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Background for the EUROPEAN LED QUALITY CHARTER

This short report is to a large extent in the format of the European LED Quality Charter and provides reference to quality requirements from organisations around, take care of comments received and gives justification for the performance and other criteria included in the European LED Quality Charter.

1. INTRODUCTION

The European Commission together with several national governments, energy agencies, public and private organisations/industries is promoting the end-use energy efficiency in lighting through several instruments as a key component of the EU energy policy and the common goal of reducing climate change.

In EU, the total domestic lighting consumption is around 86 TWh and it is predicted to raise to 102 TWh by 2020 due to growing welfare especially in some countries and rapidly increasing number of lamps per home. LED lamps efficacy and luminous characteristics are improving very rapidly. In the future, LED lamps are expected to deliver substantial energy savings. LED lamps last 5-25 times as long as the traditional lamps.

GLS and some halogen lamps are about to be phased out due to EU regulation (Eco-design). In many cases, LED lamps are a valid retrofit solution. During this decade it is expected that LED lamps will cover nearly all types of lamps. At present, LED lamps are nearly not used for indoor lighting in the residential sector but the market penetration is starting.

The challenge is to retrofit incandescent lamps with LED lamps of good quality – alternatively users will install mainly new halogen lamps with only slightly lower energy consumption. The barriers for this development are actual high prices for LED lamps of good quality and the variation in performance of LED sources in the market is far too large. Many customers may have bad experience with use of LED lamps and that will threat consumers confidence in LED lighting performance and savings. This might give a delay in market acceptance and a slowing down of the LED penetration rate.

The availability of good quality products is thus most essential along with information about the high energy efficiency and the savings for the consumer. Since the actual price of LED lamps of good quality is high, governments, municipalities and/or utilities may subsidise the LED lamps. A LED quality charter is needed in these activities, to assure public money is spent on lamps delivering real savings.

More than 20 years ago when the CFL product was introduced at the market the situation was quiet similar. After buying the first CFLs many consumer were very dissatisfied and rejected the technology. It took many years and a lot of work to overcome the barriers created during the first years at the market. It is very important not to repeat these failures when the LED is introduced at the market.

Development of the market for LED lamps is thus very important to increase energy efficiency and reduce CO_2 emissions in the European Union. Standards and Eco-design regulation are coming within the next year. The role of the European LED Quality Charter is to set a important voluntary requirements for white LED lamps (not covering LED chips, modules or luminaires) that can be used now by governments, municipality, energy savings, utilities and other active parties to ensure the quality of LEDs on the market.

2. GOALS AND SCOPE

The European Quality Charter for LED is developed in 2010 on the initiative of the European Commission Joint Research Centre (JRC) to support the European initiatives for the Promotion of Efficient Lighting in the Residential Sector.

The scope of the present version LED Quality Charter is limited to **LED lamps intended primarily for use in the residential sector**. At this stage the European Quality Charter for LED does not include LED modules, luminaires and lamps specific for use in the commercial sectors. This limitation is due to the urgent need to publish a quality charter as soon as possible for support of customers replacing banned incandescent lamps (GLS and some halogen lamps), and other promotion programme at national or local level (e.g. white certificates).

The aim of the European LED Quality Charter is to offer a high quality voluntary standard to be used by European utilities, industries and other bodies for:

1. Manufacturing, marketing and/or sales of high quality LED lamps in the European Union
2. Raising consumer awareness and confidence in the LED, by assuring an acceptable quality and performance level are reached.
3. Supporting promotion and procurement campaigns providing quality, comfort, energy and money saving and decreasing the CO_2 emission.

The final goal of the European LED Quality Charter is thus to further increase the sales and penetration of LEDs in the EU and thus contribute to the goals of the EU energy and environmental policies.

The European LED Quality Charter is a voluntary set of criteria established by the European Commission JRC in collaboration with a number of private and public organisations, including:

- NL Agency
- Danish Energy Agency
- The Danish Energy Saving Trust
- STEM
- ……

The above indicated organisations have agreed to support and promote the present European LED Quality Charter in their recommendations to public and private organisations and when running promotion of LED lamps meeting the requirements of the European LED Quality Charter.

3. WHAT ARE the MAIN PROBLEMS WITH LED QUALITY?

The technology and performance of white LEDs are developing very fast. Actually, the availability of specific LED products at the market is very short as new and more efficient LEDs come on the market every six months. For customers buying LEDs one or two times a year, it is difficult if the products are different every time they visit the shop.

Some testing programs[1] have also found that the performance within individual batches of identical sources varied as much as 40%. That indicates that the actual manufacturer has not performed a proper binning maybe caused by downward pressure on pricing increase the temptation for manufacturers to “cut corners”.

Some manufacturers overstate their LED performance and consumers unlucky enough to purchase low performing LEDs (not performing as claimed by the manufacturer) may be very dissatisfied and reject the technology, and the overall reputation of LED will suffer.

LED luminaires and replacement lamps available today often claim a long lifetime, e.g. 50,000 hours. These claims are based on the estimated lumen depreciation of the LED used in the product and often do not account for other components or failure modes. Lifetimes claimed by LED luminaire manufacturers should take into account the whole lighting system. Anyway in order to set requirements quickly in the actual emerging market, the present version of the European LED Quality Charter only sets requirements to the lifetime of the lamp.

LED’s are often integrated permanently into the fixture/luminaire, making their replacement difficult or impossible – this may be could be all right if the lamp lifetime is 50,000 hours but it could be a problem if the lifetime is short. One of the key lessons learned from early market introduction of CFLi[2] is that long life claims need to be credible with appropriate manufacturer warranties.

A very long lifetime of 30-50,000 hours is somehow abstract as the lamps might rest at least 40-60 years pending on the yearly operation time. This means that the lamp might burn longer time than the luminaire is in use, the owner live in the home or live. A much shorter lifetime might be all right if the price of the LED is acceptable (i.e. relatively low) and the quality is preserved.

Both the correlated colour temperature (CCT) and the colour-rendering index (CRI) vary within large intervals. A new study of colour rendering of LED

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1 “The Need for Independent Quality and Performance testing of Emerging Off-grid White-LED Illumination systems for Developing Countries”, Evan Mills, LBNL and Arne Jacobsen, Schatz Research Center, Technical report 1, The Lumina project, August 2007, http://light.lbl.gov.

2 US DOE. “Compact Fluorescent Lighting in America: Lessons Learned on the Way to Market”. 2006.

sources[3] with a paired comparison of halogen and fluorescent to 7 different clusters of LED at 3000K (CCT). They found, that in general, that the colour rendering was found more attractive with some of the LEDs mixing than with standard light sources. In general, alternative scales for measuring the colour rendering are discussed. The investigation finds that neither of the alternative scales for measurement of colour rendering are optimal – they all have their weak and strong points: attractiveness (Gamut is the best scale), naturalness (CRI best) and colour difference (CIECAMO2 best).

The beam characteristics of LEDs are usually determined by discrete optical elements attached to the LED or LED board. The beam and field characteristics are different from a reflector optic with a single source and this might result in a non-circular beam pattern, colour variation across the beam (especially for single LED devices) and failure to achieve good beam definition at beam angles below 24 degrees[4]. For more detailed setting of requirements to LEDs, the rated lumen output of the LED luminaire is thus important. Requirements to the manufactures could be measurement of total luminous flux e.g. by use of photo-goniometer in order to characterize the light-distribution pattern.

Formalisation of product quality and a performance testing process is needed urgently. Independent testing has to start as soon as possible and the results have to reach the key audiences. The availability of standard test procedures can support manufacturers' product development efforts, evaluation of progress towards achieving higher quality (comparison to established benchmarks) and competitive analysis. This will be taken care of in the new IEA 4E SSL annex.

On the other hand, it is important to ensure the cost of testing is not overly burdensome to manufacturers. High-cost testing can be less successful than a more moderate approach because small firms might be unable to afford the entry cost to high-cost testing and some manufacturers might avoid markets where quality assurance is required. The testing methods has to adapt to that LED products have such long lives that lifetime testing and acquiring of real application data on long-term performance can become problematic as new versions of products might be available before current ones are fully tested.

An example of lamp performance measurements including LED lamps can be found at the Renewable Energy Olino web site[5] including use of different fittings.

UV/blue light radiation and high intensity glare are identified as a potential risk factors [6] and quality requirements plus care has to be taken[7].

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[3] "Colour Rendering of LED sources: Visual experiment on Difference, Fidelity and Preference", Jost-Boissard, Fontoynont and Blanc-Gonnet, Ecole Nationale Travaux Publics de l'Etat,CIE Light and Lighting Conference with emphasis on LED, 27-29 May 2009.

[4] Comment from PLDA in the Eup Eco-Design pre study concerning domestic lighting, lot 19, May 2009.

[5] http://www.olino.org/

[6] European Commission Health and Consumer DG, Commitee SCENIHR: "Light Sensitivity" 26th Plenary 23/9 2008, and EU directive 2006/25/EC including photobiological hazard of visible radiation.

[7] Health issues to be considered with lighting systems using LEDs (In French), ANSES, October 2010.

4. EXISTING REQUIREMENTS FOR LED

Different sources describe quality requirements of importance for the consumer when buying LED lamps, modules and luminaires:

- ENERGY STAR
- LBNL reports
- IEC/PAS 62612 Ed.1 "Performance requirements for Self-ballasted LED lamps" giving a complete survey of relevant parameters
- CIE 127:2007 standard addressing individual LEDs
- EU Commisssion Regulation No 244/2009 for NDLS (Non-Directional Lamp Sources) used in the household sector
- EuP Ecodesign suggestions regulation for DLS LED lamps used in the household sector
- ELC+CELMA suggestions on definitions and minimum performance requirements for European regulation concerning directional LED lamps.
- UK EST campaign Ultra-efficient Lighting
- Technical requirements for solid-state lighting products, NLTC, sep. 2010, published by NDRC (National Development and reform Commission), People's Republic of China

On September 30, 2008, the ENERGY STAR Solid-State Lighting (SSL including LEDs, OLEDs and PLEDs) Criteria quality program went into effect. Manufacturers who are ENERGY STAR partners can submit products for qualification, retailers can promote qualified products in their stores and showrooms, utilities and energy efficiency organisations can implement incentive programs for ENERGY STAR products, and consumers can look for ENERGY STAR products meeting the efficiency and performance criteria established by DOE in collaboration with industry stakeholders.

The US Caliper testing program shows many LED lamps suffer from inaccurate performance claims or insufficient color quality. CALiPER along with other DOE commercialization support programs is working with manufacturers, industry trade groups, and standards committees to address issues that may threaten long-term market potential for LEDs. Insight from Round 9 (October 2009) of CALiPER testing is being used to improve and extend criteria for efforts such as ENERGY STAR criteria and the Lighting Facts label program.

The rapid pace of the SSL technology advances led DOE to a two-phase approach:

1. First phase for early participation of a limited range of market-ready products
2. Second phase sets out more rigorous performance targets that are continually updated to keep pace with the technology advances.

The EuP Ecodesign pre-study lot 19 for domestic lighting give a suggestion on how to complete the Commission Regulation (EC) No 244/2009 with the most important minimum requirements for both NDLS and DLS retrofit LED lamps and mention that other or more strong requirements could be the subject of a new European quality label for LED lighting.

March 9th 2010, ELC+CELMA gave suggestions on definitions and minimum performance requirements for new European regulation on directional LED lamps.

The UK EST campaign Ultra-Efficient Lighting concentrating on shifting halogen MR16 and GU10 lamps to equivalent LED lamps (version 1) have set a number of requirements to the LEDs. Version 2 of the program also includes GLS directional, GLS non-directional, R50 and R63 lamps. They also include luminaires in this program.

NDRC (China) has just published “technical requirements for solid-state lighting products” prepared by NLTC (Natioal Lighting Test Center) including definitions, csope and requirements for self-ballasted LED reflector lamps, LED downlights plus LED street/tunnel lighting and finally test methods.

5. REFERENCE STANDARDS AND PROCEDURES

ENERGY STAR refer to clauses in the following standards unless their requirements are more restrictive:

US Standards

- ANSI C78.377-2008 *Specifications for the Chromaticity of Solid State Lighting Products*
- ANSI C79.1– 2002 *American National Standard for Electric Lamps – Nomenclature for Glass Bulbs Intended for Use with Electric Lamps*
- ANSI C78.20 – 2003 *American National Standard for Electric Lamps – A, G, PS, and Similar Shapes with E26 Medium Screw Bases*
- ANSI C78.21 – 2003 *American National Standard for Electric Lamps – PAR and R Shapes*
- ANSI C78.24 – 2001 *American National Standard for Electric Lamps – Two-inch (51 mm) Integral-reflector Lamps with Front Covers and GU5.3 or GX 5.3 Bases*
- ANSI/IEC C81.61-2003 *American National Standard for Electric Lamp Bases*
- ANSI/IEEE C62.41 – 1991 (01-May-1991) *Surge Voltages in Low-Voltage AC Power Circuits, Recommended Practice*
- CIE Publication No. 13.3 – 1995 *Method of Measuring and Specifying Color Rendering of Light Sources*
- CIE Publication No. 18.2 – 1983 *The Basis of Physical Photometry*
- IESNA LM-16-1993 *Practical Guide to Colorimetry of Light Sources*
- IESNA LM-28-89 – 1989 *Guide for the Selection, Care, and Use of Electrical Instruments in the Photometric Laboratory*
- UL 1993 – 1999 *Standard for Self-Ballasted Lamps and Lamp Adapters*
- UL 8750 – 2009 *Light Emitting Diode (LED) Equipment for Use in Lighting Products*

Performance Characteristics Test Procedure

- **Lumen Output and Efficacy:** IESNA LM-79-08 Electrical and Photometric Measurement of Solid State Lighting Products
- **Lumen Maintenance and Life:** IESNA LM-79-08 at T=0 hrs and T=6,000 hrs or other target time; OR IESNA LM-80-08, Approved Method for Measuring Lumen Maintenance of LED Light Sources + IESNA LM-79-08 at T=0 hrs, T=3000 hrs, and T=6,000 hrs or other target time
- **Color Rendering Index:** CIE Publication 13.3 – 1995

- **Transient Protection:** ANSI/IEEE C62.41 (01-May-1991), Category A, 7 strikes
- **Electromagnetic Interference:** FCC 47 CFR including Part 2 (Equipment Authorization) and Part 18 (Technical Standards and Emission Limits) for consumer RF Lighting Equipment limits.

DEFRA has in their study made a survey on standardization, test methods, procedures and activities (presented at stakeholder meeting June 9th 2010):

LED Test Methods and White Papers - ANSI (ANSI typically lends their name to standards developed by other groups, but recently formed the American National Standard Lighting Group (ANSLG)).[8]

ANSI typically does not develop standards. However, recognizing the demand for standards in a particular area, the ANSI Secretary for Committees C78 and C82 established the American National Standard Lighting Group (ANSLG).

The ANSLG Secretary is based out of the National Electrical Manufacturers Association offices, enabling good coordination.

Relevant standards identified:

- ANSI C82.SSL1: “Power Supply”
- NEMA/ANSI C82.77-2002: “Harmonic Emission Limits – Related
- Power Quality Requirements for Lighting”
- NEMA/ANSLG/ANSI C78.377-2008 – “Specifications for the Chromaticity of Solid-State Lighting Products“

LED Test Methods and White Papers - IES (Illuminating Engineering Society of North America is actively developing standards for LED testing).

IES publishes technical documents and jointly develops programmes and standards with other organisations. They have over 10,000 members from a variety of sectors within the lighting industry.

Relevant standards identified:

- IES LM-79-2008: Approved Method for the Electrical and Photometric Testing of Solid-State Lighting Devices.
- IES LM-80-2008: Approved Method for Measuring Lumen Depreciation of LED Light Sources
- IES LM-XX1: “Method for the Measurements of High-Power LEDs”
- IES LM-XX2: “LED Characterization of Light Engines and Integrated LED Lamps”
- IES RP-16 Addendum a & b: “Nomenclature and Definitions for Illuminating Engineering”
- IES TM-16-05: “Technical Memorandum on Light Emitting Diode (LED) Sources and Systems”
- IES TM-21: “Lumen Depreciation Estimation Method for LED Light Sources”
- “IES Application Guide: Guidelines for LED Applications”

[8] The next descriptions of standardisation and testing comes from a DEFRA survey presented June 2010

LED Test Methods and White Papers - CIE (International Commission on Illumination (CIE) is an international not-for-profit lighting standards organization).

The CIE undertakes a variety of activities including: international conferences; development, guidance and publishing of lighting standards. Relevant standards identified:

- CIE 177:2007: "Colour Rendering of White LED Light Sources"
- Technical Report 127-2007: "Measurement of LEDs" (2nd ed) – updating CIE 127-1997

Present CIE TC working in the LED area are:

- Technical Committee 1-69: "Colour Quality Scale"
- Technical Committee 2-46: "CIE/ISO Standards on LED Intensity Measurements"
- Technical Committee 2-50: Measurement of the Optical Properties of LED Clusters and Arrays
- Technical Committee 2-58: "Measurement of LED Radiance and Luminance"
- Technical Committee 2-63: "Optical Measurement of High-Power LEDs"
- Technical Committee 2-64: "High Speed Testing Methods for LEDs"
- Technical Committee 2-66: "Terminology of LEDs and LED assemblies"
- Technical Committee 3-50: "Lighting quality measures for interior lighting with LED lighting systems"
- Technical Committee 4-47: "Application of LEDs in Transport Signalling and Lighting"
- Technical Committee 6-55: "Photobiological Safety of LEDs"

LED Test Methods and White Papers - IEC (International Electrotechnical Commission (IEC) is a standards organisation for electrical, electronic and related technologies). The IEC publishes a range of documents including:

- BS EN 60838-2-2:2006 Miscellaneous lampholders
- IEC 62031 (2008) LED modules for general lighting - Safety specifications
- IEC 60061: Lamp caps and holders together with gauges for the control of interchangeability and safety.
- IEC/PAS 60612 Edition 1: Performance Requirements for Self-ballasted LED lamps.
- IEC 60747-12-3 Discrete semiconductor devices; Part 12-3: Optoelectronic Devices
- IEC 62384 Ed.1. Performance of control gear for LED modules D.C. or A.C. supplied electronic controlgears for LED modules
- IEC 62471-2: Photobiological safety of lamps and lamp systems.
- IEC TS 62504: Terms and Definitions for LEDs and LED modules in general lighting.
- IEC 62560: Safety Requirements for Self-ballasted LED lamps > 50V
- IEC/PAS 62612:2009: Self-ballasted LED-lamps for general lighting services.
- IEC 62663-1: Non-ballasted single capped LED lamps for general lighting - Part 1: Safety requirements
- IEC 62663-2: Non-ballasted single capped LED lamps for general lighting - Part 2: Performance requirements

LED Test Methods and White Papers - NEMA (National Electrical Manufacturers Association (NEMA) publishes technical standards, guides and papers).

NEMA's lighting standard division "LSD" prepares industry standards for solid-state lighting "SSL". NEMA's current standards that pertain to LEDs:

- NEMA LSD 44-2009: "The Need for a New Generation of Sockets and Interconnects"
- NEMA LSD 45-2009: "Recommendations for Solid-State Lighting Sub-Assembly Interfaces for Luminaires"
- NEMA LSD 49-2010, Solid-State Lighting for Incandescent Replacement—Best Practices for Dimming.
- NEMA/ALA LSD-51: "Solid State Lighting—Definitions for Functional and Decorative Applications"
- NEMA SSL-1: "Electric Drivers for LED Devices, Arrays, or Systems"
- NEMA SSL-3: "High Power White LED Binning for General Illumination"
- NEMA SSL-4: "Form Factors"
- NEMA SSL-6: "Solid State Lighting for Incandescent Replacement – Dimming" (working title, may be revised).

LED Test Methods and White Papers - UL (Underwriters Laboratories (UL) provides safety certifiction and testing standards for thousands of products, incl. LEDs). UL Marks appear on over 20 billion products in Asia, Europe and North America. UL has been operating in the lighting industry for over a century.

UL currently has the following safety standard that relates to LEDs:

- UL 153: "Portable Electric Luminaires"
- UL 1012: "Power Units Other than Class 2"
- UL 1310: "Class 2 Power Units"
- UL 1574: "Track Lighting Systems"
- UL 1598: "Luminaires"
- UL 2108: "Low Voltage Lighting Systems"
- UL 60950-1: "Information Technology Equipment—Safety—Part 1: General Requirements"
- UL 8750: "Safety Standard for Light Emitting Diode (LED) Equipment for Use in Lighting Products"

LED Test Methods and White Papers – Zhaga and CITADEL

Zhaga Consortium is a new (February 2010) industry-initiated group set up to discuss, develop and standardize LED interconnections (sockets). Membership includes Cooper, Philips, Toshiba, OSRAM, Panasonic, Zumtobel, Acuity Brands, Havells Sylvania, General Electric and Tyco Electronics. Their standards will address physical dimensions, photometric, electrical and thermal behaviour.

CITADEL (Charactérisation de l'Intégration et de la Durabilité des Dispositifs d'Eclairage à LED dans le Bâtiment) is a French R&D initiative consisting of the French Centre for Building Science and Technology (CSTB), the major French academic lighting laboratories and Philips Lighting-France. Studying use of LEDs in buildings; 3-year project started March 2009, Partly modelled after the US DOE's CALiPER, develop protocols, benchmarking, and will define new metrics and measures of visual comfort and colour rendering for LEDs.

6. EU LED QUALITY CHARTER for LED lamps

Scope

The quality charter is a European voluntary set of requirements for **LED lamps** for use mainly in the **residential sector** as **replacement** for the phased-out incandescent lamps. The Quality Charter is **not a label** to be place on the lamp or lamp package (nor a labelling scheme) but a set of requirements that can be used to ensure high quality in LED manufacturing, marketing, consumer awareness and confidence.

The charter could also apply to use of the products in other sectors (e.g. hotels). The requirements address products from both European and non-European manufactures.

The Quality Charter is mainly intended to be used by utilities and other large purchasers (e.g. supermarket chains) in their promotional campaigns and procurement (e.g. as part of white certificates schemes).

US Energy Star defines an integral LED lamp as **"**a lamp with LEDs, an integrated LED driver, and an ANSI standardized base designed to connect to the branch circuit via an ANSI standardized lampholder/socket"

ELC suggest the definition: "a LED lamp incorporating a LED light source and any additional elements necessary for stable operation of the light source, provided with a lamp cap conforming IEC 60061-1, which cannot be dismantled without permanent damages. The lamp cap is defined as the part of a lamp which provides connection to the electrical supply by means of a socket or lamp connector which holds the lamp in position, usually by having the cap inserted in it".

At the DEFRA stakeholder meeting 9th June 2010, Kathryn Conway, Conway and Silver, defined LED lamps as "Systems that typically include one or more packaged chips; a circuit driver; a thermal heat sink to cool the chips; a housing; and, a lamp base. Often a plastic lens or bulb is used to shape the lamp's light distribution. If the LED chip gets hot inside, it emits less light, so thermal management is crucial for good performance."

The EU Quality Charter use the definition in IEC/PAS 62612, point 3.1:

A self-ballasted LED-lamp is a unit that cannot be dismantled without being permanently damaged, provided with a lamp cap conforming to IEC 60061-1 and incorporating a LED light source and any additional elements necessary for starting and stable operation of the light source. In addition, the content of a lamp is explained: *A LED lamp* typically include one or more packaged LED chips, a thermal heat sink to cool the chips, a housing, and a lamp cap providing connection to the electricity supply. Often a circuit driver is included. Plastic lens or bulb might be used to shape the lamp's light distribution.

Safety

The LED included must be safe both when installed, in use and when they reach the end of their life. The lamps but meet the safety requirements of IEC 60061, IEC 62031 (2008), IEC 62471, IEC 62560 and IEC 62663-1 plus comply with relevant CE marketing legislation.

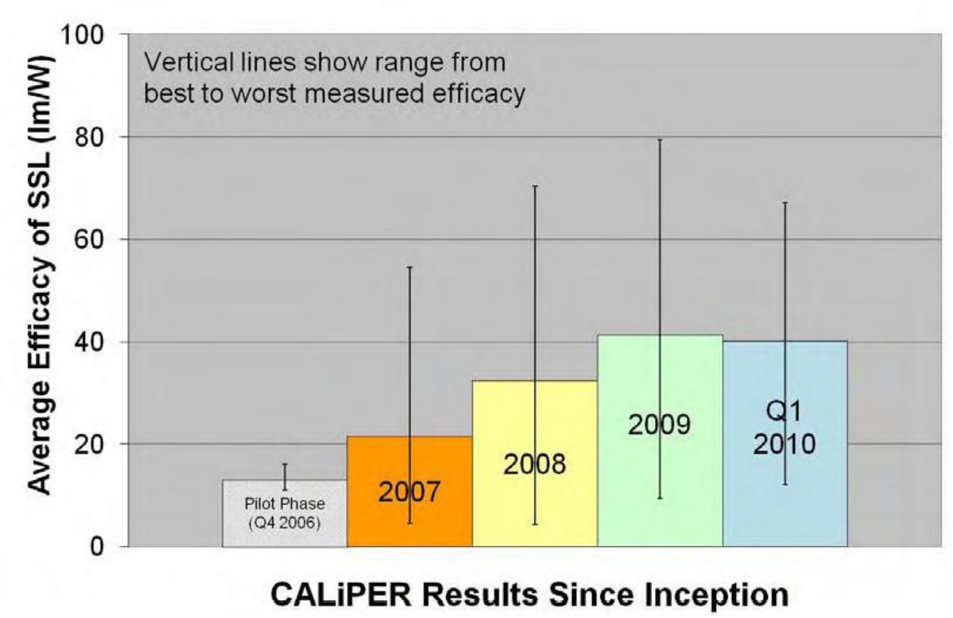
Performance

1. Lamp efficiency

Requirements to minimum lamp efficacy in lm/W is very important and they have to be for real operating conditions and not information for the chip operating at 25°C junction temperature and 350 mA.

Both US Energy Star and UK EST requires that the energy consumption shall be at least 75% less than for incandescent (GLS) lighting for the same quantity of lumen output (lumens). UK EST expect to specify lm/W requirements per lamp type in 2011 (the value might be as high as 90 lm/W).

In general, US Energy Star has the goal of an efficacy as good as or better than for fluorescent lighting which is 60-100 lm/W**.** The last (Round 10, Spring 2010) exhibit a wide range of efficacy from 12 to 67 lm/W with average 40 lm/W (the results for the rounds are depend on what kind of LED products are included in the round).



Actually, US Energy Star requires:

- for non-direct lamps <10W 50 lm/W and ≥10W 55 lm/W.
- for directional lamps <20/8 inch diameter 40 lm/W and >20/8 45 lm/W.

ELC forecast[9] an estimated LED lamp performance a shown below:

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[9] Due to MTP presentation at DEFRA stakeholder meeting 9th June 2010

Year	2009	2010	2012	2015
lm/W	35	45	60	75

In China, minimum efficacy from 2010 is regulated[10] to be:

- 60-65 lm/Watt for NDLS
- 55-60 lm/Watt for DLS

All the requirements in EU Directive 98/11/EC (energy class) and EU Regulation 244/2009 have to be met by any lamp placed in the EU market. According to Regulation 244/2009, non-clear lamps are required to be energy class A with CRI≥80. For lamps with CRI≥90 the requirements are reduced by a correction factor 0.85.

As result due to the above legislation lamps providing an output within the interval 0 –1500 lumen must have the following minimum efficacy:

- Non-clear lamps have to provide at least 61 lm/W
- Non-clear lamps with CRI≥90 have to provide at least 52 lm/W

The EU LED Quality Charter efficiency requirements (including ballast) are[11]:

	CRI	Min efficacy	2011	2012	2013	2014	2015
NDLS	>80	lm/W	61	65	70	75	80
	>90	lm/W	52	55	60	65	70
DLS	>80	lm/W	50	55	60	65	70
	>90	lm/W	40	45	50	55	60

2. Lamp life

High-quality LEDs can maintain high lighting levels for tens of thousands of hours, while the output of low quality products declines more rapidly. Long-term measurements is therefore required (more than one year) so it is important to identify a valid a short-term approach for measuring.

Other lamps typically stops to provide lighting and thus have a clear defined lifetime while LEDs typically continues to provide lighting but gradually with a lower luminous flux. The built-in electronic driver, however, may show a sudden end of life failure.

The LED lamp (not the single chip) lifetime is defined as the period of operation time during which a given fraction of the total number of lamps (Fx) provide more than a pre-defined percentage of the rated luminous flux (Lx), under standard test conditions, eg. $L_{70}F_{50}$ =20,000 hours means that 50% of the lamps give less than 70% of the rated luminous flux after they have been used 20,000 hours.

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10 Technical Requirements prepared by NLTC and published by NDRC in China.

11 In the future, 2012 to 2015 targets might be revised according to the development in the efficacy of the LEDs

The US Energy Star has set the general goal that LED lamp should last 35 - 50 times longer than incandescent (GLS) lighting and about 2 - 5 times longer than fluorescent lighting. US Energy Star also requires the light output shall remain constant over time only decreasing towards the end of the rated lifetime. The goal is thus at least 35,000 hours lifetime equal to use 8 hours per day in 12 years. The minimum is 70% lumen maintenance (L_{70}) after 25,000 hours of operation. The rapid cycle-test is specified to be 2 minutes on/off once for every two hours of the required minimum L_{70} life e.g. 15,000 cycles for a lifetime of 30,000 hours. Additionally is required at least 6,000 hours of lumen maintenance testing with at the end minimum lumens maintenance of 93.1% (L_{70} 30,000 hours) and 91.8% (L_{70} 25,000 hours) for NDLS respectively DLS.

March 2010, ELC and CELMA propose to require $L_{70}F_{50}$ lifetime ≥ 10,000 hours with switching cycle test (half the rated lamp life due to IEC 62612 Ed1) > 5,000 cycles (30 sec on/off) without any failure.

UK EST requires a L_{70} lifetime ≥ 15,000 hours with an ambitious improvement to L_{80} in 2012.

The EuP lot 19 pre-study recommends a minimum rated lamp lifetime $L_{70}F_{50}$ ≥10,000 hours with a future goal ≥ 30,000 hours and it recommends the test include >20,000 (30 sec on/off) (Tier 3) switching cycles (IEC 62612 Ed1) with future goal >100,000 cycles. The EuP lot 19 pre-study also recommends a minimum premature failure rate $L_{85}F_{05}$ ≥ 200 hours which is considered to be very low due to the experience of NLTC in China.

NLTC suggest the requirement $L_{85}F_{05}$ ≥ 1000 hours. ELC and CELMA March 2010 proposed to require a little more by requiring maximum early failure rate (at 10% of rated life in hours (in case that is 10000 hours)) < 2% (lower than 5%).

A very long lifetime of 30-50,000 hours is somehow abstract as these lamps will then burn at least 40-60 years or even longer pending on the yearly operation time – this means that the lamp might burn longer time than the luminaire is in use, the owner live in the home or than the owner remain alive. A much shorter lifetime might be all right if the price of the LED is rather low and the quality else is acceptable.

To evaluate the compliance with the lifetime requirement, data support for the test methods used will be needed. NLTC, China, informs[12] the lifetime related issues are:

- Input Voltage and Current -ripple held to 2%
- Input Current Regulation -regulated within 3%
- Line Voltage Waveshape -Within 3%

NLTC also informs that a demanded test report to assure compliance with the EU LED Quality Charter lifetime requirements shall contain:

1. Number of LED Light Sources tested
2. Description of LED sources

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[12] Personal combination with Kalle Hasmi, STEM, and Dr. Zhang Wei, NLTC, China.

3. Description of auxiliary equipment
4. Operating cycle
5. Ambient conditions airflow including airflow, temperature & humidity
6. Test point temperature
7. Drive current (voltage)
8. Initial luminous flux and forward voltage at current
9. Lumen maintenance data for each LED light source (median, standard deviation, min and max LM values)
10. Chromaticity shift reported over the measurement time. Time point here should be regulated.

The EU LED QC requirements are:

A minimum rated lamp lifetime $L_{70}F_{50}$ ≥15,000 hours for typical operating condition (not information for the chip operating at 25°C junction temperature) with future goal of reaching ≥ 30,000 hours. Testing shall follow IEC/PAS 62612 Ed1 including a temperature cycling shock test and a supply voltage switching test with a number of cycles equal to half of the rated lamp life without any failure.

A minimum premature failure rate $L_{85}F_{05}$ ≥ 1000 hours meaning that maximum 5% of the lamps have lumen maintenance below 85% after 1000 hours.

3. Stabilised lighting output

It is important to set requirement to how fast the light should come on when turned on.

US Energy star requires the light should come on instantly when turned on.

March 2010, ELC and CELMA propose to require starting time < 0.5 sec and run-up time to 95% rated lumen output < 30 sec. This is a rather unusually long period of time, as LED don't seem to require such long run-up periods. NLTC (National Lighting Test Centre) in China informs that since LED is a digital technology, starting time < 0.5 sec and run-up time to 95% rated lumen output < 2 sec would be met without any problems. NLTC will continue to test to see if it is necessary to specify such requirements.[13]

EU LED QC requirements are:

- **Starting time < 0.5 sec**
- **Run-up time to 95% rated lumen output < 2 sec.**

4. Colour temperature and colour rendering

Alternative scales for measuring the colour rendering are discussed and investigation finds that neither of the scales are optimal as they all have their

[13] Personal communication with Kalle Hasmi, STEM, and Dr. Zhang Wei, NLTC.

weak and strong points: the scale Gamut seems to be best concerning attractiveness, CRI seems to be best concerning naturalness and CIECAMO2 seems best to identify colour difference. Several organisations including CIE and NIST are working at improving the measure. This will take some time and until a new and accepted measure is developed, the CRI scale is used.

US Energy Star requires:

- CRI (Colour Rendering Index) minimum 80 for indoor applications.
- CCT (Correlated Colour Temperature) limited to warm white ANSI bins (nominal 2700, 3000, 3500 and 4000 with defined tolerance).

The UK EST program requires:

- CRI >80 in 2010, > 85 in 2011 and >90 in 2012.
- CCT target range 2700-3500 K.

In the future, UK EST expect to set requirements to maintenance of CRI and CCT.

The Eup Ecodesign lot 19 pre-study for domestic lighting requires for any LED lamp that is referred to as being a 'halogen or GLS retrofit lamp':

- CRI should minimum be 80 with future goal 90. Verification method: CIE 13.3 - 1995.
- CCT should maximum be 3200 K with future goal 2700-2900 K.

EU Regulation No 244/2009 excludes household lamps with chromaticity coordinates x and y:

- — x < 0,200 or x > 0,600
- — y < – 2,3172 x2 + 2,3653 x – 0,2800 or
- y > – 2,3172 x2 + 2,3653 x – 0,1000

The EU LED QC requirements are:

- **CRI >80. Testing due to CIE No. 13.3 – 1995.**
- **CCT in the interval 2600 – 3500 K. With reference to IEC/PAS 62612 Ed.1. and IEC 60081, Annex D.2 modified, the rated colour of the lamp shall preferably be one of the three values: F2700 (CCT=2720, X=0.463 and Y=0.420), F3000 (CCT=2940, X=0.440 and Y=0.403) or F3500 (CCT=3450, X=0.409 and Y=0.394). Testing: A tolerance category of 7-step MacAdam ellipse size shall be assigned as maximum spread, that includes (circumscribes) the chromaticity co-ordinates of all LED lamps in the tested sample.**

5. Dimensions

UK EST requires the dimensions of the existing lamp outlines or that it fits existing luminaire.

US Energy Star requires dimensions are not to exceed target diameter and length as per ANSI C78.20.2003.

March 2010, ELC and CELMA propose to require that directional retrofit LED lamps shall be designed physically and functionally to replace GLS and halogen reflector lamps with reference to the maximum outline specified by IEC.

EU LED QC requirements:

Directional retrofit LED lamps shall be designed physically and functionally to replace GLS and halogen reflector lamps with reference to the maximum outline specified in IEC 60630.

6. Glare, Light distribution and Blue light hazard

Measurement of the intensity of light from the source itself is important given the small size of LED lights and their corresponding brightness, which can cause discomfort glare as well as injury if users look directly into the light e.g. a test report [14] informs glare varied by a factor 1.4 and that glare was above the acceptable threshold in most cases. Unfortunately, many DLS applications with halogen lamps also give glare. At least, the problem should not be increased with use of LED lamps. Limiting glare (UGR) values are specified for many commercial applications.

US Energy Star requires brightness equal to or greater than existing lighting technologies and well light distribution over the area lighted by the fixture.

Blue light hazard is a very important issue that many people. In France[15], they have made some calculations based on the 2006/25/EC directive and found that for some cold white LEDs with flux higher than 200 lm should be considered as class 2 hazard = irreversible eye damage for exposure time in the order of 50 to 100 seconds while warm white LEDs are always class 0 with no risk. For class 2 lamps (available at the market), UK recommends to mark on the LED package to use protection glasses.

It could be recommended that brightness shall stay lower than 15,000 cd/m^2[16] in direct vision (= that the eye can see at normal standing or sitting position) for CCT corresponding to cold and neutral white while higher values might be acceptable for CCT corresponding to warm white. This requirement is directly linked to the blue light hazard for the retina[17].

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[14] "Measured off-grid lighting system performance", Evan Mills, LBNL and Arne Jacobsen, Schatz Research Center, Technical report 4, The Lumina project, December 2008, http://light.lbl.gov.

[15] Personal communication with professor Georges Zissis, LAPLACE University Paul Sabatier, Toulouse, France.

[16] Empirical value used by lighting engineers with origin from CIE work

[17] CIE Light and Lighting Conference with Special emphasis on LEDs and Solid State Lighting, May 2009, "Assessment of Optical Radiation Hazards of LEDs", Prick von Nandelstadh, Finnish Institute of Occupational Health, New Technologies and Risks, Helsinki, Finland.

EU LED Quality Charter requirements:

The visible radiation hazard class (ranging from 0 to 3) shall be 0 or 1 for all LED lamps sold in the residential marked.

7. **Dimming, automatic daylight shut-off and/or motion sensors**It is important to know if the lamp is available with dimming, automatic daylight shut-off (especially important for outdoor models) and/or motion sensors.

LENI (Light Efficiency Numeric Indicator) will require there are LE lamps including occupancy sensors and daylight sensors and perhaps also brightness sensors at the market primary for use in the commercial sector but this information may be passed on for application in the household sector.

For some indoor models, US Energy Star requires the LED lamp shall be available with dimming. For some outdoor models, US Energy Star requires that automatic daylight shut-off plus motion sensors shall be available.

UK EST requires that dimmable LED lamps shall be compatible with all dimmers available through major retailers. In the future, UK EST expect to require that all lamps shall be capable of dimming.

EU LED QC requirements:

No performance requirements concerning dimming.

8. **Stroboscope effect and flicker**

Power supplies using pulse-width modulation makes the LED blink/flicker with a certain frequency (typically between 100 and 150 Hz). The flicker frequency is not directly visible but may lead to: a) Stroboscopic effects on rotating objects (making it look like it is not moving or like it rotates at another speed or direction). b) "Cascades" of bright points in the visual field when moving the visual direction rapidly i.e. when turning the head.

US Energy Star requires the frequency ≥120 Hz and no flicker when the LED is dimmed at all light output levels.

EU LED QC requirements:

The frequency is required to be ≥100 Hz. No flicker must appear when the LED is dimmed covering all light output levels.

9. Power factor

There is no power factor regulation requirements for appliances and lamps with power below 25W which include all LED lamps for sales as replacement lamps for incandescent lamps.

For thirty years, it has been discussed whether the potential benefits to the electric grid of requiring high power factor CFLs and later LEDs outweigh the potential costs and risks that such requirements would produce. The debate often expose a lack of understand of the difference between active, reactive and apparent consumption and that the concept of the power factor (PF) is based on the fundamental frequency (50/60 Hz) whereas in practice we are dealing with non-linear loads leading to the presence of harmonics there might be of more concern than the power factor.

The LED active power consumption (lamp and active power grid losses) are the same independent of the size of the power factor. The size of the losses in the grid from reactive and harmonic currents are dependent on the sum of power for all lamps and appliances connected to the actual grid. The reactive load in the grid is often inductive whereas the switched electronics in LED contribute with capacitive reactive power thus counteracting the inductive part[18]. The apparent consumption in the grid might in that respect even benefit shifting from incandescent lamps to LEDs or CFLs.

It is important to note that the consumption per lamp change to be several times lower when shifting from incandescent lamps to LEDs regardless of if the size of the PF is 0.5-0.6 (typical value) or higher for the LEDs.

In the domestic sector, lighting constitutes around 15-17% of the total consumption. Replacement of incandescent lamps by LEDs will reduced the lighting consumption to less than 5-8% of the total domestic consumption. This explain why practical measurements on the total domestic load find no significant noticeable changes due to changing to LED/CFL lighting. The addition of other appliances like a heat pump, washing machine or dish washer impacts the reactive power consumption and harmonic distortion much more.

Addition of a PF corrector-circuit in a LED changing the frequency content might have both positive and negative consequences e.g. Swedish waveform investigations at Luleå University[19] showed that the corrector-circuit reduced the distortion for low-order harmonics but introduced new types of distortion where the practical consequences are unknown. Anyway, the measurements at Luleå at domestic customers, in a hotel and in the laboratory did show that there is no need for requirements for lamps below 25W.

A new report[20] reviews and summarizes the current power factor findings available documented research results from the last 15 years including laboratory research, experimentation, simulation, field installation plus measurements and interviews with researchers and policy experts. This report conclude with relative certainty that the totality of the research to date, and especially field research, has not proved that CFLs or LEDs with high power factor are needed or even beneficial. Current data indicate that a high power factor LED does not deliver any additional value to either the grid-operator or the end-user under most conditions, other than in cases of isolated, micro, or mini grids with high peak lighting loads. The report state that addition of corrector-circuit gives a number of disadvantages:

- consumes a small amount of additional power,

[18] Communication with Peter Bennich, STEM (referring to the Swedish Lulå project in 2010), and others.

[19] Waveform distortion due to new types of lighting, Luleå University of technology, September 2010.

[20] Power factor: Policy implications for the scale-up of CFL programs, USAID, Dec. 2010

- generates a small amount of heat that might speed the failure of other components in the ballast compartment,
- gives more electronic waste material,
- can affect the LED reliability as a new potential ballast failure point is introduced,
- might increases the lamp size from the added electronics,
- typically adds an estimated 15-25% to the cost.

The first version of US Energy Star didn't include requirements to the power factor while the current version requires 0.7 for residential products. Due to the last rounds of the US Caliper testing[21] the power factors are within the interval 0.52-0.99 (Round 7) and 0.31-1.00 (Round 8) with most LED lamps having a power factor in the interval 0.5 – 0.6. PF is not shown in the Round 9 and 10 reports that seems to concentrate on the information included in the Lighting Facts label.

From the manufactures side, both NEMA (US)[22] and ELC (Europe)[23] have published position papers that support that existing regulation is adequate and that additional power factor requirements would be counterproductive. In ELC comments of 9 March 2010 concerning Directional LED lamps to become part of a new European Regulation, ELC recommended a minimum power factor of 0.5 for lamps of 2-25W.

In conclusion, the current power factor documented research results referred above clearly states that a minimum power factor of 0.5 is appropriate for LED of wattage below 25W in the European countries. This conclusion was agreed by all participants in the EU LED Quality Charter meetings.

European LED Quality Charter requirements:

Minimum power factor of 0.5 for lamps of wattage 2-25W.

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[21] Caliper Summary Report, January 2009, Round 7 and 8 of products testing (prepared for DOE), that are available at http://www1.eere.energy.gov/buildings/ssl/caliper.html

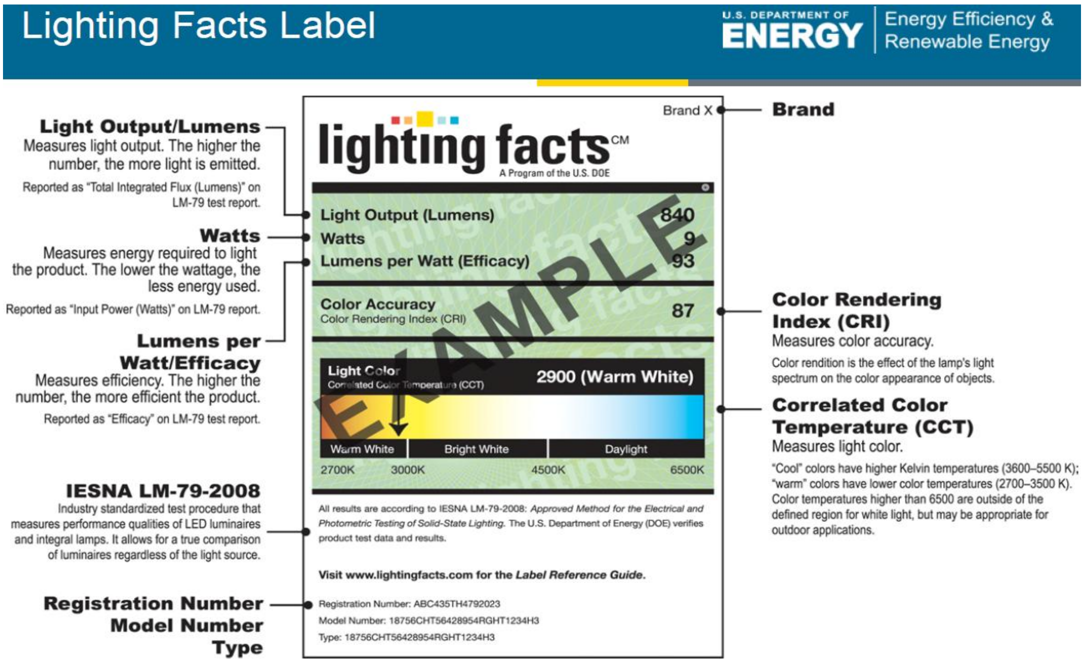
[22] National Electrical Manufacturing Association (NEMA), 1999, Power Quality Implications of Compact Fluorescent Lamps in Residences, LSD-8-1999.

[23] European Lamp Companies Federation, Mains Power-Quality Effects by Electronic Lighting Equipment, May 2009, and ELC, Power factor of energy-saving lamps with an active input power <25W , Sep. 2010.

Information at Package

10. Watt, Rated Lumen Output, Life, Energy label

The US Lighting Fact Label program managed by DOE require information about Lumen Output, Watt, Lumen/W, CRI and CCT shall be shown on the individual package of each lamp.



EU Regulation 98/11/EC specify energy labelling of household lamps. The revised energy label will require display of energy class, lumen, estimated yearly energy cost (instead of W), CCT, lifetime and wattage. In addition, beam angle is also required for DLS.

EU Regulation No 244/2009 specifies to display lumen output, life time, CCT, warm-up time and a warning if the lamp can't be dimmed.

11. CRI

EU LED Quality Charter **recommends that CRI is displayed at the package**.

12. Comparison of LED lamps with GLS and/or halogen lamps

The US Energy Star requires for replacement lamps product packaging, supporting documents and marketing material may only reference ANSI standard lamp types indicated on Energy Star product application providing the following information: 1) Lamp type e.g. A, R, MR, PAR etc., 2) Size e.g. A19, MR16, PAR38 etc., 3) Wattage and 4) beam angle for directional lamps.

For non-directional lamps US Energy Star respectively EU Commission regulation No 244/2009 for NDLS household lamps requires minimum initial light output as specified below:

Lamp to be replaced (Watt)	Minimum initial light output of LED lamp (lumens)	
	US Energy Star	EU No 244/2009
15	-	136
25	200	249
35	325	396
40	450	470
60	800	806
75	1000	1055
100	1600	1521
125	2000	1987
150	2600	2452
200	-	3459

For directional lamps US Energy Star requires the lamps shall have minimum light output equal to the target wattage of the lamps to be replaced multiplied by 10, e.g. for a 60W lamp 600 lm.

For directional lamps the March 2010 paper from ELC and CELMA propose the minimum initial light out as shown below. For all 230V lamps the proposed levels are very low and very much below the requirements of US Energy Star.

ELC+CELMA equivalence proposal March 2010

Low voltage (12 V) Reflector type		
Type	Wattage	Flux 90° cone
MR11 GU4	20	200
	35	400
MR16 GU 5.3	20	200
	35	385
	50	600
AR111	35	350
	50	550
	75	800
	100	1050
Mains Voltage (230 V) Blown Glass Reflector type		
Type	Wattage	Flux 90° cone
R50/NR50	25	90
	40	170
R63/NR63	40	180
	60	300
R80/NR80	60	300
	75	350
	100	580
R95/NR95	75	350
	100	540
R125	100	580
	150	1000
Mains Voltage (230 V) Pressed Glass Reflector type		
Type	Wattage	Flux 90° cone
PAR16	20	90
	25	125
	35	200
	50	300
PAR20	35	200
	50	300
	75	500
PAR25	50	350
	75	550
PAR30S	50	350
	75	550
	100	750
PAR36	50	350
	75	550
	100	720
PAR38	60	400
	75	555
	80	600
	100	760
	120	900

Depending on the beam characteristics of the Directional lamps, ELC + CELMA requires a correction factor shall be applied to the above lumen values with seven beam-width categories representing available GLS, halogen and CFL-i reflector lamps.

Lumen correction factor according beam-width category

Group NSP 3 – 9°	Group SP 9 – 15°	Group NFL 15 – 20°	Group FL 20 – 30°	Group WFL 30 – 40°	Group VWFL 40 – 60°	Group XWFL > 60°
Min Flux (lm) % of reference	Min Flux (lm) % of reference	Min Flux (lm) % of reference	Min Flux (lm) % of reference	Min Flux (lm) % of reference	Min Flux (lm) % of reference	Min Flux (lm) % of reference
80%	85%	90%	100%	100%	100%	100%

The new EU ecodesign for directional LED lamps is expected to specify the minimum light output equivalence.

The EU LED QC **will refer** EU regulation 244/2009 and the new regulation for directional LED lamps.

13. Retrofit labelling

March 2010, ELC and CELMA propose to require that directional retrofit LED lamps shall be designed physically and functionally to replace GLS and halogen reflector lamps with reference to the maximum outline specified in IEC. They also propose LED lamps can be called “Retrofit” with reference to type of lamp and cap. For halogen, “Halogen Retrofit” is suggested for LEDs with CCT between 2600 and 3200 K, CRI ≥ 90, fully dimmable in 230 V or 12 V system, operational with conventional or electronic transformers and fulfilling the general requirements to dimensions.

The EU LED QC **will not include any requirements.**

14. Dimming, automatic daylight shut-off and/or motion sensors

It is important to know if the lamp is available with dimming, automatic daylight shut-off (especially important for outdoor models) and/or motion sensors.

US Energy Star requires the product packing must clearly indicate whether the lamp is dimmable or not dimmable and manufactures must provide dimmer compatibility information at their Web page.

The EU LED QC **will not include any requirements**.

Guarantee and Quality Assurance

15. Warranty and Safety

US Energy Star requires minimum three-year warranty.

In EU, the warranty is already two years by law.