Connected LED street lighting: Enabling smart cities

An introductory guide for cities

Smart city initiatives offer an unprecedented opportunity for municipalities to use emerging technologies to improve the liveability, sustainability and connectivity of the places we live and work. Using a network of sensors and monitors, data can be collected and interpreted to gain valuable insights on how a city operates; leading to innovations in policy, transport systems, energy and environment, health and social care and connectedness, for example.

The drive towards connected LED street lighting 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-enabled products and services. These insights can help cities to become more sustainable, liveable, and benefit both city halls and citizens alike.

The unprecedented energy savings of 50-70% from LED street lighting compared to traditional lighting (and up to 80% when coupled with smart systems), presents a compelling urgency to raise the priority of LED adoption. Many cities and municipalities around the world are beginning to explore smart city options; however, with the wealth of technologies, suppliers and stakeholders involved, many are delaying implementation due to the complexity of options, as well as other barriers such as financing and data security concerns.

The United Nations estimate that 68% of people in the world will live in cities by 2050. With many cities experiencing restricted budgets and strained resources, using data to increase operational efficiencies and allocation of resources can aid city hall planning, as well as engaging with citizens. This document from The Climate Group, in partnership with Signify (formerly known as Philips Lighting), aims to give an overview of the basic principles of smart cities – including the technology, the benefits, data collection considerations and funding options. It will also present compelling case studies from around the world to showcase best practice examples to enable city managers, mayors, policy makers and other stakeholders to start exploring their own smart city opportunities.

WHAT ARE WE TRYING TO SOLVE?

Before any smart city initiative is undertaken, the key question which must be asked by city decision makers is “What are we trying to solve?” This is imperative to ensure future smart city schemes are effectively planned and the key issues addressed.

For example, what are the priorities of the city: Tackling air quality, reducing traffic congestion, improving health outcomes, better connectedness with citizens, etc.

There have been instances of data being collected with no clear plan of how this will be used, or if it will be useful. Big data collection also brings with it public privacy concerns, therefore having a clear vision of what outcomes are required is critical. Ensuring public buy-in to any smart city scheme is essential; and as examined in the case studies, many forward-thinking municipalities have consulted with the public from an early stage.

Turning ambition in to reality

The document will also examine how municipalities can turn their smart city ambitions in to reality. Many cities around the world are beginning to explore their smart options; however, translating theory into practice can be an abstract proposition. In the city case studies, the various routes which cities have taken to achieve their ambitions will be examined to give other municipalities a view on how they can achieve their own smart goals.

A TRANSITION TO CONNECTED ENERGY EFFICIENT LED LIGHTING CAN DELIVER IMMEDIATE AND SIGNIFICANT SAVINGS, AND CATALYZE AND SUPPORT ROLL-OUT OF NEW SMART TECHNOLOGIES AND LINKS TO THE INTERNET OF THINGS.

Case study – Manchester

Manchester, UK, has implemented an ambitious smart city program, which aims to put its citizens as the number one priority, as well as driving innovation and creating jobs in the city. The smart city initiative will focus on four key areas; transport, energy and environment, health and social care and culture and community.

Integral to Manchester’s smart city program is a large-scale LED street lighting program, which will replace 56,000 luminaires over three years. The new LED system is expected to achieve 60% efficiency savings compared to the old-fashioned lamps, which is expected to save the city around £2m (£2.3m) per year in energy costs and reducing the city’s carbon emissions by 7,500 tonnes annually. The LED street lighting system is connected via a CMS so city managers can control and monitor the street lights remotely. Sensors on the street lights can be used to monitor air quality and traffic flow, for example.

Manchester has adopted a collaborative approach between the city, businesses, academic institutions and service providers. This ecosystem approach, with citizens at the focal point, is expecting to bring greater efficiencies to city services, local businesses and transport systems, as well as improving the liveability and sustainability of the city.²

² [https://www.manchester.gov.uk/info/500315/smarter_city/7013/manchester_smarter_city_programme](https://www.manchester.gov.uk/info/500315/smarter_city/7013/manchester_smarter_city_programme)
WHAT IS A SMART CITY?

The term smart city has existed for many years, but many municipalities are still not entirely sure what a smart city entails or how to implement such a scheme. It is important to note that there is no one agreed definition of what a smart city is, and the term can mean different things to different people. However, in the context of this document, smart city refers to a solution in which several technologies work together, enabled by data collected from an array of sensors and monitors and transmitted to the Cloud via wired or wireless networks. Data is analyzed and automated systems created to enable cities to become more liveable, sustainable and to deploy city resources more efficiently and effectively.

This wealth of data can also be made available as a way to engage with citizens and offer a great deal of information on city life—pollution levels, traffic congestion and public transport information, via smart phone apps, for example. In a later section, we will present numerous smart city case studies which will demonstrate the wealth of opportunities available to cities by using technology and the benefits which can be derived from such schemes—not just for municipalities, but for citizens as well.

The Internet of Things (IoT)

A term which is widely used in conjunction with smart cities discussions is the Internet of Things (IoT). But what does it actually mean? In essence, the IoT refers to any connected device that can send and receive data over a communications network. Examples include a smart home thermostat, connected traffic signals, security cameras etc. Many such “things” could be embedded in a smart city system. For example, a phone app could enable motorists to find the nearest available parking space, which can help reduce traffic congestion and the associated air pollution. Smart traffic signals could detect when emergency vehicles are approaching and change to green. As more and more devices are connected, the Internet of Things presents opportunities to link previously siloed networks to create better connected cities.

THE SMART CITY MARKET IS LIKELY TO BE WORTH OVER US $2 TRILLION BY 2025. INTELLIGENT LIGHTING CONTROLS CAN SERVE AS A PLATFORM FOR FUTURE SMART CITY SERVICES.

Case study – Cardiff, Wales

Cardiff, the capital of Wales, is a truly international city and attracts around 20m visitors per year. Cardiff has ambitious environmental and sustainability targets, with the city aiming to be a One Planet City by 2050, and they have committed to the EU’s Covenant of Mayors to reduce citywide per capita CO₂ reduction target of 26% by 2020.

Cardiff’s ambitious LED retrofit program, installing 14,000 connected street lights, is expected to deliver 60% energy savings and estimated financial savings of £750,000 (€855,000) per year for the council. All 14,000 light points are connected wirelessly to a centralized management system (CMS), which allows city managers to monitor and control the lighting assets remotely; as well as giving powerful operational analysis to further optimise savings.

Cardiff has a wide-ranging IoT network, which have been linked in to their transport policy. For example, 3,300 smart parking sensors enable motorists to find spaces more efficiently, easing congestion and the associated air pollution.

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4 https://www.cardiff.gov.uk/ENG/resident/Parking-roads-and-travel/parking/On-street-parking/smartMap/Pages/default.aspx
The role of connected LED street lighting in smart city initiatives

Street lighting is a citywide core infrastructure, and the proliferation of modern, energy-efficient LED street lighting systems present the opportunity to build upon a connected and secure city lighting network with an expanding array of data-enabled products and services.

Implementing a connected LED street lighting program via mobile network with a centralized management system (CMS) can bring immediate benefits to cities by enabling the remote control and monitoring of lighting assets for city managers. For example:

- Lighting can be scheduled, dimmed, or turned on/off remotely, either individually or in groups.
- Automatically notify city managers of light point outages, allowing more efficient maintenance scheduling.
- Provide real-time and historical energy consumption data.
- Provide powerful analytic tools to monitor and improve street lighting system performance.
- Open systems allow integration with future smart city initiatives.

Fig. 1 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.

CONNECTED LED LIGHTING GENERATES BENEFITS FAR BEYOND SIMPLY THE DELIVERY OF LIGHT
THE DECISION TO UPGRADE TO LED STREET LIGHTING

Light mapping and asset inventory

In procuring new lighting infrastructure, there are a number of fundamental processes that city managers must undertake. Once the decision has been made to upgrade the 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. In LED consultations, we often find that expanding cities have 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 funding and support.

Connectivity, future-proofing and interoperability

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 (e.g. NEMA/SR etc.) and open (but data secure) protocols to allow future procurement flexibility for customers as well as to drive standardization in the industry.

Case study – Los Angeles

Los Angeles was an early adopter of LED street lights, with a replacement program commencing in 2009. To date, the city has fitted 180,000 units, achieving energy savings of 65%, which equates to $10m annually in cost savings and CO2 reduction of 65,000 metric tons per year. The city ensured the system was future-proofed and connected to a Centralized Management System (CMS), thereby enabling future smart city applications could be developed.

In 2015, the city began smart city initiatives and installed 100 smart poles which integrate LED lighting and 4G LTE wireless connectivity. This enables the city to expand its broadband network without having to erect more cell towers. 500 more smart poles are set to be deployed over the next four years. The city has also raised further revenue by leasing the valuable digital real estate on top of the light poles, which can then be reinvested in further smart city initiatives.

The Los Angeles smart city is continually evolving, with pilot programs that have installed various monitors and sensors on street lights to evaluate environmental factors in the city, such as noise, traffic levels and pollution, for example. This data can be used to drive further innovations, including traffic flow management plans, air pollution initiatives and health planning, for example. 5

Today, more and more lighting manufacturers are offering modular upgradeable LED luminaires, as well as full-function connected luminaires. Therefore, cities can upgrade to LED street lighting systems immediately and develop a smart city strategy at a later date, or when municipal budgets allow, for example. However, cities should not delay the implementation of an LED street lighting program due to uncertainties in their smart city initiatives, as they will face ‘the cost of waiting.’ That is, cities will not benefit from the immediate and significant energy savings of 50-70% if they choose to delay the roll-out of LEDs. Ensuring systems are future-proofed can avoid any unnecessary delays.

LED LIGHTING IS NOW CATYLZING WIDER ADOPTION OF SMART, CONNECTED AND DATA-ENABLED LOW CARBON SOLUTIONS.

Fig. 2 Cities can imagine a hierarchy of options when upgrading to LED street lighting, with increasing benefits as more connectivity is added. If cities are not going for full connectivity immediately, future proofing must be considered to ensure street lights can be connected at a later stage.

**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 (e.g. 20+ years). Where procurement may be phased due to budget limitations, city managers may seek to select a future-proof socket (e.g. 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.
**Smart where smart is needed**

A common misunderstanding encountered in discussions around smart cities is that each street light in a city would be equipped with a smart sensor/monitor. However, in the vast majority of cases, only a small percentage of luminaires would have smart capabilities; for example, in city centres, business/tourist districts etc. One city manager who participated in The Climate Group’s LED consultations stated, ‘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’.

Therefore, it is unlikely that every traditional city street light pole will be required or enabled to deliver such capabilities. In Los Angeles, 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.

**Case study – Barcelona**

Barcelona has been hailed as one of the smartest cities in the world and holds the annual smart city Expo. Barcelona has city-wide sensor networks collecting data on many aspects of city life, including smart water sensors, energy meters, transport monitoring and noise levels. In recent years, the city has adapted the approach to their smart city initiatives, moving away from gathering data and then deciding how to use it, to a more strategic approach whereby the tech agenda is aligned to that of the city. Barcelona is also leading the way in engaging with and involving citizens in decision-making and smart city policies.

City hall has stipulated to service providers that data must be open access. Citizens can also control which of the data is available to service providers, giving them greater control. With mass data collection under more and more scrutiny in recent years, engaging with citizens in the process is seen as key to gaining public buy-in to smart city initiatives. Giving citizens greater control over what data is collected and how it is used can also bring further benefits than just gathering data for data’s sake.6

**Data – privacy, security and ownership**

One of the most crucial considerations when embarking on a smart city initiative is around data collection. The gathering of city data and the growing interest in Big Data projects may encompass many activities; e.g. 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, including denial of service attacks.

Therefore, a balance must 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 cloud of external connections and services – where any potential requests for lighting changes triggered by external systems can be managed by the lighting managers.

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

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defined in many countries. Therefore, caution should be exercised when building the financial business case for lighting upgrades and exploring the potential for generating future revenues from unvalidated sale or use of city data projects (particularly to help repay financial loans).

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.

**Case study – Copenhagen**

Copenhagen, Denmark, is one of the world’s smartest and most sustainable cities and has an ambitious target of becoming carbon neutral by 2025. Copenhagen’s smart city initiative has been a collaboration between city hall, government, research institutions and solution providers. Copenhagen’s installation of 20,000 connected LED street lights has been the core element of the smart city initiative, which has achieved energy savings of 65%.

Copenhagen is well known as one of the foremost cycling cities in the world, with half of all commuter trips in the city being made by bicycle. The LED street lights are fitted with smart modules and these are being used to increase cyclist safety. When the modules detect a cyclist, the lights become brighter as the cyclist approaches a junction. The lights then dim when no one is in proximity to save energy and reduce light pollution. Copenhagen’s cyclists are assisted further by smart traffic signals, which can help them avoid red lights and inform them of the quietest or fastest route, for example.

Copenhagen has also established an ‘open lab’, whereby developers can test smart technologies to help tackle the challenges of urban life and climate change.7

**Local champions - driving innovation**

In many instances, smart city initiatives have been driven by a local champion such as a mayor or other influential figure who can see the benefits to the city for undertaking such a project. Many cities are now establishing departments specifically dealing with technology and innovation and creating posts such as Chief Technology Officer or Chief Information Officer (or similar), who are tasked with driving smart city initiatives. This may not be possible in all cases; however, having local champions with the vision for a more sustainable and liveable city can be key to successfully implementing smart city programs.

**Addressing barriers**

As discussed previously, many cities are beginning to explore smart city concepts; however, key barriers remain which may be delaying municipalities undertaking projects. Further support on national and regional level is required to address such common barriers as:

- Difficulties accessing funding
- Lack of a committed champion/visionary leader
- Lack of in-house resource/expertise
- Lack of clarity of the benefits
- Departmental silos
- Lack of public buy-in/readiness
- Concerns around data privacy and security

Through The Climate Group’s LED consultation work, we try to address some of these barriers though dissemination of information and awareness-raising in our documents, regional

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workshops and webinars—for example, highlighting examples of best practice, encouraging peer-to-peer learning and facilitating dialogue between key stakeholders. However, lack of funding for the upfront capital costs remains a major barrier for many cities. With many municipal budgets already stretched, innovative financial solutions will need to be explored if more cities are to benefit from smart city initiatives.

Project payback and ROI

In developing any large-scale infrastructure projects, project payback and return on Investment (ROI) will often be a requirement of project funding. However, every city and project is unique and project scope can vary significantly. For example, the payback period for a project that replaces 1,000 luminaires could be very different from one in which 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.

Smart city initiatives present the opportunity for future revenue streams in terms of developing data-enabled products and services. However, caution must be exercised with any future predictions of revenue in ROI calculations as many of these schemes can be uncertain and laws around data sharing and privacy are still being formulated in many regions.

Case study – Amsterdam, Netherlands

Amsterdam has one of the most established and earliest smart city programmes in the world. Its aim is to tackle numerous issues in the city along 8 distinct themes. These encompass, not just environmental targets, but also transportation and poverty alleviation, for example. The city developed a clearly defined vision and required outcomes of the smart city program, led by the Chief Technology Office.

Amsterdam recognized that their smart city approach cut across many diverse departments and therefore an ecosystem approach was used, whereby various working groups were established to develop smart solutions for specific themes. This approach included external consultants, solutions providers, city departments, local businesses, academia and citizens.

The city’s first step was to create an inventory of what data is available and established that there are 12,000 datasets across 32 city departments. This was a long and laborious process; but was vital in laying solid foundations for the smart city project.6

Recommendations and next steps

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)
• Data ownership and rights of commercial use

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, technologies which bring immediate and significant cost savings.

It is becoming increasingly clear that all aspects of the energy system are going to have to be better integrated if the Paris Agreement targets are going to be met. These include energy efficiency, renewable energy and low carbon transport. Recent advancements in technology enable better linkage of these aspects within smart energy systems. Implementing connected LED street lighting can provide the opportunity for economic growth, foster innovation, engage communities and improve the sustainability and liveability of cities and be the catalyst for smart city initiatives.

The opportunities are there for cities; however, it is imperative that there is strong leadership and policy makers have a clear vision of what and how they wish to benefit from a smart city initiative. Cities need to be visionary, innovative and proactive to ensure that the full benefits of the available technology are gained.

As well as benefiting city halls, policy makers need to put citizens at the heart of any smart city initiative, and engage with them at an early stage to ensure public buy-in.

Case study – Jakarta, Indonesia

With over 9 million inhabitants, Jakarta is one the most densely populated and fastest growing cities in the world. Jakarta established a Smart City Unit to take forward their ambitious plans to embrace Big Data and increase citizen engagement to improve city services. As part of the plans, over 90,000 street lights in the city have been replaced an LED lighting system, making it one of the largest connected systems in the world (and achieving 70% energy savings). The connected lighting system is integrated with the cities other smart city systems and enables to city to remotely manage the lighting and adjust levels according to the needs in each district.

The aim is to enhance city living for citizens, with the use of Big Data and improving connectedness and community safety. The smart city platform enables feedback through mobile and social media networks to fully engage with citizens and benefit from their input. This, in turn, enables the city to gain valuable insights and run smarter government services.

LEDS REPRESENT A PRIORITY #1 ACTION ON CLIMATE CHANGE.

FINAL WORD: DRIVING LED ADOPTION

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

The Climate Group’s 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, LED@TheClimateGroup.Org

The document is intended to be a working document as part of The Climate Group’s ongoing LED consultations activities in partnership with Signify (formerly Philips Lighting).

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