The LED future

Outdoor lighting for sustainable, livable cities

White paper

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Foreword

These are exciting times, especially for our leaders in local government. Because right now these leaders have perhaps the biggest opportunity yet to take visionary steps, shape the future and make a lasting positive impact. Not just for the benefit of their own citizens, but for everyone across the globe. And they can do this by embracing LED outdoor lighting technology.

In a world where the need for light is rising fast, switching to LED lighting can reduce the cost of global energy consumption by €130 billion per annum. It will also prevent 670 million tons of CO_2 being emitted into the atmosphere each year. These economic and environmental benefits are utterly convincing reasons on their own to take action now. But there are even more reasons to adopt LED-based outdoor lighting.

The last few years have seen enormous advances in this truly inspiring technology. Today, not only is it extremely energy-efficient, very long-lasting and easy to maintain, it can also be networked and integrated with a vast range of digital systems to deliver intelligent lighting solutions. Solutions that can 'sense' when they are needed, know how brightly they should illuminate, and can even change the color of the light if required. No other lighting can be controlled so accurately or so extensively.

All of which means that town planners, architects, municipal authorities and elected representatives can use LED outdoor lighting to maximize safety and security on their roads and in other public spaces, as well as to beautify the urban environment, thus enhancing people's feeling of well-being and civic pride. And all that while dramatically reducing energy consumption and the associated costs.

The following pages have been prepared jointly by the R20 Regions of Climate Action organization, the Lighting Science Group and Philips. They show you what's possible. And they show how we can partner with you to realize the full potential of these truly exciting times.

Eric Rondolat
CEO Philips Lighting

Christophe Nuttall
R20 Executive Director

Executive summary

Challenge

More than half of the world's population now lives in cities, and that percentage continues to rise at an unprecedented rate. By 2050 more than two-thirds of the world's population will live in cities – and more than 3 billion people will live in new, expanded, or renovated urban settings. Given that cities account for 70% of the world's energy consumption and greenhouse emissions, this rapid urbanization has tremendous implications for our use of energy and natural resources

Opportunity

Outdoor lighting – which includes roads, streets, paths, parks, city centers, landmarks and public spaces – is central to making our cities smarter, sustainable and more energy-efficient. At present, outdoor lighting accounts for up to 40% of the total electricity consumption of cities and municipalities. Street lighting alone is the biggest line item on a municipality´s utility bill, accounting for 10 to 38% of a municipality´s budget. In the US alone, an estimated 26.5 million public streetlights (most of them more than 25 years old) consume as much electricity as 1.9 million households, and generate greenhouse gas emissions equal to those produced by 2.6 million cars. Increasing the energy efficiency of street and public lighting therefore stands to have an immense impact on the overall sustainability of our societies.

In addition to sustainability, the notion of "livability" is gaining momentum. As urbanization accelerates, cities have to compete more for people and businesses, which requires them to create strong civic identities and attractive living environments. The Philips Livable Cities Think Tank has identified the three essential ingredients of a livable city: resilience, inclusiveness, and authenticity. Resilience focuses on a city's flexibility and ability to adapt to changing conditions and requirements; inclusiveness refers to a city's ability to generate a sense of community in all sections of the population, irrespective of gender, age and ethnicity; and authenticity is the local character or identity of a city.

Solution

No less than one-third of all road lighting worldwide still uses lighting technology dating back to the 1960s. Cost and energy savings of 40-65% could be made simply by switching to newer, more energy-efficient lighting solutions – most notably: Light-Emitting Diode. It is estimated that switching to LED lighting globally would result in savings of up to €130 billion in reduced energy costs each year and prevent the annual release of 670 million tons of CO_2 into the atmosphere – an impact equivalent to the elimination of 640 medium-sized power stations.

Further energy savings are possible with adaptive, networked lighting solutions that remain dimmed for much of the time, but intensify automatically when more light is needed (for example when a car or pedestrian approaches, or in unfavorable weather conditions). Both on-site occupancy sensing and/or publically available online information can be used to control lighting levels.

And the advantages don't end there: when combined with smart controls, LED lighting offers a virtually endless array of possibilities to address the specific needs of streets or neighborhoods. Smart LED lighting can transform the mood and atmosphere of public spaces in an instant, bringing people together for late-night festivals or sporting events, or preserving the night-time quiet of residential streets. LED installations also reduce light pollution and light hindrance because they allow for much better control of light distribution and brightness than conventional installations. In short, they can ensure that light supports the full range of activities that contribute to contemporary city life.

Thanks to recent solar and battery developments, LED technology can even provide practical lighting to the one-third of the world's population currently living without electricity. Areas in which there is no electricity grid, or where the grid is unreliable or costly to expand, will benefit from low-energy-consuming LED technology.

Ultimately, LED lighting can take its place in a broader vision of smart connected cities, where a whole range of intelligent digital systems and services are interconnected for maximum sensitivity and efficiency. Network connectivity will unlock the full potential of next-generation digital lighting, enhancing the livability and sustainability of our cities. Government, industry and science need to cooperate and focus efforts on the integration of lighting in emerging "Smart City" infrastructures.

The use of LED technology for outdoor lighting is rising, but at present it faces barriers common to many ascending technologies: insufficient awareness of its advantages, reluctance to make the initial investment required, and a lack of clear performance standards.

About the contributing authors

R20 Regions of Climate Action

The R20 Regions of Climate Action is a non-profit organization founded in 2010 by Governor Arnold Schwarzenegger and other global leaders in cooperation with the United Nations. The R20 is a coalition of partners led by regional governments that work to promote and implement projects that are designed to produce local economic and environmental benefits in the form of reduced energy consumption and greenhouse gas emissions, strong local economies, improved public health, and new green jobs. These local actions can help the world achieve our shared global environmental and economic goals. For more information on the R20 please visit our website: www.regions20.org.

Lighting Science

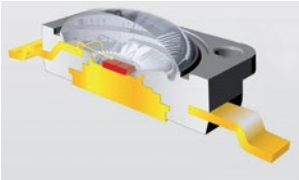
Lighting Science is a leading global provider of intelligent, environment-friendly LED lighting solutions.
Our products provide sustainable illumination by bringing into balance a need to protect the earth and its resources with the need to responsibly illuminate it. Our patented LED lighting designs are engineered to enhance lighting quality and performance, reduce energy consumption, lower maintenance costs, eliminate the use of hazardous materials and can offer important biological features to enhance the way we live.
Our capabilities range from research and development to the design and manufacture of LED replacement lamps and fixtures. We believe that LEDs are the most environmentally responsible and sustainable lighting technology available. That's why we design and produce innovative LED lighting solutions and encourage our customers to think sustainable for every lighting application.
For more information on Lighting Science, please visit our website: www.lsgc.com.

Philips Lighting

Philips Lighting is a global market leader with recognized expertise in the development, manufacturing and application of innovative lighting solutions. We have pioneered many of the key breakthroughs in lighting over the past 123 years, laying the basis for our current strength and ensuring we are well-placed to be a leader in the digital transformation. We aim to further strengthen our position in the digital market through added investment in LED leadership while at the same time capitalizing on our broad portfolio, distribution and brand in conventional lighting. For more information on Philips Lighting please visit our website: www.lighting.philips.com

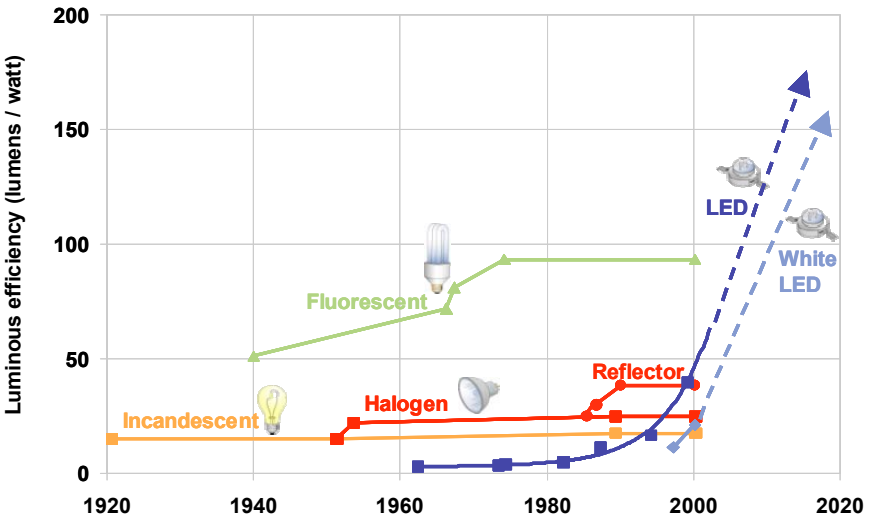
Light-Emitting Diode (LED) technology explained

LED lighting is fast emerging as the lighting technology of the future for a wide variety of applications, including adaptive, intelligent outdoor lighting. Unlike light bulbs, LED lights are based on the same technology as computer chips. As indicated by its name, LEDs are diodes that emit light.



Appearing as practical electronic components as early as the 1960s, the first LEDs emitted a low-intensity red light, and were most often used as indicator lamps in electronic devices. In recent times, however, they have evolved and developed rapidly and are now available across the visible, ultraviolet and infrared wavelengths with very high brightness. White light is generated by applying a phosphorous layer over a blue LED.[1]

With the development of high-efficiency and high-power LEDs, it has become possible to use LEDs in lighting and illumination. Today, LED lighting systems are viable for a wide range of applications, with illumination distances of 400 feet (150 meters) or more. White LEDs have achieved performance of over 100 lumens per watt in the laboratory, making them suitable for significant energy-saving general illumination applications.[2]
Essential components for optimum LED performance are the heat sink and driver. The heat sink dissipates the generated heat. The driver is an electrical component that regulates the power to the LED. Both are essential to have the LED operate efficiently and reliably.



Historical and predicted efficacy of light sources. Source: Lumileds.

1 Chuji Nakamura UCSB - http://www.sslec.ucsb.edu/

2 LED University, http://www.lighting.philips.com/main/connect/Lighting_University

Energy-saving benefits

LED is a more energy-efficient technology than the conventional high-pressure sodium lamps that currently light the majority of cities – and this efficiency is increasing with each new generation of LEDs. LED consumes less energy and produces a broader range of color temperature. In 2009, for example, a typical 106 watt LED lamp emitted 8800 lumens, which is equivalent to a standard 100 watt HPS bulb.[3] By 2011, the same results could be achieved by a 53 watt LED lamp.

At present, LED street lights use around half the energy of the more commonly used High Pressure Sodium street lighting. In the table below, you can see the energy savings made possible by switching to LED technology.

Lamp type	Luminous efficacy (lm/W)	Color rendering index (CRI)	Lamp life hours
High-Pressure Sodium (HPS)	80 - 130	24	15,000 - 24,000
Low-Pressure Sodium (LPS)	100 - 190	5	18,000 - 24,000
Metal Halide (MH)	60 - 100	65	8,000 - 12,000
Mercury Vapor (MV)	35 - 65	17	10,000 - 15,000
Light-Emitting Diode (LED)	70 - 160	70 - 90+	40,000 - 90,000
Induction	61 - 76	82	100,000 - 120,000

N.B.: The efficacy numbers listed for HID sources are based on bare lamp lumens, not the delivered-from-fixture lumens as with LED. The HID delivered-from-fixture lumens would be anywhere from 30-40% less than the bare lamp lumens.

Lamp Technology Summary. Source: Pike Research

This reduced energy consumption could result in very significant savings on cities' utility bills – an important issue in the present economic climate. What's more, while a standard 100 watt HPS lamp has an expected lifespan of 16,000 hours, an LED can continue to operate with reduced efficiency for 100,000 hours – more than 6 times longer than an HPS lamp. This very long lifetime and high durability further reduces the costs associated with maintenance and replacement.

Energy efficiency, of course, is not simply an economic imperative – it is also increasingly important in the context of climate change, pollution and resource scarcity. By consuming less energy, LED technology reduces the carbon footprint of cities. In the US, one kilowatt-hour of electricity causes around 610 g of CO_2 emission.[4] Assuming the average street light is on for 10 hours a day, one 40-watt incandescent bulb will cause 89 kg of CO_2 emission per year – whereas the 6-watt LED equivalent will only cause 14 kg of CO_2. The savings potential, both in environmental and economic terms, is therefore immense (see below).

Saving potential	Global	Europe	North America	Latin America incl. Mexico	Asia Pacific	Middle East and Africa
Euros (x billion)	128	28	40	9	36	15
Tonnes of CO_2 (x billion)	670	98	210	24	236	102
Number of power stations @ 2 TWh/year	642	141	198	46	181	76
Car emissions @ 10,000 miles/year	260	38	81	9	95	40

Source: International Energy Agency (IEA), www.iea.org. Energy saving figures based on average electricity price of € 0.10/kWh, source (among others): eurostat

3 DOE Solid-State Lighting CALiPER Program Summary of Results: Round 7 of Product Testing. U.S. Department of Energy. February 2009.

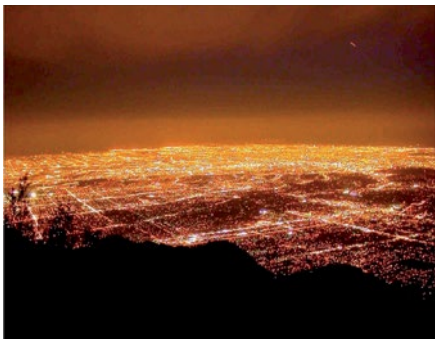
4 US DOE EIA: Electricity Emission Factors. Eia.doe.gov. Retrieved on 2012-03-16.

Qualitative benefits

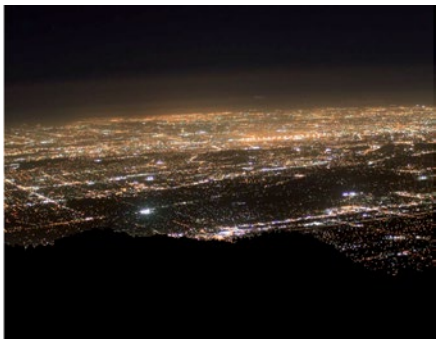
High- and low-pressure sodium lamps (the most commonly used street lighting option) produce high levels of illumination, but poor color rendering. This makes it difficult to distinguish colors, giving our urban streets an orange tint after dark. LED lights and fixtures, on the other hand, are equipped with special optics and other features that provide superior color rendering and light diffusion.

The result is greatly improved visibility, which enhances the look, safety and security of roads and public spaces. Members of the public feel safer when they can see clearly, and security cameras also benefit as images are clearer, and therefore more effective. UK studies that linked improved outdoor lighting with drops in crime rates concluded that in the first year, financial savings from crime deterrence alone exceeded the cost of the lighting retrofits. Meanwhile, by increasing visibility for motorists, pedestrians and cyclists, the roads become safer as well. Research has shown that the white light produced by LED enables drivers to see movement at the roadside from a greater distance, giving them more time to brake.

Thanks to its better rendering of colors, LED's white light is also experienced by the majority of people as brighter, more natural and more pleasant. LED lighting also helps to lessen light pollution in the form of "sky glow", preserving the darkness of the night sky so that the stars shine brighter and the wilderness beyond the city's edges remains unpolluted by artificial light. This is particularly true when adding lighting solutions that use sensors and smart controls to dim lights when no one is there.



2008



2012

Los Angeles before and after LED retrofit project

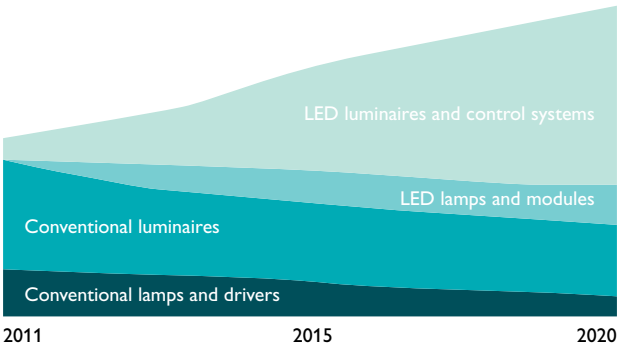
The ability of LED to enhance the urban environment goes even further: LED lighting offers remarkable freedom in terms of controlling LED lighting effects, design, color and intensity. We can choose the brightness and color temperature to suit the occasion or the mood, transforming our cities into inspiring, spectacular places that offer unique experiences to their inhabitants. In this way, LED is driving a shift from merely functional lighting to intelligent lighting that enhances the urban experience.

Spotlight on architectural lighting: Gateshead Millennium Bridge, Newcastle, UK

Gateshead Millennium Bridge is acclaimed as the world's first and only tilting bridge and the LED solution supplied is in itself a revolutionary development in lighting technology. It's the first LED architectural floodlight which is powerful enough to illuminate large-scale structures, having more lumen output than any other comparable fixture for exterior illumination.

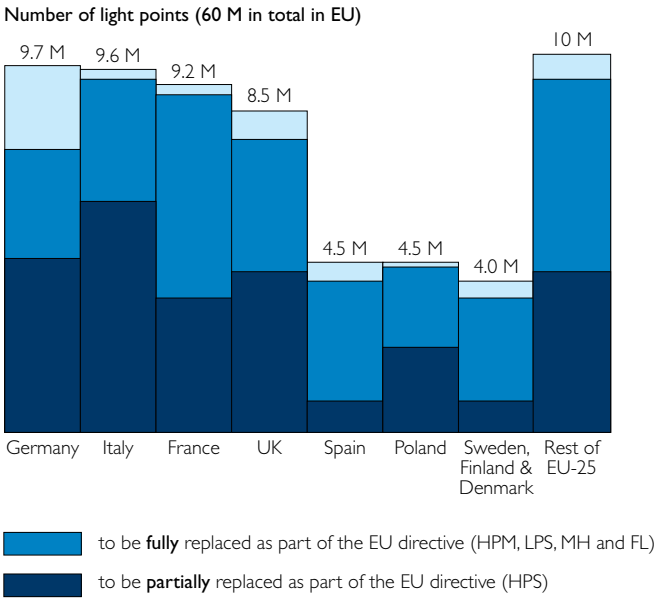
An investment in the future

The superior performance and energy efficiency of LED have stimulated rapid growth of the LED lighting sector. The figure below shows the growth of LED lighting in comparison to conventional lighting in the overall illumination market.



Source: Philips Lighting

Furthermore, with governments worldwide striving to lower their CO_2 emissions, legislation is already phasing out energy-intensive outdoor lighting solutions. In Europe, for example, more than 35% of all lamp types will become obsolete by 2015 (see the graph below).



N.B.: The EuP Directive does not forbid all High-Pressure Sodium lamps but will gradually phase out the inefficient ones.

Source: Preparatory Studies for Eco-design requirements of EuPs 2007; Humatica interviews; Lighting and Cleantech incubator

Cities will, therefore, have no choice but to move towards smarter, more energy-efficient outdoor lighting – and this transformation requires long-term investment. Cities able to make this investment in LED outdoor lighting will soon discover that savings begin immediately and the long-term benefits clearly outweigh the initial cost. Various business models to unlock investments are described later in this document.

Outdoor lighting applications

With its many economic, environmental and aesthetic benefits, LED lighting technology is ideally suited to a wide range of applications in the urban environment. Indeed, independent research has found that LED is by far the best candidate to replace existing technology in almost all outdoor lighting applications, including highways, roads, parking lots, city parks and public areas (see table below).

	High ways	Roads	Parking Lots	City parks and public area	Sports parks
High-Pressure Sodium (HPS)	★★★★	★★★★	★★★☆	★★☆☆	★★★☆
Low-Pressure Sodium (LPS)	★☆☆☆↓	★☆☆☆↓	☆☆☆☆	☆☆☆☆	☆☆☆☆
Metal Halide (MH)	★★☆☆	★★☆☆	★★★☆	★★★☆	★★★★↑
Mercury Vapor (MV)	★☆☆☆↓	★☆☆☆↓	★☆☆☆	★☆☆☆	★☆☆☆
Light-Emitting Diode (LED)	★★★★↑	★★★★↑	★★★★↑	★★★★↑	★☆☆☆
Induction	★★★☆↑	★★☆☆	★★☆☆	★★☆☆	★☆☆☆

Best fit	★★★★
High	★★★☆
Medium	★★☆☆
Low	★☆☆☆
Minimal/zero	☆☆☆☆
Trajectory (up/down)	↑↓

Spotlight on major roads: A44 highway, Netherlands

In 2010, the A44 in the Netherlands became the first highway in the world to be lit by LED lighting. The highway's conventional HPS lighting was replaced with an LED lighting solution that allows the light to be dimmed from 100% during rush hour to just 20% during times of lower traffic flow. This cuts energy usage by more than half – the 180,000 kWh saved annually amounting to the annual consumption of some 50 households! The flexible dimming system can also respond immediately to accidents or poor weather conditions, increasing safety for road users.

More about this project:
http://ledsmagazine.com/news/8/2/21

The most common application areas for LED outdoor lighting are:

Major roads
LED streetlights make major roads safer for both drivers and pedestrians.

Urban streets
In recent years, society has become more aware of the importance of making people feel safe, comfortable, and connected with their cities and communities. Intelligent lighting has proven to be a highly effective and cost-efficient way to re-humanize our urban environments – reducing crime, promoting tourism and encouraging a real sense of civic pride and identity.

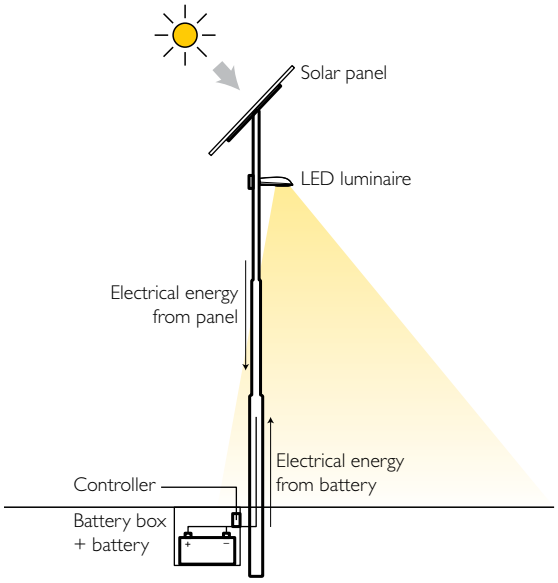
Residential areas
Lighting is key to making residential areas safe, secure and attractive – especially in those parts of cities that have been long overlooked. Highly efficient optics* and dimming possibilities make LEDs the perfect choice for residential areas. Their precise beam control also minimizes light spillage. Light is distributed only where and when it is needed, preserving the night sky and ensuring that city residents enjoy a sound night's sleep.

City centers
Cities are looking for solutions to their lighting requirements that go beyond just providing light points; they want inspirational ideas that contribute to the identity of the city and instill a real sense of pride. Intelligent lighting solutions enhance city centers, creating an attractive and inviting atmosphere that encourages socializing and enriches the city's night life. During daytime too, luminaires should be a pleasing feature of the city's streetscape.[5]

* IES has BUG (Backlight, Uplight Glare ratings) to evaluate luminaire optical performance related to light trespass, sky glow, and high-angle brightness control

5 Pool of Light Liverpool & Wirral external evaluation report March 2009

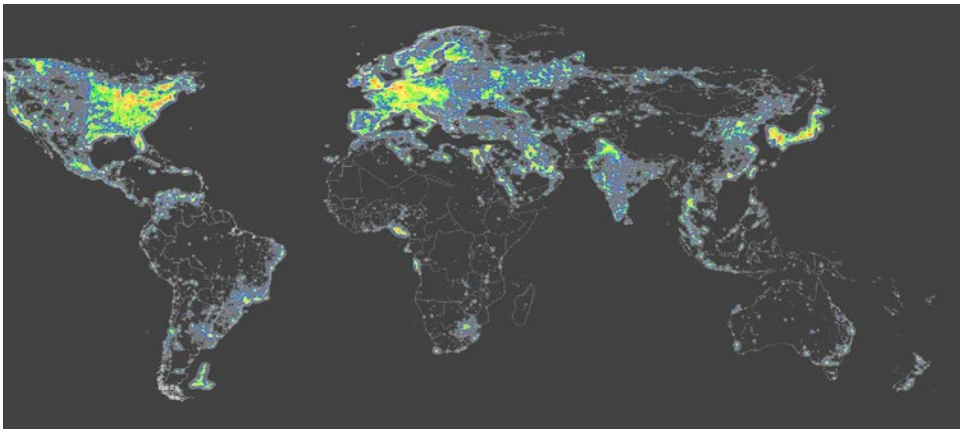
Off-grid lighting



Approximately 1.6 billion people in the world still have little or no access to electricity. For such people, when the sun goes down at the end of the day, it takes with it the possibility of participating in any outdoor social, cultural or recreational activities.

This is all changing, however, thanks to the emergence of "off-grid" LED solutions powered by solar energy. When the sun shines during the day, the solar panel converts solar energy to electrical energy and stores it in the battery. During the night, the battery is discharged, releasing the electrical energy required to power the LED luminaire – and lighting the road or public space.

Solar-powered LED outdoor lighting systems have already been installed in several villages around the world. They have met with an enthusiastic response from residents, who feel that the systems have greatly enhanced the safety, security and livability of their communities.



Spotlight on residential areas: Guiyang, China
In 2009, the rural Chinese village of Guiyang was provided with solar-powered LED street lighting as part of the 1,000 Villages Project. This remote, "off-the-grid" community now enjoys safer streets and can carry on valuable economic and social activities after dusk. And because the lighting solution runs entirely on sunlight, it produces zero carbon emissions. Little wonder, that it was recognized as a Best Practice at the 2011 UN Climate Change Conference!

LED lighting systems and controls

Street and outdoor lighting is no longer purely an on/off system: increasingly, cities are moving toward outdoor lighting systems that are more dynamic, intelligent and flexible.

The main advantage of this adaptability is energy efficiency. While switching to LED lighting already results in 40-60% energy savings, adaptive and interactive lighting systems are required to bring savings to the next level. Enabling LED luminaires to dynamically change lighting levels in response to local conditions will lead to total system savings of up to 90% in low traffic areas. "Reducing the amount of wasted light during long periods of typical vacancy is one of the single largest opportunities for energy savings in this country," says CLTC Director and UC Davis Professor Michael Siminovitch, "and the technology exists today for it to be easily integrated into the ongoing LED transformation." Furthermore, controlling the intensity, color and direction of lights in different areas opens up a range of further social benefits for lighting users. Dimming and directional light reduces light pollution, while increasing light intensity during bad weather or at the site of traffic hazards can enhance the safety and security of urban environments.
Some of the most common controls can be implemented on a local basis. They are described below.

Astronomical timer

The most basic function of a street light is to turn on at dusk and off at dawn. This can be achieved through the use of an astronomical timer, which adjusts on/off times with the change of sunset and sunrise times each day. Lights can also be pre-set to dim during off-peak traffic hours, providing energy savings of up to 35%.

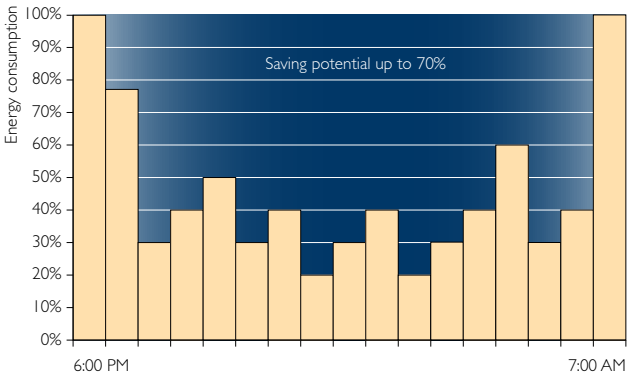
Ambient light sensing

Light sensors can also be used to turn street lights on when ambient light levels fall below a certain point. The figure below shows the potential energy saving difference between ambient light sensing (on the left) and astronomical timer (on the right).

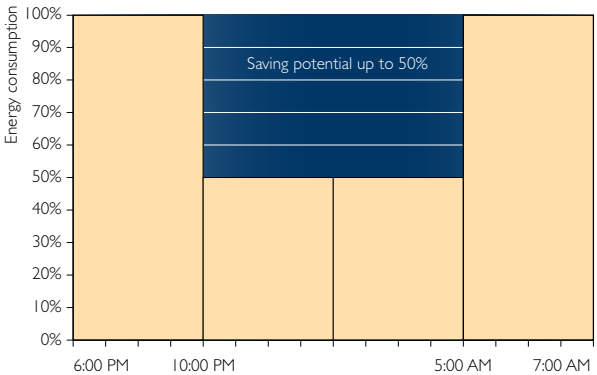
Motion sensing

The level of light can also be controlled using occupancy sensors for one or more luminaires. To save energy, lights remain dimmed when no one is around, and light up to increase visibility when motion is detected.

Simulations of interactive and fixed dimming



With interactive dimming

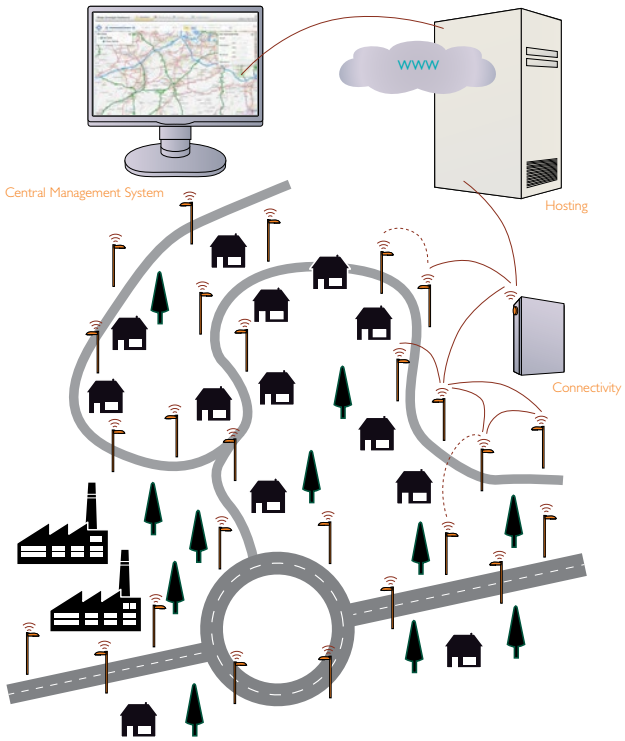


With fixed / pre-set dimming

Spotlight residential areas: Tilburg, Netherlands

All street lights in Tobias Asserlaan in Tilburg, Netherlands, were replaced with LED luminaires fitted with a motion detection system. The lights remain dimmed until a pedestrian or cyclist approaches, and then gently intensify to light the path ahead. The new solution ensures that light is produced only when it is needed, reducing energy consumption by 50-80% and minimizing light pollution. Passers-by feel safe and secure – and residents enjoy a peaceful night's rest.

Smart lighting networks



The next step in the evolution of outdoor lighting is the smart lighting network. A smart lighting network is created when individual lighting controls (most commonly remote on/off switching and dimming) are coordinated with various sensors into an integrated system that can be managed with the click of a mouse from a remote computer. Powerline or wireless communication solutions can then be used to control entire sections of luminaires, aided by software that provides continuous monitoring, metering and a range of intelligent management options.

A smart lighting network of this kind offers a sweeping range of advantages. It enables managers to respond to the specific needs of neighborhoods and areas in real time, allowing them to adapt light intensity, color and direction to suit local conditions, enhance safety and security, and create a range of moods and atmospheres.

For example, cities could adapt lighting in response to changing local weather conditions, shop owners could control the lighting of their storefront to interact with customers, and in the case of an emergency, functional and decorative lighting could be combined to provide better visibility and dynamic routing to direct emergency services to a specific location.

Furthermore, the ability to remotely monitor and adjust LED output through smart controls opens up three significant sources of financial savings:

- Maximizing energy savings by dimming lights to match the required standard, reducing output at sunset and sunrise, and dimming during periods of lower pedestrian/traffic activity
- Maximizing LED lifespan by dimming, and by adjusting light output upward as the product depreciates over time
- Minimizing maintenance costs by remote detection of faults and failures, and by GPS mapping of luminaires.

It is estimated that LEDs in combination with remote management can reduce energy bills by up to 70% and maintenance costs by up to 75%.

With less than 1% of all our road and street lights currently part of a remotely monitored and controlled network, there is a tremendous opportunity for progress in this area.

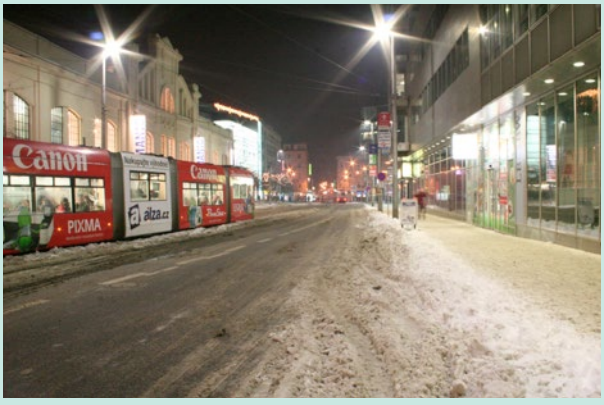
Outdoor lighting and "Smart City" development

Investment in smart lighting networks also lays the foundation for long-term cost reduction by serving as a backbone and launching pad for "smart city" development. Due to the tremendous inroad of internet-connected "smart" devices and applications, cities now employ a wide range of "intelligent" non-lighting systems, such as traffic control, parking, security cameras, electric vehicle charging stations, pollution sensors, digital signage, vehicle-infrastructure communications, waste management and park watering. Integration of these systems and the information they contain is essential to optimize the efficiency of urban infrastructure. Cities investing in the long-term efficiency of their infrastructure are therefore increasingly seeking to migrate as many services as possible to a singular and integrated ICT ecosystem: the "Smart City" concept.

A networked outdoor lighting system provides both power and communications to public spaces throughout a city. This is important in older cities, where constructing new power lines can be prohibitively expensive. Networked lighting infrastructure can therefore be leveraged to deploy other smart city applications and services with relative ease. In the near future, therefore, smart street and outdoor lighting will be integrated with multiple intelligent non-lighting systems as a core application in urban ICT ecosystems. As a result, shipments of smart outdoor lighting systems (which numbered less than 200 worldwide in 2012) are projected to reach more than 1,100 by 2020. Shipments of lighting communications nodes will, likewise, rise from 550,000 in 2012 to 4.8 million in 2020. Given the ubiquitous nature of outdoor lighting systems and the quantities of data generated by the network of light points, sensors, cameras, and other intelligent assets in the public space, the opportunities for new applications and innovations are almost endless.

Evidence of the efficacy of lighting infrastructure as part of an interconnected "Smart City" ecosystem is already mounting. In 2012, EFFICity, a consortium of companies and research centers in Barcelona, Spain, conducted a pioneering project using street lights as communication nodes. Connected to a sub-set of smart sensors, the luminaires and other incorporated devices are able to adapt independently to their surroundings. Meanwhile, city authorities in Chattanooga, Tennessee, launched an $18.5 million investment in a network of 27,000 public street lights controlled through embedded, wirelessly connected smart meters. This installation will ultimately save the city $2.7 million a year in energy and maintenance costs. And the San Francisco Public Utility Commission began a pilot program for a city-wide service delivery platform built on a wireless mesh network of more than 20,000 street lights and numerous other non-lighting devices. Fully compliant to the 6LoWPAN protocol, this system is a multipurpose, open-standard platform, to which future services can be added without the need to build additional networks. These and many other smart city innovation programs, however, have one critical challenge in common. Current policies, technology standards, recommended application practices and legacy public governance models are mostly based on yesterday's analog city infrastructure. As such, they are not yet well-equipped to enable "Smart City" infrastructure. Clear and universal open-standard architecture for lighting hardware and software is an essential pre-requisite for ICT integration. Government, academia and industry must therefore work together to define technology standards that enable interoperability and context-driven adaptability of the diverse networked devices that make up the infrastructure of the modern "Smart City."

Spotlight on Smart Cities: Prague, Czech Republic
The city of Prague chose to combine its LED lighting installation with a wireless intelligent control system based on RF technology.
The web-based solution is flexible, easy to install, and provides intelligent lighting control with real-time data and dimming possibilities. The dynamic solution has been a great success. It maximizes energy and maintenance savings while also providing attractive, high-quality light that doesn't compromise the safety of motorists and pedestrians.



From TCO to TVO: the case for sustainable infrastructure

As our society has become more sustainability-minded, we have moved away from traditional tendering (which focused on initial cost) to considering the entire lifetime cost of infrastructure, or total cost of ownership (TCO). The notion of TCO takes into account all the costs linked to new infrastructure: from the initial investment (CapEx) to the operating costs (OpEx), such as costs of maintenance, re-lamping, energy, disposal, and so forth.

In the age of "Smart Cities", outdoor lighting becomes a dynamic platform enabling continuous innovation, and therefore needs to be looked at from a different point of view: total value of ownership (TVO).

Developing infrastructure with a TVO-based approach includes:
- Linking the project to the city's vision in terms of livability, economic growth, and sustainability
- Defining the connected outdoor lighting infrastructure as a "network of networks" and a platform for service innovation
- Working actively with stakeholders such as city officials, retailers, shop owners, police, telephone operators, ISPs and of course citizens to create meaningful use cases
- Investing operational cost savings (not only from lighting) in the platform to enable new functionalities
- Measuring the total value generated year-on-year in terms of savings and revenues, jobs created, and livability improvements.

In the context of the total value of ownership, the case in favor of sustainable, livable lighting infrastructure becomes all the more clear.

Implementing a new outdoor lighting system

Evaluation criteria

The first step for cities is to evaluate the status of their current outdoor lighting and evaluate their future needs. Factors to take into consideration may include:

1. Age of the installation and necessity for renovation/replacement
   - Lamps beginning to break down more frequently; replacement parts no longer match outdated installation
   - Installation is written-off and maintenance costs are rising
   - "Up-lamping": current installation contains lighting technology soon to be banned.

2. Sustainability
   - Necessity/desire to reduce energy costs
   - Necessity/desire to reduce emissions

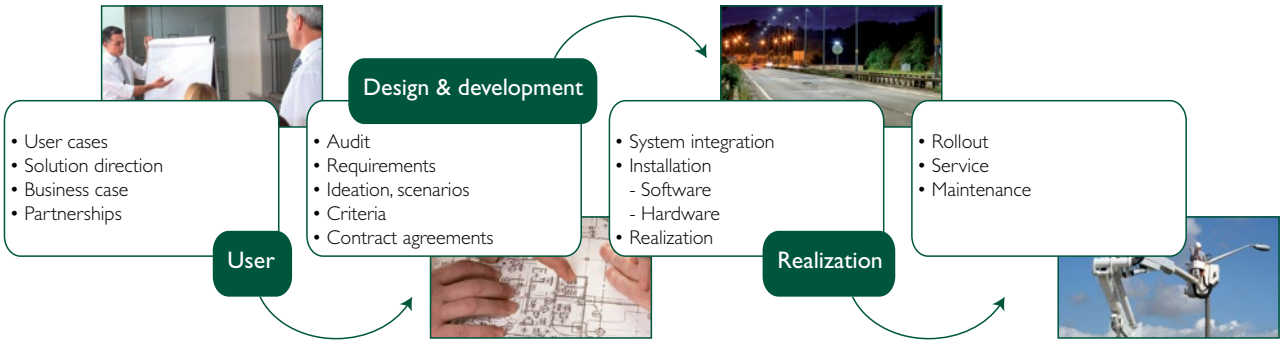
3. Change in function of specific area(s)
   - Population changes; increases in pedestrian or vehicle traffic
   - Newly developed or revitalized retail, commercial, industrial or leisure areas
   - Trend towards combining business, leisure and public spaces.

For some areas, it may well be sufficient to simply retrofit the existing installation with LED lighting. In this situation, authorities will only need to undertake a "light design" to ensure that the selected luminaires and pole heights are in line with required (legal) light levels. If more substantial economic, environmental, social and aesthetic benefits are desired, however, investment in a more comprehensive lighting solution is recommended.

N.B.: The superior visibility per lumen provided by LED is not presently accounted for by lighting standards. As a result, there is a risk that LED retrofits will over-light public spaces, creating more glare and using more energy than strictly necessary. In such a situation, dimming the LED lamps or using a lower wattage alternative will produce the same perceivable result, while keeping energy consumption to a minimum.

General approach

The approach below can be used as a guideline when implementing almost any new LED outdoor lighting project.



1. User

The first phase in implementing a new outdoor lighting system is to clearly articulate the vision of the city authority in a way that fully justifies the expenditure of public funds and demonstrates the expected benefit to the community.

The function of the area to be lit should be well documented, as should the city's requirements with regard to the timeline, serviceability and dynamic capabilities of any proposed lighting solution. The sustainability dimensions – the expected energy savings and their impact on carbon emissions and utility costs – should be discussed, and any relevant regulation explicitly highlighted.

Comprehensively documenting the perspectives and interests of all relevant stakeholders will create a transparent overview of the lighting needs to be addressed.

2. Design & development

In this phase, the city's requirements are translated into a workable design. The first step is an audit to determine the total cost of ownership (TCO), which includes the cost of energy consumption, service and maintenance.

Based on the audit and the desired business model, a lighting design can then be drawn up that includes product specifications for a possible tender process. It should deal not just with luminaire hardware and control systems, but also with integration with other relevant systems (e.g., back office, control room, traffic system, etc.).

Depending on the business model, city authorities will then select partners or consortium members, ranging from direct hardware sellers to maintenance contractors and/or energy services companies.

3. Realization

In the case of a re-lamping project, realization will be relatively simple and limited to scheduling the project to reduce impact on the surrounding area. For larger projects, installation and integration will be more complex. Project management of the partner network is essential to realize the project on time, within budget, and in conformity with quality requirements.

4. Rollout

A carefully planned rollout schedule will increase the chances of a smooth rollout. Extra attention should be given to verification and monitoring, especially when using energy-performance or energy-servicing business models.

Tips for a smooth implementation process:

- Select a good and experienced project manager from your organization
- Ensure cross-department alignment on the project
- Ensure the involvement of dedicated expert resources (luminaire and control specialist/manufacturer, installation, maintenance, finance, utility)
- Closely examine and monitor stakeholder relationships to determine mutual goals and address conflicts.

Business models and finance options

Future-oriented, intelligent and sustainable lighting solutions require investment, and various business models are being developed to make this investment easier for cities and municipalities. Some of these models are country-specific, and contracts and/or financing possibilities depend on local legislation.

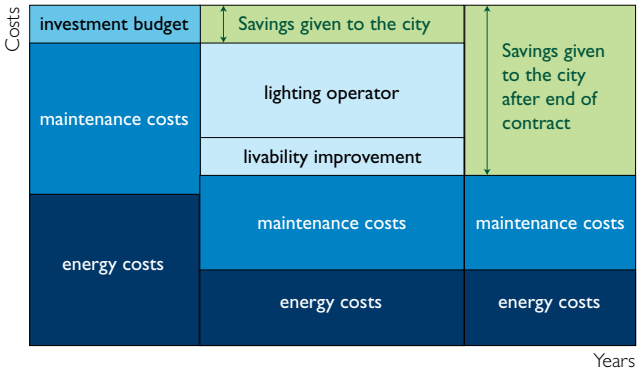
Many variations are possible, but an overview of the main business models is provided below:

Model	what	advantage	disadvantage
Supplier-to-customer direct	Municipality purchases the products/services directly from lighting manufacturers/ suppliers	• Complete transparency of costs involved • Direct line of communication with lighting experts	• Municipality responsible for the capital investment • Municipality takes on project risk
Public energy service deal (PES)	Utilities team up with municipalities to offer energy-efficient lighting solutions. Often the utility sub-contracts the lighting (installation and maintenance) to servicing companies.	• All parties strongly incentivized to achieve energy savings • Municipalities need only deal with one company • Utilities can create economies of scale	• Often only applicable to residential streets (larger roads the responsibility of national government)
Energy performance contract (EPC)	Municipality outsources lighting project completely* in exchange for guaranteed energy savings. Most commonly a partnership with an energy servicing company (ESCO) – itself usually a joint venture of utility, financing, infrastructure servicing and hardware companies.	• No capital investment required from municipalities: ESCO provides financing and takes on the risk • ESCO takes care of maintenance • Guaranteed energy savings	• Long contract period required to pay off the ESCO's capital investment • Focus on minimizing costs rather than maximizing functionality and value for users • Usually only between private parties
Public-private partnership (PPP)	Similar to an EPC, but municipalities retain a stake in the project. Municipalities partner with major PPP players, or tender for large PPP projects that comprise a significant lighting element (such as city street lighting).	• Municipality maintains equity share in the project • Performance and energy/ maintenance savings guaranteed by private partners because of direct public involvement	• Municipalities also take on some of the risk • Most often used for projects broader than just outdoor lighting

**If the municipality brings its own lighting system into the project, the model is a PPP rather than an EPC (see below).*

In recent years, there has been a strong trend towards those business models that outsource lighting projects either partially or entirely to third parties, in exchange for guaranteed energy savings (e.g., EPCs and PPPs). The advantage of these kinds of arrangements is that they allow all parties involved (municipality, utility, lighting or service company) to focus on their own core strengths, expertise and operational excellence. Municipalities benefit from energy savings guaranteed by their private partners, who in turn benefit by gaining secure business and long-term relationships.

The following example shows how such a model results in savings for the city:
An energy performance contract for outdoor lighting systems often includes a consortium or service provider that invests in upgrading the lighting system to reduce energy and maintenance cost. The municipality will benefit from energy reductions guaranteed by the service provider, warranties and maintenance, and the elimination of technology risks. These kinds of agreements are long-term commitments between municipalities and service providers. Penalties for underperformance may apply.

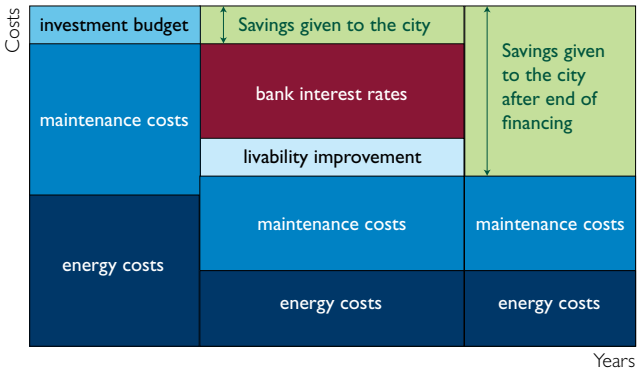


Typical EPC contract period: 8-15 years

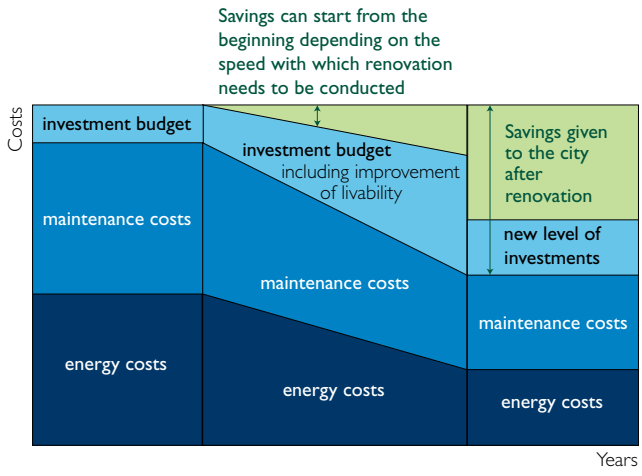
Financing

Depending on the business model, a capital investment may still be required.

Private vs. public funding



Typical financing period: 10-20 years



Time to achieve full renovation: 15 years

Upgrades or renovation of outdoor lighting can be funded either privately or publically, depending on legislation, system lifetime and political landscape. In private funding, a bank (or consortium) loan is used to pay for the capital investment, while in public funding, the government organization uses its normal investment budget to upgrade the lighting system.

The main difference between these two methods of funding is that private funding can usually provide all the funds necessary upfront, so an entire lighting system can be upgraded in one go. This results in a more immediate impact which is clearly visible to citizens and may, therefore, be of value to politicians. With public funding, on the other hand, funds are usually set aside from a government's budget over a period of years. Lighting upgrades are therefore executed on an ongoing basis, with cost savings resulting from reduced energy consumption and maintenance progressively re-invested to enable further renovation of the entire lighting system. The impact of publically-funded lighting upgrades is therefore typically more gradual.

Particularly in the current economic climate, in which government budgets are under severe pressure and budget items must be strictly prioritized, it is vital to ensure that the funds required for the project are actually available and accessible. For this reason, financing or budget-neutral solutions should be considered when executing outdoor lighting projects. Such options may include:

- Direct bank loan
  This is a straightforward loan by a bank to the customer, to be repaid by the customer on a monthly or quarterly basis over a number of years (the payment installments could be aligned with the energy savings realized by the introduction of a new lighting system). In this way, the customer does not need to pay the entire investment amount upfront, while the suppliers will still get their money upfront.
- Financial lease
  This solution is similar to a direct bank loan, but may be preferable in some countries due to more favorable tax charges or accounting treatment.
- Supplier's credit followed by a sale of the receivable
  The supplier (lighting supplier or integrator) could extend payment terms to the customer, but sell the receivables to a bank on day one. In this way, the customer does not enter into a direct bank loan, but still pays by installments on a monthly or quarterly basis over a number of years, while the supplier still gets his money (from the bank) on day one. This solution can deliver the same benefits to all parties as a direct bank loan, and therefore may be preferred by customers who are not permitted, either by regulators such as the central government or by their headquarters, to obtain a direct bank loan. In this case, the bank will charge the financing costs to the supplier, meaning that the supplier has to include these costs in the sales offer given to the customer.
- Tailor-made financial solutions via financial partners.

Funds may also be obtained via subsidies or carbon financing (Clean Development Mechanism, Carbon credits, White certificates).

LED performance standards

At present, LED lighting technology is still relatively new in the outdoor lighting market, and there is a lack of clear performance standards. This makes it difficult for users of LED luminaires (e.g., specifiers, lighting designers, technical engineers and policy makers) to effectively evaluate the performance claims of different manufacturers when preparing lighting projects or tender specifications. Standardization of performance requirements is an important first step towards like-for-like comparison of LED module and LED luminaire manufacturer claims. The lighting industry is therefore driving a process in the International Electrotechnical Commission (IEC) to define international performance standards for LED products.

Recently, two important IEC documents have been published on performance:
- IEC/PAS 62717 performance requirements for LED modules
- IEC/PAS 62722 performance requirements for LED luminaires.

Both documents lay out "definitions" of a set of initial quality criteria, plus a description of "how to measure" them. Adding a definition of "limiting values" to this standardized set of quality criteria will make the performance claims of different LED luminaire manufacturers truly comparable. Reputable LED module and luminaire manufacturers are currently applying these IEC standards to their product specifications.
It is important that policy makers refer to the IEC/PAS documents when deciding on tender requirements for professional projects. Minimum requirements (limiting values) for all eight quality criteria should be defined. If the accuracy of the manufacturer's performance claims is doubted, third-party verification can be included in the tender specification.

Spotlight on city centers: Rouen, France
Philips supplies lighting to the city of Rouen, France, through a PPP with Vinci – a world leader in infrastructure services. The 18-year contract covers design, financing, building, operation and maintenance of traffic management equipment and some 15,000 wirelessly networked lighting points in the old center. It's a clear demonstration of how PPPs can be used to support sustainable cities over the long term.

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For an overview of published LED-related IEC, UL and IES standards, see:
http://www.iec.ch/
http://www.ies.org/
http://www.ul.com/global/eng/pages/offerings/industries/lighting/

Other useful links:
http://www1.eere.energy.gov/buildings/ssl/consortium.html
http://www.c40cities.org/
http://www.worldbank.org/
http://ec.europa.eu/digital-agenda/en/news/new-commission-report-lighting-cities-accelerating-deployment-innovative-lighting-european