Topten Product Criteria Paper on

Light Emitting Diodes (LED's) For Directional Lighting

Marcus Hofmann

AEA – Austrian Energy Agency

30.11.2011

Supported by

Supported by
INTELLIGENT ENERGY
EUROPE

Coordinated by

ADEME
Agence de l'Environnement
et de la Maîtrise de l'Energie

The Project in brief

Topten is part of the international Euro-Topten Plus initiative supported by the European programme Intelligent Energy Europe and several national institutions (energy agencies, WWF, consumer associations, research institutes). On global level, Topten is coordinated by TIG, the Topten International Group. This association promotes to the Topten Charter, TIG statutes and Rules of Procedure (www.topten.eu).

Topten is a service that supports the market for energy efficient products. It aims at making energy efficient products the first choice for consumers, by offering them a user-friendly tool for product comparison and selection. The key element is an online information platform for consumers presenting the most energy efficient appliances currently available in various product categories, including household appliances, office equipment, consumer electronics and cars. Information on energy consumption and performance of products as well as several other characteristics (i.e. brand, model, price, picture) is provided. Product data is based on labels and standardized declarations as well as tests from accepted well-known institutions. The service is independent of manufacturers and retailers.

Consortium

The project is co-ordinated by the Agence de l'Environnement et de la Maitrise de l'Energie (ADEME). The other 19 project partners are:

Project Partner	Country
Austria : Austrian Energy Agency	AT
Belgium: World Wide Fund for Nature – vzw/asbl	BE
Belgium: WWF European Policy Office	BE
Czech Republic: SEVEn, o.p.s	CZ
Finland: Motiva Oy	FI
France: WWF Fonds Mondial pour la Nature	FR
Germany: dena, Deutsche Energie-Agentur	DE
Germany: Oeko-Institut e.V.	DE
Germany: Wuppertal Institute	DE
Germany: ICLEI, European Secretariat	DE
Greece: WWF Greece	GR
Italy: WWF Italia Onlus	IT
Lithuania: LNCF, consumer federation	LT
Luxemburg: Oeko-Zenter, asbl	LU
Norway: Norges Naturvernforbund	NO
Poland: FEWE Polish Foundation for Energy Efficiency	PL
Portugal: Quercus	PT
Romania: ICEMENERG	RO
Spain: ADENA / WWF, Asociacion para la defensa de la natureza	ES

Contact

Therese Kreitz (project leader)
500, routes des Lucioles
F-06560 Valbonne
France
+33(0)493957984
therese.kreitz@ademe.fr

Sophie Attali
20 place de la Chapelle
75018
Paris
+331 8394 8209
so-phie.attali@topten.info

Eric Bush
Rebweg 4
7012 Felsberg
Switzerland
+41 81 252 63 64
info@topten.info

Marcus Hofmann
Mariahilfer Strasse 136
1150 Vienna
Austria
T: +43 1 586 15 24 - 143
mar-cus.hofmann@energyagency.at

Contents

1 Introduction

Starting in 2006, the European Commission (Commission) initiated a study of domestic lighting products titled, Lot 19: Domestic Lighting; Preparatory Studies for Eco-design Requirements of Energy Using Products. Originally slated to cover all domestic lighting products, the analysis is now in two parts: non-directional general service domestic lamps (part one) and directional lamps combined with household luminaires (part two). The Preparatory Study for Lot 19 part one was finalized in October 2008 and the COMMISSION REGULATION (EC) No 244/2009 has already been published in March 2009. However, for LEDs this regulation only sets minimum requirements on lamp efficiency, lumen equivalency with incandescent lamps and product information requirements. Functionality requirements for LED lamps (like lamp lifetime, switching behaviour, starting time, colour rendering, etc.) have not been included.

The European Commission is currently evaluating ecodesign requirements, i.e., minimum efficiency performance standards (MEPS), and energy labelling proposals for directional lamps as the second part of the so-called domestic lighting ecodesign requirements (Lot 19). A new EU Ecodesign Regulation “Directional lighting: luminaires, reflector lamps and LEDs” (expected in the first quarter of 2012) will include the missing functionality requirements and cover the remaining (LED) products like directional LED lamps (spots).

This paper contains the product specification for Topten Light Emitting Diodes (LED’s) for directional lighting. Within the methodology of WP3, it was intended to use the implementation measures of the Ecodesign directive as a basis for the criteria definition. The information provided in this criteria paper is therefore mainly based on the “Preparatory studies for Eco-design Requirements of EuPs – (Tender TREN/D1/40-2005) Lot 19: Domestic lighting, 2009” and on the corresponding drafts of implementing measures and the discussion papers of the consultation forums.

The purpose of this criteria paper is to provide a common basis for the selection of criteria for the specific product group as a basis for the national website. It is a clear goal to consider the same basic criteria for products throughout the Euro-Topten network. However, the range of products differs significantly in European member States in terms of price level, configuration, energy classes and energy consumption corresponding to levels of purchasing power and behavioural aspects (mentality, customs, etc.). Consequently, specific quantitative thresholds for the individual criteria as a basis for the Topten lists may be different from country to country.

2 Product Definition

This chapter provides an overview of Light Emitting Diodes (LED's). It also gives a technical analysis of the product and some background information.

2.1 Technical principle of a LED

A Light Emitting Diode (LED) is a semiconductor light source. It has the characteristics of a diode, i.e. it only allows electrical current to flow through in one direction, from the anode to the cathode, thus producing light of a specific colour. Simply put, the LED works on the reversed principle of a solar cell. Whereas the solar cell transforms (sun) light into direct current – the LED turns direct current into light.

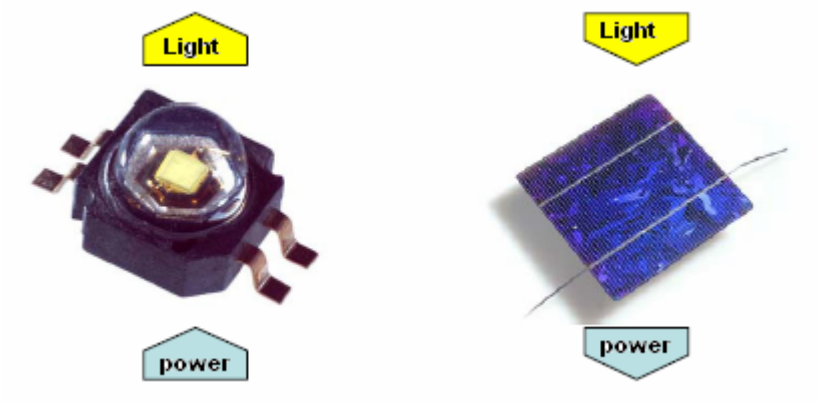

Figure 1 Principle of a LED[1]

In the early 1960ies, the red LEDs were invented and used for watches. 10 years later green and yellow LEDs came on the market. The blue LED, which is necessary for generating white light, was invented in 1995. Blue LED light is generated on the basis of the semiconductor material gallium nitride (GaN) or gallium-indium nitride (GaInN). For conversion into white light, the blue LED is coated with phosphors (eg. yellow). Depending on the concentration and color of the phosphor, different white tones can be generated.

The typical white LED chip today is 1 mm² in size, takes on an electrical power between 1 and 5 watts, and has a range from 50 to 150 lumens of visible light. The higher-wattage LEDs are realized by lining up single chips. For example, 2009 modules offered capacities of up to 100 watts.

[1] Source: Qualitätsmerkmale der LED-Beleuchtung – Aktueller Stand der Technik, Vorteile, Problempunkte und Entwicklungspotential, Bundesamt für Energie BFE, Auftragnehmer: eteam GmbH, Autor: Stefan Gasser, 1.09.2099

The maximum size is limited by the possibilities of heat dissipation. The emitted light beam of the LED does not contain any infrared components and therefore produces no heat. But the heat is produced on the back of the LED due to the warming of the semiconductor material. Temperatures above 60 degrees reduce the life time of the LED, as well as their light output. If overheated, the LEDs are destroyed.

2.2 Development trends

In recent years, the main focus in the development of LEDs has benn the field of energy efficiency. The development of energy-efficient LEDs is shown in the chart below. In the years 2003 to 2009, the efficiency of LEDs has tripled. In 2009 it reached the efficiency of the energy saving lamp. In the next 10 years a doubling of the efficiency is expected.

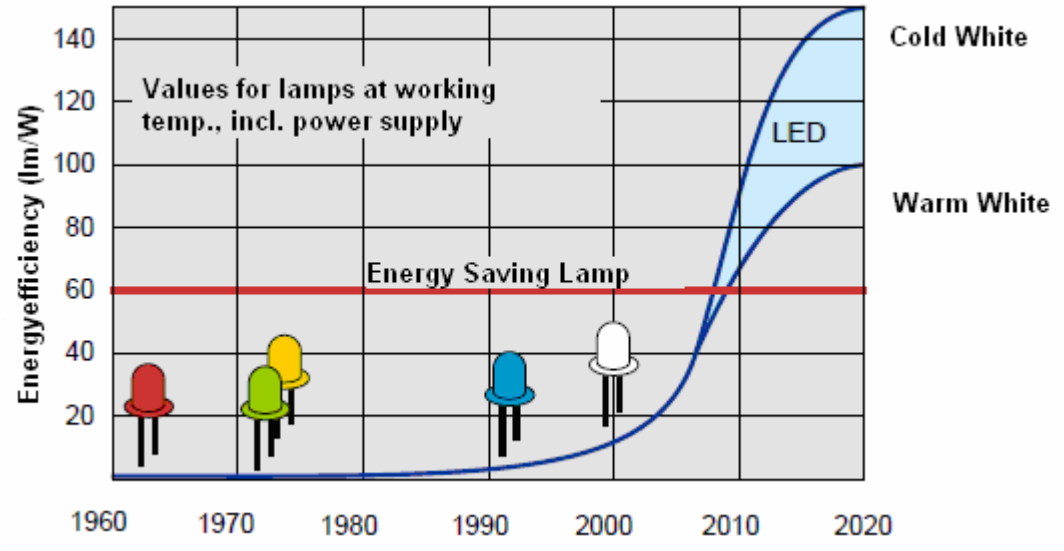

Figure 2 Development of energy efficiency[2]

In addition to the (mono-crystalline) LEDs, work on the development of organic light-emitting diodes (OLED) is ongoing as well. In the future, OLEDs could tackle the material and cost problem currently encountered in LED's. OLEDs are a flat display technology (see Figure 3) realized by placing a series of organic thin films between two conductors. When electrical current is applied, a bright light is emitted. This technology is well suited for indoor area illumination and could appear as "glowing wall paper" without the need for luminaires.

[2] Source: Qualitätsmerkmale der LED-Beleuchtung – Aktueller Stand der Technik, Vorteile, Problempunkte und Entwicklungspotential, Bundesamt für Energie BFE, Auftragnehmer: eteam GmbH, Autor: Stefan Gasser, 1.09.2099

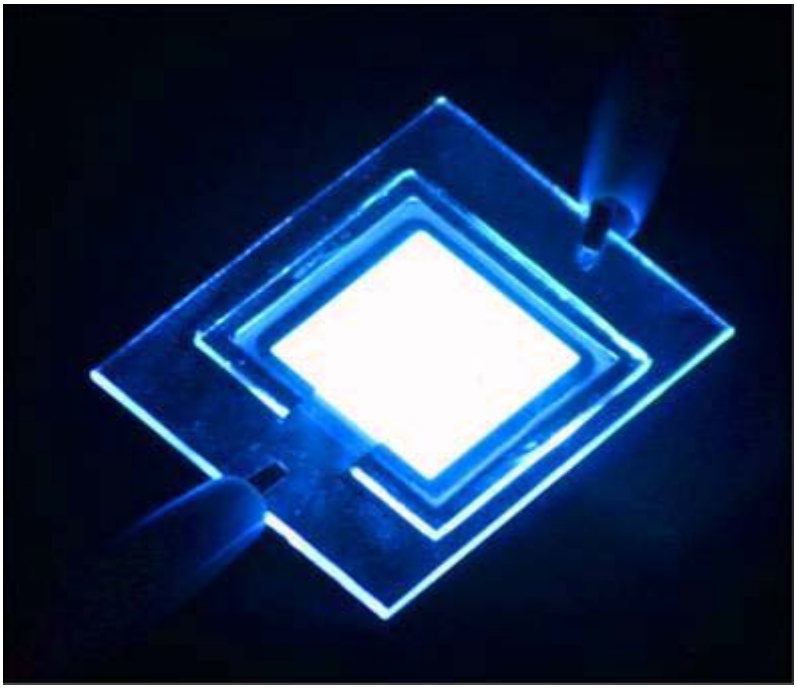

Figure 3 OLED prototype (Picture courtesy of OLLA project)[3]

OLEDs based on organic material are still part of current R&D. The first OLEDs are already on the market for particular very flat illuminated displays in portable devices, but not yet for domestic general lighting applications. The current OLEDs still have to prove their efficacy in working conditions (e.g. temperature and required life time). OLEDs are therefore classified as "Best Not Available Technology" (BNAT) and will not be considered in further chapters.

2.3 Quality criteria of LEDs

2.3.1 Key quality criteria

Three key quality characteristics are crucial for LED technology:

- **Lamp efficiency:** this is the quotient of the luminous flux[4] emitted (Φ) and the power consumed by the lamp (P_{lamp}). With values of 40 to 95 Lumen/Watt (lm/W) when in use, current LED lamps on the market are competitive with energy saving lamps. The average energy efficiency of high quality LED products lies in the range of 50 to 60 lm/W. The best value measured for a

[3] Source: Qualitätsmerkmale der LED-Beleuchtung – Aktueller Stand der Technik, Vorteile, Problempunkte und Entwicklungspotential, Bundesamt für Energie BFE, Auftragnehmer: eteam GmbH, Autor: Stefan Gasser, 1.09.2099

[4] 'Luminous flux' (Φ), which is a quantity derived from radiant flux (radiant power) by evaluating the radiation according to the spectral sensitivity of the human eye, measured after 100 hours of lamp running time.

product available on the market was 95 lm/W. The energy efficiency of an compact fluorescent lamp (CFL) is about 60 lm/W. Fluorescent lamps reach 100 lm/W. Experts expect the luminous efficiency of LEDs to double within the next five years. The real issue is that, at present, declaration is often poor and sometimes the declared values seem to be mere phantasms.

- **Light quality:** The quality of color is expressed through the so-called color rendering index (CRI or Ra)[5]. The best value is Ra = 100. Today's good LEDs reach a color rendering index of 80 to 95, with a continuous light spectrum (for CFL, Ra = 80 to 90). Fluorescent lamps reach an index of 80 to 90. Incandescent lamps and halogen lamps reach a maximum of 100.

- **Lamp life:** A lamp life of up to 50000 hours can only be reached if the heat dissipation is ensured and if the quality of the electronic control unit keeps up with the LED's life time. According to the experts, many of today's LED products on the market don't meet these two requirements. The life time of a LED is very difficult to determine without measurements. Realistic values given by manufacturers for LEDs used in practice today are about 25000 hours.

Spots are used for the targeted illumination of objects or surfaces, therefore it is called "directed lighting". An additional quality aspect for directed lighting is the maximum luminous intensity in candelas, together with the angle in degrees.

- **Luminous intensity:** Is a measure of the wavelength-weighted power emitted by a light source in a particular direction per unit solid angle, based on the luminosity function, a standardized model of the sensitivity of the human eye. The SI unit of luminous intensity is the candela (cd).

2.3.2 Additional quality criteria - colour temperature

The correlated colour temperature (Tc [K]), is the temperature of a Planckian (black body) radiator whose perceived colour most closely resembles to that of a given stimulus of the same brightness and under specified viewing conditions.

The color temperature has nothing to do with the quality of light but very much with the subjective perception and habit. The color temperature indicates the amount of red or blue light. Reddish light is referred to as warm white, blue light as cold white. In

[5] 'Colour rendering index' (Ra), which is the effect of an illuminant on the colour appearance of objects by conscious or subconscious comparison with their colour appearance under a reference illuminant.

between is the so-called neutral white. The color temperature is measured in Kelvin. Especially in the household sector, a warm white light is generally prefered.

- Warm white: 2700 to 3500 Kelvin (2700 K incandescent lamp, halogen lamp 3000 K)
- Neutral white: 3500 to 5000 K
- Cool white: 5000 to 10000 Kelvin (Daylight 6500 K)

The problem is that for the currently offered products a very wide range of color temperature for LEDs is available which is a consequence of the large manufacturing tolerances[6]. There are products available with specific and accurate color temperatures, but at relatively high-cost.

It is currently discussed to define standard values / fixed color temperatures, similarly to FLs (proposed in the LED quality charter[7] and as requirement in the new regulation)

- Bulbs (halogen and incandescent): range between 2500 to 2800 Kelvin
- Fluorescent: fixed color temperatures: 2700, 3000, 4000, 5400, 6500 Kelvin
- LEDs: all versions between 2700 and 10000 Kelvin

2.3.3 Quality in production phase

In the last production phase of a LED, the dividing into different fine-grained quality classes is called “binning”. The “binning” has a major influence on the quality of the LED product. It takes place through the measuring of photometric and electrical characteristics of the individual chips. Each bin is different in terms of color temperature, brightness and current flow. For the further processing of LED components to modules, the quality of bins is the main criteria. A bin will be generated through robot-controlled assembly of wafers with the same properties. A LED manufacturer must therefore consider at which price he buys which qualities of bins and at which price he sells the finished product. Moreover, there are not always all qualities of bins available on the market. Generally speaking:

- LEDs with high energy efficiency are more expensive
- LEDs with small manufacturing tolerances are more expensive
- LEDs with low color temperarture (warm light) are more expensive

[6] See chapter 2.3.3

[7] The link to this quality charter is mentioned in the bibliography (chapter 7).

- LEDs with colder color temperatures are more efficient

2.4 Range of use

Today LED lighting is attractive and economic where its unique advantages can be applied:

- very long life-span
- no heat in the luminous flux
- UV-free light
- colour modulation
- dimming with little losses

Applications today include:

- Professional field: operating time > 3000 hours per year, e.g. shop illumination or downlights in a hall (hotel, administration, etc.). Further spotlights in museums, working place table light fixtures, hybrid solutions (e.g. indirect fluorescent lamp, direct LED).
- Domestic field: working place and reading lamps, suspensions for dining table, reflectors (low luminance, no heat radiation, instant start up, brilliant light).
- Street lighting: highly precise illumination of streets and walkways without diffused light.

2.5 Product types

Currently most of the LED lamps for domestic lighting are manufactured as so-called retrofit lamps. Retrofit lamps can be seperated into classical lamps and spot lamps. The classical retrofit LED lamps are bulb-, ball- or candle-shaped and emit their light around the room. They are therefore catagorized as "undirected lighting". The spot retrofit LED lamps are used for the directed illumination of objects or surfaces and are therefore catagorized as “directed lighting”. Within this paper, only the LED lamps for directed lighting are considered.

Retrofit lamps are shaped like traditional incandescent bulbs. These products have the same sockets as conventional bulbs and can be screwed into existing luminaires. Normally those are the E14 and E27 sockets. Because LED modules claim to live (or will in the future) up to 50000 hours, a replacement lamp may no longer be necessary

in the future and could disappear with time. It should be noted however, that the life of a LED also depends on the quality of the power supply. Concerns were expressed that simple power supplies may have a shorter lifetime than the life expectancy of LED modules. Long term studies will show if this is the case.

Due to the retrofit shape, the LED modules have an unfavorable dissipator which has a negative influence on quality and lifetime of the lamp. Currently LED retrofit lamps are available up to 8 watts. With rising efficiency of LED performance in the upcoming 2–3 years, the output power will be approximately doubled. A retrofit LED "bulb" light currently costs about 50 to 200 euro. During long operating times (> 3000 hours per year), LED lamps can be an economical alternative to the incandescent lamp.

The following figure shows all possible replacement lamps for the confentional light bulb based on the different sockets:

Socket	Standard allowed	Eco Halogen -20%	ESL -80%	LED -80%
E14				
E27				
		not available		
GU10				
GU5.3 (12V)			not available	

Figure 4 Retrofit replacement spot lamps[8]

[8] Adapted from: http://www.topten.ch/deutsch/ratgeber/rec_led.html&fromid=

3 Current status of legislations and standards at EU level

3.1 The EUP regulation

The EU Ecodesign directive 2005/32/EC will define energy efficency criteria for more than 30 product groups within the next years. These criteria are implemented in specific EU-Regulations. For non-directional domestic lighting the *COMMISSION REGULATION (EC) No 244/2009* has already been published in March 2009.

This regulation sets minimum performance requirements for non-directional household lamps. For LEDs minimum requirements on lamp efficiency, lumen equivalency with incandescent lamps and product information data have been defined. Functionality requirements for LED lamps (like lamp lifetime, switching behaviour, starting time, colour rendering, etc.) have not (yet) been included.

A new EU Ecodesign Regulation “Directional lighting: luminaires, reflector lamps and LEDs” (currently in preparation, outcomes are expected in the first quarter of 2012) will include the remaining (LED) products: Directional LED lamps, all LED modules and LED control gear. Besides the efficiency and information requirements, also the missing functionality requirements of EU Regulation 244/2009 for LED lamps will be covered here.

To get a first impression here is an example of the efficiency criteria and the functional parameters discussed right now. The full working document for the ecodesign requirements can be downloaded here: WD on regulation for directional lighting.

3.2 Proposed Requirements

The ecodesign requirements shall apply in three stages:

- Stage 1: one year after entry into force
- Stage 2: two years after entry into force
- Stage 3: four years after entry into force

3.2.1 Energy efficiency requirements for directional lamps

The useful luminous flux of a directional lamp is determined as follows [yellow highlight indicates places where formal revision is still needed]:

Model	Useful luminous flux (Φ_{use})
Directional lamps with a beam angle ≥90° and carrying a warning on their packaging according to paragraph (k) of point 3.1.2 of this Annex	Rated luminous flux in a 120° cone ($\Phi_{120°}$)
Other directional lamps	Rated luminous flux in a 90° cone ($\Phi_{90°}$)

The maximum rated power (Pmax) for a given useful luminous flux (Φuse) is provided in Figure 5.

The correction factors applicable to the maximum rated power are in Figure 6. The correction factors are cumulative where appropriate.

Application date	Maximum rated power (P_{max}) for a given rated luminous flux (Φ) (W)	
	Filament lamps	Other lamps
Stages 1 to 2	[formula to calculate energy class equivalent to xenon-filled mains voltage halogens]	[formula to calculate energy class equivalent to compact fluorescent lamps, reflector HID]
Stage 3	[formula to calculate energy class equivalent to IRC coated halogens]	[formula to calculate energy class equivalent to top-class LEDs 2012]

Figure 5

Correction factors	
Scope of the correction	**Maximum rated power (W)**
filament lamp requiring external lamp control gear	P_{max} / 1.06
LED lamp requiring external lamp control gear	P_{max} / 1.20
fluorescent lamp requiring external lamp control gear	$P_{max} / \frac{0.24\sqrt{\Phi} + 0.0103\Phi}{0.15\sqrt{\Phi} + 0.0097\Phi}$
high-intensity discharge lamp requiring external lamp control gear	P_{max} / 1.10
lamps other than filament lamps with colour rendering index ≥ 90	P_{max} / 0.85
LED lamp with 15° ≤ beam angle < 20°	P_{max} / 0.9
LED lamp with 10° ≤ beam angle < 15°	P_{max} / 0.85
LED lamp with beam angle < 10°	P_{max} / 0.80

Figure 6

3.2.2 Functionality requirements for non-directional and directional LED lamps

The lamp functionality requirements are set out in Figure 7 for both non-directional and directional LED lamps, including retrofit LED lamps.

For the purposes of testing the number of times the lamp can be switched on and off before failure, the switching cycle shall consist of periods comprising 1 minute on and 3 minutes off. For the purposes of testing lamp lifetime, lamp survival factor, lumen maintenance and premature failure, the standard switching cycle shall be used.

Functionality parameter	Requirement from Stage 1
Rated lamp lifetime at 50% lamp survival and 70% lumen maintenance	≥ 15000 h ≥ 10000 h for retrofit LEDs with integrated control gear
Number of switching cycles before failure	≥ 7500 ≥ 5000 for retrofit LEDs with integrated control gear
Starting time	< 0.5s
Lamp warm-up time to 60% Φ	< 2s
Premature failure rate at 10% of rated life in hours	≤ 2.0%
Colour rendering (Ra)	≥ 80 ≥ 90 if claimed to be retrofit to halogen or incandescent lamp
Colour consistency	Correlated Colour Temperature (CCT) spread within a 6-step MacAdam ellipse or less.
Lamp power factor (PF)	P ≤ 2W : no requirement 2W < P ≤ 5W : PF > 0.4 5W < P ≤ 25W : PF > 0.7 P > 25W : PF > 0.9

Figure 7

Directional and non-directional LED lamps that are claimed to be retrofits to halogen or incandescent lamps shall also comply with the following functionality requirements:

(a) the Correlated Colour Temperature shall be between 2600K and 3200K;

(b) the lamps shall be fully dimmable using dimmer systems compatible with mains voltage or extra low voltage halogen systems, as applicable;

(c) extra low voltage LED retrofit lamps shall be able to operate on all types of halogen lighting converters;

(d) if the lamp is claimed to be a retrofit to a specific halogen or incandescent lamp, its dimensions shall not exceed the maximum standard dimensions of the replaced lamp type.

3.3 Current Status of discussion

New proposals on ecodesign requirements and energy labelling for directional lamps, light emitting diode lamps and halogen lighting converters were discussed at Consultation 5 July 2011. A technical subgroup examined the technical issues in relation to the proposed regulations on 23 September 2011. The main points of discussion are:

- Scope of regulation
- Definitions for LEDs
- Estimated EU energy savings from early action on halogen lamps
- Bill of materials for an IRC halogen lamp
- Proposed ballast correction factors
- Calculation of the energy label
- Label layout
- Efficiancy of directional lamps
- Halogen lighting converters
- Lamp functionality requirements
- Product information requirements
- Etc.

Two studies currently address the current issues for discussion:

- CLASP published a "Supplemental Research Report: Lot 19 Part 2: Analysis Relating to Working Documents on Directional Lamps and Household Luminaires and Ecodesign Requirements for Directional Lamps, LED Lamps and Halogen Lighting Converters[9]" in October 2011. The purpose of this report is to provide input to the European Commission on a few specific issues that arose in discussions at the meeting of the Ecodesign Consultation Forum's Technical Subgroup held on 23 September 2011.

9 http://www.eceee.org/Eco_design/products/directional_lighting/2011%2010%2015%20CLASP%20Supplemental%20Directional%20Lighting%20Report%20FINAL.pdf

- The European Council for an Energy Efficient Economy (eceee) published a report recommending two-tiered minimum performance ecodesign requirements for directional lamps[10]. The report proposes to eventually base the lowest acceptable level on the performance of highly efficient infrared-coated (IRC) halogen technologies.

3.4 Other relevant legislation at EU-level

- ***Electromagnetic Compatibility (EMC) Directive 2004/108/EEC***

Though at a very low level, LEDs produce electromagnetic radiation, as any other product connected to the mains. The Council Directive 2004/108/EEC of 15 December 2004 on the approximation of the laws of the Member States relating to electromagnetic compatibility (EMC Directive) on the one hand regulates the electromagnetic emissions of lighting equipment in order to ensure that, in its intended use, such equipment does not disturb radio and telecommunication nor other equipment. On the other hand, the Directive also regulates the immunity of such equipment to interference and seeks to ensure that this equipment is not disturbed by radio emissions normally present used as intended.

- ***Directive 2002/95/EC on Restriction of the use of certain Hazardous Substances in electrical and electronic equipment (RoHS)***

The RoHS Directive stands for "the restriction of the use of certain hazardous substances in electrical and electronic equipment". This Directive bans the placing on the EU market of new electrical and electronic equipment containing lead, cadmium, mercury, hexavalent chromium, polybrominated biphenyl (PBB) and polybrominated diphenyl ether (PBDE) flame retardants. The LEDs are covered by the directive because of the LED platine with its power cords, wires and contact points.

Exemptions from these requirements are for example:

- o mercury in compact fluorescent lamps not exceeding 5 mg per lamp
- o mercury in straight fluorescent lamps for general purposes not exceeding halophosphate 10 mg
- o tri-phosphate with normal lifetime 5 mg
- o tri-phosphate with long lifetime 8 mg

10 http://www.eceee.org/Eco_design/products/directional_lighting/halogen_technologies_report/eceee_report_halogen_technologies

- mercury in straight fluorescent lamps for special purposes
- mercury in other lamps not specifically mentioned in this annex
- lead in glass of fluorescent tubes.

There are no exemptions for luminaires and ballasts.

- ***Directive 2002/96/EC on waste electrical and electronic equipment (WEEE)***

The WEEE Directive aims at:

- reducing waste arising from electrical and electronic equipment (EEE);
- making producers of EEE responsible for the environmental impact of their products, especially when they become waste.
- encouraging separate collection and subsequent treatment, reuse, recovery, recycling and sound environmental disposal of EEE.
- improving the environmental performance of all those involved during the lifecycle of EEE.

- ***93/465/EEC: Council Decision of 22 July 1993 concerning the modules for the various phases of the conformity assessment procedures and the rules for the affixing and use of the CE conformity marking, which are intended to be used in the technical harmonization directives***

This Decision establishes a range of procedures for assessing the conformity of industrial products to the "essential requirements" laid down by the technical harmonisation Directives. It aims to protect public interests such as the health and safety of product users.

- ***Low Voltage Directive (LVD) 73/23/EEC***

The Low Voltage Directive (LVD) 73/23/EEC seeks to ensure that electrical equipment within certain voltage limits both provides a high level of protection for European citizens and enjoys a Single Market in the European Union. The Directive covers electrical equipment designed for use with a voltage rating of between 50 and 1000 V for alternating current and between 75 and 1500 V for direct current. It should be noted that these voltage ratings refer to the voltage of the electrical input or output, not to voltages that may appear inside the equipment.

3.5 Relevant International Test Standards

This chapter shortly lists some relevant 'test standards or guidelines' related to LED lamps. A “test standard or guideline” is defined as a procedure that sets out a test method.

- ***IEC 60061: "Lamp caps and holders together with gauges for the control of interchangeability and safety"***

Contains the recommendations of the IEC regarding lamp caps and holders in general use, together with relevant gauges, with the object of securing international interchangeability.

- ***IEC 62031 (2008-01) Ed. 1.0: "LED modules for general lighting – Safety specifications"***

This International Standard specifies general and safety requirements for LED modules: LED modules without integral control gear for operation under constant voltage, constant current or constant power; self-ballasted LED modules for use on d.c. supplies up to 250 V or a.c. supplies up to 1 000 V at 50 Hz or 60 Hz.

- ***IEC 62471 (2006-07) Ed. 1.0: "Photobiological safety of lamps and lamp systems"***

This standard provides guidance for evaluating the photobiological safety of lamps and lamp systems including luminaires. In particular, it specifies the exposure limits, reference measurement technique and classification scheme for the evaluation and control of photobiological hazards from all electrically powered incoherent broadband sources of optical radiation, including LEDs but excluding lasers, in the wavelength range from 200 nm through 3000 nm.

- ***IEC 62560 ed1.0: "Self-ballasted LED-lamps for general lighting services by voltage > 50 V – Safety specifications"***

IEC 62560:2011 specifies the safety and interchangeability requirements, together with the test methods and conditions required to show compliance of LED-lamps with integrated means for stable operation (self-ballasted LED-lamps).

- ***IEC/PAS 62612:2009(E): Self-ballasted LED-lamps for general lighting services – Performance requirements***

Specifies the performance requirements for self-ballasted LED lamps with a supply voltage up to 250 V, together with the test methods and conditions required, intended for domestic and similar general lighting purposes, having a rated wattage up to 60 W and a rated voltage of up to 250 V AC or DC.

- ***DIN EN 62663-1 (Draft): "Non-self-ballasted LED lamps – Part 1: Safety requirements (IEC 34A/1399/CD:2010)"***

This draft specifies safety and interchangeability requirements, together with the test methods and conditions, required to show compliance of non-self-ballasted LED lamps, intended for general lighting purposes, having a rated wattage up to 60 W, a rated voltage up to 120 V ripple free d.c.

- ***IES LM-79-2008: "Approved Method: Electrical and Photometric Measurements of Solid-State Lighting Product"***

This approved method describes the procedures and precautions for performing reproducible measurements of total luminous flux, electrical power, luminous intensity distribution and chromaticity of solid-state lighting (SSL) products for illumination purposes under standard conditions.

- ***IES LM-80-08: "Measuring Lumen Maintenance of LED Light Sources"***

This document provides the methods of the measurement of lumen maintenance of sources including LED packages, arrays and modules only. Lumen maintenance is a characteristic measured under controlled conditions. Performance in a particular application may be different.

- ***ANSI Standards on Product Performance, Measurement and Safety***

The American National Standards Institute (ANSI), Washington, D.C., www.ansi.org, oversees the creation, promulgation, and use of thousands of industry norms and guidelines, including the following key standards of relevance to solid-state lighting (SSL) products.

- C78.377, "Specifications for the Chromacity of Solid State Lighting Products," will specify the recommended chromacity ranges for white light LEDs with various correlated color temperatures (CCTs) and ensure communication of chromacities to consumers.

- C82.SSI1, "Power Supply," will specify operational characteristics and electrical safety of SSL power supplies and drivers.

- C82.77-2002, "Harmonic Emission Limits - Related Power Quality Requirements for Lighting," will specify the maximum allowable harmonic emission of SSL power supplies.

- TM-16-05, "IESNA Technical Memorandum on Light-Emitting Diode (LED) Sources and Symptoms," will provide a general description of LED devices and systems and answer common questions about the use of LEDs.

- RP-16, "Nomenclature and Definitions for Illuminating Engineering Addendum," will provide industry-standard definitions of lighting terms, including all lighting technologies. The document is currently being updated to include definitions of SSL lighting terms.

- LM-79*, "IESNA Approved Method for the Electrical and Photometric Measurements of Solid-State Lighting Products," will specify procedures for

measuring total luminous flux, electrical power, luminous efficacy, and chromaticity of SSL luminaires and replacement lamp products.

- LM-80*, “IESNA Approved Method for Measuring Lumen Depreciation of LED Light Sources,” will specify procedures for determining lumen depreciation of LEDs and LED modules (but not luminaires) related to effective useful life of the product.

- NFPA 70-2005, “National Electrical Code,” requires that most SSL products must be installed in accordance with the National Electrical Code.

- 47 CFR Part 15, “Radio Frequency Devices,” specifies FCC requirements for maximum allowable unintended radio-frequency emissions from electronic components, including SSL power supplies and electronic drivers.

- 8750, “Outline of Investigation for Light-Emitting Diode (LED) Light Sources for Use in Lighting Products,” will specify the minimum safety requirements for SSL components, including LEDs and LED arrays, power supplies, and control circuitry.

- 1598, “Luminaires,” specifies the minimum safety requirements for luminaires. The requirements in this document may be referenced in other documents such as UL 8750 or separately used as part of the requirements for SSL products.

- 1012, “Power Units Other Than Class 2,” specifies the minimum safety requirements for power supplies other than Class 2 (as defined in NFPA 70-2005).

- 1310, “Class 2 Power Units,” specifies the minimum safety requirements for Class 2 power supplies (as defined in NFPA 70-2005).

- 1574, “Track Lighting Systems,” specifies the minimum safety requirements for track lighting systems.

- 2108, “Low-Voltage Lighting Systems,” specifies the minimum safety requirements for low-voltage lighting systems.

- 60950-1, “Information Technology Equipment - Safety - Part 1: General Requirements,” specifies the minimum safety requirements for electronic hardware.

3.6 IEA - 4E Solid State Lighting Annex

Launched in July 2010, this annex aims to work internationally to support the work that is being done on a national level to address the main challenges with SSL technologies. Everyone needs straighforward, reliable and internationally recognised prodecures to test for basic SSL quality.

Main tasks of the SSL Annex:

- Develop SSL Quality Assurance - work to clarify the SSL market worldwide, reduce the risks in using SSL and provide governments and consumers recommendations that they can trust when investing in SSL products.

- Harmonize SSL Performance Testing - work with global testing labs to increase the quality and confidence of SSL labs' test results, work to assess a range of existing SSL test procedures and build a system of testing that is manageable, robust and acceptable to a broad range of stakeholders.

- Standards and Accreditation - work with existing accreditation bodies to develop a structure for world-wide interim reliability of SSL testing labs' performance data.

More information can be found on http://ssl.iea-4e.org/.

Driven by government subsidies and soaring demand from new applications such as LCD-TV backlighting and general illumination, China’s Light-Emitting Diode (LED) market is set to more than double from 2009 to 2014. The domestic Chinese LED market covers numerous applications, including LED displays, street lighting, general illumination, traffic signals, flash lighting for handset key pads and digital still cameras and the backlighting of large-sized LCD panels in LCD-TVs, laptops and other displays.

4 Selection Criteria

This chapter does not define specific target values to be met by Topten products in all Euro-Topten partner countries. According to the Topten concept, each country has to develop specific Topten lists of its own depending on the products available on the national market. Thus, the specific thresholds for Topten lists depend on the products offered at national level and will be more or less stringent depending on the number of efficient products available.

The intention is rather to provide some recommendations regarding the criteria to be considered in Topten product listings and to give an idea of the efficiency of products currently offered on the market.

4.1 Lamp categorisation

Lamp categorisation for Topten lists should consider the different lamp types offered on the market respectively requested by the consumers. Lamp categorisation for directional LED lighting for the convenience of consumers shall distinguish between the following categories[11]:

- Spots GU10
- Spots GU5.3 (low voltage 12V)
- Spots E27/E14

4.2 Lamp information

The following information should be shown on the Topten websites (in the tables) to ensure that the consumer gets sufficient information also on quality criteria other than energy efficiency:

- Wattage (W)
- Luminous efficiency (lm/W)
- Luminous intensity (cd)
- Angle of radiation (degrees)
- Nominal flux of the lamp (lm)
- Nominal life time of the lamp (hours)
- Color rendering index (Ra)

[11] Based on www.topten.ch

- Color temperature (in Kelvin)
- Power factor
- Lamp base (E14/E27)
- Dimmable (yes/no)
- Lamp dimensions in millimeters (length and diameter)
- Equivalence with incandescent lamp (W)
- Price, electricity costs in 15 years

4.3 Lamp selection criteria

The following section provides some recommendations regarding requirements for Topten LED spot lamps. It is not the intention to indicate precise mandatory requirements since real requirements for Topten lists will differ from market to market according to the country. The selection of topten products should be based on the:

- Luminous efficacy: >= 40 lm/W
- Lamp life: minimum 20,000 hours
- Color temperature: between 2700 - 3200 K
- Color rendering index: CRI >= 80

5 Additional Considerations

5.1 Short time goals

No claims for efficiency are made for spot lamps up to now, and there is no energy label. However, the EU is currently working on a corresponding regulation for spot lights.

Until 2016 all incandescent and most halogen lamps in the EU have to be phased out in a 5 step process. All lamps with directional light (so all the spot lights) are temporarily exempt from this prohibition. For spot lights appropriate regulations are currently drafted by the EU.

5.2 Health issues

Issues relating to the effects on health and well-being of artificial light are discussed in three recent publications. The links to the full reports can be found in chapter 7.

IES position statement and DOE white paper:

The Illumination Engineering Society (IES) has released a position statement entitled "Effects of Exterior Lighting on Human Health (PS-03-10)," which is not specific to LEDs. The document states that "optical radiation detected by the retina impacts an individual's behavior, psychology, and perception of the environment. The position of the IES is to promote and encourage a more complete understanding of human responses to optical radiation leading to improved designs for all lighted environments." This has to be achieved through additional research with specific emphasis on additional field research to document typical exposures to optical radiation in exterior settings.

Meanwhile, the DOE Solid-State Lighting program has produced a White Paper entitled "Light at Night: The Latest Science," in July 2010. The white paper concludes that, given the available research, it is unclear what changes, if any, should be made to current best-practice lighting design. "It is clear that additional peer-reviewed research and validation are required to determine the relative significance of the visual and the photo-neural effects of typical light exposures," says the report.

ANSES highlights risks from LED lighting:

ANSES, the French Agency for Food, Environmental and Occupational Health & Safety, has published a report entitled (in English): " Lighting systems using light-emitting diodes: health issues to be considered," which focuses squarely on potential problems caused by LED lighting. The full report is available in French only, but the report summary (in English) says that risks have been identified concerning the use of

certain LED lamps, raising potential health concerns for the general population and professionals. "The issues of most concern identified by the Agency concern the eye due to the toxic effect of blue light and the risk of glare," says the report, adding that the blue light necessary to obtain white LEDs causes "toxic stress" to the retina.

Blue light causes a photochemical risk to the eye, says the report, the level of which depends on the accumulated dose of blue light to which the person has been exposed, which is generally the result of low-intensity exposure repeated over long periods. The report says that 3 groups are particularly at risk: children, populations which are already light-sensitive, and workers likely to be exposed to high-intensity lighting.

The other main risk is from glare. The report say that, for indoor lighting, it is generally agreed that luminance higher than 10,000 cd/m² causes visual discomfort whatever the position of the lighting unit in the field of vision. Because the emission surfaces of LEDs are highly-concentrated point sources, the luminance of each individual source can be 1000 times higher than the discomfort level.

6 Bibliography

Commission Decision of 6 June 2011 on establishing the ecological criteria for the award of the EU Ecolabel for light sources (notified under document C(2011) 3749) (2011/331/EU), http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32011D0331:EN:NOT

COMMISSION REGULATION (EC) No 244/2009 of 18 March 2009 implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for non-directional household lamps, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:076:0003:0016:EN:pdf

European Led Quality Charter, European Commission, Directorate-General JRC Joint Research Centre, Institute for the Energy Renewable Energy Unit, February 2011 , http://ceebel.se/wp-content/uploads/2011/04/european-led-quality-charter.pdf

Qualitätsmerkmale der LED-Beleuchtung – Aktueller Stand der Technik, Vorteile, Problempunkte und Entwicklungspotential, Bundesamt für Energie BFE, Auftragnehmer: eteam GmbH, Autor: Stefan Gasser, 1.09.2099,

Test of 14 LED retrofit lamps in October 2010 – Summary of Test Results (in English). PDF download at: http://www.topten.eu/uploads/File/Test_LED-lamps_Oct2010.pdf

Position Paper of the Illumination Engineering Society (IES): http://www.ies.org/store/position_statements.cfm

White paper of the DOE Solid-State Lighting program: http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/ssl_whitepaper_nov2010.pdf

ANES report on "Lighting systems using light-emitting diodes: health issues to be considered": http://www.afsset.fr/index.php?pageid=2248&parentid=523