that LED street lighting is effective, energy efficient, and a mature technology ready for mass deployment.

Following this initial work, The Climate Group made a call at the United Nations Conference on Sustainable Development, Rio+20, that all new upgraded public lighting, both street lighting and public buildings, should be LED, or as efficient, by 2015.

A growing number of cities around the globe are already experiencing the benefits of LEDs, including Los Angeles[5], Birmingham[6], Buenos Aires[7] and New York City[8], with other cities announcing plans to explore full-scale plans to upgrade to LEDs.

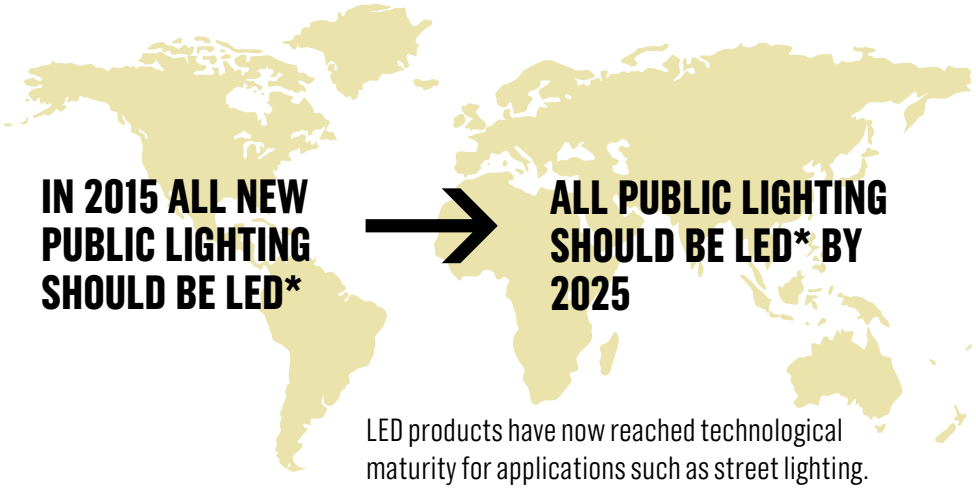
*or as efficient

CONFERENCE OF MAYORS IN 2014 NAMED LED AND ENERGY EFFICIENT LIGHTING AS THE 'TOP PRIORITY' ENERGY TECHNOLOGY IN THEIR CITIES WITHIN THE NEXT TWO YEARS[13]

Through 2014-15 The Climate Group, supported by Philips Lighting, started a rolling global consultation program designed to help accelerate adoption of LED street lighting in cities around the world. The initial findings from the last 18 months were published in a new report 'The Big Switch: Why it's time to scale up LED street lighting[9].

Even though the rate of adoption has been slower than expected, the consultations have revealed that the remaining challenges causing delays are predominantly regional, addressable, and are no longer around the performance of the technology. As a result at Climate Week NYC in September 2015, The Climate Group launched a new campaign 'LED= Lower Emissions Delivered' – to specifically focus on addressing the remaining identified regional and local adoption barriers. The campaign will run alongside the ongoing consultation program with the aim of supporting local governments, cities and utilities to realize the low carbon and cost benefits of LEDs.

WE ALSO CALLED TO ACTION:



LED products have now reached technological maturity for applications such as street lighting.

*or as energy efficient

The Climate Group calls on governments and every single city and utility globally to schedule the switch of their street lighting assets to LED (or energy-efficiency equivalent) by 2025.

(AND LOTS OF EXTRA DOLLARS SAVED)

95% OF US CITIES THAT HAVE IMPLEMENTED LEDS ... WERE SATISFIED WITH THE PERFORMANCE AND HAVE SAVED NEARLY 60% IN COSTS.[10]

"IT'S NOT A QUESTION OF WHETHER TO [ADOPT LED STREET LIGHTING], BUT A QUESTION OF WHAT AND WHEN AND HOW TO..."[11]

THE EUROPEAN UNION HAS SET ITSELF A TARGET TO REDUCE ENERGY USED FOR GENERAL LIGHTING BY AT LEAST 20% BY 2020.[12] SOLID-STATE LIGHTING* COULD SAVE UP TO 70% OF ITS ELECTRICITY USED FOR LIGHTING.

*Solid-state lighting refers to a type of lighting that uses semiconductor light-emitting diodes (LEDs) and other types of LEDs.

THE SCOPE OF THE CONSULTATION AND BENEFITS TO PARTICIPANTS

AIMS AND OUTCOMES

For those of you that have already made the switch to LEDs, we would like to ask your participation – to highlight your achievements, share your learning and help develop procurement guidance based on best practices.

We are inviting The Climate Group's members, partners and States & Regions Alliance network, together with other city and municipality representatives, to participate in a series of events, roundtables, webinars and workshops around the world, that are designed to focus on solutions to current challenges around LED adoption.

WHAT BARRIERS DO YOU STILL FACE IN ADOPTING LEDS? AND HOW CAN WE HELP YOU TACKLE THEM? WHAT INFORMATION DO YOU NEED?**

OVER THE NEXT DECADE LED LIGHTS WILL TRANSFORM CITIES AND MUNICIPALITIES ACROSS THE GLOBE, WITH THE GLOBAL MARKET EXPECTED TO REACH A VALUE OF US$63.5 BILLION. LEDS AND SMART STREET LIGHING ARE PROJECTED TO REPRESENT RESPECTIVELY 84% AND 37% OF THE GLOBAL STREET LIGHTING MARKET BY 2025[15]

As part of the process, corporations, service providers, finance and consulting organizations will be invited to participate and contribute to defining improved support mechanisms that will facilitate cities and municipalities in the adoption of LED street lighting.

A series of general themes will be addressed during the consultation process. These will seek to develop better education and information on LEDs, helping to address any questions and concerns raised by the public, analysis of the LED business case options, current and new approaches to LED financing, as well as understanding different options for the allocation of project risk and lighting asset ownership.

At the operational level, guidance notes and checklists will be developed around the following areas:

- analysis and design of LED solutions
- intelligent and smart luminaires
- linked smart controls
- lighting management systems
- approaches for future-proofing of lighting infrastructure
- LED product quality thresholds, local standards and warranties.

We do not intend to duplicate the efforts of the many large national, regional, lighting standards and trade organizations that are focused on promotion of LED adoption. Many extremely valuable information resources on LEDs already exist that are designed to help and support cities in the adoption of LEDs, usually with a regional focus designed to support the local challenges.[14]

We aim to work alongside consultation participants in their regional capacities—working directly with those who express the need for support as they consider the benefits of LED street lighting, and convening experts to help address requested topics of direct interest.

** The broad questions we will ask city participants as part of the consultation process will be introduced throughout this report, and are designed to prompt areas of discussion, identify areas where further information is needed, and to help shape the consultation themes and direct event agendas.

WE NEED LEADERS AND DECISION-MAKERS

The role of leaders and policymakers will also be key in achieving our goals.

Leaders can support us by developing and driving policies and incentives around reducing energy consumption and demanding broader adoption (and central funding) for energy efficiency measures in the public sector.Such leadership[16] can critically demonstrate high-level commitment, help drive local stakeholder consensus, help boost investor confidence, and the broader public acceptance of the need for adoption.

Policies that provide financial incentives for investors and corporations that can also help share the costs of energy efficiency initiatives in the public sector, and finance from savings, can also play an important role.

Most critical of all, as business and government leaders, we ask that you publicly support our call for wider LED adoption and to help achieve our 2025 scale-up target.

LEDS ACHIEVE THE EXPECTED 50 – 70% ENERGY SAVINGS, AND REACH UP TO 80% SAVINGS WHEN COUPLED WITH SMART CONTROLS.

ACCELERATING ADOPTION OF ENERGY EFFICIENT LED STREET LIGHTING

Climate change is real, and the urgency for action to address it is no longer under debate. The question is now: what can we do—and how quickly can we do it? G8 and G20 communiques and the Copenhagen Accord all outline the need to limit warming to 2˚C or less, and to peak global emissions of CO_2 by 2020 or before.

We must take dramatic steps to reduce energy demand in order to achieve this emission reduction target. One immediate action we can take is through applying available energy efficient technologies and increasing education and awareness about the benefits of energy efficiency. And the lighting sector is where we can make a huge impact.

Lighting represents around 19% of global electricity consumption[17], with use concentrated in cities where over half of the world's population now live. Almost 75% of global energy consumption is in cities, with estimates of outdoor city lighting contributing 20-40% of a city's energy budget[18,19]. It is clear the potential energy savings of 50-70% that can be realized from large-scale replacement of aging street lighting with more energy efficient solutions can no longer be ignored.

"MORE THAN HALF OF THE WORLD'S POPULATION LIVES IN CITIES, A FIGURE EXPECTED TO RISE TO 70% BY 2050." [22]

For this reason, in partnership with Philips Lighting, we launched and have extended our global LED consultation program. To date we successfully hosted workshops in the UK, India, Dubai, Beijing, Shanghai, USA and Brazil and are planning further activities in other regions in China, South Asia, Latin America, and Africa, and are also exploring off grid solutions where LEDs are coupled with solar PV.

UNDERLYING CHALLENGE: EVERY CITY IS UNIQUE[21]

Each city has a unique history in terms of existing lighting infrastructure status, funding capacity, asset ownership and political support. Each city therefore needs to develop a unique technical and financial business case for their circumstances. The availability of lighting modelling tools, case-studies and online guides each provide useful guidance for cities. But reduced staff capacity and familiarity with the most suitable LED options and latest available financing schemes for their circumstances, can result in significant delays in finalizing tendering documentation and the subsequent procurement process. **Availability of central government funding for short-term independent business support during the initial project analysis phase was a common request from city lighting managers.**

"AS AN EMISSION CUTTING AND MONEY SAVING TECHNOLOGY, LED STREET LIGHING IS THE BIG NO BRAINER. OUR GLOBAL TRIALS AND STAKEHOLDER CONSULTATION HAVE SHOWN THAT, WHEN IT COMES TO TACKLING CLIMATE CHANGE, LEDs ARE THE LOWEST OF THE LOW HANGING FRUIT AND EASIEST TO IMPLEMENT"

MARK KENBER, CEO, THE CLIMATE GROUP CLIMATE WEEK NYC, 2015.

LEDS: REAL ENERGY SAVINGS[20]

The case for LED adoption is proven. There are now many examples of successful trials and large scale city rollouts of LED street lighting showing dramatic energy savings and direct economic benefits. But two very important lessons were learned from these early LED installations: namely that both product quality and representative trials play key roles in the adoption process as well as in securing stakeholder consensus.

Given the growing weight of 'real-world' evidence, we would expect to see a new drive towards adoption of LED street lighting around the globe. The benefits of LEDs as an energy efficient, long life and flexible replacement street-lighting solution are now no longer in doubt, and the announcements in support of LED street lighting (see figure below)—through LED trials, case studies, and large city-scale rollouts—are steadily increasing in number.

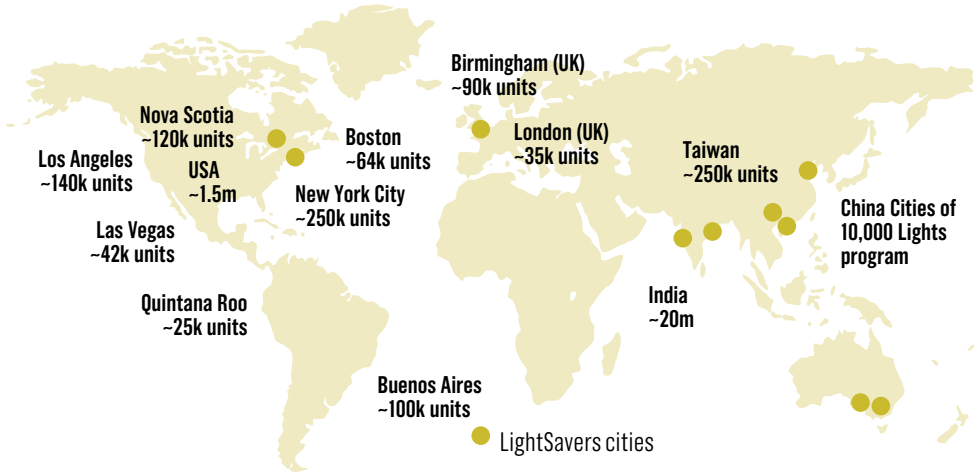


DIAGRAM: Examples of some of the recent large scale LED street lighting projects.

There is the potential to replace conventional street lighting with LEDs on a vast scale to benefit from the associated energy savings, as indicated by further statistics on street lights:

- 350 million street lights predicted by 2025 around the globe[25]
- 7.4 million UK lighting columns; almost 3.5 million over 30 years old[26]
- 90 million street lights across Europe , with more than 75% of them over 25 years old[27]
- 50 million street/highway lights in the US[28]
- China has various national programs such as "China's 21 City Program", "50 cities, 2 million LEDs"[29]
- India has reported program to upgrade 20 million street lights[30]

Commitments to energy efficient lighting have also been made by governments including President Obama's Presidential Challenge for Outdoor lighting to retrofit 1.5 million LED street lighting poles by 2016 in the US.[31] India announced their 100+ cities program which aims at installing domestic and outdoor LEDs in 100 cities in India by March 2016.[32]

Unfortunately however, recent announcements of LED adoption around the world still represent only a small fraction of the global potential. Regional barriers to adoption clearly still remain, and so we want to support city managers to overcome these remaining barriers and help them decide if, how, and when to upgrade to LEDs.

Every city and location has a unique lighting and upgrade history, and will face unique operational and budgetary challenges. In this ongoing consultation process we will seek to identify the remaining challenges together with consultation participants to help develop solutions.

DO COMPLEXITIES EXIST AROUND THE OWNERSHIP OF THE CITY LIGHTING ASSETS – IS THIS DELAYING STAKEHOLDER AGREEMENT AND PROGRESS?

"WHEN WE STEP UP OUR EFFORTS ON ENERGY EFFICIENCY FROM TODAY'S 1% PER YEAR TO AN ANNUAL IMPROVEMENT IN ENERGY INTENSITY OF 3%, WE REDUCE FUEL BILLS IN THE US BY A STAGGERING US$300 BILLION PER YEAR IN 2020, AND US$550 BILLION BY 2030."[33]

NOVA SCOTIA, CANADA[23]

The province of Nova Scotia in Canada passed a law that requires it to convert all of its 120,000 roadway lights to LED lighting, which is expected to save US$5 million a year upon completion.

Nova Scotia announced it is converting to all LED street lighting, a project which will be completed by 2023. This move has made it the first jurisdiction in North America to mandate the use of energy-efficient LED roadway lighting. Nova Scotia's Energy Minister Charlie Parker said: "With LED road lighting, Nova Scotia will save millions of dollars by using about half the energy of current lighting, and improve our air quality while reducing our carbon footprint."

CHICAGO, US[24]

In September 2015, the City of Chicago, IL announced a Smart Lighting Project with the goal of converting the bulk of the city's outdoor lighting to energy-efficient LED sources. 348,500 luminaires will be upgraded to LED. This could potentially be the biggest upgrade in the country.

"By improving lighting throughout the City of Chicago, we will continue to find more cost-efficient ways to operate and provide longer-lasting services for city residents," said Chicago Mayor Rahm Emanuel "In addition, ensuring that our neighbourhood streets and parks are appropriately lit creates better living environments for our residents."

LONDON, UK[34]

London is set to embark on the UK's largest energy efficient road lighting project, installing 35,000 LED street lamps.

By 2016, the program aims to have cut CO_2 emissions by 9,700 tons a year through reduced electricity consumption and have contributed to £ 1.85 million (US$2.8 million) annual savings for TfL.

"With tens of thousands of lights marking the way on our road network it makes complete sense to focus energy and resources on bringing them up to 21st century standards," London City Mayor Boris Johnson said.

"This is the largest investment to modernize street lighting on major roads in our capital's history and will not only cut carbon emissions and save money but it will also lead to even better and safer roads for Londoners."

LOS ANGELES, US[35,36]

The US city of Los Angeles was one of the first cities to adopt LEDs on a large scale and have verified LED performance:

- Total LED units installed to date: 140,000
- Energy savings: goal–40%, actual savings–63,4%
- Registered monetary savings to date US$ 8,8 million

The participants reported valuable key lessons learned about LED lighting including:

- "Trust but verify—not all claims manufacturers make are true"
- "Reality versus theory"—the change from high pressure sodium (HPS) to white light LEDs was perceived as causing a significant increase in lighting levels.
- "Energy savings are real"—As the LEDs improve and the manufacturers develop the technology, energy savings are being realized and continue to increase.
- "Improved visibility"—The change from HPS to white light improved visibility as noticed by residents and encouraged by the LA Police Department.

The city recently announced the integration of its LED poles with a Centralized Management System, which would integrate lighting with other sensors and form part of a move towards 'Smart City' infrastructure[37].

SHEFFIELD, UK[38]

Hundreds of new street lights installed in Sheffield have been praised for making residents feel 'safer'.

Sheffield Council contractor Amey has so far put in more than 1,000 low-energy LED street lights across the city—with another 8,000 to come this year. The work is part of the £2 billion (US$3.3 billion) Streets Ahead project to replace 68,000 lights—as well as resurfacing pavements and roads—over the next five years.

ABU DHABI, UAE[39]

Abu Dhabi is planning on replacing 35,000 streetlights to LEDs as part of its sustainable lighting plan devised in 2011 by Abu Dhabi's lighting expert Martin Valentine. The city is already saving nearly US$ 1 million a year thanks to a low energy lighting strategy.

IF WE LEAPFROGGED TO LED LAMPS IN ALL SECTORS, GLOBAL ELECTRICITY CONSUMPTION FOR LIGHTING WOULD BE REDUCED BY MORE THAN 52% AND AVOID 735 MILLION TONS OF CO_2 EMISSIONS PER YEAR.[45] THIS IS EQUIVALENT TO CUTTING[46,47]: THE EMISSIONS OF UK AND SPAIN COMBINED OR; THE EMISSIONS OF TEXAS AND IOWA COMBINED.

LED STREET LIGHTING: THE TECHNOLOGY

BENEFITS OF LEDS

The benefits of LEDs over conventional discharge street lighting have been summarized in various presentations and reports.[40]

Some of the key features of LED technology worth emphasizing in the context of city street lighting can be summarized in the following terms:[41]

- **High energy efficiency:** LEDs produce more light per watt than conventional bulbs. (It is typically measured in emitted lumens generated per watt of electrical power.)
    - Switching to LEDs can provide comparable levels of traditional lighting with significant energy savings of up to 50-70%.
- **Solid-state lighting (SSL):** LEDs are based on semiconductor structures that can be manufactured in high volume and mounted onto printed circuit boards. This means:
    - LEDs are more robust to shock compared to conventional bulbs.
    - LEDs do not radiate high levels of direct heat (IR).
    - LEDs generate heat at the base mounts, and this is removed using conventional heat sinks.
- **Long lifetimes:** LEDs can typically have a functional operating life of up to 50,000 hours (to a maintained light level such as LM-79 / LM-80 standards)[42], with some LEDs boasting an overall lifetime up to 100,000 hours.[43]
    - LEDs have long lumen maintenance compared to conventional discharge lighting.
    - Long functional lifetimes allow lighting managers to make significant savings through the reduced maintenance and replacement costs of street luminaires.[44]
    - As efficiency falls over time, the drive current to LEDs can be gradually increased to compensate, in a process called 'trimming'. This can allow lighting managers to maintain the desired light levels and potentially extend the operational lifetime of the LEDs.
    - Manufacturers are also now starting to offer warranties up to and exceeding 10 years.
- **Efficient and flexible use of generated light:** The small light ('point-source') emitting area of LEDs allows the use of very efficient, optical design to maximize the use of the generated light and to deliver it over the required area at a defined level.
    - This light direction control is particularly useful in designing luminaires that minimize light pollution.
    - Rapid turn on of LEDs to full illumination provides options for on-off triggered lighting where appropriate.
    - Improved and attractive city lighting provides a wide range of parallel socio-economic benefits.

- **Broad 'smart' lighting applications:** many of LEDs' benefits are ideal for use with 'smart' controls and applications, as they do not require a warm up period for maximum light output:
  - LEDs can tolerate frequent and rapid on/off switching.
  - Rapid turn on/off is a key requirement for any smart lighting applications, where the lighting levels must change rapidly in response to a smart sensor 'trigger'.
- **Adaptive lighting, dimming and multi-level operation:** LED light output can be controlled by varying the drive current (or pulse width) to achieve a range of selectable fixed light levels as well as continuous dimming capabilities. However, in some regions dimming and adaptive lighting may not be permissible by law, where a fixed and minimum level of road lighting must be maintained.
- **Selectable light colors:** LEDs can be designed to emit a range of light spectra, different combinations of phosphors to provide 'white light' at various color temperatures, and also used in combinations to provide tunable colors for architectural lighting.
  - LEDs can provide an improved and tailored city lighting landscape, using selected color temperature options; eg. warm, neutral, and cool white.
  - Different LED color temperatures (and associated level of blue light) can be selected for specific locations; eg. residential, main arterial roads, interstate highways, dark sky areas etc.
  - Color stability over time has been an issue with early, and low quality LED products, and manufacturers are now able to specify and warranty long term color maintenance.
- **High color rendering index (CRI):** the LED CRI can be very high compared to existing lighting. For example LEDs can render colors from objects as if they were illuminated by an 'ideal' or natural light compared against a defined set of standards. CRIs can be used to help decide the most suitable light rendition for the required application.
- **Environmentally friendly:** at the end of their operational life, LEDs have the potential to be recycled safely.[48]
- **High wattage applications:** as well as being capable of providing energy efficient solutions for street lighting applications, LED products have also reached maturity in outdoor and tunnel high wattage lighting applications that are typically reserved for HID/halogen lamps. Such LED lighting solutions can now reliably provide efficient 24-hour lighting in road tunnels, underpasses, sports fields, stadiums, bridges, underground or multi-storey car parks, and in large open 24/7 work areas such as ports and harbors, train stations and airports. The advent of high wattage solutions can now help remove any need for lighting managers to maintain a mix of LED and conventional high power lighting technologies, and thereby provide an opportunity for a fully integrated LED lighting solution.

The range of configurations and possible modes of operation with LED lighting, while providing great flexibility for lighting designers and end users, can sometimes create initial confusion around product selection for lighting managers. However, LED products available on the market may vary in their properties. Light output and color quality can be different

SOCIO-ECONOMIC BENEFITS

The linked socio-economic benefits of enhanced and modern city lighting are commonly presented as secondary to the energy efficiency claims, but nevertheless play a key role in the broader strategic business justification for cities to adopt energy efficient LEDs and smart control capabilities.

between manufacturers and also in different ranges and product batches from the same manufacturer. It is therefore necessary to specify, test and demand associated warranties for LED products in order to meet the requirements of the particular application and location.

For municipal lighting managers, two key advantages of LEDs compared to conventional lighting that are worth re-emphasizing, stem from their long projected operational lifetime. They are:

1. LIGHT PERFORMANCE OVER TIME

As with conventional discharge lamps, the amount of lumens/watt (lumen maintenance) that an LED provides will gradually fall over time. However, compared to conventional lamps, LED lumen output can remain above the required operational level for an extended period of time (for example, 70% lumen maintenance, for up to 50,000 hours). For an equivalent LED luminaire, conventional discharge lamps would need to be replaced multiple times over the same operational period—with the associated inconvenience for the general public and the costs of the light fittings and maintenance crews.

LED vs HID life and lumen maintenance

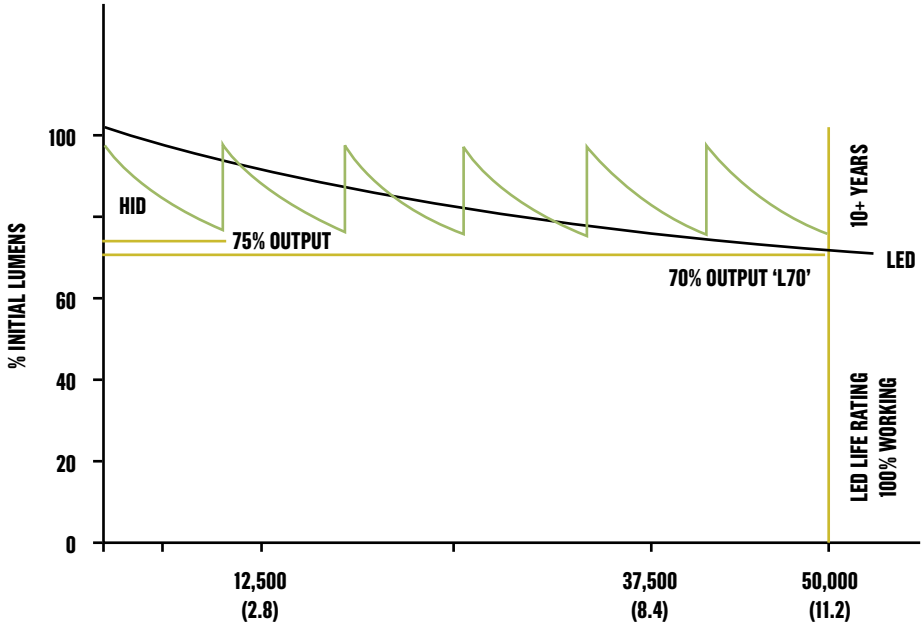
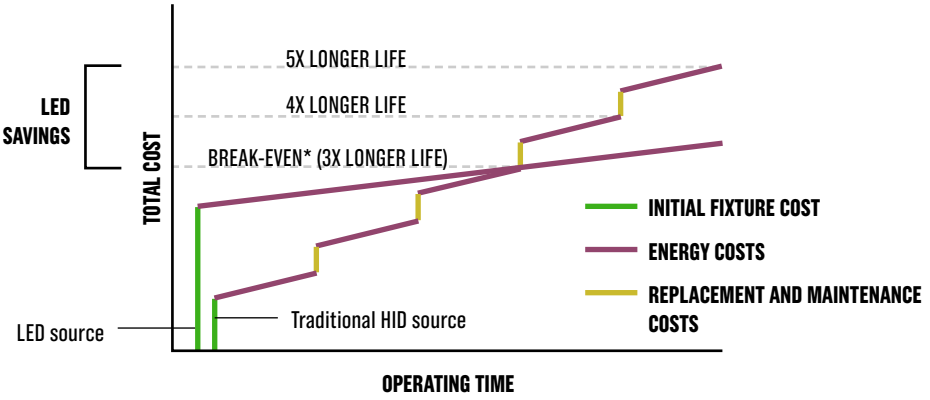


DIAGRAM: Comparison of lamp life and lumen maintenance between high intensity discharge (HID) lamps and LEDs. The LED efficiency and lumen maintenance can negate the need to replace multiple HID lamps over the same period.[49]

2. ENERGY AND COST SAVINGS OVER TIME

The extended operational lifetime of LEDs provides associated cost savings over time—and forms the economic case for adopting LED lighting. The energy efficiency savings, extended functional lifetime and reduced maintenance costs associated with less frequent replacement of failed luminaires are key benefits to lighting managers.

Where are the savings for LED lighting?



*Note: break-even is a function of a number of parameters

DIAGRAM: An example of indicative cost savings for LEDs versus traditional light sources. Despite the higher initial fixture costs, LEDs are replaced less frequently and provide ongoing energy cost savings.[50]

ADOPTION OF LEDS CAN MEAN FUNDAMENTAL CHANGES IN BOTH MAINTENANCE SCHEDULES AND APPROACHES TO CITY LIGHTING FINANCING. DO YOU HAVE ACCESS TO APPROPRIATE MODELING TOOLS THAT CAN HELP YOU ACCURATELY QUANTIFY COST AND ENERGY SAVINGS?

LUX MAGAZINE[51] REPORTS THAT 'STREET LIGHTING IS UNDERGOING ITS GREATEST REVOLUTION IN A GENERATION'. IT'S TRUE. LEDS, SMART CONTROLS AND CENTRAL MANAGEMENT SYSTEMS ARE TRANSFORMING THE TECHNOLOGY IN THE SECTOR.

LEDS IN THE FUTURE

LED manufacturers widely advertise increased performance and efficiency of chip units, and the industry expects LED manufacturing research to continue developing and improving over the next 10 years, anticipating further gains in the efficacy and performance of chips available on the commercial market.

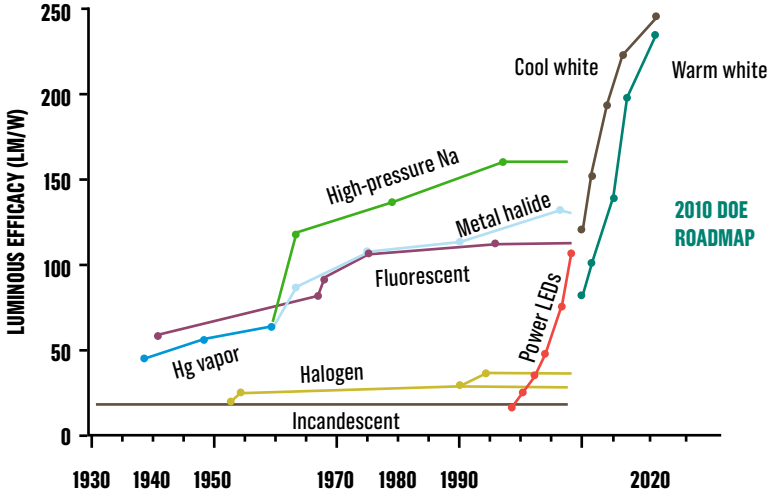


DIAGRAM: Historical and projected luminous efficacy for different lamp technologies[50]

While it can be difficult to predict the speed at which technology will develop, the US Department of Energy (DoE) has undertaken research which sets out white light LED package efficacy targets within their report Solid-State Lighting Research and Development; Multi Year Program Plan[52]. The report found that current commercial warm white LED packages are achieving a laboratory chip efficacy of 140 lm/W and cool white LED packages 175 lm/W. The DoE technology fact sheets predict a significant, but slowing, increase in energy efficiencies over time. In 2020, the target LED package has a predicted efficacy of 250 lm/W for both cool and warm white solutions.

LED PERFORMANCE IS PREDICTED TO IMPROVE, AND COSTS ARE PREDICTED TO FALL[55]. WHAT IS YOUR SPECIFIC CRITERIA FOR ADOPTION?

FUTURE PROOFING AND INTEROPERABILITY

If lamps cannot be interchangeable for different manufacturers' products, the owners of LED assets will be constrained and at risk of being tied in for long periods [54].

LED STANDARDS

With the promise of long operational LED lifetimes, the practical issue of interfacing any selected LED product with existing or future fittings and hardware can represent an adoption risk if LED and street lighting luminaire standards are not in place. Developing clarity and consensus on industry standards also allows end users to assess product quality and performance and allow fair comparisons to be made across a range of different product suppliers.

Industry standards for the LED lighting sector are in the process of development, as they cover many different aspects of LEDs and lighting; from LED construction, luminaire design, electrical interoperability and light output, to operating efficiencies and the implementation of LEDs in specific applications—including public street lighting. By way of example, a summary of the status of related standards in different regions has been released by the Lighting Industry Association[53].

While many governmental, corporate and trade agencies are working to bring consensus on LED standards, there remain regional variations in approach that will be reviewed as part of our consultation process.

PROVISION OF LIGHT

One alternative approach that may be applicable in some cities and regions could negate the need for traditional warranties by providing a lighting service over a defined time period. This approach being explored on small scales could be encompassed in a 'provision of light' agreement between the city or municipality and a service provider, where the LED operation and performance risk could be transferred to a lighting service provider.

LED PERFORMANCE WARRANTIES

As with all new products, the terms and conditions of warranties can also play a key role in the end-user adoption decision. LED products are regularly quoted with functional lifetimes in excess of 50,000 hours, and some even as high as 100,000 hours, often with unrelated short-term warranties[56]. Also, while the LED may be warrantied for such a long period, it is possible one of the many other electrical or mechanical components would have a shorter projected lifetime.

Therefore LED product suppliers might well be expected to offer warranties that reflect confidence in their luminaire products, and that support their claims of such a long operating life, and lumen maintenance.

However, for a street lighting manager faced with a luminaire failure, the cost of a maintenance crew to undertake the replacement work can be far more than the cost of the luminaire itself. So are traditional LED warranties meaningful for cities and municipalities?

MANCHESTER,UK[58]

Every street light in Manchester could be replaced with LED upgrades in a £32 million (US$53.2 million) overhaul. Town hall bosses are considering swapping all 56,000 lamps for energy-efficient LED lanterns. Now is the right time to introduce LED lights, the town hall believes, because the new technology has got much cheaper – and electricity bills are continuing to soar.

All manufacturers need to recognize the needs of lighting managers to have representative warranties, and that these warranties could ultimately influence their adoption decision. Therefore a discussion on actionable warranties that reflect the true costs of replacing failed units, or where any replacement costs are managed within new 'lighting as a service' business model, will also form part of this consultation process.

ARE PRODUCT WARRANTIES REALISTIC AND MATCHING YOUR CITY EXPECTATIONS AND NEEDS?

UPGRADING TO LED LIGHTING IN CITIES

DECISION FOR CITIES TO UPGRADE

Many cities have grown organically over the years, with investment in infrastructure being undertaken in various stages as the city develops. As a result very few lighting managers have the luxury of being able to design and install a new city lighting infrastructure from the beginning.[57]

The decision to upgrade existing street lighting is typically driven by a need to replace old and failing infrastructure, with up-to-date and future-proofed hardware that can provide an effective and attractive lighting solution. This is coupled with LEDs' attractive long operational life, and ability to quickly increase energy efficiency and reduce running costs.

From the city resident perspective, energy efficient LED street lighting can serve to increase safety and security around the city at night, provide a sense of public well-being and pride, and play a key role in encouraging local business, tourism and regional economic growth.

DURHAM, UK[61]

LED street lights which are installed as part of the street lighting energy reduction project will have the facility to be dimmed in Durham, UK. The updated policy proposes that, where these LED lights are installed:

- Between 10:00pm and midnight, lighting levels will be dimmed by 25%
- Between midnight and 5:00am, lighting levels will be dimmed by 50%

APPROACHES TO UPGRADE STREET LIGHTING

The process of upgrading street lighting will clearly depend on the scale and current status of the existing infrastructure. Also, despite the immediate energy-saving benefits offered by LEDs, there may be existing contracts, allocated budgets and lighting management plans that require the continued operation of current lighting systems—at least in the short term.

Because of these hurdles, one of our key consultation themes will focus on providing guidance and tools to help assess the suitability, approaches and timing of LED street lighting upgrades. We will cover different hardware solutions and various approaches to financing that allow replacement, retrofitting, or a complete infrastructure upgrade.

ARE YOU CONSIDERING A RETROFIT, REPLACEMENT OR A FULL LIGHTING UPGRADE?

IN THE UK, 78% OF MOTORISTS SAY THAT SWITCHING OFF ESSENTIAL STREET LIGHTING IS AN APPALLING AND DANGEROUS IDEA. NEARLY A THIRD (30%) THINK LOCAL AUTHORITIES SHOULD CARRY OUT CONSULTATION BEFORE IMPLEMENTING THE MEASURE.[59]

Many cities and regions, in an effort to reduce energy costs, have already started exploring how they can reduce their street lighting costs still further, such as reduced lighting in the early hours of the night when city activity is at its minimum. While in some regions adaptive street lighting may not be permitted due to legislation, in areas such as the UK, cities with existing discharge street lights have been trialing part-night lighting by simply turning them off in the early hours of the night. This has resulted in some inevitable negative public reactions, as well as potential legal implications in different territories.[60]

Existing discharge street lamps can take an extended period to warm up to maximum light output, so while they can be turned on and off, they do not lend themselves to dimming and rapid changes in light levels (for example, in response to a trigger of a 'smart' pedestrian or traffic sensor).

By contrast, LEDs can turn on rapidly and be dimmed in a controlled way, and so the general energy saving benefits of upgrading to LEDs can be augmented by developing fixed or flexible dimming schedules where local laws allow, as well offering opportunities to 'future-proof' for future smart controls and sensors.

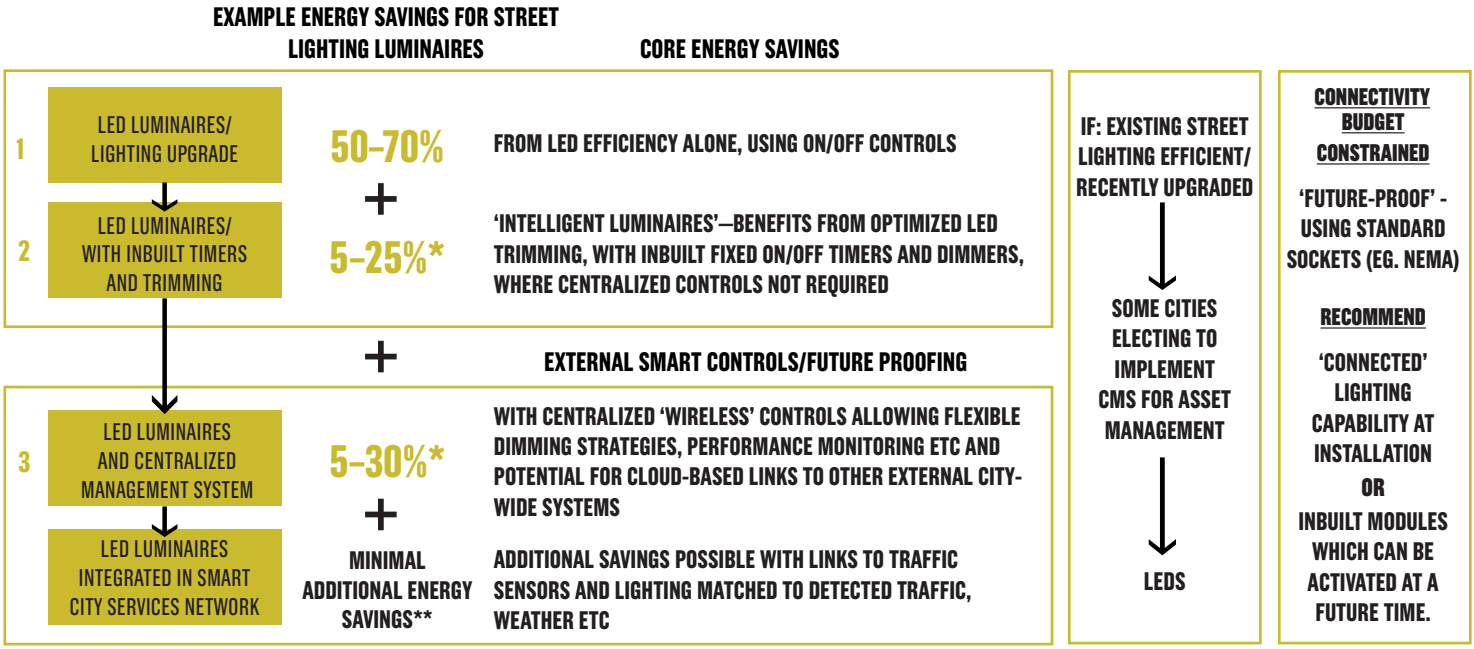
LEDs can therefore provide lighting managers with a range of options for extremely flexible city lighting, with options to implement different lighting schedules through the year, at selected lighting levels, and that can be adjusted if required by future changes in legislation, political or public demands.

LED STREET LIGHTING OPTIONS

During the consultation process we will aim to discuss the adoption of LEDs for city street lighting on four simplified levels:

1. Direct replacement of conventional luminaires with equivalent LED luminaires.
2. Replacement with LED luminaires including internally programmed intelligent on-off and/or fixed dimming timing controls. This could also include some localized basic 'smart' motion/proximity sensors on light poles.
3. Replacement with LED luminaires linked via a centralized management system (CMS), for example using wireless controls, which would allow city-wide LED lighting controls, performance monitoring and operation updating.
4. A fully integrated LED lighting system with centralized management controls, linked to external inputs and other future 'smart' city infrastructure.

The relative benefits of these different approaches in terms of potential energy savings can be summarized in the figure below:



* Depending on allowed levels of dimming

** Primarily socio-economic benefits from a fully smart/intelligent integrated city.

DIAGRAM: Potential energy savings that LEDs can provide. Note: there are diminishing relative contributions to energy savings from options 1 through 4, but offering increased flexibility in the modes of operation and interactivity as part of a future integrated 'smart city'or 'precinct' project.

Options 1-3 in the figure above all offer immediate energy saving benefits of LEDs, but only options 3 and 4 offer lighting managers additional future-proofing via centralized management controls, and strategies for linking with future city-wide 'smart city' service controls.

For circumstances where basic lighting solutions are sufficient (e.g. simple on/off control and fixed level programming with an internal clock) then Option 2 could be considered a minimum specification. Where this option is selected due to available budgets, this could be specified with a modular capability to facilitate upgrade units in the future, with communication and replaceable control units to provide the capabilities of Options 3 and 4 above.

'INTELLIGENT' AND 'SMART' LED LUMINAIRES

For the purposes of the consultation we shall use the term 'intelligent' luminaires as meaning simply a pre-programmed luminaire with 'local intelligence', programmed at the street pole level. The on-board LED light controllers can be set to follow a fixed (and reconfigurable) program of lighting, which could be updated at a later date (e.g. via a wireless link if linked via a CMS or local wireless module).

A 'smart' luminaire can be considered as one that modifies its standard lighting operation in response to an external sensor or control signal. For example on individual light poles, a 'smart' proximity sensor could be added to change a 'standard' programmed or preset operation in response to a variable and unpredictable external stimulus—such as detection of increased traffic, or the presence of pedestrians.

Such features can provide 'additional' energy saving solutions in such bespoke situations, but may not be required for wide-scale city and residential street lighting. In practice very few LED luminaires in cities are envisaged to need a full suite of smart sensors for weather, traffic and temperature.

Examples of future smart cities with fully integrated multi-sensor 'smart' lighting poles have been envisaged for the future.[62] But rather than being applicable to every street light pole, these could be situated at key strategic points in the city, or at major road junctions and intersections, designed to interact via a centralized management system that controls local street lighting.

The undeniable energy savings of LEDs are here, but architectures for fully integrated smart cities are not. By future-proofing the lighting infrastructure, they can be ready for the smart cities of the future.

DO YOU THINK THE VAST MAJORITY OF CITY AND MUNICIPALITY LIGHTING NEEDS CAN BE ADDRESSED USING 'INTELLIGENT' LUMINAIRES?[63]

ARE YOU EXPLORING OPTIONS FOR ADAPTIVE SMART SENSOR LIGHTING?

ARE YOU EXPLORING OPTIONS ON HOW BEST TO FUTURE-PROOF YOUR INSTALLATIONS ?

DEMONSTRATING POTENTIAL ENERGY SAVINGS: LEDS COMPARED TO HPS

A common request in our consultations is for examples of real world data comparing LEDs with traditional lighting. Below is one example of the power consumed through a typical night with different lighting solutions; using high pressure sodium (HPS) luminaires and then after replacement with LEDs.[64,65]

Comparative example of energy use (area under curves) for LEDs and HPS lamps

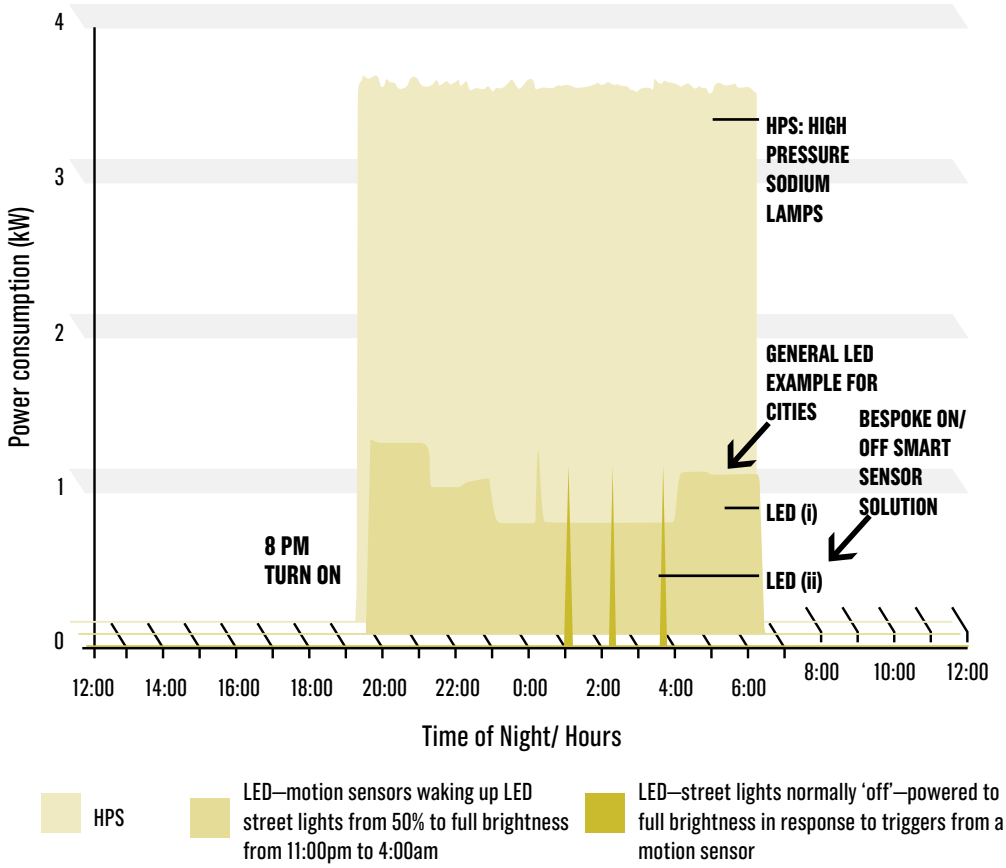


DIAGRAM: Comparison of electricity consumption of two street lighting systems (HPS vs LED) over the course of a 24 hour period.

The total energy used for lighting can be considered as the area under the different plots. In the example above the switch to using LEDs can clearly provide dramatic energy savings when compared to traditional HPS luminaires. Such LED configurations could serve the vast majority of municipal street lighting applications.

In the plot LED(i) the LEDs were pre-programmed to dim to around 50% illumination in the early hours of the night, and were also linked to smart motion sensors which temporarily triggered 100% LED illumination if nearby motion was detected (as indicated by the spike in the LED power consumption).

Extending this concept still further in LED(ii), to model bespoke locations where luminaires can be turned 'off' through the night and only activated when pedestrian or vehicle motion is detected, the additional energy saving potential (ie. area under the LED(ii) spikes) and flexibility of LEDs becomes clear.

While the prospect of street lights turned off for the majority of the night may not be legally feasible or acceptable to the public—such smart triggered systems could be ideally suited to selected illumination of parks, car parks, walkways and footpaths, where public usage may be over a short time period and constant lighting may not be required[66].

THE NEW SOUTH WALES GOVERNMENT IN AUSTRALIA REVEALED PLANS TO REPLACE ITS 250,000 EXISTING MERCURY VAPOR STREET LIGHTS WITH LED TECHNOLOGY ACROSS 41 COUNCIL AREAS IN SYDNEY.[67]

CENTRALIZED MANAGEMENT AND CONTROL SYSTEMS

The addition of a Centralized Management System (CMS) can provide the capability to control LEDs individually, by street, and by zone, to dim, performance monitor and reprogram LED luminaires individually, as well as to provide the central node to which other current or future city infrastructure and smart technologies can connect.

CMS can also help lighting managers make better business decisions, for example regarding budget allocation, by increasing transparency and enabling deeper insights about the state of the entire street lighting infrastructure.

While the CMS represents an additional expense for lighting managers, both in terms of a two-way wireless communication module required for each LED luminaire and the central control system hardware, these costs can be outweighed by the benefits and future-proofing that a CMS can provide.

FUTURE-PROOFING FOR SMART CITY CONCEPTS

Many cities have long-term strategic plans in place for future growth and modernization, which may envisage an evolution to a 'smarter city'—involving an increasing number of products and services interfaced seamlessly, optimized to work together for the benefit of the city and its residents (see figure below).

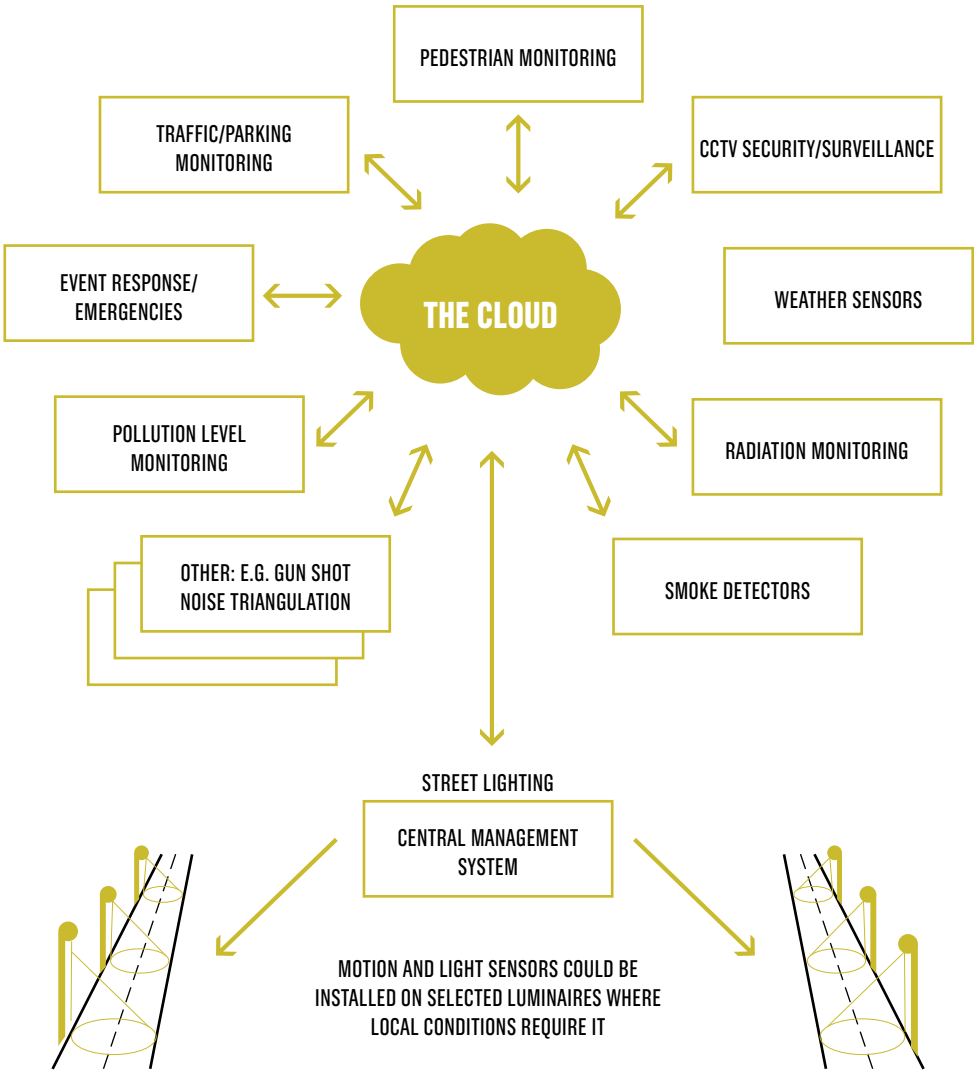


DIAGRAM: Data management within a 'smart city'—LED street lighting can remain a standalone system linked to a data cloud. Via a CMS lighting can be linked to other city sensors and services as they each become available, and their interoperability is tested and finalized.

However, many of the smart-city concepts of linked infrastructure and systems are still in evolution and may require periods of trialing and testing to assess their benefits and business cases. But is linking a city or municipal LED street lighting controls within a fully integrated smart city feasible today?

Each technology and service may have different:

— speed of innovation/product development

— technical specifications

— applicable standards

— legal operating requirements

— interfaces/protocols.

Multiple services and technologies could ultimately link together in future smart cities—but many are in development, and the protocols defining how they would interact still need to be defined and trialled.

One approach is to define interfaces to a city 'digital cloud'—and avoid trying to specify the operating requirements and standards across a multitude of technologies—many of which are still in the process of evolution.

It is important that any uncertainty around the next 10-20 year vision for smart cities should not delay or hinder the adoption and rollout of LED lighting and other energy efficient and cost effective city infrastructure. Future-proofing technologies will be key to facilitate the connection to existing and new city systems and services as they evolve and grow—and LED lighting is no different.

DO YOU THINK THERE IS A RISK THAT AMBITIOUS SMART CITY CONCEPTS CAN CREATE CONFUSION AND DELAY THE ADOPTION OF LEDS ?

LIGHT MAPPING

Light mapping is a key activity to understand the lighting assets currently in place, and their location, coverage, age, operation and maintenance costs, and current contracts.

This mapping should also identify the quality of light required in different areas and how the systems are currently financed and risks allocated.

The overall potential for an LED upgrade program can then be identified, including a project timeline for its delivery.

LED PROCUREMENT PROCESS AND CHECKLISTS

The underlying goal of the consultation process is to accelerate the adoption of LEDs—and a key output is to develop guidance notes and standards, and a series of checklists covering both the assessment, technical and financial aspects of LED adoption.

In undertaking the large-scale procurement of any new lighting infrastructure, there are a number of key processes that need to be undertaken in order to achieve the smoothest transition with the least exposure to the associated risks. The below diagram sets out these basic processes, each of which may have very localized issues, which need to be addressed by city managers.

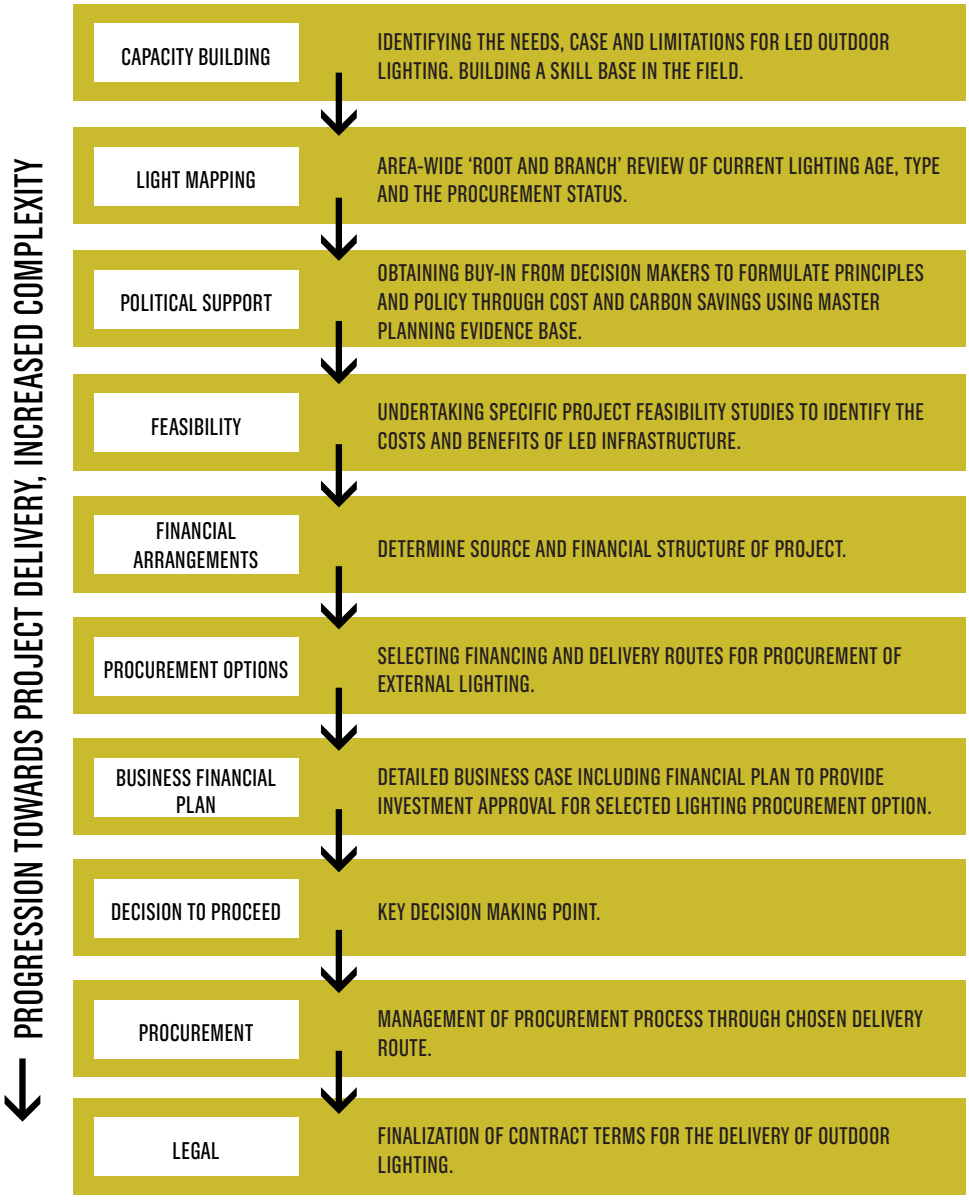


DIAGRAM: Key processes along the path of review, assessment, procurement and adoption of LED street lights; many of the consultation participants may already be at different stages along this path.

GLASGOW, UK[69]

The city plans to convert its 70,000 streetlights to LEDs in a bid to reduce costs, energy consumption, and light pollution, as part of a scheme that the Green Investment Bank (GIB) hopes will be adopted by other councils across the UK.[70]

The GIB says the scheme could save hundreds of millions of pounds if extended nationwide.

BOLTON, UK[71]

The municipality of Bolton, UK in March 2015 announced a £10 million (US$15.4 million) roll out of new energy efficient LED street lighting to replace 26,000 orange sodium bulbs. The environmentally friendly lights could save up to £700,000 (US$1.1 million) a year and £14 million (US$21.5 million) over 20 years—as well as reducing the authority's energy use by half.

The council's cabinet member for highways and transport Cllr David Chadwick said: "This is a big investment which will save us money by reducing energy bills, maintenance costs and carbon taxes."

As a core element of this consultation process we want to ask participants at what stage they are in considering LEDs for their respective cities and regions and most importantly what information and support in that process would they wish to receive advice and support.

WHAT INFORMATION OR SUPPORT DO YOU NEED TO HELP ACCELERATE YOUR LED ADOPTION ?

LED FINANCE AND RISK ALLOCATION

LED technology has developed rapidly over the last five years. From a position where the upfront costs were prohibitively expensive, and the savings were not enough to justify the investment, the installation costs have now reduced dramatically with the scale and reliability of savings significantly improved. These savings have been further enhanced in many countries by the rising cost of energy, which is another significant driver of LED uptake[68].

These factors have vastly increased the range of financially viable projects for investors and financiers, and means that more cities and municipalities globally can now benefit.

As the LED street lighting market matures with the confidence in LED performance improved, a number of trends are likely to emerge. The reduction in financial risks means delivery structures where these risks are transferred to the private sector become more attractive, opening up private finance structures to a far greater range of cities and municipalities.

Navigating the many options for funding of LED upgrades is clearly a challenge for cities and municipalities. It may also be difficult to identify viable routes to finance LED street lighting using existing finance mechanisms that cities are familiar with. Therefore while new and flexible approaches to financing are needed, support and education on how they can be effectively adopted in the public sector will factor in the acceleration of LED rollout.

ARE YOU FINDING IT DIFFICULT TO DEVELOP A COMPELLING BUSINESS CASE FOR LED ADOPTION?

IS FINDING SUITABLE FINANCING STILL A KEY BARRIER FOR YOU?

IS THE MANAGEMENT OF EXISTING SERVICE AND MAINTENANCE CONTRACTS A KEY BARRIER WHEN CONSIDERING UPGRADING TO LED?

OVERVIEW OF FINANCE MODELS

There are a large range of potential financial and commercial models that can be used to implement LED lighting. The most appropriate options may depend on factors including:

- The financial constraints of the procurer, particularly in terms of financing upfront costs, and credit rating.
- The desired risk allocation.

ENERGY EFFICIENCY

The drive for energy efficiency should not be at the expense of LED luminaire quality, nor result in the inappropriate replacement of traditional fixtures or lack of flexibility in light adjustment to help avoid excessive glare at installation[73]. Early consultation with the end-users and sample trials of lighting fixtures can help identify possible local challenges and refine specifications for final large scale rollout.

- The size of the intended installation.
- The availability of third party finance in the local market.
- The internal capabilities and resources of the procurer.
- Local regulatory factors.
- Track record of deliverability of product in territory.
- How well developed Public Private Partnership (PPP) / Energy Service Company (ESCO) and leasing arrangements are in the locality.
- Use of lighting service/management Special Purpose Vehicles (SPVs).

WOULD YOU CONSIDER EXPLORING 'PROCUREMENT OF LIGHT' AS A SERVICE TO HELP ELIMINATE UPFRONT COSTS AND TRANSFER RISK?

With the support of partners a finance consultation theme will focus on the following areas, with a view to identifying potential solutions for participants:

- Finance approaches:
  - Self-funding
  - Third party finance
  - Leasing/debt financing
- Allocation of risk
- Asset ownership
- Financing: future trends and concepts
- Key lessons learned

PROCUREMENT OF LIGHT CONCEPT[72]

Philips Lighting recently announced a contract with Washington Metropolitan Area Transit Authority (WMATA) to install LED lights at 25 parking garages at Washington Metro stations. The fixtures, or luminaires, have a wireless control system with sensors for daylight and motion to optimize energy efficiency, while delivering enough light to meet WMATA's safety requirements. Replacing 13,000 fixtures is projected to reduce electricity use 68%, the equivalent of the electricity used by more than 1,400 homes, according to WMATA.

The company will finance and install the luminaires, which will be paid for by an estimated US$2 million in annual energy savings, requiring no capital investment upfront. Without financing, it is unlikely WMATA or many other municipalities would have the budget for high-tech lighting upgrades such as this one.

"Many municipalities are broke or budget constrained and, of course, they're all looking for ways to meet their sustainability goals, reduce energy and improve the safety for residents. That's why it's a natural fit," says Bill McShane, director of public sector programs for Philips Lighting North America. He expects that more commercial customers will also opt for such lighting performance contracts.

DISPELLING MYTHS

Green light for controversial £9.3 million (US$15.5 million) LED street lamps scheme delayed by one-man opposition campaign.[74]

"Trafford council wants to replace all 27,000 of its street lamps with eco-friendly LED technology but were forced to withdraw the plans after Simon Nicholas raised concerns over their cost and effect on people's brains.

A statement from Councilor Alan Mitchell said: "We recognize that there have been issues raised on potential health implications, which is why we commissioned an independent health impact assessment. This study concluded that there were no health impacts."

ADDRESSING PUBLIC CONCERNS

While the responsibility for the delivery of street lighting in cities usually resides with a local authority, council or sub-national organization, it is the general public that is the main beneficiary of the service.

There are examples where councils and cities have elected to turn existing street lights off in the early hours in order to save money, but this has been met with a public backlash, with reports of increased traffic accidents and risk of increasing crime. There are also lingering concerns around blue light emissions from high color temperature LEDs, which may not be suitable for residential areas.

Therefore assessing the response of the public to LED lighting necessitates the need for early public consultation in any upgrade plans.

ARE THERE PARTICULAR AREAS OF PUBLIC CONCERN OR REMAINING MISCONCEPTIONS AROUND LEDS IN YOUR LOCALITY?

ARE YOU CONSIDERING REPRESENTATIVE LED TRIALS?

CONSULTATION PROCESS: HOW CAN WE SUPPORT YOU?

Any remaining doubts or myths around the underlying LED technology and its ability to deliver on energy efficiency and reliability estimations have now been addressed. LEDs are delivering, and in many cases exceeding, on projected performance and energy savings.

But the practical reality even in 2014, is that a number of largely 'non-technical' blockages to adoption of LEDs still remain. Many of these are addressable, and the purpose of this consultation process is to bring the remaining blockages that cities face to the forefront—and to help address them.

By convening the relevant stakeholders, we aim to identify solutions and solution providers to remove these hurdles and help provide city managers with a range of solutions to finally release LED street lighting upgrades around the globe.

Adoption of any new technology requires an extended period of assessment, validation and acceptance, and LED street lighting has been no exception. Combined with the natural caution exercised by city officials to ensure the efficient and accepted use of central government and public city funds, it is no surprise that LEDs have met with high expectations and hurdles to overcome. As with adoption of new technologies in the past, the early large-scale LED upgrades were achieved owing to the presence and determination of a senior level project 'champion for change', who personally took the lead in driving LED acceptance and adoption.

The development and demonstrations of LEDs have now reached a point where achieving consensus around the benefits and adoption of LEDs is no longer dependent on the bravery of a select few individuals.

Global adoption of LEDs for municipal lighting must now accelerate to leverage the immediate 50–70% energy savings that are possible. We aim to help identify and break down the remaining barriers to support all cities, states and regions to make the switch.

We look forward to your active participation in this consultation process and supporting you in assessing, trialling and ultimately exploiting LED street lighting in your city, region or municipality.

ARE THERE ANY ADDITIONAL TOPICS YOU WOULD LIKE US TO INCLUDE IN OUR CONSULTATION WORKSHOPS?

THERE IS NO NEED TO WAIT.

For further information on this activity, related events and how to participate please contact:
Dr Ben Ferrari, Director of Partnerships, The Climate Group
Email: BFerrari@theclimategroup.org

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