LED SCALE-UP

DRIVING ENERGY EFFICIENCY AND CITY RENOVATION

PRIORITY #1: TRANSITION TO ENERGY EFFICIENT LED LIGHTING

LED SCALE-UP

This document is one of a series of briefing notes designed to support The Climate Group's ongoing global city LED street lighting consultations and LED Scale-Up work.

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Over the past three years The Climate Group, in partnership with Signify, (formerly Philips Lighting), has been holding city consultations to highlight the energy saving benefits of energy efficient light emitting diodes (LED) in cities and municipalities around the world, and to accelerate adoption scale-up. With a global population expected to reach 9.7 billion by 2050[1], cities will play a key role in driving emissions reduction and technological innovation. In many locations, city infrastructure such as lighting may be based on a technology that is over 30 years old, having expanded as the city population has grown, and is in urgent need of modernization.

The unprecedented energy savings of 50-70% from LEDs compared to traditional lighting, presents a compelling urgency to raise the priority of LED adoption. The drive towards connected energy efficient lighting also serves as a stimulus for wider renovation of aging city infrastructure, and for further innovations in 'smart city' development and the Internet of Things (IoT). It also presents the opportunity to build upon a connected and secure city lighting network with an expanding array of city-to-citizen data-based products and services.

Our LED consultations have revealed that cities want to benefit from the significant energy and maintenance savings that LED systems provide, and they see the technology as a priority - but many seek guidance on the best technology options, best practices and funding solutions. This document is designed to support our ongoing consultation activities with cities as they explore LED options and develop their supporting business case. We showcase key topics and themes that have arisen during our consultations and we seek to highlight options and solutions for the lighting stakeholders.

We also seek to provide leaders and policymakers with compelling examples of the energy and emissions savings that can be realised with LEDs, the wider socio-economic benefits of LED-based lighting, and the critical role that supporting energy efficiency policies can play in driving change.

signify
the meaning of light

PRINCE ALBERT II OF MONACO FOUNDATION

FOREWORD

At the COP21 United Nations climate summit in 2015, world leaders sent a clear signal of strong political support for efforts to tackle the effects of climate change and limit the increase in average global temperatures. If we are to transition to a cleaner environment and a prosperous 'net-zero' economy, it is the right time to shift the global climate narrative from commitments to concrete actions, through the scale-up of low carbon energy solutions and energy efficient technologies.

The technologies that can make this transition a reality are now available, and energy efficient LED lighting is a mature, demonstrated and ready-to-implement solution capable of delivering unprecedented energy savings. With energy savings, also come opportunities to renovate aging city infrastructure around the globe, and to create a better and safer environment in cities.

Recognizing and highlighting the savings opportunities provided by LEDs since 2011, The Climate Group has focused on actions to raise awareness of the technology and the breadth of options available, to dispel lingering myths and ultimately to help accelerate the transition to more energy efficient lighting in cities around the world.

This document supports our call to action for cities and global stakeholders to switch to LED street lighting by 2025, by offering support and guidance to those who want to make the transition. We encourage cities and other stakeholders to participate in our global LED consultations and to explore the benefits of a renovated, energy efficient, and better lit city environment that LEDs provide.

Damian Ryan
Acting CEO, The Climate Group

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INTRODUCTION

The coming into force of the Paris Agreement, which commits nearly 200 countries to make efforts to limit global temperature increase to under 2 degrees Celsius above pre-industrial times, presents the challenge of identifying urgent 'next step' practical actions to drive down global emissions.

Total energy use from the lighting sector accounts for around 19% of global electricity consumption[2] with its use concentrated in cities, where over half of the world's population live. Cities can consume almost 75% of global energy and outdoor city lighting alone can represent up to 20-40% of an individual city's energy budget[3].

With the capability of LEDs to offer savings of up to 50-70% energy savings[4] - and up to 80% when coupled with smart systems - LED lighting has been recognized as a high priority action if nations are to peak global emissions over the next decade and successfully transition to a low carbon global economy.

IN 2016 FOR THE SECOND CONSECUTIVE YEAR, THE US CONFERENCE OF MAYORS NAMED ENERGY EFFICIENT LIGHTING AS THE 'TOP PRIORITY' TECHNOLOGY FOR CITIES TO REDUCE EMISSIONS AND SAVE MONEY IN THE COMING TWO YEARS[5]

Since 2011, The Climate Group has been driving adoption of LED street lighting in cities around the world starting with the Lightsavers[4] programme; a series of LED lighting trials in 12 major global cities. These early city trials served to demonstrate LED street lighting as a mature, highly energy efficient technology ready for deployment at scale. Since then a growing number of 'early-adopter' cities are seeing the benefits of LEDs, with Los Angeles[6], Birmingham[7], Buenos Aires[8], New York City[9], and Madrid being widely referenced examples. However, these city installations represent only a small percentage of the 300+ million upgradeable streetlight points globally. It is clear that LED adoption by cities is not happening as fast as expected, or as fast as is needed.

In 2014, in partnership with Signify, (formerly Philips Lighting), The Climate Group launched a rolling global LED consultation program to identify and help address the remaining adoption barriers and to support cities in LED scale-up. The Climate Group has since run multiple regional LED workshops and presentations in the UK and other EU states, India, Dubai, Singapore, China, Korea, the USA and Brazil, as well as wider general consultation support activities. The initial findings are summarized in the Big Switch briefing report[10], and revealed that challenges around LED technology have largely been addressed and the remaining barriers and causes for delays are predominantly localised and regional, but surmountable.

The role that energy efficient lighting technologies can play in reducing global energy demand, and the speed at which the reduction can be achieved should not be underestimated or ignored. The Climate Group is therefore urging adoption of such energy efficient technologies at scale, and calling for wider national policy actions that can help increase the rate of city infrastructure renovation around the globe.

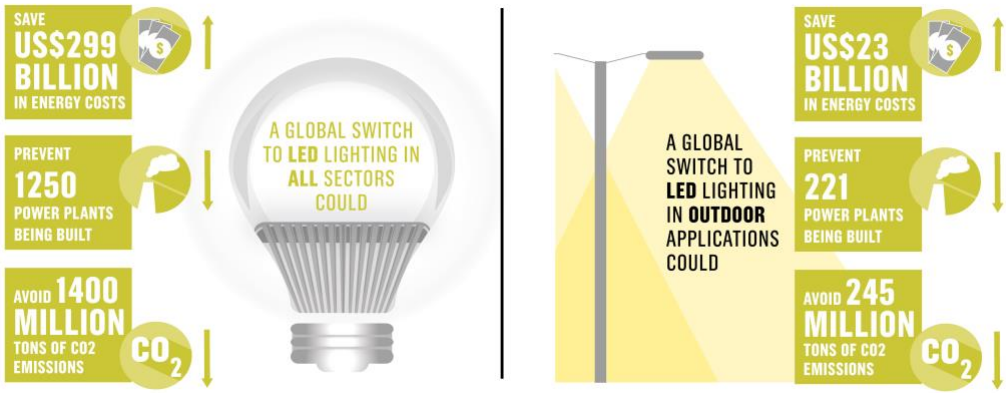
LOS ANGELES IS ANNUALLY SAVING OVER 61,000 TONS OF CO_2, AND US$ 9 MILLION FROM 63% REDUCED ENERGY USE AND US$ 3 MILLION IN REDUCED MAINTENANCE[8].

To help focus greater attention on the wider opportunities that LEDs can provide, and to help prioritise and accelerate broader city adoption, **in September 2015 The Climate Group made a global call to action:**

Our call also complements many regional lighting initiatives around the world as well as the Global Lighting Challenge[11]; a call endorsed by leading governments, to reach a cumulative global sale, across all sectors, of 10 billion high-efficiency, high-quality, and affordable lighting products, such as LEDs.

As part of wider city actions, energy efficient lighting also directly complements the drive for clean energy source development and increased energy productivity (ie. optimizing the productivity from each unit of energy). These overlapping and complementary actions of 'Using Better Energy, Better' are core themes that The Climate Group is promoting in cities and in all our parallel corporate actions for wider adoption of renewables (RE100), increased energy productivity (EP100), low carbon transport and electric vehicles and LED scale-up.

LED LIGHTING GLOBAL SAVINGS POTENTIAL[12]



THERE ARE OVER 300 MILLION STREETLIGHTS GLOBALLY, GROWING TO 352 MILLION BY 2025. SMART LED SYSTEMS WILL CUMULATIVELY REPRESENT A US$ 63.5 BILLION MARKET OPPORTUNITY.[13]

CONSULTATION: AIMS AND OUTCOMES

The Climate Group's consultations and events are designed to support cities in exploring and ultimately adopting energy efficient LED lighting, and meet our 2025 adoption target

We do not intend to duplicate the efforts of national, regional, lighting standards and trade organizations that support the adoption of LED lighting. Many sources of information on LEDs exist and are a valuable resource for covering general and specific regional examples and they are widely referenced throughout this document[14,15,16.] Our goal is to support cities in achieving our 2025 public lighting target.

For cities considering the switch to LEDs: we invite you to participate in our series of events, roundtables, webinars and workshops around the world. These activities are all designed to provide effective forums for reviewing key topics of interest, addressing specific project queries, facilitating expert advice, and reviewing adoption routes and solutions.

For cities that have already switched to LEDs: we would like to highlight your achievements and savings by sharing your regional experiences and developing advice on standardized procurement guidance based on best practices. We would also like to explore with you the latest innovations and product offerings/upgrades that may be on the horizon and as smart city and IoT themes develop.

For solution providers: alongside city representatives, we also invite technology corporations, service providers, and consulting organizations to participate and contribute to the conversations, discuss local and regional topics and highlight perceived challenges. We would like to grow our wide network of stakeholders who can help facilitate the adoption process.

POLICY LEADERSHIP: MALAYSIA [17]

In 2015 the Malaysian government initiated a nationwide LED lighting program to promote green lighting and to bring environmental and economic benefits to the country. The government estimates that by 2020 all streetlights nationwide will have switched to LED.

For leaders and policy makers: the role of leaders and policymakers in helping to facilitate adoption of energy efficiency technologies, and LEDs in particular, is critical. Policies, incentives, and central funding for city capacity building can all help to accelerate adoption of energy efficient LEDs, and broader city renovations. Commitments to LEDs by city, regional and national leaders can also help to drive stakeholder alignment, build public consensus, boost investor confidence, and broaden public awareness and support for accelerated adoption. Most importantly, to governing leaders, we ask that you join us and publicly support our call for wider LED adoption to help achieve our 2025 scale-up target.

For finance organizations: the opportunities for financing city infrastructure projects at scale is growing, and LED based projects are attracting strong interest. The Climate Group has developed a finance theme as part of our LED consultation work to identify the needs of cities, and the criteria financiers require to help trigger project investments at scale. We seek your participation in the review of financing mechanisms tailored for LED projects, and to explore new investment models that can help drive LED adoption in cities based on future savings.

For foundations and donor organizations: the roll out of LEDs could be greatly facilitated with the involvement of donor and philanthropic organisations particularly in developing regions where traditional financing may not be available. Support of specific demonstration lighting projects can help validate project financing approaches and build wider confidence to expand roll out in new regions, and unlock access to conventional financing sources.

WHAT LED ADOPTION BARRIERS DO YOU FACE**? WHAT GUIDANCE OR INFORMATION DO YOU NEED?

** Throughout this report, we present common questions raised by city consultation participants. Each is intended to raise awareness of the key topics around LED adoption, highlight where supporting information may be needed, and to help shape the ongoing LED consultation content, workshops, and events.

Our city LED consultations are ongoing and will expand to include South Asia, Latin America, and Africa, where we are exploring grid connected and off-grid solutions, where LEDs are coupled with solar photovoltaics (PV).

THE POTENTIAL ENERGY SAVINGS BY 2030 FROM DIFFERENT TECHNOLOGIES (HEATING, AIR CONDITIONING ETC.) HIGHLIGHT THE SCALE OF THE LED OPPORTUNITY. FOR EXAMPLE IN INDIA LIGHTING CAN POTENTIALLY REPRESENT UP TO 31% OF THE SAVINGS.[18]

POLICY LEADERSHIP: LESSONS FROM INDIA[19]

The Indian Government has announced its intention to upgrade all its lighting to energy efficient LEDs by 2019. India will upgrade 35 million street lights and 770 million bulbs to LEDs, saving US$6 billion annually from reduced electricity consumption.

The leadership and commitment demonstrated by India on LED lighting nationwide is unprecedented. The commitment at the national level will help to drive investor confidence, and many new projects are underway. India's national commitment to LEDs must be applauded; it is a fundamental step that is needed to help align key stakeholders towards a common goal.

With this commitment comes the need for parallel support to cities to help ensure existing lighting inventories and status checks are made, and that the status of supporting power cabling and infrastructure are also verified. Required product performance and standards must be met by all LED suppliers and delivered product quality monitored and quality assurance enforced. With the national growth in LED adoption, wider availability of testing facilities and enforcement will be required.

With such national commitments also comes a need for consideration of the long-term lighting roadmap and future actions to help stimulate growth of free-market competition so that the LED adoption drive is maintained and expanded by the wider lighting industry.

CONSULTATION: EARLY FINDINGS

The initial findings from our ongoing LED city consultations are summarized in the Big Switch[10] report and feature in our regular consultation workshops. What we have identified and highlighted is that whilst many lessons, best practices, and experiences can be shared between cities, fundamentally every city has a unique lighting history and may face specific local challenges around adoption strategy, asset ownership, operation and control, as well as political and budgetary considerations.

As a result, many cities reported the need for support and additional staff capacity as they review lighting assets and future needs, and to help develop the technical and financial business case options for the lighting upgrade, for their own unique city circumstances.

WOULD YOU SUPPORT A CALL FOR AVAILABILITY OF CENTRAL GOVERNMENT FUNDING FOR CITIES AS THEY DEVELOP THEIR LED LIGHTING BUSINESS CASE?

The related activities can extend to undertaking lighting asset inventories and status checks, early trials of technology options, assessment of technical specifications and tendering, as well as financial modelling on structuring loans and service contracts to best suit the city's finance capabilities. Such tasks may be new to many traditional city lighting managers, and these are one of the key participant groups in our consultations.

The consultations also identified various examples of regional findings and challenges related to topics such as local climate and weather conditions, colors of lights, strategies for future-proofing, complex ownership of lighting assets, and political conditions among other things. In each case, we seek to tailor events and convene experts to discuss and review solutions and help cities move forward in their LED adoption process. Examples of some of the regional findings from our global consultations can be found in the Appendix.

DO MULTIPLE STAKEHOLDERS OWN AND MAINTAIN YOUR CITY LIGHTING ASSETS? ARE ALL STAKEHOLDERS ABLE TO MUTUALLY BENEFIT FROM LED ADOPTION AND SAVINGS?

CONSULTATION: TOPICS AND THEMES

The following sections discuss a range of key topics and themes that have arisen during our LED consultations and seek to highlight a broad range of examples that would be of interest to a broad range of city lighting stakeholders.

The sections are ordered to initially discuss the supporting business case validation, through proven energy savings, and review some of the underlying decisions that policy makers may face when reviewing infrastructure upgrades. The underlying technology benefits are then presented, followed by a discussion of the upgrade options, the options around connectivity and smart technologies, an overview of the adoption process, and finally approaches to financing.

THE CURRENT ANNUAL GROWTH IN ENERGY DEMAND IS 3%, WHILE WE ONLY BECOME CLOSE TO 1.5% MORE EFFICIENT PER YEAR. DOUBLING THE RATE OF ENERGY EFFICIENCY IMPROVEMENTS CAN HAVE SIGNIFICANT ECONOMIC BENEFITS[12].

UPGRADING TO LED LIGHTING IN CITIES

PROVEN ENERGY SAVINGS

The underlying energy savings and efficiency business case for LED adoption is proven. There is now a growing number of successful city installations showing dramatic energy savings and wider socio-economic benefits for adoption.

Given the growing weight of 'real-world' evidence of LED successes and savings) we would have expected to see a faster drive towards adoption around the globe. A contributing factor in the delay may be experiences during the early adoption of LEDs, which highlighted the need for ensuring product quality thresholds, enforcement of standards, and representative trials – all of which play fundamental roles in helping to make the LED adoption process successful and secure stakeholder consensus.

Our consultations will therefore focus on highlighting examples of successful city roll outs, business cases and payback, lessons learned, and in supporting city managers as they assess the level of savings they can expect for their unique circumstances, as they seek to build their business case for LED upgrades.

LOS ANGELES, US [20]

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 lighting units installed to date: over 173,000
- Energy savings: target was 40%, actual savings is 63.4%
- Energy savings of US $9.2 million and US$ 3 million saved in maintenance.
- Carbon emissions reduced by over 61,000 tons per year

LA Lighting Goes Smart [21]: In 2016, the city of Los Angeles is now integrating a Centralized Management System (CMS) where LED poles will be connected wirelessly, and selected poles integrated with sensors and other bespoke services.

Lessons learned [22]: As a result of the work in Los Angeles, a series of lessons learned were developed:

- "Energy savings are real"
- "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 notable increase in lighting levels.
- "Improved visibility"—the change from HPS to white light helped to improve visibility

BUENOS AIRES, ARGENTINA[23]

Buenos Aires plans to retrofit over 70% of its street lighting to LEDs. Currently, up to 55% of the city's 126,000 luminaires have already been upgraded to LEDs. The LED system is fitted with a control system that allows light levels to be monitored and adapted to specific needs. With adaptive lighting it will be possible to reduce the light output and increase savings from an estimated 50% up to 80% compared to HPS.

DECISIONS FOR CITIES TO UPGRADE

Most cities have grown organically over many years, with investment in infrastructure being undertaken in various stages as the city develops and expands[25]. As a result, very few city lighting managers have the opportunity to design and install a city lighting infrastructure from scratch[26]. The approach to upgrading therefore has to take into account future lighting needs, the existing equipment and possible reuse, the ongoing requirement to light the city, and how best to complete the transition smoothly with a limited budget.

The decision to upgrade is typically driven by a need to reduce lighting operation and maintenance costs, and to replace old and failing infrastructure with up-to-date, efficient and attractive city-lighting solutions. LEDs can help to address all of these needs, offering cities an opportunity to reassess lighting requirements, with a wide range of new flexible lighting options and colors, long operational life, high energy efficiency, smart controls, and opportunities to dramatically reduce running and maintenance costs.

ABU DHABI[24]

"Abu Dhabi Municipality is implementing a sustainable street lighting strategy to cut the total cost of lighting by approximately 60% to 75% over the next 20 years.

The municipality explained that the strategy aims to implement policies and procedures based on the principle of sustainability and achieving rationing in power consumption."

SAVINGS FROM LED LIGHTING CAN COME FROM REDUCED ENERGY USE AND MAINTENANCE COSTS. DO YOU HAVE ACCESS TO FINANCE MODELING TOOLS THAT CAN HELP YOU EXPLORE YOUR SAVINGS AND BUSINESS CASE OPTIONS?

LED ADOPTION: NOW OR LATER?

The potential for energy savings of between 50 and 70% with LEDs compared to older HPS lamps, and the longer LED operational lifetime, clearly make the technology a very attractive infrastructure investment. However, a key challenge commonly faced by cities is how to assess the optimum time to make the transition to LEDs based on existing assets and running costs, the availability of finance options, and the practicalities of scheduling the hardware upgrade. Cities may also have existing lighting service contracts, and may have to consider linked costs of early contract termination and redundant 'usable' stranded assets. As a result, some cities may elect to postpone upgrading to LEDs, and this is where the 'cost of doing nothing', and 'opportunity costs' need to be balanced.

ARE YOU DELAYING LED PROCUREMENT?
WHAT IS YOUR SPECIFIC CRITERIA FOR ADOPTION?

MADRID, SPAIN [27]

Madrid is replacing all of its 225,000 street lights with more energy efficient lighting solutions, saving 44% on the city's energy bills and leading to CO_2 emissions reductions equal to taking 100,000 vehicles off the roads.

A common question in our consultations concerns the potential for future improvements in LED efficiency. Over the next five years, incremental improvements in LED efficiency are to be expected, but a balance has to be made between benefitting from up to 50-70% savings today and waiting to benefit from additional improvements in the future.

Similarly, questions have also been raised on the opportunity for significant LED luminaire price reductions in the future[28]. Whilst increased volume production of LEDs and assembled luminaires means prices will continue to fall over time, the LED element forms a relatively small part of the overall assembled light/luminaire costs (i.e. LED, housing, driver electronics, lenses, diffusers, connectors etc.) Therefore, savings linked to the LED component are likely to have a reduced impact on the final assembled luminaire price.

Due to these considerations, one of our key consultation themes focuses on providing guidance and tools to help assess the technical approaches and timing of LED street lighting upgrades. We also seek to cover different LED solutions and approaches to financing that could allow different options such as luminaire replacement, retrofitting, or complete city infrastructure upgrades to be explored.

BEYOND SIMPLE ILLUMINATION: SOCIO-ECONOMIC OPPORTUNITIES

LED lighting options provide city managers with a wide range of choices to upgrade lighting infrastructure, to not only realize significant energy and cost savings, but the potential benefits can go beyond this. Upgrading provides an opportunity to reassess the lighting needs and future requirements across the city, to trial different lighting designs, colors, area coverage, system connectivity, and smart adaptive operation that would allow modernization of the city infrastructure to better match the needs of an ever changing 24/7 city environment.

With the flexibility that can be achieved with LED lighting come opportunities to use new lighting solutions to help increase public safety and security around the city at night, to provide an increased sense of public well-being. Various studies and trials have explored the benefits of modernized city lighting, including examples of improved public and road safety, crime deterrence and increased night-time and city center activity, as well as opportunities for wider city monitoring. With city lighting poles connected wirelessly to a control center, there are additional opportunities to have city-wide light controls and asset management, and links to future smart city sensor technologies currently under development.

Modernized lighting can also play a key role in city regeneration, encouraging local business development, tourism and wider regional economic investment and growth. These additional social and economic benefits can be difficult to monetize in an LED business case, but nevertheless play a key role in the broader strategic business case for LED adoption.

SAN FRANCISCO BAY [29]

The Bay Lights is a light sculpture-art installation that commemorates the 75th anniversary of the bridge opening in the western span of Bay Bridge connecting San Francisco with Oakland. The installation will cost US$ 30 per day to light and is expected to drive tourism revenue to the Bay Area.

LOS ANGELES – SAVING MONEY AND IMPROVING THE CITY LIVEABILITY [30]

Los Angeles is registering additional benefits to the already unprecedented 63% reduction in electricity consumption from upgrading city lighting to LEDs. Early findings indicated that between 2009 and 2011 the city night crime rate dropped by 11%. Though this is likely to be one of many factors, improved visibility in residential areas where the LED fixtures were installed may have played a contributing role in a drop of 13.6% in vehicle theft, a 7.8% drop in burglary/robbery/theft and a 10.9% reduction in vandalism. However, verifying definitive links between enhanced lighting and the level of impact on public safety, accident rates and crime are the subject of ongoing studies.

OFF-GRID SOLAR LED LIGHTING – AN UNEXPECTED BENEFIT IN CASE OF NATURAL DISASTER [31]

Off grid LED lighting can play a key role in providing a core lighting capability in remote locations, and also where electricity grids are unreliable. Their high efficiency help to maximise the impact of the linked renewable energy sources. Unexpectedly, off-grid solar LED lighting has also proved to be an invaluable resource in cases of extreme weather conditions or natural disasters. In 2010 a 6.9 magnitude earthquake hit the city of Yushu in China, leaving hundreds of people dead and thousands injured. In that tragic incident, the off-grid solar LED lighting system installed in one of the main roads in the city was the only remaining light source and played a major role in supporting the rescue work after the earthquake.

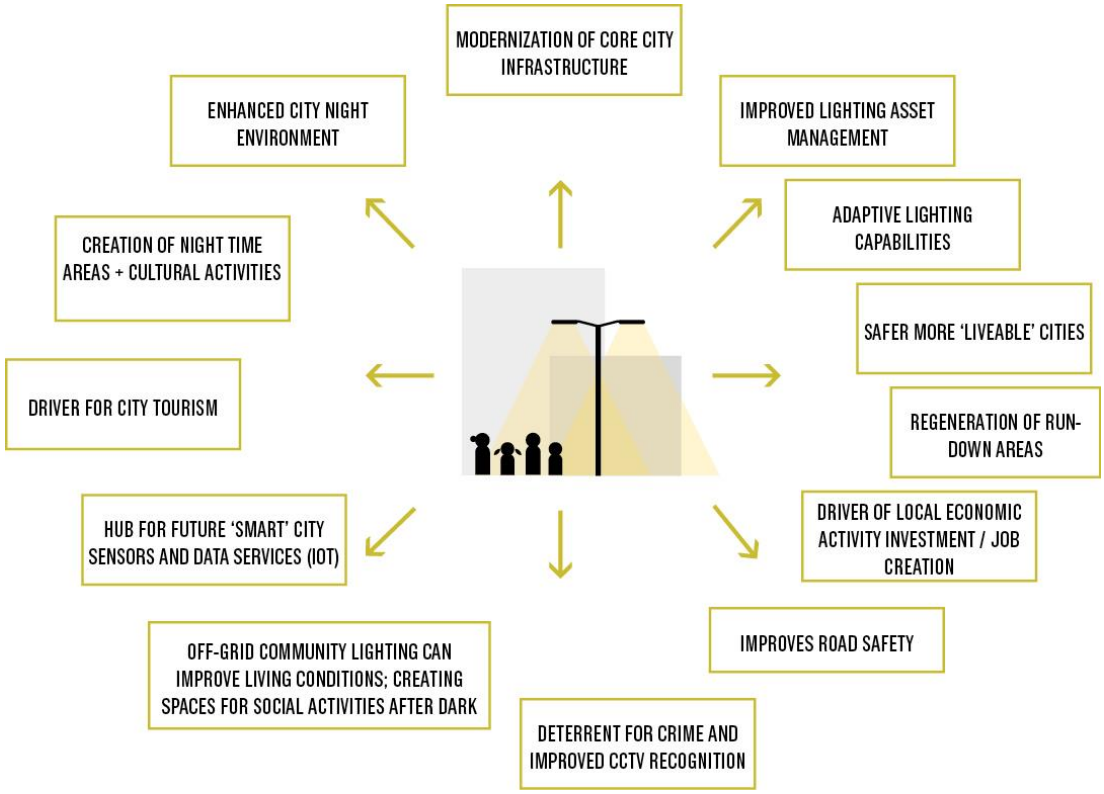


***DIAGRAM**: Examples of broader socio-economic benefits that can come from enhanced, smart, connected LED lighting in cities. City managers may find it challenging to assign a monetary benefit to the topics and themes, but they can play a key role in helping to align stakeholders, develop policy support, and support the LED business case.*

The socio-economic benefits of LEDs can also be further expanded in cities, towns and villages where lighting may not be reliable or available, and where off-grid lighting may be a more appropriate solution. Energy efficient LED street lighting can provide a reliable, environmentally sustainable, and affordable option for many communities that are currently not connected to the power grid, and can help to maximize the impact of the region's renewable energy sources. Unlit remote villages can be illuminated after dark with dramatic benefits to communities. In particular, safety[32] for women and children is improved, opportunities for increased night-activity, sports and social events are created as well as corresponding night-time business activity.

I'VE HAD A NUMBER OF PILOT PROJECTS IN MY CONSTITUENCY. SURVEYS SHOWS THAT [RESIDENTS] FAR PREFER LED STREETLIGHTS. 85% SAY THEY FEEL SAFER IN THEIR COMMUNITIES AND 95% SAY THE QUALITY OF THE LIGHT IS BETTER. [33]

LED STREET LIGHTING: THE TECHNOLOGY

CHARACTERISTICS AND BENEFITS OF LEDs

The general benefits of LEDs over conventional discharge street lighting have been summarized in various presentations and reports[34]. This section is designed to provide a technology overview of LEDs, highlighting the underlying properties and capabilities that make them an attractive opportunity for city lighting managers. From our LED city consultations, the key features worth emphasizing in the context of street lighting are outlined below.

CONSULTATION FINDING: EACH CITY IS UNIQUE

In assessing and preparing for LED upgrades, each city has a unique history in terms of existing lighting infrastructure, funding capacity, asset ownership and political support.

Wider availability of central government funding for short-term business case support was a common request from city lighting managers.

Solid-State Lighting (SSL): [35] LEDs are based on solid semiconductor structures that can be manufactured in high volume and mounted directly onto printed circuit boards. This means:

- LEDs are 'solid-state' in structure and therefore more robust compared to conventional glass enclosed, vacuum/filament and discharge bulbs.
- LEDs can be manufactured in volume, at low cost covering a broad range of output powers and color options.
- White light LEDs can be manufactured at low cost using a blue LED coated by a phosphor material (see side Box: How does an LED generate white light?)
- LEDs have long operational lifetimes, requiring less frequent replacement and maintenance.
- LEDs do not radiate high levels of 'direct' heat – eg. as with a filament.
- Discharge lamps may generate visible light by converting UV light in phosphor inside the glass envelope, and may not always eliminate residual UV emission, whereas white-light street lighting LEDs typically use blue LEDS covered by phosphors which emit negligible/zero UV levels.
- LEDs generate heat at their base, which is typically efficiently dissipated using conducting metal plates/fins.
- LEDs can be turned on/off very rapidly with no warm-up time required, making them suitable for smart controls e.g. light activated when a person/vehicle is detected by a motion sensor.
- LEDs can be operated over a wide range of intensities, making them suitable for adaptive lighting (e.g. scheduled dimming) applications.
- The long operational life of LEDs (as compared to traditional HPS lamps) means they will need to be replaced typically much less frequently, with a corresponding dramatic reduction in the number of luminaires required to be recycled [36].

CONSULTATION FINDING: MAINTENANCE SAVINGS CAN BE VERY SIGNIFICANT

In Los Angeles, the annual energy savings[37] are estimated at approximately US$ 9m, with an additional US$ 3m annual savings in annual maintenance.

In New York City, there is an ongoing upgrade of street lighting to LEDs, with the projected annual energy and maintenance savings reaching up to US$ 14m.

High efficiency: compared to conventional street lighting, LEDs have demonstrated savings of up to 50-70% and up to 80% when combined with smart sensors and controls[4]. LEDs can produce more light output 'per Watt of power' than conventional bulbs. The light output is typically measured in lumens (See box on Lumens and Watts).

Long lifetimes: [38] LEDs have a very long operating life and can maintain a minimum light level (in lumens) over an extended time period (up to 50,000 hours[39]), as defined by LM-79, LM-80[40] standards, which specify 'lumen maintenance'. This lifetime may be sufficient for most city users, as light pole inspections may occur more frequently, and managers may elect to replace aging driver circuitry. Some city managers have indeed questioned the additional cost benefits of procuring LEDs with quoted operational lifetimes of 100,000 hours (corresponding to more than 20+ years of operation)[41]. Nevertheless, the extended operational lifetime of LEDs requires fewer engineer 'visits' to replace failed luminaires, providing significant maintenance cost savings opportunities and similarly significant reduced need for recycling luminaires[42].

Efficient and flexible use of light: LEDs are typically small almost single 'point-like' sources of light, rather than a conventional glowing hot filament or a glowing gas discharge lamp. The fact that LED light comes from a small area allows lighting engineers to employ very efficient optical designs that can deliver light to the required place at the required 'lumen' light level. LED luminaire designs can be optimized for a breadth of lighting needs, and specified to reduce over-lighting and light pollution.

Early tests and trials of are always recommended to ensure the LEDs selected will sufficiently satisfy the technical and social lighting requirements.

Broad range of LED color options: LEDs can be manufactured to emit specific light colors as well as different white light options (eg. warm 'yellow', neutral and cool 'white'). Very early LED products suffered from color instability, particularly with low quality bulbs and the color would change as the LED aged. This issue has greatly improved and LED manufacturers are now able to specify and warranty long-term LED color operation.

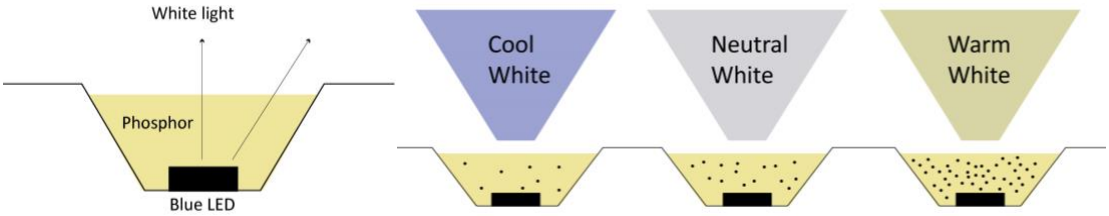
The selected white light options can affect the light brightness, and how different colours are perceived at night[43]. City lighting managers are thus able to trial and select different white light LED options and controls to match the lighting requirements and public preferences for different areas; e.g. city centers, sports venues, main arterial roads, interstate highways, quiet residential areas, areas of natural concern, dark sky designated areas, etc.

Reduced waste and recycling: Linked to the extended operational lifetime of LEDs compared to traditional lighting, there is the often overlooked corresponding reduction in the number of lighting luminaires that need recycling; potentially up to 3 or 4 times less in number.

CONSULTATION FINDING: CLARIFYING HOW LEDS GENERATE WHITE LIGHT AND 'COLORS'

LEDs were first developed in the 1960s, and since then multiple variations of color ranging from red, yellow, green and blue have been developed. A major breakthrough that allowed LEDs to be used in general lighting applications came in the 1990s with the development of high power blue LEDs based on new semiconductor materials. By using a single high power blue LED, coated with a phosphor material, a low cost white light could be developed. The blue light is absorbed by the phosphor which then emits light across a range of spectrum colors which combine to create white light. (see Figure).

By selecting the composition of the phosphor material it is now possible to create white lights with different appearances. They can range from blue 'cool' white, 'neutral' white, or yellow 'warm' white, with each characterized by a specific numerical 'color temperature'[44]. There are 8 nominal white LED 'color temperatures' defined: 2700K, 3000K, 3500K, 4000K, 5000K, 5700K and 6500K. The overall efficiency and lighting benefits can vary depending on the selected white option, with the 'cool white' (high values) being slightly more efficient compared to 'warm white' LEDs (low values).



For street lighting applications, where low cost options are important, white light LEDs are the main products of interest. However, the selection of one 'white' LED color temperature solution may be not be the most appropriate to exploit the capabilities of LEDs for different lighting applications around a city – eg. lighting requirements of major highways, tourist areas, city centres and quiet residential areas may vary significantly.

Furthermore, alternate LED lighting colours may be of interest. For major architectural projects, sports arenas, or in buildings, bespoke multi-color lighting designs may be desired. Lighting designers are able to select a combination of high intensity white LEDs together with panels of red/blue/green LEDs to create artistic and impactful lighting schemes.

CONSULTATION FINDING: CHANGING MIND-SETS: LUMENS AND WATTS [45]

The advent of LEDs has prompted a need for wider awareness of how light performance is specified. In the past, light bulbs were defined according to type (e.g. incandescent, high intensity discharge etc.) and power Wattage (eg. 40W, 60W, 100W, 250W, 400W etc.). Each delivered a known light level, colour and quality of light, over a known area.

LEDs are capable of delivering the same light output as traditional lights but using far fewer Watts of power. This means that the level of illumination of a traditional household 40W incandescent bulb can now be achieved using, for example, a 5W LED bulb. In future, as lights become more efficient, the specified Wattage may reduce even further for the same level of light output. So end users should select lighting solutions according to the amount of light needed – measured in Lumens[46] - and not by Wattage. The efficiency of the bulb is defined by how many lumens are delivered, divided by the number of Watts consumed, or in Lumens per Watt (lm/W). Manufacturers may provide 'conversion' tables, for near-equivalent traditional lights to LED products, however caution is advised. In some cases, this approach has led to examples of 'over-lighting' and 'under-lighting' in cities, and examples of procured LED luminaires providing different or insufficient lighting coverage. For city lighting we would encourage trials and for samples to be tested to ensure that adopted solutions satisfy the requirements for the lighting applications.

CONSULTATION FINDING: DATA TO HELP VISUALIZE ENERGY SAVINGS: LEDS VS HPS

To highlight the level of energy savings that LEDs can offer compared to traditional lighting, a graphical example is presented below highlighting the power consumed during a typical night (from 8pm to 7am) using different lighting solutions; HPS luminaires and LED luminaires (i) and (ii). [47]

The corresponding energy usage in each case is equivalent to the shaded areas. HPS luminaires operate at a continuous level through the night, and the total consumption is represented by the largest shaded area. The more efficient LEDs can be operated either continuously, or combined with adaptive level controls to dim the lighting level through the night (LED(i)), or only activated when nearby motion is detected (LED(ii)).

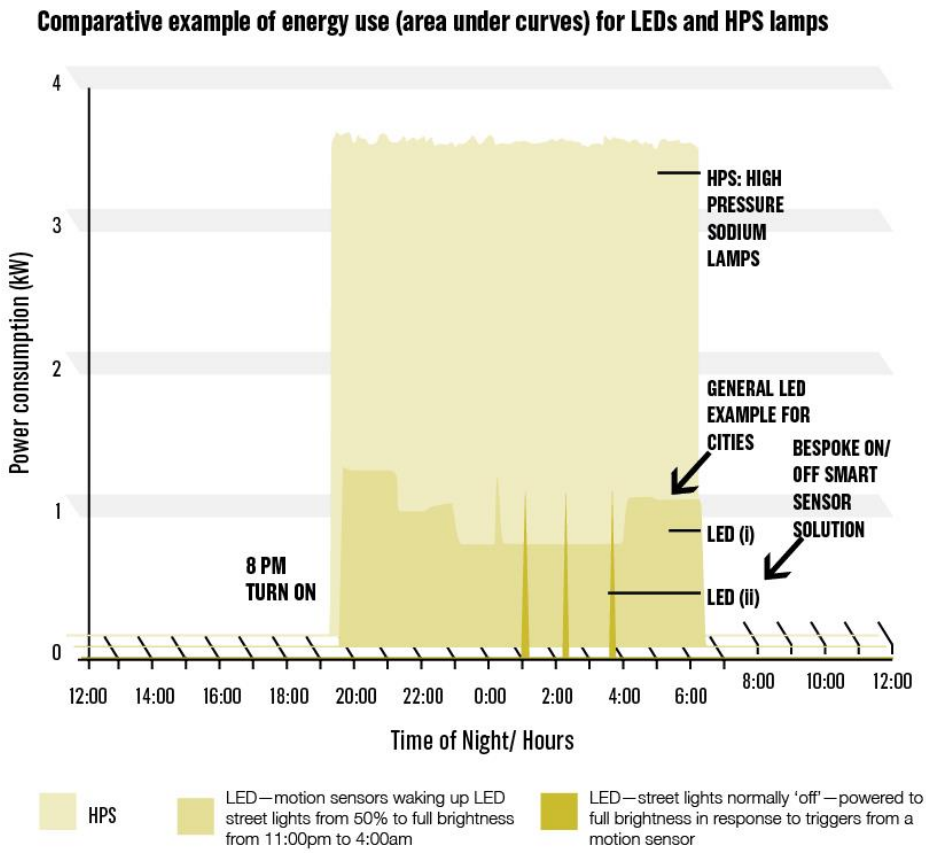


***DIAGRAM**: Comparison of electricity consumption of two street lighting systems (HPS vs LED) over the course of a 24-hour period.*

In both LED examples the corresponding shaded areas (and total energy consumed) are dramatically smaller compared to the HPS option. Example LED(i) highlights the typical savings that can be achieved, and LED(ii) represents a smart triggered example that could be suited to 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.

CITY CONSULTATIONS: RECURRING TECHNOLOGY QUESTIONS

A number of recurring technical questions are raised in consultation events, and examples include;

Light pollution, dark skies and effect of light on wildlife[48]: LEDs and linked controls can be designed and specified to address 'over-lighting' and minimise light pollution effects. LED options can offer an unprecedented opportunity to achieve significant reductions in the level of night-time lighting, particularly in sensitive applications - e.g. by selecting specific LED colors, luminaire designs to limit light pollution in specific angles/directions, and by using controls to dim lights, or to maintain lights 'on standby' and using motion detectors to turn - on lights only when needed. In natural light sensitive areas, where there is also human activity requiring a certain level of lighting at all times, a compromise must be reached, and this is an ideal example where trials can be invaluable.

CONSULTATION FINDING: TRIALS AID ADOPTION

More and more cities are exploring early LED lighting trials as they assess upgrade options.

LED trials help to verify the projected savings, lighting performance and refine procurement technical requirements.

Trials also facilitate public consultations and prepare the public for change

LED glare: There have been examples where LED luminaires[49] exhibited glare (bright light emitted at specific or extreme angles), which may appear intense to drivers and pedestrians. A selected LED luminaire design[50] may be generally applicable across a city, but have undesired effects in certain specific locations. Such undesired effects can be minimized with luminaire design, using light diffusing elements, shades/baffles and options for lighting engineers to adjust the luminaire alignment at the time of installation.

Light flicker[51]: Flicker is the high frequency variation of light which can be present in all common electric mains powered lighting. Lighting standards define procurement guidance to ensure health and safety requirements are satisfied but LED adopters may also wish to include hardware compatibility testing and functional acceptance tests at the time of installation to ensure flicker standards are satisfied.

Emission of blue light: The role of street lights as a contributor to artificial light exposure at night (and in particular 'blue light' exposure), the possible disruption to sleep and subsequent health impact is a common question raised in our consultations.

The effects of light exposure at night on the level of human alertness can depend on a variety of factors including the source of light, the amount (intensity) of light, the duration of exposure[52], the light color, the time of day the exposure occurs, the age of the observer, etc. In terms of light intensity, street lighting luminaires are specified within national safety exposure standards, where light intensity levels at street level are strictly tested and certified[53]. However, some recent lighting installations have prompted reports of street lights shining into resident's bedrooms[54], appearing to be too bright and 'over-lighting' some public areas [55]. Such cases have prompted city managers to re-position luminaires, fit shades/baffles to block excess light entering residences, and to explore light dimming options. In part as a result of these installation issues there are growing reports of city managers exploring 'warmer white' yellow LED options; a trend that appears to be driven by residents expressing strong preference for familiar and traditional warmer street colors.

The wider use of LED trials could allow opportunities for residents to experience the benefits of alternative whiter light color options, as well as adaptive and smart sensor approaches – alongside traditional colour sources.

An important factor not commonly mentioned in the context of street lighting, is that direct exposure to artificial light can come from a wide variety of familiar and accepted sources in the hours leading up to bed time – all which can disrupt subsequent sleep patterns[56]. Such exposure can come from direct sources including existing residential room lighting, bright kitchen and bathroom lighting, direct viewing of televisions, computer screens, mobile phones, tablets and e-readers[57], which could arguably impact more on sleep disruption than existing or LED lights outside on the street.

FRAMING LED STREET LIGHTING OPTIONS

LIGHTING OPTIONS

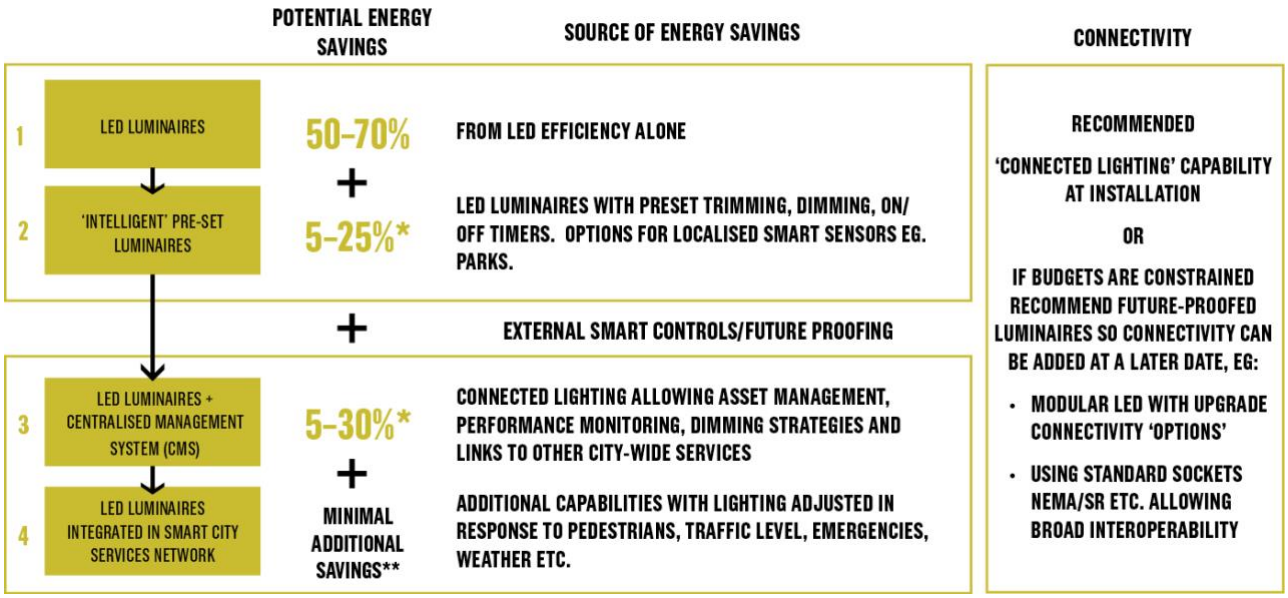
WHAT IS SUSTAINABLE LIGHTING ?

"The current goals of sustainability, reduction in energy consumption or "carbon emissions" can distract us from the far better long-term success of achieving a truly sustainable lighting design.

It's not just about the technology, but why and how that technology is applied..."[58]

Every city seeking to upgrade its lighting infrastructure will base decisions on the status of the current infrastructure, available funding, and what must be replaced to meet the cities future lighting needs and support its long-term growth strategy. By way of example, a city may be able to reuse most of its existing street lighting poles, and elect to simply retrofit traditional luminaires with LED luminaires. Where poles may be reaching the end of their service life, cities may elect to replace or reposition selected poles with new designs and LEDs. Where the underlying infrastructure needs modernization, there may be opportunities to redesign lighting across the city, optimizing pole positions, removing unnecessary fixtures, implementing new controls, etc. For the purposes of our city consultations, we discuss the adoption of LED-based city street lighting on four simplified levels. City managers may select a combination of options depending on the lighting requirements at specific locations within the city e.g. city centre, main roads, residential areas etc. The relative and cumulative benefits of the four approaches can be summarized in the figure below:

1. Direct replacement of conventional luminaires with equivalent on/off LED luminaires. In some limited cases LED modules might be installed into existing older luminaire fittings, but tests and trials should verify that the desired lighting, LED heat management and dissipation, and required long term operation is achievable.
2. Replacement with LED luminaires with pre-set 'intelligent' on/off controls, optional fixed dimming, and photo-sensors. This might include some selected lighting poles fitted with 'smart' motion/proximity sensors to trigger the lights.
3. Replacement with connected LED luminaires linked via Wi-Fi/mobile (or similar communication networks) to a Centralized Management System (CMS), which would allow city-wide LED lighting controls, performance monitoring and operation updating.
4. A fully integrated LED lighting system with CMS, with additional links to external inputs that may influence future lighting requirements in the city e.g. traffic sensors and future 'smart' city infrastructure.



* Depending on allowed levels of dimming
** Primarily socio-economic benefits from a fully smart/intelligent integrated city.

DIAGRAM: *Example of potential energy savings that LEDs can provide. Note: there are diminishing relative contributions to energy savings from options 1 through 4, but increased connectivity and flexibility in the modes of operation and as part of a future integrated 'smart city' strategy.*

Options 1, 2 and 3 each offer immediate energy savings from LEDs compared to traditional lighting. Options 3 and 4 also offer lighting managers opportunities for city-wide control and asset management capabilities via a Centralized Management System (CMS), which can also provide strategies for linking to future city-wide 'smart city' service controls.

For circumstances where basic lighting solutions are sufficient (eg. simple on/off control and fixed level programing with an internal clock) then Option 2 could be considered a minimum specification. If this approach is selected, this could be specified with a modular capability (or industry standard connectors) to allow options to upgrade and add functions in the future. (e.g. Wi-Fi/mobile network communication modules, dimmable drivers, etc.)

ASSESSING 'TOTAL COST' AND 'TOTAL VALUE' OF LED OWNERSHIP

The benefits and value of LED ownership can extend far beyond simply a reduced $ cost per light unit (lumen), and reduced maintenance costs.

Longer LED lifetimes also means far less luminaire replacement and recycling. The addition of smart controls, and lighting connectivity can provide additional value supporting future smart city services, facilitate asset management, and provide opportunities for city data collection.

DIAGRAM: *Cities may have a range of lighting needs. The vast majority of city lighting can be residential lighting and may benefit from a standardized lighting solution. However, other locations may have bespoke and different lighting requirements; e.g. city centers, highways, tourist areas, architectural buildings, landmarks etc. All lighting can be connected to a CMS asset management system and ultimately to other 'smart' city services.*

ARE YOU CONSIDERING A SIMPLE LED RETROFIT, A LIGHT AND POLE REPLACEMENT PROGRAMME, OR A FULL INFRASTRUCTURE UPGRADE?

CONNECTED LIGHTING

For the different upgrade options outlined above, depending on the scale of upgrade, town and city managers may wish to explore options for luminaires to be fitted with 'connected' capability (e.g. via Wi-Fi/mobile networks) to link to a control center, or to be fitted with an industry standard 'connection-ready' option that would allow simple upgrades at a later date.

Connected lighting may be new for many cities, but this can immediately offer city-wide lighting controls that assist in LED roll-out and commissioning, system monitoring and maintenance scheduling, and provide the basis for core links to an asset management system and expanding future links to wider 'smart city'/IoT initiatives. Based on our city consultations, many cities are exploring connected lighting solutions, and where budgets are constrained, alternative interim 'future-proof' connector strategies are being considered.

A LOOK INTO THE FUTURE: Future-Proofing Connectivity

A common consultation question is how city managers can be expected to specify which potentially fast evolving communications system (Wi-Fi, mobile 4G and 5G etc.) they should select to support their cable/pole LED infrastructure where lifetime expectations may be on very long timeframes (eg. 20+ years). Where procurement may be phased due to budget limitations, city managers may seek to select a future-proof socket (eg. NEMA/SR etc.) or consider upgradable modular luminaire designs. Procurement will necessitate solution providers to offer cities robust, forward-looking, adaptive and flexible connectivity and communications solutions that can best enable hardware to be supported securely over extended periods – and enable future smart city and IoT services to be added over time. A good example is Los Angeles where mobile networks are used to connect to individual lights, and in bespoke locations poles are separately being leased to telecom service providers, allowing new technologies and new business models to be trialled and implemented without impacting on the wider lighting requirements of the city[59].

MILAN, ITALY [60]

More than 140,000 LED luminaires have been installed around Milan. The largest road lighting upgrade to use LEDs in Italy, the savings are estimated at 31%, with energy savings of US$10.6 million (€10 million), and over 23,000 tons of CO_2 emissions annually.

'INTELLIGENT' AND 'SMART' LED LUMINAIRES

For the purposes of the consultations, we use the term 'intelligent' luminaires as meaning a pre-set luminaire programed at the street pole level. These may be used where the lighting requirements are fixed and there is limited benefit of installing additional functionality, e.g. for footpaths, parks, selected residential areas etc.

A 'smart' luminaire modifies its standard lighting operation in response to an external motion sensor trigger or control signal. Such features can provide 'additional' energy savings, particularly if lights can be turned off, dimmed and only activated when needed. City managers may decide that individual smart triggered lighting poles are not suitable for wide-scale deployment, however they may elect to use groups of lights that are triggered to dim together, or turn on/off by street or locale etc.

SMART LIGHTING IS NOT NEEDED EVERYWHERE. 95% OF MY STREET LIGHTS ARE IN QUIET RESIDENTIAL AREAS. I NEED THEM (CONNECTED) TO TURN ON AND OFF AND SAVE ME MONEY.[61]

Some extreme examples of 'smart poles' have been presented where lighting poles are fitted with a large array of multi-sensor technologies[62], integrated with Electric Vehicle (EV) chargers, Wi-Fi and new telecom services, etc[63]. However, it is unlikely that every traditional city street light pole will be required or able to deliver such capabilities, as the additional power requirements would make such approaches impractical for most cities without costly modification of pole replacement and cabling.

In Los Angeles[37], selected new 'smart' poles are being adopted, in addition to the conventional lighting poles, to serve as nodes for their lighting communications, but also to add additional city services, e.g. telecoms services, new EV charger points, sensors etc. where they are needed.

ARE YOU EXPLORING OPTIONS FOR ADAPTIVE AND SMART SENSOR TRIGGERED LIGHTING?

BERLIN, GERMANY[64]

Berlin's has seen 5,500 LED street lights deployed, with a further 2,500 being fitted this year. The installed intelligent lighting minimises energy waste and lowers light pollution by ensuring that the city streetlights do not burn at 100% at night when the streets are not occupied.

SMART CITY CONCEPTS – INTERNET OF THINGS

Many cities have long-term strategic plans for future growth and modernization, including adoption of new smart city concepts, city services, data gathering capabilities and links to a city data 'cloud' and the IoT. Street lighting is a city-wide core infrastructure which can potentially be managed based on multiple city sensor data inputs, as well as specific requests from other city services (traffic managers, police, waste collection, adverse weather reports, accident response, etc.)

Currently many smart city concepts are in early development and will require extended periods of trialling and testing to assess their benefits and business case. Therefore, there may be inherent risks in directly linking city street lighting procurement today to the many evolving technologies and future IoT services under consideration – all of which may have different:

- Speeds of innovation and product development;
- Ranges of key adopters and managing stakeholders;
- Technical specifications and applicable standards;
- Physical connection interfaces, power requirements, and data protocols;
- Safety and security requirements;
- New and 'unproven' operating business models;
- Legal operating requirements;
- Data gathering rights e.g. of public and citizen information; and,
- Data ownership and rights of commercial use.

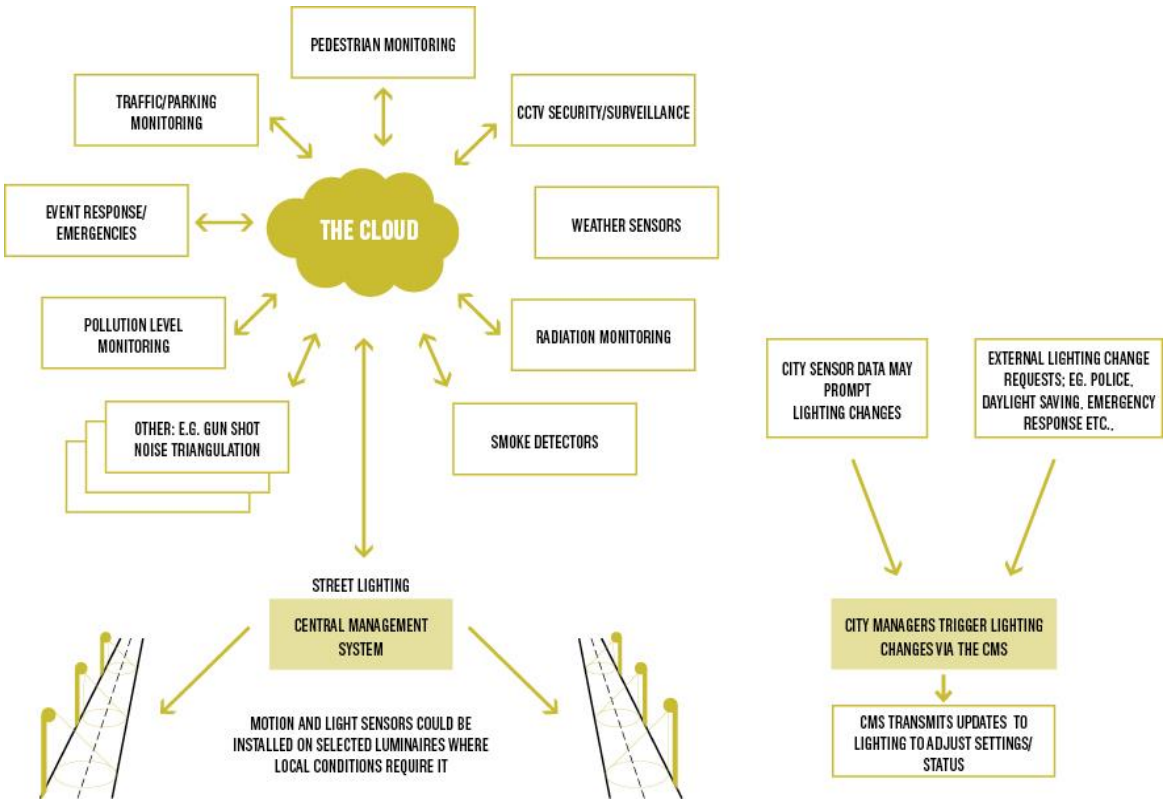


DIAGRAM: *Concept of linking street lights to the wider city 'data cloud'. LED street lighting can remain a standalone system and linked to the cloud via a Centralized Management System (CMS). This allows city lighting to be controlled independently or in response to lighting adjustments prompted by city sensor data or requests from other city services.*

Future-proofing of city lighting technology is important, but uncertainties around the next 10 to 20-year future visions for smart cities should not unnecessarily delay or hinder the rollout of LED lighting and other such energy efficient technologies available today.

THE SMART CITY MARKET[65] IS LIKELY TO BE WORTH US $ 1.5 TRILLION BY 2020. INTELLIGENT LIGHTING CONTROLS CAN SERVE AS A PLATFORM FOR FUTURE SMART CITY SERVICES.

One solution could be to define fixed and manageable interfaces to a city 'digital cloud' (e.g. via the CMS – see figure above) and reduce the dependence of specifying today all the different possible operating permutations, requirements and standards for the multitude of new and evolving smart and IoT technologies.

A LOOK INTO THE FUTURE: Forget Wi-Fi, get ready for Li-Fi [66, 67]

This ultrafast new technology uses light to transmit data and is 100 times faster than current systems

There is a growing interest in exploiting lighting (both indoor and potentially outdoor) as a potential hub for new high speed data communication. Whilst Wi-Fi is commonplace, a faster light based communication system Li-Fi is being trialled. By modulating Li-Fi lights at extremely high speed - faster than the human eye can see - it is possible to send and receive data using light. The limitation is that there must be a line-of-sight (or sufficient level of scattered light) between the light emitter and the receiving portable devices. Also the Li-Fi lights must be on all the time, so may not be widely suitable for city public lighting. Li-Fi is being trialled in bespoke locations where traditional wireless communications cannot operate, or where higher data rates may be required (e.g. underground railways, in new office buildings, lifts, trains, etc.).

DO YOU THINK THERE IS A RISK THAT TRYING TO ANTICIPATE ALL FUTURE SMART CITY CONCEPTS CAN CREATE CONFUSION DURING PROCUREMENT AND RISKS DELAYING ADOPTION OF LEDS?

EQUIPMENT INTEROPERABILITY

With the growing range of city products and services, and potential for increased public access (via IoT) there is a need to ensure 'secure' and protected installations. Conversely, there is also a desire for wider, more standardized 'plug and play' approaches for new city hardware and demand for more interoperability across different manufacturers.

Cities must typically follow public, open tendering procurement processes, and given the nature of long-term city infrastructure investment, consideration must be given to the operation, servicing and upgrading of city lighting over many years, as well as the possible need for new future contracts with different suppliers.

Each competitive tendering and procurement process may therefore inevitably lead to the use of equipment from different manufacturers, and there is growing recognition of the need for wider use of non-proprietary sockets and open (but data secure) protocols to allow future procurement flexibility for customers as well as to drive standardization in the industry. An early, but powerful example of this approach is that taken in Los Angeles. The city upgraded to LEDs in 2009/10 and

elected to install an industry standard socket on the top of the luminaire. This approach subsequently allowed the city in 2015 to competitively tender for a wireless connectivity upgrade, adopting connected Wi-Fi/mobile network modules and a centralized management system from a different supplier.[68]

In 2016, more and more lighting manufacturers are offering modular upgradeable LED luminaires, as well as full-function connected luminaires.

ARE YOU HAVING DIFFICULTY IDENTIFYING OPTIONS TO BEST FUTURE-PROOF YOUR LIGHTING INSTALLATIONS AND BE READY FOR FUTURE SMART CITY TECHNOLOGIES?

DATA PRIVACY, DATA SERVICES, SECURITY AND OWNERSHIP

The gathering of city data and the growing interest in 'Big Data' projects may encompass many activities; eg. core city services, energy use, public transport, policing, business activities, traffic management, CCTV monitoring, citizen movements, etc. As the number and variety of city services increases, there is a corresponding increase in the number of potential users and access points, all of which are potentially vulnerable to hacking, and even 'denial of service' attacks. There is therefore a balance to be made between maintaining the operational security of fundamental city infrastructure such as lighting, and the level to which it is allowed to be connected to other city users and cloud based systems. One approach mentioned above could be for the lighting Centralized Management System (CMS) to provide an isolating 'interface' between the lighting and the internet 'cloud' of external connections and services – where any potential requests for lighting changes triggered by external systems can be managed by the lighting managers.

Data and system security considerations form part of the wider connected smart city and IoT themes and will be discussed and featured in our events and consultation workshops.

Finally, it is apparent from our consultations that the laws governing public data collection, the rights of ownership, and rights of commercial use are largely unknown and may not yet be clearly defined in many countries. Therefore, when building the financial business case for lighting upgrades and exploring the potential for generating future revenues from un-validated sale or use of city data projects (particularly to help repay financial loans) caution should be exercised.

LED STANDARDS, QUALITY AND ENFORCEMENT

With the advent of LEDs many new lighting solution providers are offering products and services, and there is a need to ensure that all lighting products meet defined quality thresholds, and that local, regional and established international lighting manufacturers are all held accountable to the same standards and quality control enforcement. This allows city lighting managers to undertake fair comparisons and assess product quality and performance from a range of providers.

While many governmental, corporate and trade agencies are working to bring consensus on lighting standards, it is clear from our consultations that regional variations still remain. City lighting managers therefore face an ongoing challenge of satisfying applicable local lighting standards, applying wider international guidelines and industry best practices, undertaking appropriate trials and assessments, and benefiting from lessons learned by their peer cities.[69]

The role of government and policymakers is therefore critical, not only in committing to energy efficiency initiatives such as LED adoption, but also in parallel capacity building initiatives to ensure that national testing labs and published standards are put in place, and strictly enforced[70].

A summary of the status of related standards in different regions has been released by the Lighting Industry Association [71]. Other organizations[69] also publish suggested guidelines on LED product performance for different applications as a guide to policymakers and lighting stakeholders.

LED WARRANTIES

As with all new products, warranties can play a key role in the LED product and supplier selection processes. LED components can regularly be quoted with operational lifetimes in excess of 50,000 hours (e.g. at 10 hours per day equates to 13-14 years' operation). However, it is important to ensure that any warranty is on the whole lighting luminaire product (ie. housing, driver electronics, LED etc.), as it is possible an electrical driver or mechanical component may fail before the LED element. Furthermore, city lighting managers need actionable and applicable warranties appropriate for LEDs, as the total cost of engineers and cranes attending to replace a failed luminaire on a pole service may far exceed the simple replacement cost of an LED luminaire.

Some stakeholders may similarly argue that lifetime claims of more than 100,000 hours (25+ years) are of limited value, and city managers may wish to review and add upgrades on a shorter timeframe. There is also the practical management challenge and enforcement of warranties with commercial organizations over such extended timeframes.

A key part of our consultations is therefore to discuss actionable and appropriate long-term LED warranties that match city needs.

WHAT LED LUMINAIRE WARRANTY TERMS AND DURATION DO YOU REQUIRE IN YOUR CITY?

THE DECISION TO UPGRADE TO LEDS

LED ADOPTION: PROCESS OVERVIEW

In undertaking procurement of new lighting infrastructure there are a number of fundamental processes that city managers will undertake. There are examples of lighting review checklists and flow charts[72] available, and the key themes are outlined in the diagram below;

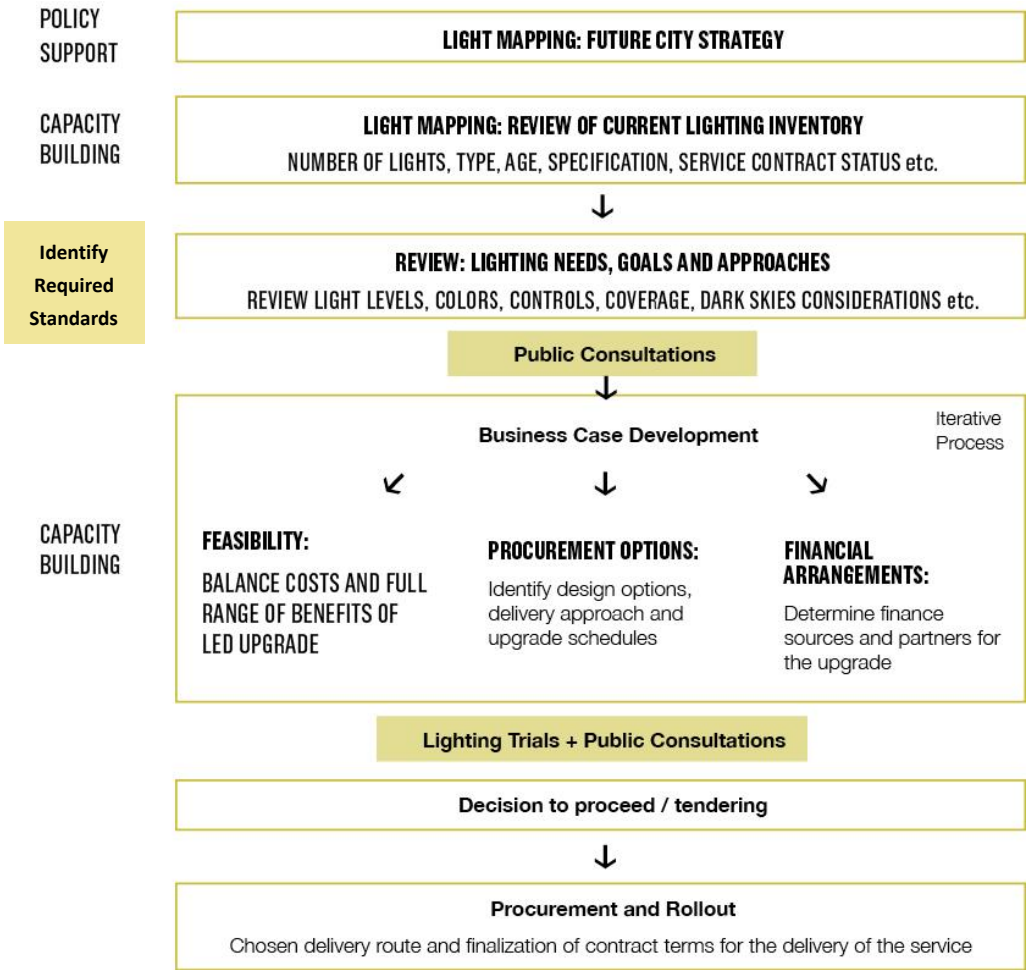


DIAGRAM: *Key processes along the path of review, assessment, procurement and adoption of LED street lights. Many of the consultation participants are already be at different stages along this path.*

STANDARDS AND QUALITY THRESHOLDS

It is critical to define the required lighting product quality thresholds and lighting standards that suppliers must meet.

This helps to ensure that all suppliers are assessed on a 'level playing field' rather than simply on cost for what may be very different levels of product quality, build, reliability and operating standards.

Once the decision has been made to explore the upgrading of lighting infrastructure, it is critical to conduct a light mapping review. This involves a full 'baseline' inventory of the existing lighting assets, to create a log of the lighting assets in place, their location, status, lighting coverage, age, specification, energy use, etc. and to identify stakeholders responsible for operation and maintenance, and any existing service contracts.

From our LED consultations it is a common finding that many expanding cities may have operated their city lighting and incrementally added new hardware over many decades, and may not have an up-to-date inventory of their street lighting assets. This baseline asset mapping activity may therefore require internal capacity building and/or central government support to help fund this important early task.

CONSULTATION FINDING: ACCURATE LIGHTING INVENTORY IS CRUCIAL

When assessing projected energy savings from LEDs, an inventory and baseline of lighting assets and operational status is crucial.

There is a high risk that unknown old and inoperative city lighting will be replaced and result in actual savings being lower than estimated.

The next step is to review the city's current and projected future lighting needs. This may allow managers to explore new opportunities for removing or repositioning lights and poles, addressing over-lighting and light pollution, and identifying the colors, coverage and quality of light and services required in different areas of the city. As highlighted previously, the lighting needs may vary across the city, and the breadth of options available with LEDs and matched controls can provide managers with new opportunities to enhance lighting, make necessary asset redesigns, and maximize potential savings.

This assessment of needs, drafting of requirements, definition of required standards, and quality thresholds forms the framework for the business case, as different options can be explored and associated costs can be estimated. The business case development can represent a major undertaking for many cities who again may need additional in-house capacity to review the technology options, and in parallel, plan and negotiate the most appropriate financing options. This is typically an iterative process as refinements of project scope, scale, technology options, and timing of upgrades may be needed as available financing options may require revisions and compromises to be made.

During this phase of project assessment, a commonly misplaced comparative metric is discussed; the project 'payback period'. It should be remembered that every city is unique, and caution should be applied when comparing different city projects based solely on quoted 'payback periods' (see consultation finding below).

City consultation participants may be at various different stages of the review and adoption process, and we seek to provide guidance materials, examples and links to relevant peer cities.

CONSULTATION FINDING: BEWARE COMPARING REPORTED 'PROJECT PAYBACK PERIODS'

A common question in our LED consultation workshops is 'what is the typical project payback period?' Every city's project scope and circumstances are unique in terms of lighting design and financial approach. Project payback periods may depend on a multitude of variables. Some cities may elect to pursue a fast payback, whereas others may deliberately spread their loans over a longer period for their particular financial circumstances. Project scope can also vary significantly; the payback period for a project that replaces 1,000 luminaires could be very different to one where 1,000 luminaires and street poles are replaced, and where a Wi-fi communication and asset management system are added as part of a much larger city-wide upgrade program.

"The 'payback period' can vary depending on your unique upgrade and financing circumstances."

ARE YOU FINDING IT DIFFICULT TO FINALIZE YOUR LED BUSINESS CASE? IS THIS DUE TO LACK OF INTERNAL STAFFING CAPACITY?

WHAT ADDITIONAL INFORMATION OR SUPPORT DO YOU NEED TO PREPARE YOUR BUSINESS CASE FOR LED UPGRADE?

ROLE OF TRIALS: ADDRESSING PUBLIC CONCERNS AND DISPELLING MYTHS

While the responsibility for the delivery of street lighting in cities resides with a local authority, council or sub-national organization, the general public are ultimately the main beneficiary of the service. There are examples where councils and cities have upgraded key elements of their infrastructure without trials or public consultations and in some cases this has resulted in strong negative public reactions[73].

Whilst trials or limited tests can introduce an element of delay, they are also a key part of facilitating the adoption process and wider familiarization of LED technology and its capabilities. Trials can allow verification of performance, and help to refine final technical specifications, and they can help to demonstrate the justification and potential savings to the public, as well as address any lingering questions around color, light pollution etc.

As more and more neighbouring cities and regions adopt LED solutions, the need for repeating trials dramatically reduces as national example sites, peer-to-peer learning, and case studies become widely available.

ADDRESSING LED COLOR - LEARNINGS FROM MUMBAI AND TAIPEI

The city of Mumbai in India recently replaced yellow sodium vapour bulbs with white LED lights along Marine Drive, one of the city's most famous tourist spots[74]. This resulted in changes to the iconic aesthetics of the walk, which is famous for its bay area street that resembles “the Queen’s Necklace”. This led to complaints from locals and political representatives claiming that LED lights had “stolen the charm”. Conversely, complaints also mentioned that inappropriate lighting had left ‘dark patches on the footpath', thus risking safety of pedestrians.

In order to compensate for the mistake, the Energy Efficiency Services Limited (EESL) - a governmental body which promotes and funds energy efficiency projects in the country - decided to replace the current white LED lights with more traditional looking yellow LEDs to restore the “iconic street’s golden glow” [75].

A similar event happened in the city of Taipei in Taiwan[76] where white LEDs were installed along a famous romantic panoramic view point in the suburb, leading to complaints from local residents and tourists arguing that the upgrade reduced the romantic atmosphere characteristic of the spot.

ARE THERE SPECIFIC TOPICS OF PUBLIC CONCERN OR REMAINING MISCONCEPTIONS AROUND LEDS IN YOUR REGION?

LED FINANCE AND RISK ALLOCATION

FUNDING CHALLENGES

The financing of any large scale city infrastructure upgrade can represent a significant budgetary challenge. This involves not only securing available funds against a variety of competing city budgetary demands, but also exploring the best options appropriate for each city's unique circumstances[77].

The scale of projected energy savings from LEDs can be compelling, but many city adopters still report struggling to identify suitable sources of finance to fund the initial procurement cost. Some cities with available funds may elect to fund LED upgrades from their reserves, or secure attractive terms for a loan, whilst others may choose to use an Energy Service Company (ESCO)[78] model, or a Public-Private Partnership (PPP)[79] approach to fund the project over the long-term. For cities with limited funding capabilities, and particularly those in developing regions, available loan options may be very limited, or the financing terms unattractive. Cities may not have spare funding capacity, and individual city credit ratings may be low. The resulting risk premiums, when coupled with some loan providers' unrealistic high project return expectations, can lead to prohibitively unattractive finance options; leaving many cities around the globe simply unable to adopt one of the most energy efficient technologies available today.

There is a wide variety of financial and commercial models that can be explored for lighting upgrades, and the most appropriate option can depend on factors such as:

- Project Scale: size of the installation, age of existing infrastructure, light inventory at time of upgrade, and the long-term future plans for city growth.
- Legal: ownership of lighting assets and value, current lighting contracts and duration, and location specific regulatory factors.
- Financial: existing contracts, financial capability of the city, credit rating of the city/loan receiver, expected level of financial return, level of financial risk and the 'owner' of risk, mechanisms to guarantee security of repayment (e.g. ESCROW[80] accounts for 'lighting' tax revenues), use of new lighting service/management companies or Special Purpose Vehicles (SPVs), and support from first loss guarantors (eg. foundations)
- Local specific: the presence and investment interest of third party finance sources in the local market and local capacity for PPP / ESCO and leasing arrangements.

IS FINDING SUITABLE FINANCING STILL A KEY BARRIER FOR YOU?

IS COMPLEXITY AROUND CITY LIGHTING ASSET OWNERSHIP A BARRIER TO YOU UPGRADING AND FINANCING LEDS?

CITY AND FUNDER EXPECTATIONS

From our city consultations, there are many cities seeking to secure LED financing solutions, both in developed and developing regions. Conversely, there is a common complaint from participating finance organizations that there are not enough 'investor ready' city projects available. Investors commonly report difficulty in finding sufficient LED investment opportunities at scale and with standardized comparable deal structures. Some LED finance consultation participants have expressed a desire for a portfolio of de-risked investments in LED city projects, rather than having to individually manage a variety of city projects, in different geographical regions, on different terms and conditions. This desire for standardizing projects is aimed at helping to facilitate the investment process, by

reducing transaction costs, and helping to open up the investment opportunities to attract a wider range of finance/loan providers.

The desire for aggregation of city projects highlights the critical role that third party national coordinating bodies and supporting local government policy can play in developing a national, focussed and consistent LED project approach – in which international investors can participate. An early example of such an approach is taking place in India, where the central government made a national commitment to LED technology, calling for LED adoption across all sectors by 2019. This directive has served to drive long-term investor confidence and helped align stakeholders at all levels in the region.

WHAT ARE THE 'RETURN ON INVESTMENT' EXPECTATIONS FOR LED CITY INFRASTRUCTURE PROJECTS?

CONSULTATION FINDING: ROLE FOR NATIONAL COORDINATORS

There is a facilitating role for national 'third party' coordinators, consortia, and service providers to help aggregate and standardise, and de-risk city lighting projects.

These stakeholders could be key in helping to accelerate links between similar city projects, local and international investors.

The Government of India set EESL[81] to work as an ESCO, to build internal capacity and financial confidence and drive LED adoption in the country. EESL has so far launched a number of city projects and has sought opportunities for bulk procurement of LEDs for indoor applications. To drive down investment risk in Energy Efficiency in India, EESL has been working with the World Bank[82], International Finance Corporation and other finance organizations to provide schemes for guarantees of 'first loss' on high risk projects, capacity building, as well as mechanisms for project aggregation.

A key risk factor to keep in mind in all developing regions, is the importance of assessing and mitigating any project risks arising from national power infrastructure and electrical grid stability. Current lighting asset inventory and status mapping must also play a crucial role in baselining projects and assessing repayment risk, particularly those based on future projected, deemed, and actual energy savings.

As well as driving LED adoption and wider energy efficiency innovations, supporting policy can play a key role in stimulating future market and investment growth by developing road-maps to transition from such government LED stimulus programmes, to avoid creation of monopolies, and to create conditions for an expanding competitive market environment.

FROM 2015 TO 2025, US$ 53.7 BILLION IS PREDICTED TO BE INVESTED IN LED STREET LIGHTING SOLUTIONS[83].

India has made a major commitment to LEDs, but it is not the only territory where project standardization is being explored at scale. Our LED city consultations in Brazil, and the work of the World Bank, has highlighted many similar cities seeking to adopt LED street lighting solutions and secure suitable funding.

The World Bank recently completed a survey of 300 Brazilian[84] cities, ranking them into groups based on size to help identify applicable investment approaches and corresponding investor groups. For example, the survey identified six groups of cities of which the top three tiers by scale might be potential investment candidates based on PPP models.

The survey also highlighted the potential challenge of financing LED projects in the many smaller towns and cities which consisted of up to 90% of the municipalities, and 50% of the total light points. Individually these smaller cities may find it difficult to secure infrastructure funding, but there could be opportunities for a government sponsored coordinating organization or service providers to help aggregate projects at scale.

ROLE OF LED LOAN GUARANTORS IN MITIGATING RISK

In some developing nations and territories with particularly high financial or political risk, there may be towns and cities where private financing of infrastructure projects cannot be secured without a level of independent risk mitigation – in the form of limited repayment guarantees from governments, foundations or other independent third parties. In order to demonstrate the broad viability of loan recovery in such high risk locations, a provider of limited 'first-loss' guarantee working alongside traditional investors in the initial stages of financing could help to provide sufficient investor confidence and help unlock other private funding sources. Such projects are being explored as part of our consultations, where initial guarantors could 'step back' once the local repayment recovery is demonstrated and investor confidence established.

There is a very real and ongoing risk that many of the small to medium sized towns and cities in such high 'financial risk' territories, which could directly benefit from the savings LEDs could provide, will be unable to secure loans without the active participation of such guarantors to demonstrate security of loan repayment.

WHAT POLICIES AND APPROACHES COULD BE EXPLORED IN YOUR REGION TO HELP BUILD LOCAL INVESTOR CONFIDENCE?

LED FINANCE: NEXT STEPS

Identifying new options for financing LED city lighting upgrades is a clear and ongoing requirement for accelerating scale-up, and The Climate Group will continue to drive a focused LED finance theme[85] within our ongoing city LED consultation work. We are exploring ongoing opportunities with the World Bank, IFC, and regional investors and stakeholders to identify solutions to mitigate local investment risk in different nations.

With the support of our city and finance consultation participants, our LED finance work will continue to focus on topics, including;

- **Showcasing successful and innovative financing case studies and best practices;**
  - General and regional financing case studies.
- **Promoting supporting policy;**
  - The role of a national policy and commitment to Energy Efficiency and LEDs.
  - Actions that can build local and international investor confidence.
- **Assessing viable finance approaches for cities;**
  - Self-funding.
  - Third party finance.
  - Leasing/debt financing.
  - Exploring new finance models e.g. 'lighting as a service'.[86]
- **Assessing return on investment;**
  - Setting realistic expectations of project returns for investors.
  - Presenting project savings based on kWh ($).
  - Exploring ways of reducing loan dependency on currency exchange rates.
- **Project finance risk mitigation;**
  - Allocating project risks to stakeholders best able to manage and mitigate them.
  - Options for guaranteeing loan repayment.
  - Developing national legal frameworks to help secure repayments e.g. identifying city lighting as a specific city tax revenue item.
  - Use of third party ESCROW80 accounts.
  - Role of private sector and 'first loss' foundation and donor guarantors in high risk regions.
- **Multi-stakeholder lighting ownership and upgrade approaches**
  - Exploring mutually beneficial approaches to distribution of LED savings amongst owner stakeholders.

- **Energy efficiency finance for utilities, lighting tariffs, and stranded asset management.**
  - LED lighting tariffs; exploring fixed and ratcheted tariffs to aid management of up-front adoption costs and asset value write-downs e.g. losses linked to stranded assets.[87]
- **Addressing procurement issues and barriers.**
  - Guidance to help develop wider standardisation of procurement processes.
  - Smart city considerations and optimum 'future proofing' approaches.
- **Developing multi-city project aggregation;**
  - National 'city project' coordinators / service providers.
  - National LED project standardization to reduce transaction costs.
  - Territory-focussed investor groups.

Finally, one of the new approaches being explored to fund lighting projects (both outdoor and indoor) is based on 'procurement of light' and 'lighting as a service'. The approach involves transfer of the responsibility of lighting to a service provider over an extended period, who would assess the optimum lighting upgrade approaches, take finance and technical responsibility, and who would develop and offer future products and services. The city lighting managers would be directly involved in the 'day-to-day' operations, but the city would pay an agreed tariff for the 'lighting service', agree pricing for any new services, and share revenue for new wider public commercial services added in the future. Such an approach to public service lighting represents a new proposition for cities, and may require assessments and trials particularly where transfer of control of public assets is currently not legally, politically or publicly acceptable.

WOULD YOUR CITY CONSIDER NEW LIGHTING AND FUNDING MODELS SUCH AS 'LIGHTING AS A SERVICE'?

WHAT FINANCE TOPICS WOULD YOU LIKE TO SEE COVERED IN OUR CITY AND FINANCE CONSULTATIONS?

LED ADOPTION: HOW CAN WE SUPPORT YOU GOING FORWARD?

In the wake of COP21 and COP22, there is a renewed urgency towards low carbon energy generation, increased energy productivity, and technological innovation to drive down emissions at scale. LED lighting is one of the mature, proven, and most energy efficient low carbon technologies available today.

LED city lighting projects are delivering and, in many cases, exceeding projected energy savings whilst also providing new socio-economic benefits to citizens and local economies. With up to 50-70% energy savings, our LED consultations reveal cities around the globe want to adopt LEDs but many urgently need practical support and more flexible financing approaches to help make it a reality.

The role of supporting energy efficiency policies and national and sub-national commitments cannot be underestimated in building urgency and consensus amongst local stakeholder groups. Our ongoing consultations will seek to involve all key local stakeholders to identify new options and solutions that can facilitate LED street lighting upgrades, at scale, around the globe.

We look forward to your participation in our expanding LED consultation process.

DRIVING LED ADOPTION: FINAL WORD

LED technologies can offer unprecedented energy savings opportunities, as well as a wide range of lighting options and capabilities that were previously unavailable.

Our consultation goal is to highlight the immediate opportunity that LEDs, and connected lighting, can provide in terms of monetary and energy savings, the immediacy of accessing those savings, and the scope for stimulating wider smart city and IoT services. We seek to drive and support actions that can help accelerate LED adoption and realise our 2025 global call to action.

The Climate Group wants to help ensure that the urgent drive for energy efficient lighting is not compromised by low quality, sub-standard LED products being allowed to enter the market, nor result in inappropriate replacement of traditional fixtures, unnecessary over-lighting, or lack of flexibility in light adjustment to help avoid excessive glare or light pollution at installation. We recommend early consultations and, where necessary, sample trials to confirm and demonstrate lighting needs, and to aid in refining procurement specifications for large scale LED roll-out.

As part of the suite of low carbon and energy efficient actions cities can explore, LEDs are ready today and should be prioritised. If you have not yet actioned a review of the potential benefits and savings from energy efficient lighting – please do so today.

CONTACT INFORMATION

For further information on this activity, related events and how to participate please contact The Climate Group team. **Email:** LED@theclimategroup.org

This document was prepared by Arianna Tozzi, Toby Morgan and Dr Peter Curley, as an update to The Climate Group LED city consultation handout for participants in the LED scale-up programme. Additional background research was undertaken by Pranay Kavathekar and Henry Witt.

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APPENDIX: EXAMPLES OF CONSULTATIONS REGIONAL FINDINGS

The examples presented are not limited to the specific territories, but serve to highlight that our consultations may cover general LED themes, as well as specific regional challenges.

REGION	REGIONAL FINDINGS	CONSULTATION ACTIVITY
MIDDLE EAST 	Lingering perception and concern over the reliable operation of high Wattage LEDs in extreme desert temperatures.	Lighting design experts were convened to highlight efficient heat management solutions, and to present examples of LEDs reliably operating in high temperatures regions e.g. Abu Dhabi.
USA 	Up to 60% of US cities' lighting assets may be partly or wholly owned by commercial investor utility companies. Adoption of LEDs could result in complex tariffs, reduced revenues and losses linked to stranded assets. There is an urgent need to explore mutually beneficial solutions for key stakeholders. Some cities are exploring the option of purchasing assets from utilities.	By highlighting the energy savings potential amongst stakeholders, we are increasing broader awareness of LED benefits and other future revenue opportunities and models. Participating in events with DoE, PUCs, NARUC, EEI etc. we are exploring routes for efficiency incentives and fixed and variable tariffs to facilitate adoption.
EUROPE & ASIA  	Regular queries raised on assessing finance options for LED city lighting and approaches to 'future proofing' of LED hardware. Questions raised over LED color preferences (eg. blue white versus yellow) and city examples where different solutions are selected.	Consultations convene finance and service providers to explore options. Experts have presented approaches to connected lighting, and routes for future developments and links to smart city concepts. Balanced discussions on LED color selection, light pollution and blue light content from LED sources in the context of all sources of artificial light exposure at night. Emphasis on benefits of demonstration trials.
BRAZIL 	Recent legislation required cities to take local responsibility for street lighting, prompting interest and requests for LED city examples and solutions. Challenges exist for finding viable financing sources for LED upgrades in the region. Broad need for building finance options at scale.	Working with finance organizations events we seek to explore routes and opportunities for coordinating LED adoption by cities based on size and financing need. Exploring ways to develop city groups and portfolios, standardize projects, and explore 'first loss' guarantees to help leverage wider private investment.

REGION	REGIONAL FINDINGS	CONSULTATION ACTIVITY
CHINA & INDIA  	Major commitments made to LED adoption in China and India. With rapid expansion of LEDs, there is a risk of low quality products entering the market. Recognition of the need to ensure regional LED product quality, test facilities and Quality Assurance (QA) enforcement. The LED business case can be at risk if projected energy savings are not based on an accurate baseline of the lighting asset inventory. Grid stability: supporting city power generation and cabling must be part of the LED project technical asset review to ensure any risks are included within the business case assessment.	Directly involve local standards and testing laboratories and agencies in events to make wider calls to policymakers on the need to support the drive for regional products standards and QA enforcement. Raising awareness with local ESCOs and municipalities on the need for accurate asset inventory and monitoring energy consumption to ensure future savings and loan repayments can be achieved – and the need for capacity building to undertake these critical tasks.

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