**TOPTEN ACT CRITERIA PAPER**

**Lamps**

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**Topten ACT** aims at transforming the European market of energy-using products towards higher energy efficiency.
Topten ACT identifies the top energy-efficient products in 16 European countries, and makes this information available to consumers and large buyers on tailored national websites. The most energy efficient models in different product categories (such as household appliances, lighting, office equipment, consumer electronics, cars) are presented with comprehensive product information based on official labels and standardized declarations. Topten works with manufacturers and thus increases both market offer and consumer demand of high energy efficiency products. Topten is strictly neutral and independent from manufacturers and retailers, its selection criteria are always published online.
Topten ACT is supported by the European Commission's research and innovation programme Horizon 2020, and many national organisations (energy agencies, environmental and consumer organisations, research institutes). The Topten ACT project involves 17 partners in 16 European countries. It is coordinated by ADEME (Agence de l'Environnement et de la Maîtrise de l'Energie).
More information and access to all national websites on the European site: www.topten.eu

WP2 European Product Analysis, Task 2.1 Determining energy efficiency criteria, D 2.1 Periodic Criteria Papers (first set)

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## 1. Topten.eu: Lamps - current selection criteria and products selected

Topten.eu selection criteria was last updated in October 2015. Current criteria are:

- Energy efficiency:
  - Classic lamps non-directional lamps): minimum class A+ and minimum 85l/W
  - Spots (directional lamps): minimum A+
- Life time: minimum 15,000 hours
- Switching cycles: minimum 20,000 on/off cycles

The tables below show the number of lamp models on Topten.eu according to energy efficiency class and brightness (lumen) criteria, as of October 2015. Only Lighting Emitting Diodes (LED) lamps are able to meet such criteria:

### Classic lamps

| | A++ | A+ | Total |
|---|---|---|---|
| **E27 less bright (200 - 400 lm)** | 3 | 1 | 4 |
| **E27 medium (401 – 750 lm)** | 6 | 6 | 12 |
| **E27 bright (751 – 900 lm)** | 2 | 12 | 14 |
| **E27 very bright (901 – 1200 lm)** | 3 | 7 | 10 |
| **E14 classic shape (200 - 500 lm)** | 6 | 3 | 9 |
| **E14 candles less bright (100 - 300 lm)** | 9 | - | 9 |
| **E14 candles medium (301 - 500 lm)** | 5 | 4 | 9 |
| Total | **34** | **33** | **67** |

**Table 1: number of classic (non-directional) lamps meeting the topten.eu criteria (October 2015)**

### Spots

| | A++ | A+ | Total |
|---|---|---|---|
| **E14 R (100 - 400 lm)** | 2 | 3 | 5 |
| **E27 R / PAR (401 - 1200 lm)** | 1 | 10 | 11 |
| **GU10 medium (100 - 300 lm)** | 3 | 10 | 13 |
| **GU10 bright (301 - 600 lm)** | 1 | 11 | 12 |
| **GU5.3 medium (100 - 350 lm)** | 1 | 7 | 8 |
| **GU5.3 bright (351 - 700 lm)** | - | 7 | 7 |
| Total | **8** | **48** | **56** |

**Table 2: number of spots (directional lamps) meeting the topten.eu criteria (July 2015)**

There are 123 models of 12 different brands on the Topten.eu product list:

Ledisong, Ledon, Luxram, Megaman, Nanoleaf, Onlux, Osram, Philips, Sylvania, V-Tac, Wiva, Xnovum.
Similar models have not been counted if from the same brand.

## 2. Expected selection criteria in 2016

Expected Topten.eu selection criteria for 2016:

### Classic lamps

Given the rapid progress in LED efficiency, especially regarding filament lamps, that are mostly in efficiency class A++, it would be thinkable to determine criterion A++ for all classic lamps.

### Spots

For spots an additional efficacy criterion , e.g minimum 60l/W or 70l/W might be possible.

## 3. Technical background

A Light Emitting Diode (LED) is a semiconductor light source. In very simple terms, LEDs follow the reverse principle of a solar cell: whereas solar cells transforms (sun)light into direct current, LEDs turn direct current into light.

Four key quality characteristics are crucial for the assessment of LED quality:

- **Lamp efficacy:** this is the ratio between the luminous flux (measured in lumens) and the power (Watts) consumed by the lamp. Current consumer LED lamps already provide 80-110 lm/W. Figure 1 shows that efficacy levels of 200lm/W respectively 250lm/W are expected within the next decade for different types of LEDs:

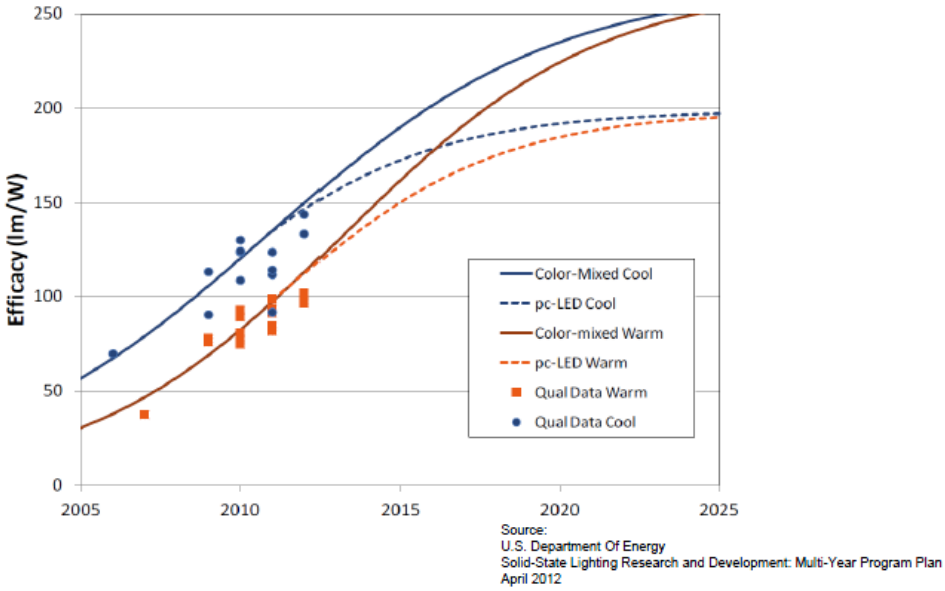



**Figure 1: LED efficacy projections to 2025 (source: US Department of energy)**

- **Light quality:** The ability of a light source (lamp) to show the colours of lighted objects in a most natural way is indicated by the so-called colour rendering index (CRI). CRI assesses how well 8 defined standard colours are rendered, the best value being 100. Fluorescent lamps reach an index of 80 to 90. Incandescent lamps and halogen lamps reach a maximum of 100. Today's good LEDs reach a colour rendering index of 80 to 95. There is therefore scope for improvement, and indeed

improving LEDs' CRI values might be something that manufacturers will pay more and more attention to, particularly as differences in efficacy become smaller and smaller between brands. It is important to note that there is some trade-off between high efficacy and high CRI levels.

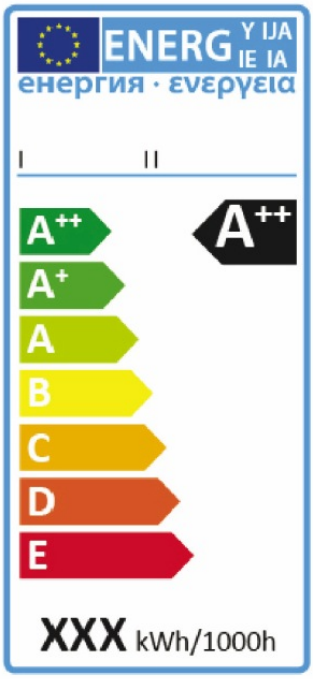
- **Lamp life:** The lifetime of LEDs is typically declared as the useful lifetime. The useful lifetime does not only consider the average nominal life time (until 50% of the lamps of a lamp sample has failed) but the time until the luminous flux has decreased to the minimum acceptable level (e.g. 70% of the original flux). The declared lamp lifetime of consumer LED products is typically between 10.000 and 30.000 hours. Long lamp lifetime can only be achieved if effective heat dissipation is ensured and good quality electronic components are used, which makes the products more expensive.

- **Switch on/off cycles:** Unlike for fluorescent lamps, there is no limit to how fast and how often LEDs can be switched. Tests conducted by Stiftung Warentest on 10 LED lamps, 7 compact fluorescent lamps (CFLs) and 2 halogen lamps show that high-quality LED lamps easily reach high switching cycles: after testing 70,000 switching cycles, none of the LED lamps had failed while 2 CFLs and 1 halogen lamp broke during the test[1]

## 4. Policy measures, standards and labels

### Energy Label

A new label for lamps was introduced in September 2013[2], replacing the old 1999 energy label. The new label covers both directional and non-directional lamps, and adds two additional energy classes A+ and A++.




For non-directional lamps, the old class limits remain mostly unchanged, with very minor exceptions for some lamp types. Many LED lamps are now labelled A+, with some lamps reaching the A++ level (see table 1 above). Most compact fluorescent lamps remain in class A.

Class limits are less tight for non-directional lamps (spots), reflecting the reality that they typically have lower luminous efficacy than classic lamps. A number of LED spots are now labeled A+ (see table 2 above). It is a disadvantage that the steps from one class to the next are more irregular than with other EU energy efficiency labels. This makes it almost impossible to understand and communicate what the efficiency improvement (e.g. from class B to A, or from class A to A+) means.

[1] Stiftung Warentest, TEST 10/2013, p. 70-75, "Kleine LED ganz gross"
[2] Commission Delegated Regulation (EU) No 874/2012 with regard to energy labelling of electrical lamps and luminaires.

| Energy efficiency class | Energy efficiency index (EEI) for non-directional lamps | Energy efficiency index (EEI) for directional lamps |
|---|---|---|
| A++ (most efficient) | EEI ≤ 0,11 | EEI ≤ 0,13 |
| A+ | 0,11 < EEI ≤ 0,17 | 0,13 < EEI ≤ 0,18 |
| A | 0,17 < EEI ≤ 0,24 | 0,18 < EEI ≤ 0,40 |
| B | 0,24 < EEI ≤ 0,60 | 0,40 < EEI ≤ 0,95 |
| C | 0,60 < EEI ≤ 0,80 | 0,95 < EEI ≤ 1,20 |
| D | 0,80 < EEI ≤ 0,95 | 1,20 < EEI ≤ 1,75 |
| E (least efficient) | EEI > 0,95 | EEI > 1,75 |

For the calculation of the energy efficiency index (EEI) of a model, its power corrected for any control gear losses is compared with its reference power. The reference power is obtained from the useful luminous flux, which is the total flux for non-directional lamps, and the flux in a 90° or 120° cone for directional lamps.

The EEI is calculated as follows and rounded to two decimal places:

$EEI = P_{cor}/P_{ref}$

**Table 3: Energy efficiency index and efficiency classes for directional and non-directional LEDs**

## Ecodesign

### Non-directional lamps

The energy efficiency requirements for non-directional lamps were defined in 200[3]. Requirements for lamp efficacy have been implemented in a staged process between September 2009 (stage 1) and September 2012 (stage 5). This last requirement banned classic lamps with energy efficiency below class C (according to the label index), effectively leading to the complete phase-out of the standard incandescent lamp.

The original 2009 regulation also required under stage 6 a phase-out of lamps not reaching class B efficiency (most halogens are below class B) by September 2016. Based on manufacturers position that this phase out would restrict consumer choice of classic lamps however, the European Commission recently backtracked on this requirement and allowed for a 2-year delay of the entry into force of this measure, now scheduled for September 2018. Recent studies estimate that delaying the phase-out of halogens will slow the uptake of LED lamps in Europe, resulting in 33 TWh of lost electricity savings over a ten-year period from 2016 through 2026. These savings represent approximately €6.6 billion in higher electricity bills for Europeans.

### Directional lamps

Similarly to classic lamps, energy efficiency requirements for directional lamps come into force in a staged process[4]; stage 1 becomes effective in September 2013 and last stage 3

[3] COMMISSION REGULATION (EC) No 244/2009 with regard to ecodesign requirements for non-directional household lamps

[4] COMMISSION REGULATION (EU) No 1194/2012 with regard to ecodesign requirements for directional lamps, light emitting diode lamps and related equipment

should be implemented as of September 2016, effectively banning mains-voltage halogen lamps with efficiency below class B. For LED lamps and fluorescent lamps only products of class A or better will be acceptable after 2016.

Table 4 below shows a timeline of past and upcoming impact of Ecodesign regulations for directional and non-directional lamps in the EU:

| | Non-directional household | Directional (reflectors) |
|---|---|---|
| 2009 | Ban of 100-watt incandescent lamps + all frosted incandescent lamps | |
| 2010 | Ban of 75-watt incandescent lamps | |
| 2011 | Ban of 60-watt incandescent lamps | |
| 2012 | Ban of 15-, 25- and 40-watt inc. lamps | |
| 2013 | | Ban of incandescent reflectors;<br>Shift to conventional main voltage halogens (phase out of poorest);<br>Shift to infrared coated or xenon filled low voltage halogens >450lm. |
| 2014 | | Shift to infrared coated or xenon filled low voltage halogens <450lm. |
| 2015 | Review of the regulation. | Review of the regulation. |
| 2016 | (Delayed to 2018) Shift to mains voltage halogens with transformer;<br>Exception for R7s and G9. | Shift to mains voltage halogens with transformer;<br>Phase out of CFL reflectors;<br>Shift to today's best HID and LED. |

**Table 4: timeline of Ecodesign measures for lamps**

In addition to these energy efficiency requirements, a number of lamp functionality requirements and information requirements are set under the 2009 Ecodesign regulation for lamps. The lamp functionality requirements are set out in Table 5 for compact fluorescent lamps and in Table 6 for lamps excluding compact fluorescent lamps and LED lamps:

| Functionality parameter | Stage 1 | Stage 5 |
|---|---|---|
| Lamp survival factor at 6 000 h | ≥ 0,50 | ≥ 0,70 |
| Lumen maintenance | At 2 000 h: ≥ 85 % (≥ 80 % for lamps with second lamp envelope) | At 2 000 h: ≥ 88 % (≥ 83 % for lamps with second lamp envelope)<br>At 6 000 h: ≥ 70 % |
| Number of switching cycles before failure | ≥ half the lamp lifetime expressed in hours<br>≥ 10 000 if lamp starting time > 0,3 s | ≥ lamp lifetime expressed in hours<br>≥ 30 000 if lamp starting time > 0,3 s |
| Starting time | < 2,0 s | < 1,5 s if P < 10 W<br>< 1,0 s if P ≥ 10 W |
| Lamp warm-up time to 60 % Φ | < 60 s<br>or < 120 s for lamps containing mercury in amalgam form | < 40 s<br>or < 100 s for lamps containing mercury in amalgam form |
| Premature failure rate | ≤ 2,0 % at 200 h | ≤ 2,0 % at 400 h |
| UVA + UVB radiation | ≤ 2,0 mW/klm | ≤ 2,0 mW/klm |
| UVC radiation | ≤ 0,01 mW/klm | ≤ 0,01 mW/klm |
| Lamp power factor | ≥ 0,50 if P < 25 W<br>≥ 0,90 if P ≥ 25 W | ≥ 0,55 if P < 25 W<br>≥ 0,90 if P ≥ 25 W |
| Colour rendering (Ra) | ≥ 80 | ≥ 80 |

**Table 5: Functionality requirements for compact fluorescent lamps**

| Functionality parameter | Stage 1 | Stage 5 |
|---|---|---|
| Rated lamp lifetime | ≥ 1 000 h | ≥ 2 000 h |
| Lumen maintenance | ≥ 85 % at 75 % of rated average lifetime | ≥ 85 % at 75 % of rated average lifetime |
| Number of switching cycles | ≥ four times the rated lamp life expressed in hours | ≥ four times the rated lamp life expressed in hours |
| Starting time | < 0,2 s | < 0,2 s |
| Lamp warm-up time to 60 % Φ | ≤ 1,0 s | ≤ 1,0 s |
| Premature failure rate | ≤ 5,0 % at 100 h | ≤ 5,0 % at 200 h |
| UVA + UVB radiation | ≤ 2,0 mW/klm | ≤ 2,0 mW/klm |
| UVC radiation | ≤ 0,01 mW/klm | ≤ 0,01 mW/klm |
| Lamp power factor | ≥ 0,95 | ≥ 0,95 |

**Table 6: Functionality requirements for lamps excluding compact fluorescent lamps and LEDs**

Table 7 displays the functionality requirements for LED lamps, as established in the relevant 2012 Ecodesign Regulation[5]:

[5] COMMISSION REGULATION (EU) No 1194/2012 with regard to ecodesign requirements for directional lamps, light emitting diode lamps and related equipment

| Functionality parameter | Requirement as from stage 1, except where indicated otherwise |
|---|---|
| Lamp survival factor at 6 000 h | From 1 March 2014: ≥ 0,90 |
| Lumen Maintenance at 6 000 h | From 1 March 2014: ≥ 0,80 |
| Number of switching cycles before failure | ≥ 15 000 if rated lamp life ≥ 30 000 h otherwise: ≥ half the rated lamp life expressed in hours |
| Starting time | < 0,5 s |
| Lamp warm-up time to 95 % Φ | < 2 s |
| Premature failure rate | ≤ 5,0 % at 1 000 h |
| Colour rendering (Ra) | ≥ 80<br>≥ 65 if the lamp is intended for outdoor or industrial applications in accordance with point 3.1.3(l) of this Annex |
| Colour consistency | Variation of chromaticity coordinates within a six-step MacAdam ellipse or less. |
| Lamp power factor (PF) for lamps with integrated control gear | P ≤ 2 W: no requirement<br>2 W < P ≤ 5 W: PF > 0,4<br>5 W < P ≤ 25 W: PF > 0,5<br>P > 25 W: PF > 0,9 |

**Table 7: Functionality requirements for LED lamps**

Information requirements on the lamp packaging include (non-exhaustive list): the nominal life time of the lamp, the number of switching cycles before premature lamp failure, the colour temperature, warm-up time, the dimmability of the lamp, lamp dimensions, the claimed equivalent incandescent lamp and mercury content. Additional there is a requirement to include information on free-of-access websites, which includes all of the above aspects, plus: rated wattage; rated luminous flux; rated lamp life time; lamp power factor; lumen maintenance factor at the end of the nominal life; starting time, colour rendering, and information on how to clean and dispose of lamps that contain mercury.

## 5. Market analysis

From a historical point of view, progress on lighting technologies has tremendously accelerated in the last decades. After a century of not much progress (from the 1879 invention of the incandescent lamp), CFLs were invented in the 1980s. More importantly, LEDs were also invented in the late XX century, and in particular the 2014 Nobel-prize winning invention of the blue LED in 1995 has allowed for a revolution in the lighting industry in the last two decades.

Recent research shows that LED technology is ready for consumers from both a technological and affordability point of view. A 2015 study showed that LEDs were in 2014 already achieving price points expected for 2020, 2022, 2024 and even 2025. This 10-year acceleration in affordability of LED lamps available today from major European manufacturers offer consumers payback periods of less than a 1 year in sockets used 3

hours per day[6]. Additional research published in 2014 found that LED lamps meet the shape, size and light quality of the tungsten filament lamps they are replacing[7].

It is no surprise therefore that consumer and professional lighting companies are switching: IKEA, a global retailer specialising in household furnishings, announced they will only sell LED lamps starting in 2016. Erco, a professional luminaire manufacturer, announced that from January 2015 they will only supply luminaires that use LED as the light source.

Through the use of LED lighting, significant energy savings and benefits will accrue to European households and the Union. During 2014 and 2015, the LED market started to become a mass market, and this will continue to develop in the next years.

Despite these advantages, regulation is still needed to help the transition towards more efficient lamps, as shown by a 2014 benchmark study by the International Energy Agency (IEA) Energy Efficient End-use Equipment (4E) Mapping and Benchmarking Annex[8], which found that sales of mains-voltage halogen lamps were considerably higher than predicted. Between 2007 and 2013, sales of halogens grew in Europe by 477%, meaning that consumers chose to replace their incandescent lamps by halogens instead of CFLs (the most cost-effective option).

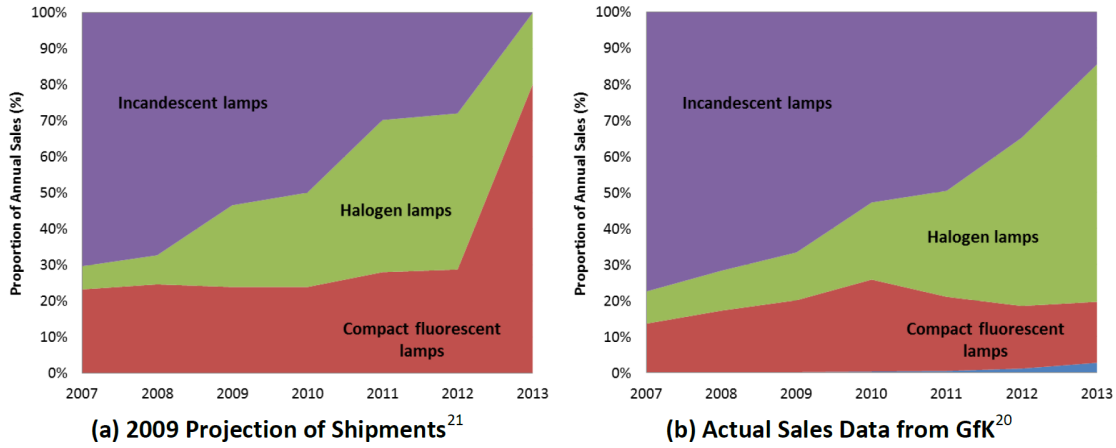



**Figure 2: 2009 projection and 2014 evaluation of the market shares of different lamp technologies**

Finally, as an example of how technologies and markets are expected to continue developing, an interesting new generation of LED lamps, the LED filament lamps is entering the European market. This technology has considerably higher performance than halogen, and payback times are becoming shorter. This type of lamps provide:

- Shape and size like an incandescent/halogen; direct mains-voltage screw-in replacement.
- 360° light distribution through clear glass envelope (i.e., sparkle effect for certain light fixtures)

[6] Danish Energy Agency, CLASP and Energy Piano (2015). 'European LED Market Evolution and Policy Impacts'
[7] Swedish Energy Agency, Belgian Federal Ministry for Health, Food Chain Safety and Environment, CLASP and eceee. 'Test Report – Clear, Non-Directional LED Lamps: A test report prepared for the European Commission and the Consultation Forum on the performance of clear LED lamps in the European Market in the third quarter of 2014.' 19 November 2014.
[8] IEA Mapping and Benchmarking report – Domestic Lighting Update, September 2014. http://mappingandbenchmarking.iea-4e.org/shared_files/643/download

- 120 lm/W (ten times better than incandescent lamps and two times better than CFL)
- Warm-white light - 2700 K, same as incandescent/halogen lamps
- High colour rendering, CRI Ra > 90
- Long lifetime – 15,000 hours (7 times longer than halogen)

## 6. FAQ

**Does the production of LED involve the extraction of rare earths?**

The LED industry uses a wide and growing range of phosphor materials to convert the light emission from LED chips into a different wavelength spectrum. LED makers rely on their supply of phosphor materials as a crucial aspect of the production process. The most common use is the combination of a blue LED chip with one or more phosphors to create a white LED. Many of the phosphors used in LEDs contain rare-earth elements, and the availability of these materials causes some concern, with China controlling some 95% of production worldwide.

Dependence on China, rising prices of rare earths and tough competition in the LED market is forcing LED manufacturers to innovate in search for alternatives, or at least a reduction in the amounts of rare earths used.

**Can LEDs cause epilepsy?**

One potentially dangerous side effect of LED lighting is seizures in people who suffer from photosensitive epilepsy, just as watching TV or playing video games can. LEDs can flicker at high frequencies causing a so-called strobe effect. Most people cannot see and are not affected by the flicker, but for people who can see the effect it can be a trigger for the seizure. Not all LEDs have the issue of causing seizures. The issue appears most problematic when LEDs are the only light source or the main light source; if other sources are lighting the room such as sunlight shining through a window, the strobe effect is minimized for causing a seizure.

## 7. References and links

**Useful links**

Topten.eu lamps product lists:
http://www.topten.eu/english/lamps/led-classic-lamps/e27-less-bright.html
http://www.topten.eu/english/lamps/led-classic-lamps/e27-medium.html
http://www.topten.eu/english/lamps/led-classic-lamps/e27-bright.html
http://www.topten.eu/english/lamps/led-classic-lamps/e27-very-bright.html
http://www.topten.eu/english/lamps/led-classic-lamps/e14-classic-shape.html
http://www.topten.eu/english/lamps/led-classic-lamps/e14-candles.html

http://www.topten.eu/english/lamps/led-spots/e14-r.html
http://www.topten.eu/english/lamps/led-spots/e27-e14-medium.html
http://www.topten.eu/english/lamps/led-spots/e27-e14-bright.html
http://www.topten.eu/english/lamps/led-spots/gu10-medium.html
http://www.topten.eu/english/lamps/led-spots/gu10-bright.html
http://www.topten.eu/english/lamps/led-spots/gu5_3-medium.html
http://www.topten.eu/english/lamps/led-spots/gu5_3-bright.html

Topten.eu lamps selection criteria:
http://www.topten.eu/english/criteria/selection_criteria_energy_saving_lamps.html&fromid=

**References**


Commission Delegated Regulation (EU) No 874/2012 of 12 July 2012 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to energy labelling of electrical lamps and luminaires.
http://www.topten.eu/uploads/File/Regulation-874-2012_label-lamps-luminaires.pdf

Amendment regarding Online Energy Labels: Regulation No. 518/2014
http://www.topten.eu/uploads/File/Online-Energy-Labels-518:2014-EN.pdf

Commission regulation (EU) No 1194/2012 of 12 December 2012 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for directional lamps, light emitting diode lamps and related equipment.
http://www.topten.eu/uploads/File/Regulation-1194-2012_ecodesign-directional-lamps-LED.pdf

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://www.topten.eu/uploads/File/lamps_regulation-244-2009-EC.pdf

Directive 2002/95/EC of the European Parliament and of the Council of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment.
http://www.topten.eu/uploads/File/RoHS-Directive_2002-95-EC_en.pdf

Stiftung Warentest, TEST 10/2013, p. 70-75, *Kleine LED ganz gross*

Danish Energy Agency, CLASP and Energy Piano (2015). 'European LED Market Evolution and Policy Impacts'

Swedish Energy Agency, Belgian Federal Ministry for Health, Food Chain Safety and Environment, CLASP and eceee. 'Test Report – Clear, Non-Directional LED Lamps: A test report prepared for the European Commission and the Consultation Forum on the performance of clear LED lamps in the European Market in the third quarter of 2014.' 19 November 2014.

IEA Mapping and Benchmarking report – Domestic Lighting Update, September 2014.
http://mappingandbenchmarking.iea-4e.org/shared_files/643/download