Public Procurement boosts Energy Efficiency

Guidelines for Sustainable Public Procurement

LED Street Lighting Equipments

- A Guide for Public Authorities -

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1.) Background and State of the Art in Public Procurement for LEDs

The LED (light emitting diode) is versatile in many different job applications and can already be found in a range of applications where reliability, color, visibility and long life are important. This technology has been used for more than 30 years. For example: we are all familiar with the LED in our video recorder and similar equipment, indicating that the equipment is switched on. The LED can now be found in signal lighting, traffic lights, automotive lighting and also in home entertainment. More recently, the LED is used in the backlighting of modern equipment and its latest application as accent and decorative lightning, for indoors and outdoors.

LED technology is known for a host of performance advantages, including their outstanding energy efficiency, optical efficiency, less weight and packaging due to a compact design and increased reliability and flexibility. This flexibility allowed LED into applications where standard lamps would not work. Now, convinced of the potential in other areas, lamp manufacturers are undertaking a significant amount of development work on LEDs for whole range of applications.

Put simply, the LEDs are tiny light sources that fit easily into an electrical circuit but unlike ordinary incandescent bulbs, they do not have a filament that will burn out. They emit light by the movement of electrons in a semiconductor material, which converts electric current directly into light. A LED consists of several layer of semiconductor material. If the diode is operated in a forward direction, light is generated in one of theses thin layers, the active layer. In contrast to the incandescent lamp, that produces a continuous spectrum of light, the LED emits light of a particular color or wavelength depending on the material used at the base of the chip.

Like many other recent technologies the LED is continuously developing and improving in performance (Table 1). That said, the technology is already functioning in ways that could not be done before and with clear benefits to society as a whole.

Table 1: Development of LED technology

	TECHNOLOGY	CHARACTERISTICS
1907	Discovery of the physical effect of electroluminescence	Material properties were poorly controlled and the emission process was not well understood
1962	First practical visible-spectrum (red) LED developed	Extremely costly, had little practical application
1968	Commercial LEDs introduced by The Monsanto Company	Still expensive, small flows of lumens, inefficient, mainly used for numeric displays
1970' s	Additional colours and wavelengths	Low brightness, failure rate much higher then with a present day technology, high production costs, still limited use as light sources
1980's	New material GaAlAs (gallium aluminium arsenide) developed	Rapid growth in the use of LEDs, the brightness was over 10 times greater than standard LEDs, increased efficiency, increased total power savings
Mid 1990's	Emergence of blue and white diodes	Steady decline of production costs, wide scale commercialization of blue and green solid state LEDs
2000's	Continuing development and technology improvements	Widespread use (cell phones and other electronic devices are the highest volume products utilizing LEDs today), 1000 times more efficient that they were in 1968 (level of efficiency is continuing to double every two years), last up to 100 000 hours, continued decline of production costs

LED systems are almost maintenance free and their total cost of ownership is significantly lower. The lifetime of the LED is considerably longer than a conventional lamp. Furthermore, unlike many filament lamps the LED is not subject to sudden failure, they gradually dim over time rather than failing abruptly like incandescent at the end of its life. Their long life makes LEDs attractive for places where changing bulbs is difficult or expensive, like on the outside of buildings of traffic signal lighting. In certain applications where regular redecorations are common (e.g. shop lighting) the LED doesn't require any attention over the period of many years.

LEDs can be operated with low voltage, making them safer and easier to work with. They produce less heat than incandescent lamps and are less fragile than fluorescents. They are built inside solid cases that protect them, they show no moving parts, no fragile glass, no exposure to toxic gasses and no filament making them hard to break and extremely difficult to cause damage. Given that they contain no mercury, they are also friendly for the environment.

In addition, over the last few years, the energy efficiency of LEDs has increased significantly, a trend that will continue in the future. It is expected that the LED will challenge many of the existing light sources when it comes to energy efficiency. Each LED measures only a few millimeters allowing for smaller constructions and considerable savings in raw materials, packaging, and transport and recycling costs. The technology also allows for better-controlled beams of light thus reducing the amount of light that is wasted, as in case of an incandescent and halogen lamp.[1]

Due to the significant functional and environmental improvements during the recent years, LEDs can play a major role in public procurement, for instance or the promotion of energy efficient street lighting systems. In other words, by changing purchasing behavior in the European street lightning sector, significant reductions in CO_2 can be achieved. Local authorities, which generally have responsibility for purchasing the majority of Europe's street lighting systems, spend between 14 and 16% of EU GDP on public procurement each year. By opting for energy efficient lighting they can significantly save on electricity costs, ensure longer lamp life time (energy efficient lamps can last up to 15 times longer than their less energy efficient equivalents) and choose more efficient options for recycling and reuse.

A wide range of energy efficient street lamps is already being marketed in Europe. Products such as High Pressure Sodium and Metal Halide are available, affordable and appropriate for the majority of Europe's street lighting needs but many of Europe's local authorities are not fully aware of or not act upon the available choices of energy efficient alternatives – market forces are not enough to convince public purchasers to make the switch. End use energy efficient street lighting can be achieved by developing the market for efficient street lighting services.

The governments of the European member states should speed up the introduction of LEDs by various tools. A strong example is the coordination of pilots. In the Netherlands 350 pilots are organized. In 2008-2009 35 pilots of 28 communities were co-ordinated with a common type evaluation (e.g. perception measurement, etc). These co-ordinations provide a lot of information and have an important impact on awareness[2]. Another tool to speed up the introduction of LEDs is by providing some of the following fiscal incentives to public

[1] European Lamp Companies Federation, "Did you know the potential of LED technology?", Brussels
[2] As the result of the co-ordinated pilot some communities like Eindhoven, Breda and Tilburg decided to implement LEDs as „the system“ in their community.

purchasers so the European governments can in turn make energy efficiency an integral part of the internal market through:

- tax rebate programmes for all municipalities and authorities who make the switch to energy efficient outdoor and street lighting
- incentives for upgrades for outdoor and street lighting systems that are more than 15 years old
- leasing programmes for the latest energy efficient outdoor and street lighting projects
- interest free loans for energy efficient outdoor and street lighting projects[3]
- financial incentives for the promotion of local energy efficient outdoor and street lighting projects
- provision for private partnerships (PPPs) for outdoor and street lighting services

Instruments such as comparison of performance measures for energy efficient purchasing and the creation of scorecards for CO_2 savings in the street lighting sector can significantly influence purchasing behavior. “Green” procurement is currently a key priority of the Commission. A code of conduct for buying energy efficient outdoor and street lighting would complement existing European and international public procurement rules by establishing guidelines for maximizing energy efficiency e.g. the promotion of an energy efficient street lighting purchasing strategy, devised to ensure that all European contracting authorities tender street lighting supplies. Contracting can be differentiated between pure service models, in which the lighting remains in the ownership of the municipality, a complete transfer of the system to private companies or rather a combination of both models. In the lighting sector basically three different models of contracting can be differentiated (Table 2):[4]

- lighting contracting (operation of facility contracting)
- light supply contracting (supply contracting)
- performance contracting (energy saving contracting)

[3] The Final Report on the Dutch pilots concludes that a lot of Communities see the lack of investments funds is hampering the large scale introduction of LEDs so a soft loan system may be effective.
[4] Berliner Energieagentur GmbH and Investitionsbank Schleswig Holstein, “Status quo on Street Lighting Contracting in Europe – short study”, Berlin, July 2006

Table 2: Different models of contracting

	Lighting Contracting	Light Contracting (Light supply Contracting)	Performance Contracting (Energy saving Contracting)
Applica-tion	Refurbishment of the lighting devices	Renewal, replacement and /or supplementing investments of the lighting system and additionally the operation of the lighting	Energy saving measures
Services	Financing (optional), Planning of the refurbishment, Installation and maintenance	Financing (optional), Planning of the refurbishment, Installation and maintenance, Additionally: Whole operation of the lighting points including purchasing of the energy	Financing, Planning, Installation, maintenance and support of specific energy saving measures
Finan-cing	Contracting rate as remuneration for the services	All costs for the supplied light (Contracting rate with basis and working price)	Contracting rate as remu-neration for the energy and operating cost savings achieved
remarks	For single refurbishment measures including maintenance	For total refurbish-ment/complex solutions including operation, can be combined with leasing/buying model	For more complex solutions with high saving potential; not so widely used (often combined model with subsidies of the lighting owner for refurbishment measures)
Type of Con-tracting	Facility Contracting	Supply Contracting	Performance Contracting

2.) European Context and EU Legislation for LEDs

LEDs are clearly mentioned in the Commission's 2006 Energy Efficiency Action Plan 2007-2012 (EEAP) which sets out 85 measures with a view to intensify the process of realizing the over 20% estimated savings potential in the EU annual primary energy consumption by 2020. According to the Action Plan, the adaptation of high efficiency Light Emitting Diode technology (LED), already available on the market, could by 2015 save 30% of today's consumption for general lighting and 50% by 2050.[5]

The EEAP is divided into six major chapters, LEDs are included under part I which deals with dynamic energy performance requirements for energy-using products, buildings and energy services. Beside the overall outline of the EEAP, several other influential policies and initiatives have to be mentioned: an additional set of comprehensive EU legislation (see below), national energy efficiency action plans, financing tools, research and development and energy efficiency collaboration on an international level. LEDs are affected by the above-mentioned comprehensive set of EU legislation through the Energy Services Directive (2006/32/EC), the Labeling Directive (92/75/EC), and the Ecodesign Directive of Energy-Related Products (2009/125/EC). The latter is the main legal instrument of the EU to address the environmental performance of energy related products and it is pushing the market by

[5] European Commission: „Communication from the Commission: Action Plan for Energy Efficiency: Realizing the Potential", Brussels, October 2006

taking out the least-performing products. On the other hand, labeling promotes the utilization of the best performing products. According to the ELC (European Lamp Companies Federation) the labels that are widely used for labelling of the solid-state lighting products are the Energy Star, CE marking, The Lighting Facts label, Energy label, Underwriter Laboratories label, and these push manufacturers to demonstrate their commitment to accurate and consistent reporting of product performance claims. They often provide information about brightness, energy cost, expected life, colour temperature and other information that are deemed necessary for consumers to fairly compare various products. As the technology is rapidly evolving, European Commission is preparing a review of Energy Labelling where LEDs will be explicitly included in the scope. First drafts are expected in the middle of 2010, while adoption by the Commission is likely in the first half of 2011.

Ecolabels for instance play a crucial role for light bulbs, and the label is awarded on a voluntary basis. Award criteria include energy efficiency, lifetime, lumen maintenance, mercury content, switch on/off cycles, CRI (color rendering index), flame retardant content, packaging materials and user instructions. An additional important ecodesign measure affecting lighting equipment is the draft regulation on tertiary sector lighting products that deals with technologies typically used in office and street lighting (e.g. linear fluorescent lamps, high intensity discharge lamps). LEDs in particular though are not included in the tertiary sector lighting equipment but form part of the so called non-directional household lamps: all lamps except those covered by tertiary sector lighting regulation (in practice incandescent lamps, halogens, compact fluorescent lamps with integrated ballast and LEDs). Main requirements of the functionality of those types of lamps comprise lifetime, light quality, starting times and UV radiation.

The public sector in the member states is playing a crucial role for the application of innovative and energy efficient street lighting equipment. Owners of street lighting system are supposed to fulfill an exemplary and stimulating role for other key-players in the sector. Increasing energy prices, restrictions of the public budgets and necessities of modernization and refurbishment are seen as a major drive towards cost reductions. Energy efficient public procurement, energy audits and energy performance contracting are therefore seen as successful tools to save energy costs and guarantee quality standards and maintenance of street lighting systems. Public authorities are encouraged to use financial instruments for energy savings such as performance contracting that stipulates the delivery of measurable and pre-determined energy savings. Purchased equipment should be based on a list of energy efficient product specifications of different categories to be drawn up by the authorities. Energy audits are a helpful tool to implement resulting cost-effective recommendations.[6]

3.) Economic Aspects and Most Efficient Available Products on the Market

LEDs have many advantages over conventional electric light sources, including low power requirements, long lifetimes, small size, optical control and operating characteristics.

▪ Low Power Requirements: LEDs require low direct current voltage and low power to operate. This ultimately results in reduced energy use. In many applications were LEDs are used today the energy savings are at least 50 percent, and up to 90 percent where they replace

[6] European Commission, "EU legislative instruments for lighting, Conference of energy efficiency in the lighting market", Brussels, February 2009

incandescent lights. For instance, energy and costs savings associated with the use of LEDs in traffic signals are approximately 90 percent.

▪ Long Lifetimes: LEDs have the advantage of a long lifetime. The lifetime of LEDs depends on temperature. Higher temperatures mean shorter lifetimes. Regarding the temperature the temperature of the LED depends on the total system and not only on the LED itself. The cooling/ventilation of the total system is a point of attention.[7] LED manufacturers claim lifetimes up to 100.000 hours (with less than 40 percent lumen depreciation after 100.000 hours of operation). This is several times greater than the operating life of conventional lighting. Because LEDs may last more than 10 years, replacing lights that are difficult to replace or costly to access are good candidate applications for LEDs, such as street lighting, traffic lights, tunnels or bridges. Considering LED-system one should not only take into account the lifetime of the LED but also that of the driver (the feature that feeds the LEDs). These systems may have a shorter lifetime than the LEDs and so attention to the lifetime this part is wanted.

▪ Color Rendering: LEDs are capable of producing light that provides an accurate rendering of object's natural color. LED products for street and parking lot applications for instance have been designed to produce a warm, white light that ranges from 85 to 90 (on a scale of 100) on the CRI (color rendering index). This is very good especially compared to other lights commonly used this application, such as high pressure sodium (CRI of 20 to 80), mercury vapor (CRI of 20 to 60), metal halide (CRI of 60 to 80), and especially low pressure sodium (CRI of 20 to 60) whose yellow color makes it difficult to discern color difference in objects.

▪ Small Size: LEDs have been referred to as the ultimate light point source. This offers products designers and integrators flexibility in their form and design for a wide range of products. The small LED size also allows mixing of different colors in small areas for meeting specific optical needs.

▪ Optical Control: LEDs offer the benefit of greater optical control due to their small size and packaging options. When combined with a well-designed fixture, the light produced by LEDs can be directed to the intended location such as roadway surface. Typical fixture losses are in the range of 40 to 60 percent, meaning that only about one-half of the source-light is directed in the desired direction. LED fixture efficiencies can be in the 80 to 90 percent range. Thus, an LED light output does not have to be as a high as a conventional light to achieve the same coverage. This makes LEDs especially advantageous for street lighting fixtures to minimize trespass to adjacent areas not intended to be lit.

▪ Operating Characteristics: LEDs have several favorable operating characteristics. The lights do not require any "strike"-time – they instantly come on and off – and on/off cycling does not affect lifetimes. As LEDs fail, they dim rather than turn completely off or cycle on/off as with other lighting. LEDs are resistant to vibration. In addition, LEDs are dimmable and operate without generating excessive heat.

According to the "White Paper: Street Lighting"[8], one of the most compelling arguments in favor of LED street lamps is the cost advantage of operating and maintaining fixtures. In part, this comes from reduced energy usage that can cut electricity bills in half. In part, it comes

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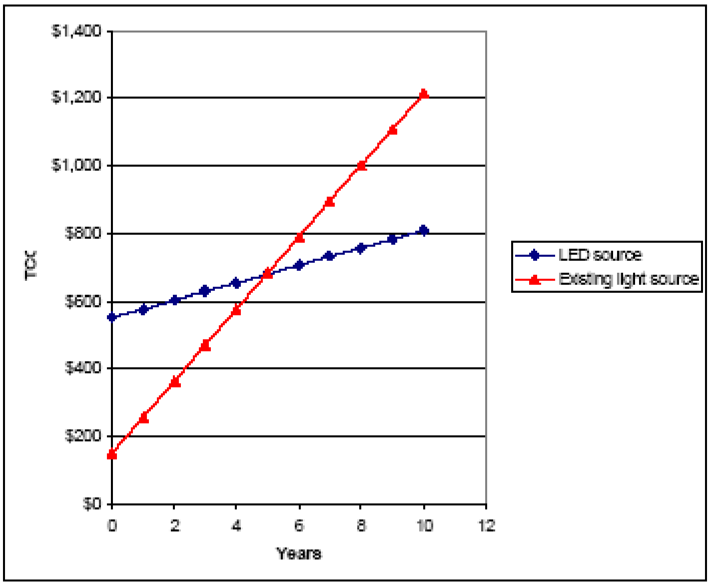
[7] It is estimated that a low temperature system has a lifetime of 3-4 times that of a high temperature system. (results of Luxeon K2 in Final Report LED Solutions in Public Lighting (Dutch Pilots)

[8] Philips, "White Paper: Street Lighting –LEDs: Coming Soon to a Street Light Near You – The Performance, Design and Cost Benefits of Power LEDs in Street Lighting", September 2008

from the longer replacement cycle made possible by longer LED life. Increasing the interval between bulb replacements from three to five years to 10 or 15 means fewer truck runs, less fuel, and less overhead of work crews. This in turn accelerates the return of investment (ROI). Even with the higher initial cost of solid-state luminaries, municipalities can recoup the costs of a LED-based street lighting installation in four to six years (Figure 1). The ROI will be even faster as power sector costs increase and technology advances increase LED output, making it possible to deliver more lumens per watt for additional energy savings.

Figure 1: Estimated Payback Time



At the end, LED lighting has the potential of bringing a new light source with different operating characteristics to the market. LED for street and parking lot lighting applications package a number of LED chips onto a coated printed circuit board and enclose them into a frame suitable for outdoor environment. The LED fixture requires no ballast or capacitors like conventional streetlights, rather it converts utility line voltage to low voltage direct current with a small electronic power supply either housed in the enclosure or mounted on the printed circuit board.

Driven by expanding market demand and production capacity, the cost of LED lights has declined over the last years. Continued price decline in LED products should be expected. This decline has primarily been driven by technology improvements resulting in fewer chips used in each lighting fixture.[9]

The following example (Table 3) depicts a cost comparison between a HPS (High Pressure Sodium) lamp and a LED street light, showing that the latter one is characterized by lower overall costs.[10]

[9] Center for Sustainable Energy California, "Technological Assessment of Light Emitting Diodes (LED) for Street and Parking Lot Lighting Applications", San Diego, August 2003
[10] *www.* redefix.com/skyleds/seguro/downs/pdfs/Street_LT_75-en.pdf

Table 3: Cost Comparison

Item	200W HPS street light	75W LED street light
Watt(W)	200	75
Unit Price (USD)	180	500
5 year electricity cost	2363.47	946.03
5 year maintenance cost	200	0
Total cost	2743.47	1446.03

The experience in the co-ordinated pilots in The Netherlands demonstrates that the long lifetime of LEDs however doesn't mean there is no need for maintenance over the long lifetime of the lamps. Depending of the design of the post/lamps, etc, cleaning is necessary because dirt etc may cause an important loss of light. The possibility to clean the surface of the lamps and the risk of "catching" dirt are important elements in the selection progamme of the procurement.

4.) Environmental Criteria and Technical Specification for the Most Efficient Products

Light emitting diodes (LEDs) are special types of semiconductors that produce light when electricity is passed through them. LEDs do not contain glass, filaments or mercury, so they have many economic and environmental advantages over incandescent and fluorescent lamps. In recent years, LEDs have become more affordable and are therefore used nowadays in many different applications. LEDs are now used in all types of electronic devices, such as remote controls, traffic and streetlights, car taillights, digital clocks and flashlights. LEDs come in two basic categories known as low-power LEDs and high-power LEDs.

LEDs, unlike incandescent light bulbs, tend not to burn out completely, but rather decline in lighting quantity and quality over longer periods of time. As already mentioned, LEDs do not contain mercury, but they do contain one or more chips that may require toxic chemical during manufacturing. LEDs also use aluminum or other metals as a heat sink, and it will be desirable to find proper ways to recycle these materials as more LEDs enter the market. The exact environmental footprint of current LED manufacturing is still unknown. Since LEDs are a newer technology, customers should be cautious of exaggerated environmental claims. Nevertheless, because LED technologies use much less energy than incandescent equivalents, other alternative energy sources like photovoltaics (solar cells) can be integrated into their systems. Street lighting, in conjunction with solar cells, can be installed in remote locations for instance where there is no or limited electricity. This reduces battery waste and costs, improves environmental safety and saves energy.[11]

[11] Center for Sustainable Energy California, "Technical Overview – LEDs", San Diego, November 2009

Additional environmental benefits of LEDs for solid-state street lamps provide the following variety of sustainability benefits that are clearly linked to the above mentioned economic aspects:[12]

▪ LEDs ability to minimize wasted light lowers power demands even further by reducing the lumen requirements for a given street fixture. Since light distribution can be controlled on an LED-by-LED basis, engineers can be effectively light the target zone without the light pollution created by a single-beam solution.

▪ Mercury-free LED construction makes solid street lamps safe for landfills while also complying with mercury bans such as the European Union's RoHS directive

▪ Long LED life lengthens replacement cycles and associated fuel usage by maintenance crews, while also existing fixture life and thereby reducing the burden on the waste stream.

▪ LED street lights reduce pollution and carbon footprint via energy savings that lowers carbon dioxide and mercury emissions from coal-burning plants, as well as reduced fuel consumption by maintenance crews dispatched for bulb replacement.

The table below considers the most common types of lamps (including LEDs) available for street lighting and provides a summary of their success in terms of cost, energy efficiency and lighting performance.[13]

Table 4: Lamp Type Descriptions

Lamp Type	Description
High-pressure mercury vapour lamp	- One of the most common types of lamp used in Europe. - Contains mercury and gives out white light. - Inexpensive to install and has a life span of 3 years. - Extremely energy in-efficient.
Low pressure sodium	- Used in older street lighting systems - Commonly used in the UK. - Contains no mercury. - Life span of 3 years. - Energy efficient. - Unable to direct the lamps light, therefore energy wasted. - Light is not immediate – must be switched on earlier than needed. - Provides orange light which lowers the quality of light for the road user.
High-pressure sodium	- Used in new lighting installations - Very energy efficient. - Lifespan of 4 years. - Optically efficient but light is not immediate. - Provide golden/pink light. - Provide reasonable colour/rendering identification.
Metal Halide	- Based on the latest technology in street lighting. - Very energy efficient. - Low mercury levels. - Longer lifespan so cost advantages achieved. - Provides high quality white light. - Significant environmental achievements.
LEDs	- Relatively new technology. - Extremely energy efficient.

[12] Philips, "White Paper: Street Lighting –LEDs: Coming Soon to a Street Light Near You – The Performance, Design and Cost Benefits of Power LEDs in Street Lighting", September 2008
[13] Northern Ireland Assembly, Research and Library Services, „Energy Efficiency in Street Lighting", Research Paper 30/09, March 2009

	- Longer lifespan of about 10 years. - Relatively high cost to implement. - Cost savings achieved through reduced labour and maintenance costs. - Able to direct light which reduces energy needed and limits light pollution. - Instantaneous light. - Dimming capabilities. - Can produce a specific colour.

Due to the fact that LEDs are a relatively new technology that is rapidly evolving, definition of the minimum technical characteristics and criteria is issue that is still being debated within the responsible organizations, such CELMA (Federation of National Manufacturers Association for Luminaries and Electrotechnical Components for Luminaries in the EU) and ELC (European Lamp Companies Federation) are. For a current moment requirements that are widely used and that are still not having its equivalent in the EU are the ones established by the Energy Star, but in the close future we can expect that the efforts of the European Union will bring fruits in this domain as well. Following Table 5 contains the requirements for Indoor & Outdoor Fixtures Employing LED Light Engines for Primary Illumination established by the Energy Star.

Table 5: ENERGY STAR Program Requirements for Indoor & Outdoor Fixtures Employing LED Light Engines for Primary Illumination[14]

Performance Characteristic	**ENERGY STAR Requirements**	**Methods of Measurement Reference Standards**
	LED Light Engine Requirements	
LED Light Engine Efficacy *Per LED light engine in lumens per watt (LPW)*	≥ 50 LPW for uncovered LED light engines ≥ 40 LPM for covered LED light engines (engines featuring integral secondary optics)	*ASSIST Recommends: Recommendations for Testing and Evaluating White LED Light Engines and Integrated LED Lamps Used in Decorative Lighting Luminaries*
LED Light Engine Color Rendering Index (CRI) *Required for indoor fixtures only.*	≥ 75	ASSIST, May 2008; ANSI C78.377-2008
LED Light Engine Correlated Color Temperature (CCT) *Required for indoor fixtures only.*	Light output must meet one of the following nominal correlated color temperature (CCT) values: 2700K, 3000K, 3500K, 4000K, 4500K, 5000K, 5700K, 6500K.	ASSIST, May 2008; ANSI C78.377-2008
LED Light Engine Maximum Measured Driver/Driver Case Temperature (During *in situ* Operation)	T_c not to exceed the LED driver manufacturer maximum recommended case temperature when measured during *in situ* operation. Note: This performance characteristic is separate and distinct from safety requirements.	ASSIST, May 200*8*
Lumen Maintenance	**Indoor fixtures:** ≥ 25,000 hours to 70% Lumen Maintenance (L_{70}) **Outdoor fixtures:** ≥ 35,000 hours to 70% Lumen Maintenance (L_{70})	*ASSIST Recommends: LED Life for General Lighting*
Color Stability	Chromaticity shift for LED packages over time shall not exceed 0.007 on the CIE 1976 (u’, v’) diagram (corresponds with a 7-step MacAdam ellipse).	
Power Factor	≥ 0.7	ANSI C82.77

[14] ENERGY STAR Program requirements for Residential Light Fixtures, Eligibility Criteria – Version 4.2., pg. 35 – 38.

Output Operating Frequency	≥ 120 Hz Note: This performance characteristic addresses problems with visible flicker due to low frequency operation and applies to steady-state as well as dimmed operation. Dimming operation shall meet the requirement at all light output levels.	Oscilloscope instruction manual
Noise	Class A sound rating for power supplies within the fixture, not to exceed a measured level of 24 dBA (audible) when the power supplies are installed in the fixture.	Class A sound rating for power supplies within the fixture, not to exceed a measured level of 24 dBA (audible) when the power supplies are installed in the fixture and are measured using a sound meter (similar in performance to B&K type 2209) where the microphone is located 12 inches from the fixture in any direction.
Transient Protection	Power supply shall comply with ANSI/IEEE C62.41, Class A operation. The line transient shall consist of seven strikes of a 100 kHz ring wave, 2.5 kV level, for both common mode and differential mode.	ANSI/IEEE C62.41
Electromagnetic and Radio Frequency Interference	Power supplies must meet FCC requirements for consumer use (FCC 47 CFR Part 15/18 Consumer Emission Limits)	Consumer Limits per FCC 47 CFR Part 15/18
Off State Power Consumption	Fixtures using integral occupancy sensors, motion sensors, or photosensors, or portable fixtures, shall consume no more than 0.5 watts in the off state. All other fixtures shall not consume power in the off state.	No Standard Available (Use manufacturer protocol)

On the other hand, criteria (Table 6) that are currently being developed at Laboratório Nacional de Energia e Geologia (LNEG) to apply in Cascais Municipality in Portugal are a result of an exhaustive research and also form the data provided by other municipalities in Portugal that have already implemented LED installations. The data is being developed in consultation with the manufacturers in order to see if they are able to provide such level of performance and if such level of performance is actually needed, and they are subject to future modifications depending on the market consultation results.
The technical and environmental criteria below can be used as technical specifications as well as awarding/bonus criteria. According to LNEG as these criteria have not yet been tested in a real tendering process, the values presented here for each parameter should be checked by the public lighting technical department and suppliers, considering the characteristics of the space/road to illuminate.

Table 6. Technical/Environmental criteria developed by LNEG for Cascais Municipality in Portugal

ISSUE	**CRITERIA**	**VERIFICATION**
	Luminaire features and performance	
LUMINOUS EFFICACY	≥ 90 lumen/watt	Product data sheet
LIFETIME	≥ 50.000 hours	Product data sheet
	Equipment must have an effective heat dissipation mechanism.	
COLOUR	CRI ≥ 90	Product data sheet

RENDERING INDEX		
COLOUR TEMPERATURE	Between 3500 K and 5000 K	Product data sheet stating available colour temperatures
INGRESS PROTECTION RATING (IP)	≥ IP65	Product data sheet
SHOCK RESISTANCE CLASS (IK)	≥ IK08	Product data sheet
POWER FACTOR	COS Φ ≥ 0,95	Product data sheet
TOXIC SUBSTANCES	Equipment must comply with Directive 2002/95/CE of the European Parliament and of the Council of 27 January 2003, regarding restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS)	Supplier statement of compliance with this legislation
	Equipment and it's components may not contain any of the substances of high concern listed under EC Regulation n.º 1907/2006 of 18 December 2006, regarding the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)	
ECODESIGN	Equipment must be designed to facilitate dismantling and recovery for reuse and recycling of its components and materials.	Supplier statement of compliance with this criteria Supplier register as producer of EEE
LUMINAIRE	Quality and/or environmental labels and/or certifications	Product labels and/or certifications
Global performance		
ILLUMINATION PERFORM	Installation design must ensure a minimum performance in accordance with the standard (DIN) EN 13201 – road lighting, considering road category. Note: Additional requirements should be defined by the contracting authority for parameters such as threshold increment (glare control), global uniformity, illuminance and others.	Global installation luminotechnic study
INTELLIGENT ENERGY MANAGEMENT	Light intensity management/dimming system, energy management software and other features to be defined by the contracting authority.	Energy management system data sheets
CO2 EMISSIONS	Indirect emissions of CO2 (kg CO2/year)	SMART-SPP LCC-CO2 tool
RETROFIT	Fixtures should enable retrofit	Product data sheet
Supplier Selection Criteria (previous qualification of suppliers)		
ENVIRONMENTAL MANAGEMENT	Implementation of acknowledged Environmental Management Systems such as EMAS[15], ISO 14001 standard or equivalent measures, for the supplier and all the intervenients along the whole supply chain.	Certification of implementation of an Environmental Management System. Environmental Management Program identifying the main environmental aspects to be treated, goals and associated measures for the supplier and all the intervenients during the whole supply chain.
PRINCIPLES AND RIGHTS AT WORK	Main International Labour Organization (ILO) conventions must be respected along the whole supply chain. More specifically conventions number 100, 111, 87, 98, 138, 182, 29 and 105; related to basic labour principles and rights[16].	Declaration of compliance from the supplier and all the intervenients along the whole supply chain. Certification of compliance of SA 8000 standard for social corporate responsibility or equivalent, for the supplier and all the intervenients along the whole

[15] REGULATION (EC) No 1221/2009 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 November 2009 on the voluntary participation by organisations in a Community eco-management and audit scheme (EMAS), repealing Regulation (EC) No 761/2001 and Commission Decisions 2001/681/EC and 2006/193/EC.

[16] Conventions: 100 and 111 – No discrimination, 87 and 98 – labour union freedom and right to organization and collective negotiation, 138 and 182 – Child labour eradication, 29 and 105 – forced labour abolition.

		supply chain.
Contract Performance Clauses		
WASTE (WEEE)	Ensuring recovery of components to be replaced (in case of maintenance to be carried out by the supplier of the equipment) and equipment in end-of-life stage, for reuse or recycling, according to national/regional legislation.	Proof of adhesion to an integrated system of management of WEEE.

Furthermore, LNEG has also distinguished legal and economical criteria as the ones that should be taken into account when LED street lighting is being selected. To evaluate the economical aspects of the tenders SMART-SPP's LCC-CO_2 tool should be used as it allows the calculation of the ownership costs, among which are considered the purchase price, the costs of operation, maintenance and end-of-life. The tool along with its user's guide can be downloaded at the SMART-SPP's website: http://www.smart-spp.eu/.

Legal criteria are shown in the following Table 7.

DIPLOMA	SCOPE
Directive 2002/96/EC of the European Parliament and of the Council of 27 January 2003 and further amendments	Waste electrical and electronic equipment (WEEE)
Directive 2002/95/EC of the European Parliament and of the Council of 27 January 2003	Restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS)
National / regional legislation about electric installations	

Note: The legislation referred in this document may not be exhaustive

Finally, the following Table 8 outlines an overall technical comparison between HPS and LED street lighting technologies.[17]

Table 8: Technical Comparison

Item	200W HPS	75W LED Street Light
Spectrum	Driven by UV	No UV
CRI	30~50%	80~90%
Max. Illumination	30lux	18lux
Average Illumination	14lux	15lux
Illumination Uniformity	0.38	0.57
Environmental Friendly	Contains Mercury and heavy metal, can not be recycled	Semiconductor chip inside, can be recycle
Smart Control	Single light source, can not be smart controlled	Multi-light source, can be smart controlled
Flicker	High voltage and frequency driven, with flicker	Low voltage DV- driven , no flicker
Working Voltage	High voltage 4000~7000V	36V DC
Working Stability	Off-Peak time over-current drive (250V) reduces the life the light source. The brightness changes with the fluctuation of the power network voltage, which increasing the power consumption, reducing the life span, shortening the light maintenance.	Over-current protection design and voltage regulator design make the brightness of the light stable, and expand the life span.
Light Distribution Design	Spherical light output, curvy reflect cover design, mature design, good light uniformity, high temperature causes reflect cover aging, effects the light output and refelctivity.	Directly light on ground, high luminous effeciency, complex light distribution design. Cold light source won't cause optical and glass aging problem.
Application	Main Road	Subsidary Road
Light Decay	3,000hrs 30%-35%	10,000hrs 5%-8%
Lifetime	5,000~15,000hrs	30,000~50,000hrs
Power Factor	0.63	0.65
Total Power Consumption	220W	83W
Total System Consumption	230W	93W
Diameter of Power Cable	2.5m 3PIN	1.5m 3PIN
Diameter of 500M Loop Power Cable	35m 4+1PIN	5 m 4+ 1PIN
Start	High voltage high currency start (3A), warm up time: 15~20 minutes	Low current start (0.6A), start time (0.06s), warm up is not needed

5.) Industrial standards

Last years have seen a rapid performance improvement of LEDs. Nevertheless, due to a great number of manufacturers and the systems they use for specifying their LED products, comparison of different products has become difficult, if not impossible. Without standards customers are having difficulties when purchasing LED-based products, and whole market

[17] *www.* redefix.com/skyleds/seguro/downs/pdfs/Street_LT_75-en.pdf

can easily become full of confusion and disorder. Given that LEDs are continuing to evolve rapidly, even existing standards have to be revisited more frequently than is the usual case with other products and technologies.
Many standards committees around the world have been working on developing standards for LED lighting products based on their energy savings and performance. So for example the first criteria being used to qualify a lighting product for Energy Star (international standard for energy efficient consumer products) is the energy-efficiency measure of luminous efficacy in lumen per watt.[18]

Various associations have followed their own path in establishing guidelines for qualifications of lighting. Two important association in the US, National Electrical Manufacturers Association (NEMA) and American Lighting Association (ALA) have suggested, for example, a two level classification for energy savings and associated performance. According to their proposition if a lighting fixture is classified as functional and if its elementary aim is to provide illumination then the qualification should be at the luminaire level, and the luminaire can be qualified for Energy Star. But, according to their proposal, if decorative features are the main purpose of the lighting fixture then the qualification should be at the light-source level, either the LED light engine or the LED lamp. Consequently, these types of products shouldn't be labeled with an Energy Star label on the fixture, but on the lamp, if an Energy Star label is issued to them. [19]

While aforementioned associations are joining their efforts with American National Standards Institute (ANSI), Underwriters Laboratories (UL) and Illuminating Engineering Society of North America (IESNA) to create standards for Solid State Lighting (LEDs and OLEDs included) in the USA, International Electrotechnical Commission (IEC) is developing LED lighting related standards for all applications in a similar system to the one that is used for other lighting devices. Accordingly, two main categories of standards are safety and performance categories. LED lighting is then divided according to the level of integration or configuration into LED luminaire, LED module and LED lamp. From that point safety and performance are specified for each integration level. Furthermore, each standard's consistency across all applications is considered as well, for example when LEDs are used for automotive lighting, general lighting or other applications. This procedure is part of the initiation of LED binning standards currently under development in IEC.[20]

Even though aforesaid efforts are to be welcomed, due to the fact that LED industry is growing and changing very fast, many industry standards should be developed faster. In this line of thinking, the publication of several performance standards in 2008 marked a turning point in establishing international standards for LED products. That year IESNA developed several standards, among them LM-79 and LM-80 standards. These and other standards allowed a comparison of test results from various laboratories. On the other hand, European Committee for Standardization of electrical products (CENELEC) has prepared different European standards that deal with various requirements that all lighting must comply with. Ambient temperature, protection against electric shock and electrical safety are consequently some of the requirements of the standard that are being checked usually in the laboratories of the manufacturers.

Taking into account all these endeavors, the problem of standard harmonization still remains. Given that a significant investment to make one product for different markets is often required

[18] LEDs magazine, April 2010, page 60.
[19] LEDs magazine, April 2010, page 60
[20] LEDs magazine, April 2010, page 62.

from manufacturers, a coordination of efforts around LED standards across the world is a must. Various requirements that LED products have to satisfy to gain Underwriters Laboratory (North America), CE (Europe), PSE (Japan), CCC (China), CB Scheme and other labels should be harmonized in order not to create confusion for customers.

Increasing utilization of LED lighting is also providing the industry's standardization community with valuable feedback from users of the technology. This is enabling various organizations to revise existing standards and to continue developing new standards and to prescribe best practices for developing and using LED lighting products. Two of those organizations are CELMA and ELC[21] who have made a joint guide of various LED related standards, overview of which is given in the following tables.

Table 9: Overview of various LED related standards[22]

1) Key standards – Safety & Performance

Product type	**Safety Standard**	**Performance Standard**
LED Drivers	IEC 61347-2-13 Published 2006	IEC 62384 Published 2006
LED Modules	IEC 62031 Edition 1 Publication 2008	Draft under preparation
LED self ballasted lamps (>50V)	IEC 62560 Edition 1 Publication expected during 2010	IEC/PAS 62612 Publicly Available Specification published 2009 Publication of IEC 62612 standard expected 2011
LED products	IEC TS 62504 Terms and Definitions for LED's and LED modules in general lighting Publication expected in 2010	

2) Key standards – Photometric Measurement

EN13032-1, EN 13032-2 and EN 15193

3) Standards related to LED products

IEC/EN 60598	Luminaire requirements
IEC/EN 62031	LED Modules for General lighting – Safety Specifications
IEC XXXXX	LED Modules for General lighting – Performance
Pr. IEC 62560	LAMPS – Self-ballasted LED-lamps for general lighting services by voltage >50 V – Safety specifications 34A/1354/CDV
Pr. IEC 62612	Lamps – Self-ballasted LED-lamps for general lighting services >50 V - Performance requirements 34A/1343/CD
Pr. IEC/TR 61341 ed 2	Measurement – Intensity & Angle) – 34A/1340/DTR
Pr. IEC 61231	ILCOS – 34A/1345/CDV
Pr. IEC 62504	LED Terms & Definitions - 34A/1355/DTS
IEC/EN 60061	Lamp Caps and holders
IEC/EN 60838-2-2	Connectors for LED-modules
IEC/EN 61347-1	Lamp control gear - Part 1: General and safety requirements
IEC/EN 61347-2-13	Lamp control gear - Part 2-13: Particular requirements for d.c. or a.c. supplied electronic control gear for LED modules

[21] CELMA – Federation of National Manufacturers Association for Luminaries and Electrotechnical Components for Luminaries in the EU; ELC – European Lamp Companies Federation
[22] Joint CELMA/ELC guide on LED related standards

IEC/EN 62384 + A1	DC or AC supplied electronic control gear for LED modules - Performance requirements
IEC 62386-207	Digital addressable lighting interface - Part 207: Particular requirements for control gears; led modules (device type 6):
IEC/EN 60825-1	Safety of laser products (see Annex A)
IEC/EN 61000-3-2:	EMC - Limits for harmonic current emissions
IEC/EN 61000-3-3:	EMC - Limitation of voltage changes, voltage fluctuations and flicker
IEC/EN 61547:	EMC - Immunity requirements
EN 55015:	EMC - Radio disturbance characteristics
EN 62471: 2008 (IEC 62471:2006 modified) (CIE S 009:2002)	Photobiological safety of lamps and lamp systems (see Annex A to the Guide)
IEC TR 62471-2	Photobiological safety of lamps and lamp systems - Part 2: guidance on manufacturing requirements relating to non-laser optical radiation safety (see Annex A to the Guide)

4) Key regional standards for the Application of LED Based Luminaries (excluding Emergency Lighting)

EN 12464: Light and lighting - Lighting of work places is published in 2 parts: Part 1: Indoor work places; Part 2: Outdoor work places
CIBSE Society of Light & Lighting - Code for Lighting 2006
CIBSE Society of Light & Lighting – Lighting Guide 2 - Lighting for Hospitals & Healthcare Buildings
LM-79-08: IES Approved Method for the Electrical and Photometric Measurements of Solid-State Lighting Products
LM-80-2008: IESNA, Approved Method for Measuring Lumen Maintenance of LED Light Sources

6.) Practical Examples of Successful Tendering of Efficient Products by Local Authorities

Local public owners of street lighting systems have the duty to keep the systems in order to ensure road safety and to fulfill the other functions of public lighting. In the lighting sector there is a large energy saving potential, modernization and refurbishment are therefore key drivers towards energy saving and cost reduction. Public private partnerships (PPP) and performance contracting can be crucial to save energy costs and guarantee quality standards of street lighting systems. Nevertheless, the market for energy savings in street lighting and the potential for increased energy efficiency in the sector are not fully exploited yet. The following examples are seen as best practices in applying LEDs in street lighting.

Example 1: The first motorway in Europe and streets in Torres Vedras Municipality lit by LED street lighting in Portugal

The companies EnergiaViva and Exporlux, contracted by the concessionaire of North of Portugal Highways AENOR/Ascendi, have undertaken the pilot project with the purpose of evaluating the solution for use in future concessions. Along 3.5 kilometres long highway in both directions on the A25 Angeja junction in Portugal, 105 UrbanLED80 lamps replaced 150W sodium vapor lamps and 115 UrbanLED160 replaced 250W HPS lamps. Luminaries were adjusted to existing fixtures, designed for pressure sodium luminaries, so height and distance between fixtures had to be considered in the solution design. This replacement will allow for a saving on consumption that is estimated around 1342.2MWh, or expressed in financial terms of approximately 153 000€. Savings from lamps or ballasts replacement and maintenance during 14 years (60 000 hours) of estimated UrbanLED lifetime are not considered in this value, so the financial savings are actually higher. Furthermore, decrease of the emission of over 40 tons of CO2 per year in Angeja will be achieved.

A similar savings will be achieved by the LED technology used as well in the 3 streets in Torres Vedras Municipality, where 23 fixtures with 80 W LED units will replace 150 W high-pressure sodium lamps. A project undertaken by EnergiaViva and Exporlux companies will bring better light quality during the expected life span of 60 000 hours (14 years), 60% lower energy consumption, easy installation, very robust electrical and optical components and low light pollution. Aforementioned advantages are just some of those that this new technology is bringing, and that have been recognised by other towns and cities in Portugal as well. Since more local communities have started to take a long-term view and are familiarizing themselves with the advantages of this state of the art technology, experts have even commenced to talk about a complete conversion to solid-state technology that should occur in the next several years in Portugal.[23]

Example 2: management of traffic street lights in Berlin (lighting contracting)

The company Nuon Stadtlicht GmbH got a contract with for modernization and maintenance of all 2.000 traffic lights in Berlin. The contractor is responsible for the comprehensive refurbishment and the operation of the systems, first measure was the changing of 618 oldest traffic lights to modern LED lights. The contract duration is 10 years and the city will pay the total amount of 126 Mio. € for this services to the contractor. Before this contract, the city of Berlin had to pay annually at least 10 Mio. € for maintenance and 2,6 Mio. € for new traffic lights. Now the saving of operation costs (and the public budget) are 10,5 Mio. € for the whole contract duration. By the end of 2007, more than 100 traffic lights were already replaced. After finishing the refurbishment by the end of the contract period, 2,75 Mio. kWh annually can be saved through the new installments (equals the amount of 2.750 tons of CO_2 per year).[24]

Example 3: replacement of existing traffic lights with LEDs in London

In August 2009, the mayor of London, Boris Johnson, announced that traffic lights at 300 junctions across London are to be made permanently "green" The plans announced are focusing on the implementation of energy-saving LEDs for a total of 3,500 traffic lights. Johnson said that Transport for London (TfL), the local government body responsible for most aspects of the transport system in Greater London, will install the new systems in order to cut energy use and carbon emissions by 60 per cent compared to existing bulbs. He also added that he intended to accelerate the rollout of LEDs in other applications, noting that they were already being used on roadside ticket machines and bus shelters and could play a major role in cutting emissions across the capital. The £2.4m project is expected to cut total annual carbon emissions by 600 tons, reducing TfL's energy bill by about £200,000 in the process. Shortly after the announcement, Transport for London issued an OJEU (Official Journal of the European Union) notice seeking companies to supply and fit the lights. The scheme is being funded through TfL's Climate Change Fund. TfL ran already a small-scale trial of LED traffic lights in Croydon between January 2007 and August 2008. These trials demonstrated

[23] http://www.ledsmagazine.com/press/19680
[24] www.energiesparende-beleuchtung.de

that a product suitable for the UK marketplace, with reduced power consumption and at a reasonable price was feasible. Alan Bristow, Director of Traffic Operations, TfL said: "These new lights will not only cut CO2 emissions but they will also last about ten times longer than standard bulbs, meaning we will save on maintenance costs. This is part of our efforts across TfL to cut CO2 emissions".[25]

7.) Conclusions and recommendations

Taken together the various advantages as described in chapters above, LED technology has great potential in comparison to more mature street lighting technologies. As shown, LED street lamps meet standard regulations for luminance level and uniformity, deliver significant energy savings, significantly extend fixture lifetime, produce more usable light and support municipalities´ efforts to go green and lower the total ownership costs. The technology can help relieve public authorities ever-present budgetary and environmental challenges as well as improve street lighting quality through features like reduced glare and better color rendering. As there is a large energy saving potential through efficient street lighting, the EU could save 4.3. billion euro in running costs through energy efficient lighting technology each year. With these incentives on the table, street lighting is a potential application for today's increasingly powerful LEDs. Since LEDs have already come of age for traffic lights (see examples), automotive lighting and a host of other products, they are more and more taken under consideration for roadway and pedestrian lighting too. Therefore efforts for developing new standards with implementation of new technical specifications and norms, the convincing of the local public owners of street lighting, transfer of know-how and dissemination of information and experiences should be intensified. Experiences and adapted standards from pioneer countries such as Portugal and Germany should be disseminated to other European countries and best practice examples will support the development of ESCO (Energy Saving Companies) markets for street lighting in such countries. Energy agencies, other experts and mediators can support public owners in the decision process to start with project preparation for street lighting contracting projects and during the implementation phase. For countries with low level of ESCO market development and experiences in this field like the CEEC it is necessary to start capacity building measures and first easy pilot projects for street lighting contracting.[26]

Given a present state of development of LED technology and numerous advantages that its utilization can bring to users, LED technology for street lighting equipment comes as a highly recommended. Even though some would like to emphasize its high initial costs, these can almost be neglected when total cost of ownership is considered. High energy efficiency, no maintenance cost, long lifetime and many other benefits when aggregated and expressed in money terms clearly show that LED technology is surpassing a traditional street lighting products in its benefits. Therefore, when strictly economical cost benefit analysis is being calculated for LED street lighting, arguments come in favor of it. The above-mentioned examples from Portugal, UK and Germany speak for themselves. Big cuts of total annual carbon emissions, better light quality during the expected life span of 60 000 hours (14 years) and 60% lower energy consumption were some of the arguments being used to persuade public authorities in these countries to switch to LED street lights.

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[25] LEDs Magazine, „London Mayor gives Green Light to LED Traffic Signals", found on: http://www.ledsmagazine.com/news/6/8/12, August 2009

[26] Berliner Energieagentur GmbH and Investitionsbank Schleswig Holstein, "Status quo on Street Lighting Contracting in Europe – short study", Berlin, July 2006

However, it is important to assess every situation where a new installation is required as not all aplications might be suitable for LED lighting, and as some of the previous lighting technologies have reached very good levels of energy efficiency, good reliability and durability values under severe conditions.

In the end, after all is said and done, even though the old lighting technologies have come a long way, rapidly developing LED lighting technology is already matured enough to be seriously considered by those public authorities who want to take a more environmentaly friendly approach when bringing their decisions of public importance.

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