

Office Luminaires: Voluntary Labels Can Pave the Way to the Next Level In Energy Saving

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Abstract

Energy savings in lighting can be taken to a new level by introducing mandatory EU minimum requirements and an energy label considering the luminaire efficiency factor (LEF).

We look back on EU policies introduced during the last 15 years regarding luminous efficacy of light sources and ballast efficiency. The third parameter however, the light output ratio that defines the efficiency of a luminaire, has not yet been addressed by labelling or ecodesign measures. High energy saving potential is left to tap here.

Four voluntary labels and initiatives (*Minergie, Der Blaue Engel, Energy Star, Topten.eu*) guide to the current best available technology. They can be an inspiration to EU labelling and ecodesign measures. This paper portrays the four labels and discusses their different approach to set LEF requirements. Most ambitious requirements are specified for ceiling-mounted luminaires and pendant luminaires with minimum LEF of 75 lm/W at 3000 lumens (requirements ease with lower luminous flux, increase with higher luminous flux). It could be useful to base future LEF requirements on the formula described in the new regulations (EU) No 874/2012 and (EU) No 1194/2012. This would mean capped LEF requirements for luminaires above 1300 lumens.

Introduction

Lighting offers great potential for energy savings. EU labelling and ecodesign policies have pushed to increase the luminous efficacy of light sources since 1999 when the energy label for household lamps was introduced. Starting in 2009, poorly performing lamps have been banned from the market in several stages. By 2016, the last stage defined in the current ecodesign regulations, only improved halogens¹ and well performing fluorescent lamps, LED lamps and high intensity discharge lamps will meet the minimum requirements. Also ballast losses have been limited in several stages since 2002. [1] - [6]

The efficiency of a luminaire is determined by three parameters: the luminous efficacy of the light source (lm/W), the efficiency of the ballast (%) and the light output ratio "LOR" of the luminaire (%). The luminaire efficiency factor "LEF" (lm/W) indicates the luminous flux emitted from the luminaire per watt electrical power consumed; it equates to the product of the three mentioned parameters as shown in Figure 1.

¹ Infrared coated or xenon filled low voltage halogens and mains voltage halogens with transformer; exceptions: lamp cap R7s and G9

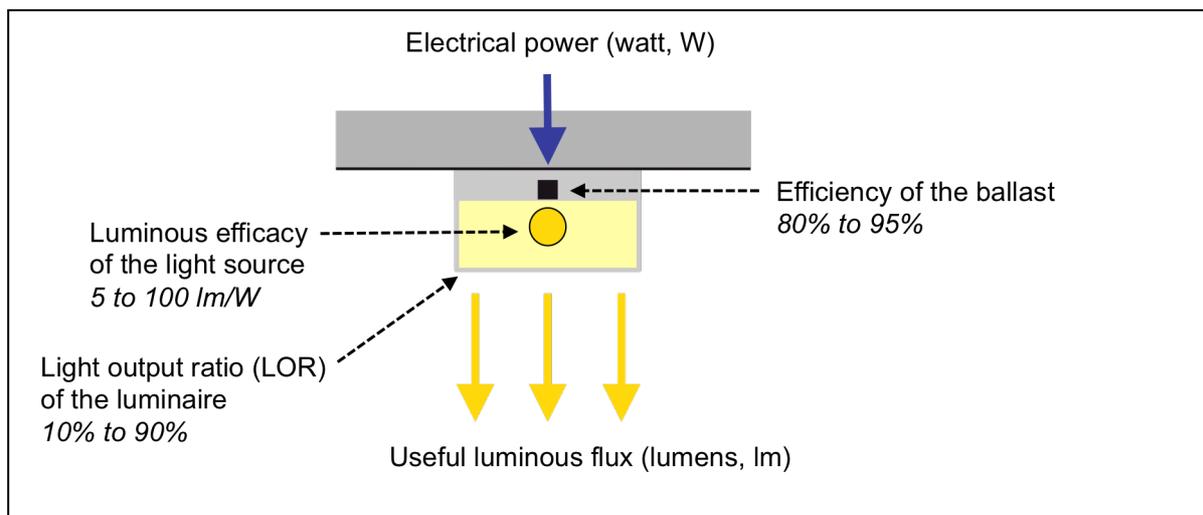


Figure 1: Parameters of the luminaire efficiency factor (LEF)

Aim of this paper

Both luminous efficacy of light sources and ballast efficiency have been in the scope of EU policies for over a decade. The third parameter however, the light output ratio that defines the efficiency of a luminaire, has not yet been addressed by labelling or ecodesign measures. High energy saving potential is left to tap here. LOR ranges from very small, where most of the lamp luminous flux is lost, to high, where the luminaire emits nearly all of the lamp's light. This leads to a range in LEF between 5 lm/W to over 90 lm/W.

Against that background the authors of this paper advocate the introduction of a mandatory EU energy label and minimum requirements for office luminaires.

In public perception office lighting is less prominent than household lighting even though it accounts for twice the energy consumption. Office lighting consumed an estimated 164 TWh in 2007; household lighting consumed 84 TWh in 2007 and 80 TWh in 2009 [11].

Energy labelling and ecodesign measures could be more easily introduced for office luminaires for several reasons:

- Product information for most office luminaires on the European market is already available in lighting simulation software such as Dialux and Relux. The standardized data format is Eulumdat with the file extension *.ldt (the American IES format can be transformed into Eulumdat).
- Office luminaires are generally installed by professionals. A mandatory energy label would be a strong incentive for electricians, planners, private and public procurement agents, and awarding authorities to consider the LEF.
- The energy label could provide information on the annual energy consumption (kWh/year) for typical use. This would directly support the goals of the recast Energy Performance of Buildings Directive 2010/31/EU which asks to consider built-in lighting installation for the calculation of energy performance of buildings. It would give EU countries a tool to implement energy performance standards. On the other hand the energy label could operate independently. Standards such as EN 12464-1 specify the minimum illuminance (lux) per square meter required for work places. These specifications can be met with manifold luminaire types. The energy label would help to distinguish whether the chosen luminaire is performing well or poorly regarding LEF.
- Office luminaires tend to require specific light sources; this makes determining the test lamps easier. Lamps with E27 cap are typically used for household luminaires and come in many variations; things become more complex.

Voluntary labels promoting office luminaires with high LEF are established in some countries. They can be an inspiration to EU labelling and ecodesign measures. This paper gives an overview of four voluntary labels and their LEF requirements.

Note that an EU energy label will be provided for household luminaires from March 2014 on [2]. This label is not important for the discussion in this paper, because it does not inform about the energy efficiency of the luminaire itself; it only informs about the type of lamps to be used in the luminaire. LEF or LOR are not addressed.

Voluntary labels promoting luminaires with high LEF – 4 portraits

“*Minergie*” from Switzerland, “*Der Blaue Engel*” from Germany and “*Energy Star*” from the USA belong to the classical type of voluntary label: manufacturers purchase the license to label their eligible products. “*Topten.eu*” is an initiative (funded by Intelligent Energy Europe (IEE) and coordinated by ADEME) aiming to stimulate demand for the most energy efficient products in national markets and to support EU labelling and ecodesign policies. For this purpose the best available technology is presented online with no cost to manufacturers.

Facts and figures for “*Minergie*” and “*Der Blaue Engel*” are summarized in Table 1, for “*Energy Star*” and “*Topten.eu*” in Table 2.

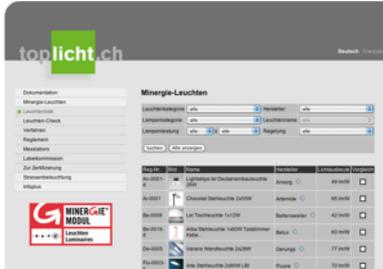
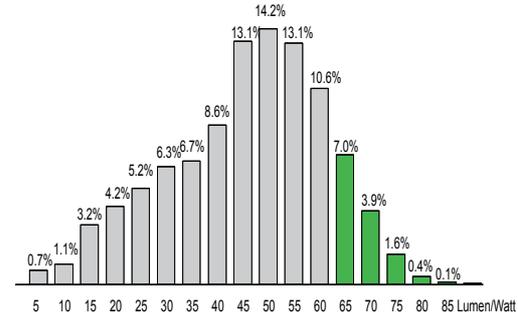
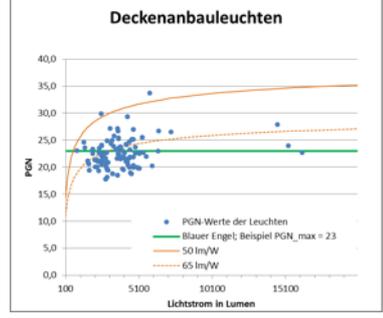
Minergie in Switzerland	Der Blaue Engel in Germany
Since 2007, today 791 luminaires of 27 brands	Conditionally adopted by Eco-Label Jury in December 2012, planned to start in mid 2013
26% LED products	-
Non-directional and directional	Non-directional and directional
<ul style="list-style-type: none"> - ceiling-mounted - recessed - suspended - floor-standing 	<ul style="list-style-type: none"> - desk - wall-mounted - spots - downlights
http://www.toplicht.ch/index.php?page=minergieleuchten	http://www.blauer-engel.de/
	
<p><i>Rationale behind LEF requirement:</i></p> <p>LEF criteria are set in order to represent the top 15% products of the market (analysis of data set from Relux for 16'000 luminaires with class A and B lamps and electronic ballasts).</p>	<p><i>Rationale behind LEF requirement:</i></p> <p>LEF criteria are based on the equation for lamps in the EU regulation 98/11/EC. They are set in order to be about 30-50% stricter than Minergie depending on the type of luminaire.</p>
 <p>LEF of 16'000 luminaires on the market in 2006 (all lamps class A + B)</p>	 <p>Minergie data for ceiling-mounted luminaires. x-axis: luminaire luminous flux (lm). y-axis: PGN as index for energy efficiency; lower PGN value means better performing. Green line: PGN requirement.</p> <p>$PGN (P, \Phi L) = P / (0.01029 * (0.88 * \sqrt{\Phi L} + 0.049 * \Phi L))$ with ΦL = luminaire luminous flux (lm) and P = power (W).</p>
<p><i>Other criteria considered [7]:</i></p> <ul style="list-style-type: none"> - Standby power (limits: 0 watt; exceptions: dimmable ballast: 1 watt, presence detection / daylight sensor: 0.5 watt) - For LED: CRI $R_a \geq 80$; life time $\geq 20'000$ hours (with Lamp Lumen Maintenance Factor LLMF $\geq 70\%$); power factor ≥ 0.5 or 0.9 depending on power - Ballast (only electronic) - Unified Glare Rating 	<p><i>Other criteria considered [8], [12]:</i></p> <ul style="list-style-type: none"> - Standby power (limits: 0.1 watt; exceptions: dimmable ballast or external power supply unit: 0.5 watt) - For LED: life time $\geq 20'000$ hours (with LLMF $\geq 80\%$ and Lamp Survival Factor LSF $\geq 90\%$); switching cycles $\geq 100'000$ - Modularity of ballasts - Modularity of LED-downlights - Ultraviolet and electromagnetic radiation - Mercury in fluorescent lamps (limits: T5: 1.4 mg; T8: 2.0 mg; CFL: 1.4 mg) - Provision of spare parts (at least for 10 years) - Comprehensive information for users and procurement agents

Table 1: Portraits of Minergie (Switzerland) and Der Blaue Engel (Germany)

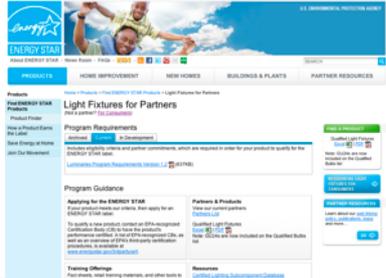
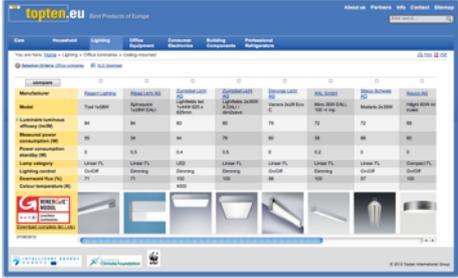
Energy Star in the USA	Topten.eu for Europe
Since 2008, today 7350 luminaires of 159 brands	Since 2012, today 71 luminaire lines of 18 brands
21% LED products	28% LED products
Only directional luminaires ²	Non-directional and directional
<ul style="list-style-type: none"> - accent lights (includes line-voltage directional track lights) - downlights: recessed, pendant, surface mount (includes SSL downlight retrofits, excludes troffers or linear forms) - under cabinet shelf-mounted task lighting - portable desk task lights 	<ul style="list-style-type: none"> - ceiling-mounted - desk - recessed - wall-mounted - suspended - spots - floor-standing - downlights
http://www.energystar.gov/lightfixtures	http://www.topten.eu/english/criteria/office_lighting_crit.html&fromid=
	
<i>Rationale behind LEF requirement:</i>	<i>Rationale behind LEF requirement:</i>
Generally, a market share of Energy Star qualified products in a particular category of 50% or higher will prompt consideration for a specification revision.	LEF criteria are based on <i>Der Blaue Engel</i> . As products improve, Topten criteria become stricter; lists stay limited to the 10 or so best luminaire lines in each class. For this reason LEF criteria for ceiling-mounted and pendant luminaires are stricter than <i>Der Blaue Engel</i> .
(no figure available)	(no figure available)
<i>Other criteria considered [9]:</i>	<i>Other criteria considered [10]:</i>
<ul style="list-style-type: none"> - Standby power (limits: 0 watt; exceptions: presence detection, daylight sensor etc.: 1 watt) - For LED: CRI $R_a \geq 80$; lumen maintenance $\geq 94\%$ at 6'000 hours; color angular uniformity; color maintenance; power factor ≥ 0.5 or 0.9 depending on power - For FL and HID lamps: CRI $R_a \geq 80$; lumen maintenance $\geq 80\%$ at minimum 4'000 hours; power factor ≥ 0.9 - All luminaires shall be shipped with a lamp for each lampholder (few exceptions) - Warranty (minimum 3 years) - And many more ... (ballast performance, thermal performance, product labeling & packaging etc.) 	<ul style="list-style-type: none"> - Same as <i>Minergie</i>; only exception standby power limit for dimmable ballast: 0.5 watt (same as <i>Der Blaue Engel</i>)

Table 2: Portraits of Energy Star (USA) and Topten.eu (Europe)

² Non-directional residential luminaires can earn the *Energy Star* label, but criteria are set for the light source, not the luminaire.

Comparison of LEF requirements

Topten.eu, *Der Blaue Engel* and *Energy Star* classify luminaires according to mounting types. *Minergie* classifies according to light source technology and directional characteristic³. For sake of comparison office luminaires that are typically directional (such as ceiling-mounted, downlight, accent and desk luminaires) are grouped and typically non-directional luminaires (such as pendant, wall and floor-standing) likewise. Figure 2 shows the minimum LEF requirements for directional luminaires as well as the future EU minimum energy efficiency requirements for directional lamps that will be applied from 2016 on ((EU) No 1194/2012 [6]). Figure 3 shows for non-directional luminaires and lamps.

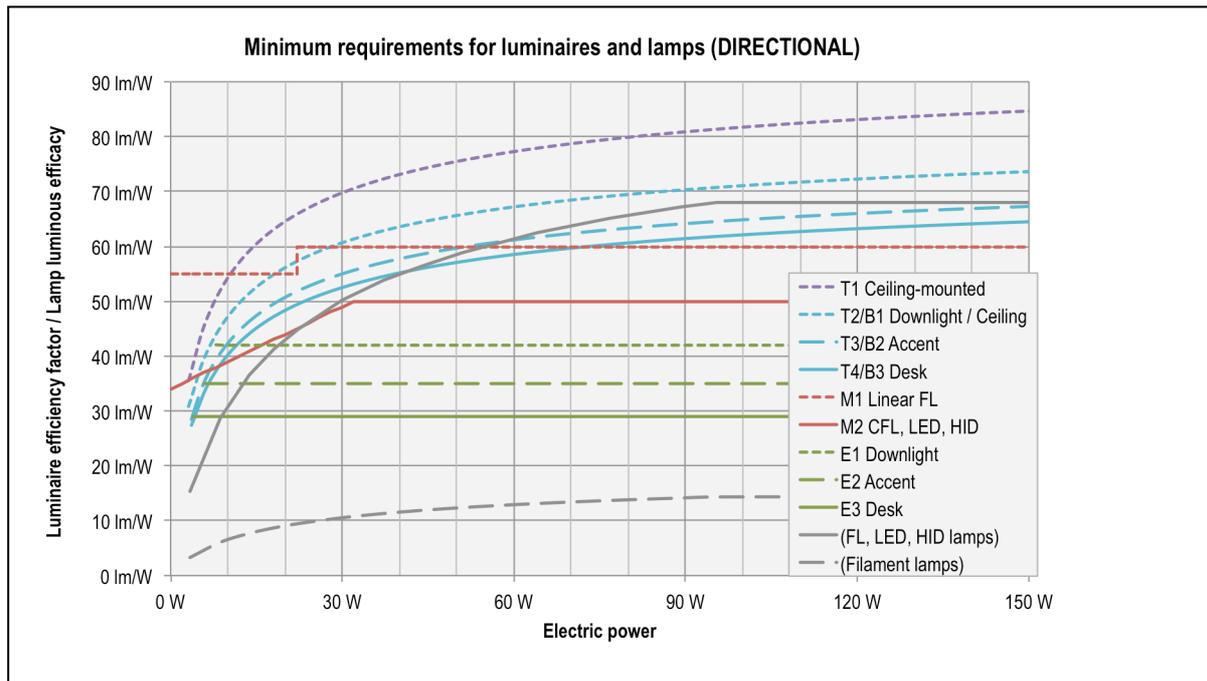


Figure 2: Minimum LEF requirements for directional luminaires. T1-T4 = *Topten.eu*, B1-B3 = *Der Blaue Engel*, M1-M2 = *Minergie*, E1-E3 = *Energy Star*, (... lamps) = EU ecodesign 2016.

Luminaires with lower power, or lower luminous flux, have a lower LEF mainly because the ballast contributes proportionally more to the power consumption. All LEF requirements with the exception of *Energy Star* are less strict for luminaires with lower power / luminous flux. This relation is described either by the equation given in EU regulation 98/11/EC for lamps [1] (*Der Blaue Engel*, *Topten.eu*) or by a simpler approach like a linear function or simply a minimum LEF value (*Minergie*). Note that none of the 4 labels uses the approach given in EU regulation 1194/2012 for lamps [6]. Those newest minimum requirements are capped for lamps over 1300 lumens.

Der Blaue Engel LEF requirements become increasingly stricter with higher luminous flux. All other LEF requirements are capped (the highest cap being 70 lm/W for non-directional linear FL luminaires set by *Minergie*).

Topten.eu sets the strictest LEF requirements for ceiling-mounted and pendant luminaires; otherwise it is in line with the German Eco-Label *Der Blaue Engel*. The latter is stricter than *Minergie*, which again is stricter than *Energy Star*.

³ A revision of the *Minergie* criteria is foreseen for January 2014 switching to a classification according to mounting types too.

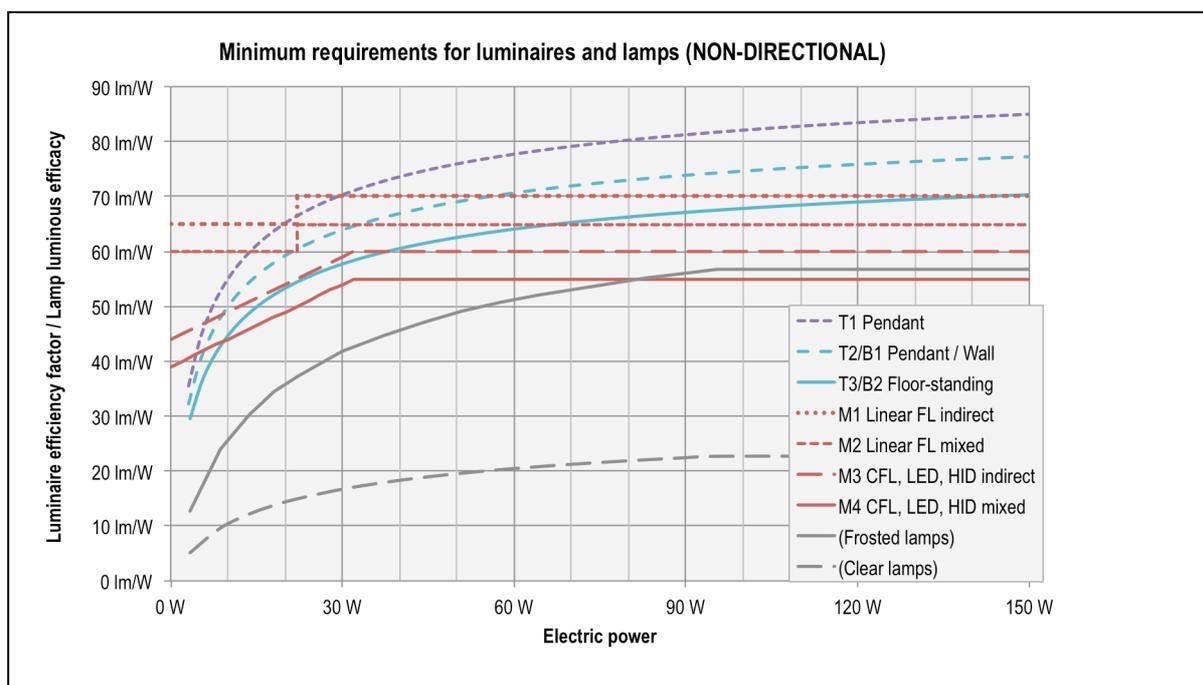


Figure 3: Minimum LEF requirements for non-directional luminaires. T1-T3 = *Topten.eu*, B1-B2 = *Der Blaue Engel*, M1-M4 = *Minergie*, (... lamps) = EU ecodesign 2016.

Discussion

The four voluntary labels promoting luminaires with high LEF can serve as guideline, should the European Commission work out measures for office luminaires. They indicate the best available technology (and in the case of *Energy Star* the average available technology). A future EU energy label could base its top classes on the labels' LEF requirements, while considering that further efficiency improvements are expected for LED luminaires.

There are different approaches how to set LEF requirements, as explained in the above chapter. At this point the authors of this paper would recommend using the same formula as the new regulations (EU) No 874/2012 and (EU) No 1194/2012 (with capped LEF requirements for luminaires above 1300 lumens). *Minergie* intends to adapt that approach at a revision planned for January 2014.

Associated with the *Minergie* revision current luminaire data from the Relux database has been analyzed. There is no publication available (yet); still we would like to mention some of the results. The database contains ca. 600'000 data sets in total, though 71% are duplicates or incomplete. Data sets for 175'680 luminaires were found to be useful. 62% are equipped with linear fluorescent lamps (LFL), 20% compact fluorescent lamps (CFL), 12% high-intensity discharge lamps, 4% filament lamps and 2%, or 3760 luminaires, with LED. The median LEF of LED luminaires is 55 lm/W, of CFL luminaires 23 lm/W and of LFL luminaires 33 lm/W. This makes LED luminaires to date typically twice or so as energy efficient compared to luminaires with fluorescent lamps. The top 10% of LED luminaires have a LEF of 77 lm/W, of CFL luminaires 46 lm/W and of LFL luminaires 66 lm/W.

The four voluntary labels also indicate which criteria beyond luminaire efficiency might be worth considering. We highlight only two criteria here; please refer to the original specifications [7] - [10] for the complete criteria sets. All four labels limit standby to 0 watt (with exceptions for presence detection / daylight sensor and dimmable ballasts). They also set requirements for LED products that in some cases go beyond regulation (EU) No 1194/2012 (e.g. lumen maintenance factor 70-80% at 20'000 hours, lamp survival factor 90% at 20'000 hours, 100'000 switching cycles).

References

EU labelling and ecodesign regulations

- [1] Commission Directive 98/11/EC of 27 January 1998 implementing Council Directive 92/75/EEC with regard to energy labelling of household lamps (to be replaced by regulation 874/2012)
- [2] 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
- [3] Directive 2000/55/EC of the European Parliament and of the Council of 18 September 2000 on energy efficiency requirements for ballasts for fluorescent lighting (replaced by regulation 245/2009)
- [4] 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
- [5] Commission Regulation (EC) No 245/2009 of 18 March 2009 implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for fluorescent lamps without integrated ballast, for high intensity discharge lamps, and for ballasts and luminaires able to operate such lamps, and repealing Directive 2000/55/EC of the European Parliament and of the Council
- [6] 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

Voluntary labels: Specifications

- [7] Reglement und Nachweisverfahren zur Vergabe des MINERGIE®-Labels für Leuchten. Durch Labelkommission genehmigte Version vom 11.9.09. Ausgearbeitet durch Schweizerische Agentur für Energieeffizienz S.A.F.E.
- [8] Vergabegrundlage für Umweltzeichen, Leuchten für die Anwendung in Büros und verwandten Einsatzbereichen, Ausgabe 2012 (DRAFT)
- [9] ENERGY STAR® Program Requirements Product Specification for Luminaires (Light Fixtures), Eligibility Criteria Version 1.2
- [10] Topten.eu Selection Criteria for Office luminaires:
http://www.topten.eu/english/criteria/office_lighting_crit.html&fromid=

Other References

- [11] Bertoldi P., Hirt B. and Labanca N. *Energy Efficiency Status Report 2012*. European Commission, Joint Research Centre, Institute for Energy and Transport.
- [12] Schleicher T., Liu R. *Top 100: PROSA Leuchten für die Anwendung in Büros und verwandten Einsatzbereichen – Entwicklung der Vergabekriterien für ein klimaschutzbezogenes Umweltzeichen*. Studie im Rahmen des Projektes "Top 100 – Umweltzeichen für klimarelevante Produkte", Öko-Institut e.V. 2013 , <http://www.oeko.de/oekodoc/1775/2013-464-de.pdf>