D2.2 - TOPTEN ACT CRITERIA PAPER

Luminaires

31 August 2018 (Update)

Francisco Zuloaga, Eva Geilinger, Caroline Dyck, Ian Rothwell, Eric Bush

Bush Energie GmbH

francisco.zuloaga@bush-energie.ch

eva.geilinger@bush-energie.ch

eric.bush@bush-energie.ch

ian.rothwell@bush-energie.ch

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 2.2 Periodic Criteria Papers (second set)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n°649647.

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

A luminaire is a complete lighting unit consisting of one or more lamps (light sources), the lighting control gear (driver, dimmer, sensor & data connection) and the fixture. For the purposes of this paper, they have been divided in domestic and office luminaires.

Domestic luminaires

There are currently no domestic luminaires on topten.eu. However, topten.ch has an ongoing project with Swiss retailers and manufacturers to label the most efficient luminaires. To obtain the Topten label for a luminaire the power, luminous flux and light spectrum of the luminaire must be measured (based on European standards and norms or the Swiss MINERGIE® label). The following criteria must be met (Table 1):

Light source	LED (halogen lamps do not achieve the required energy efficiency)
Luminous flux	>= 200 lumens (less bright luminaires are considered to have decorative function only)
Luminaire efficiency factor • < 750 lumens • > 750 lumens	 >= 55 lumens per watt >= 70 lumens per watt
Standby power	= 0.0 W except when luminaires have an in-built dimmer / sensor or communication function <= 1.0 W
Colour rendering index (CRI)	>= 80

Table 1: Topten.ch criteria for voluntary domestic luminaire label

Office luminaires

Topten.eu presents the most energy efficient luminaires for offices and other indoor use. The listed luminaires are certified by MINERGIE®, a Swiss label most famously known for building standards. Each brand is represented with their most energy efficient model per category. The complete list of Minergie-certified luminaires can be found under www.toplicht.ch (website available in German). Selection criteria can be found in detail but only in German under https://www.toplicht.ch/minergie/reglement/, or summarised in English on the Topten.eu criteria page for office luminaires.

The tables below (Table 2, Table 3) show the number of luminaire models on topten.eu and topten.ch according to the luminaire efficiency (lumens per Watt (lm/W)) and total luminous flux (lumen), as of August 2018.

Domestic luminaires

		> 100 lm/W	55 - 100 lm/W	Total
Ceiling mounted	200 – 1000 lm	4	7	11
	1001 – 2000 lm	3	14	17
	> 2000 lm	-	11	11
Suspended	200 – 1000 lm	-	1	1
	1001 – 2000 lm	1	5	6
	> 2000 lm	2	16	18
Spots	200 – 500 lm	-	17	17
Floor-standing	200 – 1000 lm	-	4	4
	2000 – 5000 lm	4	19	23
	> 5000 lm	2	3	5
Table luminaires	200 – 1000 lm	-	16	16
	1001 – 2000 lm	-	1	1
	> 2000 lm	-	1	1
Wall-mounted	200 – 1000 lm	-	5	5
	> 1000 lm	1	-	1
Total		**17**	**120**	**137**

Table 2: Number of domestic luminaires meeting the topten.ch criteria (August 2018)

Office luminaires

		> 100 lm/W	< 100 lm/W	Total
Ceiling mounted	1000 – 5000 lm	13	6	19
	5001 – 10 000 lm	3	-	3
	> 10 000 lm	2	-	2
Recessed	1000 – 5000 lm	9	3	12
	5001 – 10 000 lm	2	-	2
Suspended	1000 – 5000 lm	7	1	8
	5001 – 10 000 lm	13	-	13
	> 10 000 lm	2	-	2
Floor-standing	1000 – 5000 lm	-	2	2
	5001 – 10 000 lm	10	1	11
	> 10 000 lm	8	-	8
Wall-mounted	1000 – 5000 lm	4	1	5
	5001 – 10 000 lm	4	-	4
Spots	< 1000 lm	-	3	3
	1000 – 5000 lm	4	3	7
Downlights	< 1000 lm	-	1	1
	1000 – 5000 lm	2	3	5
Total		**83**	**24**	**107**

Table 3: Number of office luminaires meeting the topten.eu criteria (August 2018)

There are 107 models of 12 different brands on the Topten.eu product lists: Baltensweiler AG, Büro Schoch, Fluora Leuchten AG, Herbert Waldmann GmbH, Licht + Raum AG, Neuco AG, Ribag Licht AG, Regent Lighting, S-TEC electronics AG, Schätti AT Metallwarenfabrik, Tobias Grau GmbH, Zumtobel Licht AG.

And 137 models of 14 different brands on the Topten.ch product list for domestic luminaires: Artemide, B-Leuchten, Baltensweiler, Bankamp, Belux, Elesi Luce, Grossmann, Hansa, Ledeshi, Lumimart, Micasa, Osram, Philips, Ribag.

2. Expected selection criteria in 2019

In order to be in line with the latest Energy Star luminaire specifications v2.1 the standby criteria for domestic luminaires will be further tightened to max. 0.5 Watt for models with integrated dimmer / sensor while remaining at max. 1.0 Watt for models with communication function. This change is already communicated on topten.ch and will come into effect on 01.07.2019.

3. Technical background

Luminaire efficiency factor (lumens per watt)

Luminaire efficiency is expressed by the ratio of useful luminous flux in lumens and total electrical power in watts. This ratio is also called luminaire efficiency factor (LEF). It is equal to the product of the luminous efficacy of the light source, the light output ratio and the efficiency of the ballast (see Figure 1).

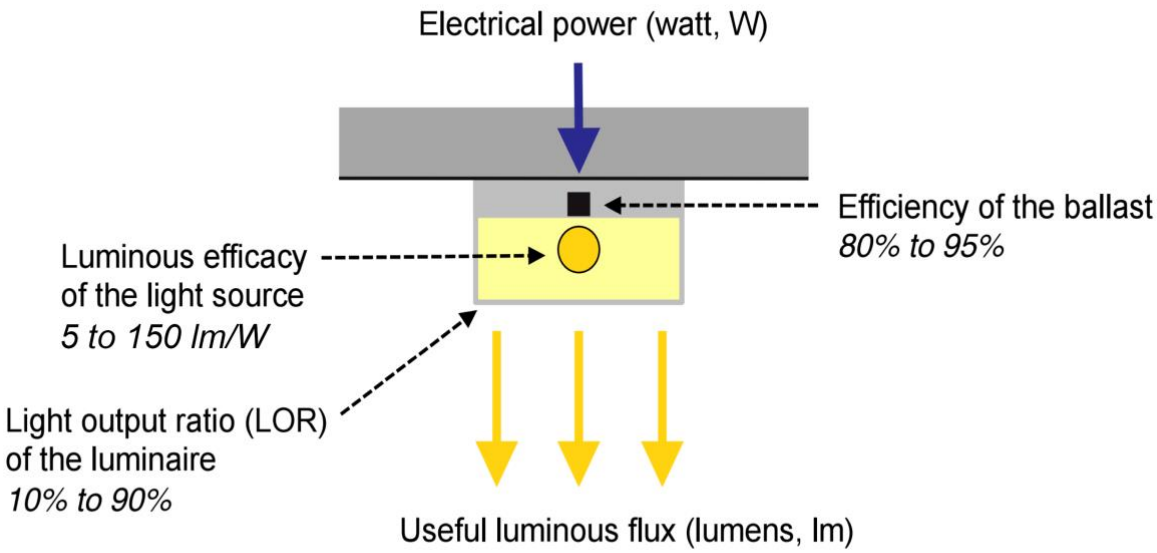


Figure 1: Schematic of the luminaire efficiency factor (LEF)

It is important to know that manufacturers display in the very most cases not the useful luminous flux of the luminaire but the luminous flux of the light source. The fixture, light shading and diffusor absorb light which can be substantial. The ongoing yearly measurements for domestic luminaires which are coordinated by Topten Switzerland show that even for selected products the deviation between declared and measured efficiency is at around 25% (the worst deviation in 2017 was at minus 63%).

Standby consumption

In the EU, standby consumption for luminaires is only very partially limited through requirements for control gear and ballasts. Other luminaire components can add to standby energy consumption. Typically they are components for lighting control like timer switches, occupancy sensors, light sensors and daylight regulation devices or illuminated switches. All these are not covered by EU requirements. In addition, dimmers are also exempted from the requirements.

About 200 measurements from 2015, 2016 and 2017 for domestic luminaires by Topten Switzerland show that around a third of them consume energy in off mode (0.1 – 2.4 W). These figures might not seem very high, but it's to be noted that Topten Switzerland already does a preselection based on a quick standby power measurement of the luminaires. The standby figures for none-selected products will be even higher. Furthermore, in average the ratio of standby energy of the total energy consumption is about 20% (range from 4 up to 40%), see also the Figure 2 for three typical examples. The standby ratio for luminaires is this high since (1) thanks to the LED technology the power consumption of the light source is rapidly decreasing and (2) since luminaires get "smarter" and more functionalities with network and sensor gear use power in standby.

	Table luminaire (Nr 4212.242)	Ceiling luminaire (Nr 4214.125)	Stand luminaire (Nr 4207.635)
			
Measured energy consumption:	7.4 W	12.9	5.7
Measured standby consumption:	0.7 W	0.7 W	0.7 W
Standby ratio (1000h on, 7760 off):	**42%**	**30%**	**25%**

Figure 2: Standby ratio for measured domestic luminaires

Colour rendering

The colour rendering index (CRI) is a measure of how colours appear in artificial light compared to daylight. For luminaires, it depends on the CRI of the lamps themselves, but it is also affected by shades and diffusors in the luminaire, which can reduce colour rendering quality. The best value is 100 and is typically reached by halogen lamps. Values between 77 and 86 are accepted as good and typically reached by fluorescent and LED lamps. To enter the EU market LED lamps must have a CRI value of at least 80 (EU regulation No 1194/2012 0). LED lamps can reach excellent CRI values of nearly 100, however there is a trade-off with luminous efficiency. With the astonishing technological development of LED luminous efficiency in the last years (reaching over 100 and up to 140 lumens per watt), demand for LED lamps with excellent CRI could increase in the coming years.

The CRI value is an average calculated for 8 pastel colours (see Figure 3). To only consider pastel colours is arguably not the best evaluation of colour rendering. There are 7 additional sample colours that would ideally be considered as well. They are saturated colours, leaf green and two skin colours. The saturated red, and to a lesser degree the saturated blue,

rarely appear natural in fluorescent or LED light. Figure 4 below shows all 15 sample colours and examples of typical CRI values for fluorescent and LED lamps.

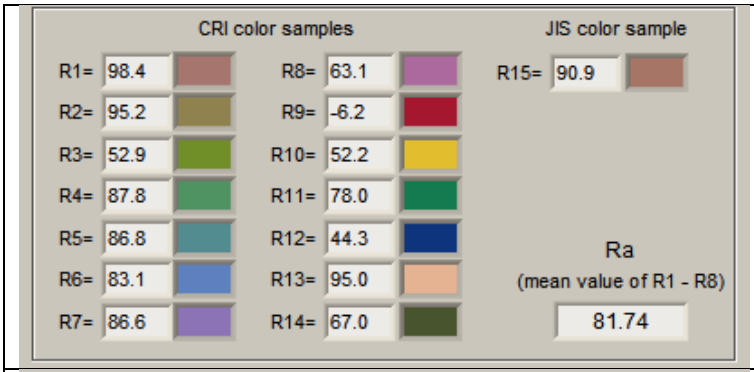
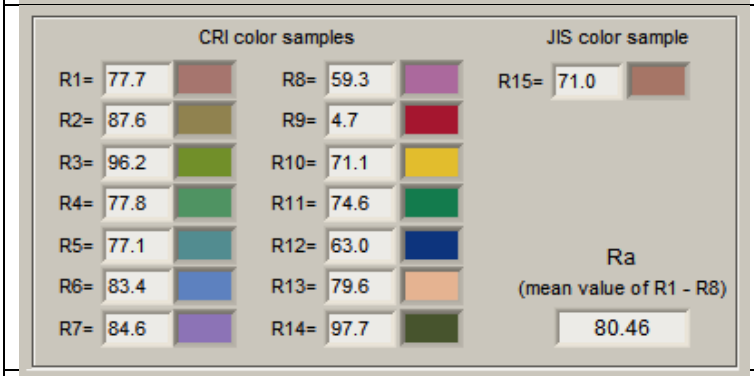
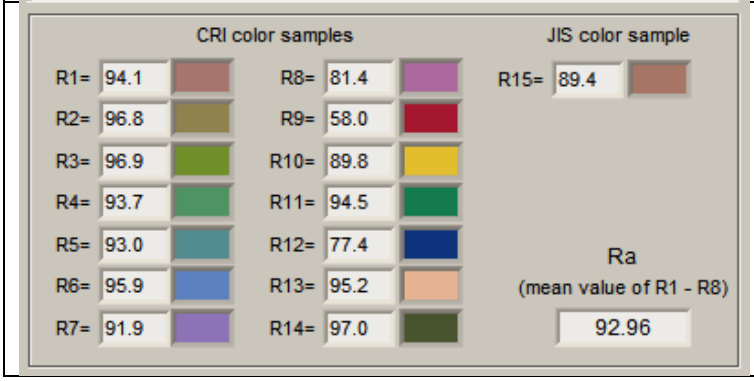
		Typical luminaire with fluorescent lamp
		Typical LED luminaire
		LED luminaire with excellent colour rendering

Figure 3: Colour rendering index (CRI) values for typical examples of different luminaires

4. Policy measures, standards and labels

The EU energy label and Ecodesign regulations currently are under revision. This will lead to several modifications. Topten is involved in the process and will set appropriate criteria for lighting products as soon as more details are known.

Up to now there are three different regulations for lighting products in force – divided into product categories:

- Domestic lighting; incandescent, halogen, LED and compact fluorescent lamps (244/2009 and 874/2012)
- Directional lighting: luminaires, reflector lamps and LEDs (1194/2012 and 874/2012)
- Linear and compact fluorescent lamps (245/2009)

The new regulation aims to merge all these three regulations into one energy label and one Ecodesign requirement regulation for *all* lighting products.

Van Holsteijn en Kemna (VHK) published a preparatory in 2017 titled “Preparatory study on lighting systems (Lot 37)”. The Consultation Forum took place in December 2017 and the Inter-Service Consultation started in the summer of 2018. Both regulations are expected to be voted upon in late 2018 respectively early 2019. Luminaires were only a side topic and mainly discussed regarding a removability requirement for the light source (see below).

Unfortunately, there is up to now no Ecodesign requirement for luminaires and no EU energy label for office luminaires.

EU Energy Label

The EU energy label for domestic luminaires is covered by EU regulation No 874/2012. This label differs from all other mandatory EU energy labels since it does not refer to the product’s energy consumption, light output or energy efficiency. Instead it indicates only the energy efficiency class of light sources (lamps) included in the luminaire and available alternatives. There are numerous designs for the label reflecting the variety of light sources (see Figure 4).

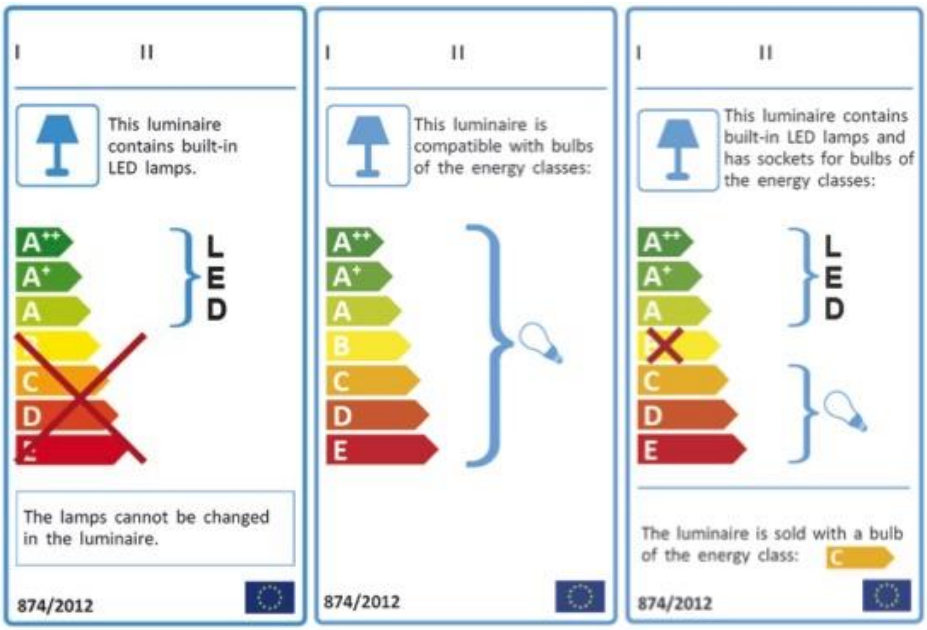


Figure 4: EU energy label for household luminaires (alternative layouts)

This label is not very useful, as it does not show the differences in real energy efficiency and consumption of different luminaires. Tests carried by Topten Switzerland show that there are large saving potentials in household luminaires: just within LED luminaires, the luminaire efficiency factor ranges from 5 - 150 lumens per watt. The EU energy label should make these differences visible to encourage more efficient luminaires. Furthermore, manufacturers and retailers indicate mostly only the values from the light source but not from the luminaire (the entire light system). This is very confusing for consumers.

Today the labelling regulation 1194/2012 (ecodesign of directional lamps and LED lamps) does not clearly formulate if product information has to be provided for the luminaire and/or the lamps. Most manufacturers declare for the lamps only, even if these are integrated and cannot be changed. It should be stated clearly that the product information should be declared for the luminaire, including standby power.

Due to the weakness of the energy label for luminaires Topten recommends:

- To update the existing EU energy label for household luminaires with a real rating of luminaire efficiency (based on measured luminaire data and the calculation of an energy efficiency index as it is done for lamps).
- This would be a transitional step to bridge the time until the label is replaced with a good solution and to quickly improve product labelling and information at least for domestic luminaires with built-in LEDs: To include luminaires with built-in LEDs into the scope of EU regulations No 1194/2012 (ecodesign of directional lamps and LED lamps) and No 874/2012 (labelling of lamps and luminaires), so that luminaires are treated in the same way as LED lamps.
- Introduce a label for office luminaires, based on the same principles that have been described above for domestic luminaires. This was already recommended in the preparatory study Lot 8 for office lighting in 2007. This is important because office lighting is estimated to account for double the energy consumption of domestic lighting. A mandatory energy label for office luminaires would be a strong incentive for electricians, planners, private and public procurement agents and awarding authorities to consider more efficient products.

Ecodesign regulations

Especially standby and removability requirements need to be tackled in the revised regulations since the existing Ecodesign regulations do not cover luminaires. They set performance requirements only for the lamps to be used in the luminaire. This is misleading because light is lost in diffusors and shades, and components for power conversion and lighting control use extra energy.

In the EU, standby consumption is partially limited through requirements for control gear and ballasts in regulations No 1194/2012 and No 245/2009. The limits are 0.5 watts for fluorescent lamps' ballasts (without integrated ballast) and 1.0 watt for other power converters like halogen convertors and transformers and LED drivers (0.5 watt as from 1 September 2016). Again, this is not enough for luminaires because many other components such as timer switches, occupancy sensors, light sensors and daylight regulation devices or illuminated switches also consume energy in standby.

Topten recommends that EU regulation No 1194/2012 (ecodesign of directional lamps and LED lamps) is revised to include minimum requirements for luminaire standby power for all luminaires (maximum 0.5 watts for luminaires in total, including integrated dimmers, touch-switches, sensors, network gear etc.).

Since luminaires with integrated LED are becoming very popular and will eventually become mainstream according to the US DOE (Energy Savings Forecast of Solid-State Lighting in General Illumination Applications, 2016), it's very important that the market is not flooded with unreparable luminaires (see also Figure 1). Since the LED light source is integrated, the entire luminaire needs to be wasted when the light source fails. We strongly support the efforts made by the Commission on the removability of light sources and control gears within luminaires. We think that the Commission should seize the opportunity and go even further by making the components of these luminaires replaceable and have interface standards such as the Zhaga consortium proposes.

5. Market analysis

No pan-European data exist on the luminaires market. However, in Switzerland there are detailed lighting market analysis by the Swiss Federal Office of Energy (SFOE) on the one hand, on the other hand Topten Switzerland is testing since years domestic luminaires of Switzerland's two largest retailers, Coop and Migros, as well as other suppliers and manufacturers.

Two trends can be seen: (1) The share sold units of luminaires is increasing and already about 20% of the sold lighting products are luminaires. (2) Sold units of lamps is decreasing since life time of fluorescent tubes, CFLs and especially LED lamps is longer than of incandescent light bulbs, therefore it takes longer until a replacement is needed. But the number of sold lamps is also decreasing since lamps are replaced by luminaires with integrated LEDs. Still, it's to be noted that the revenue for lighting products in Switzerland remained quite stable at CHF 1'100 million since LED luminaires are sold at high prices.

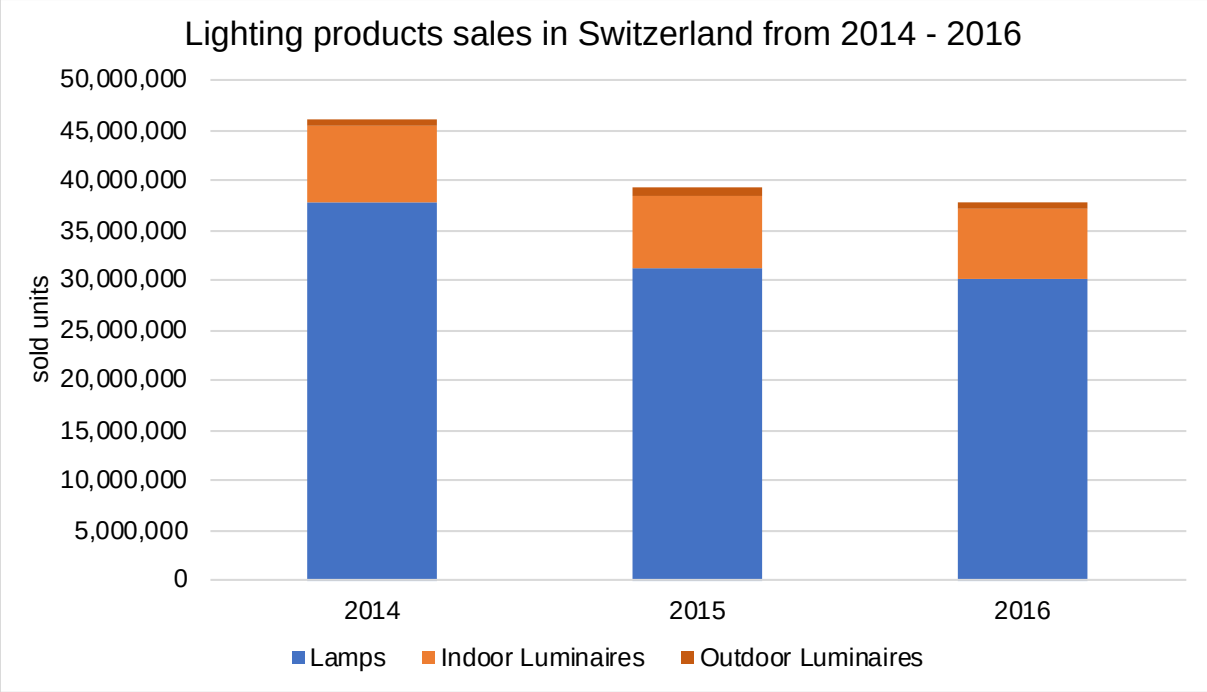


Figure 5: Lighting product sales in Switzerland 2014 - 2016 (source: Swiss Federal Office of Energy)

These two trends will be intensified in the upcoming years, when looking at linear fixtures (see Figure 6). The US Departement of Energy estimates that also LED luminaires will become mainstream for linear fixtures. This trend might be even intensified when a T8 linear fluorescent lamps phase-out in the next EU lighting regulation will become reality.

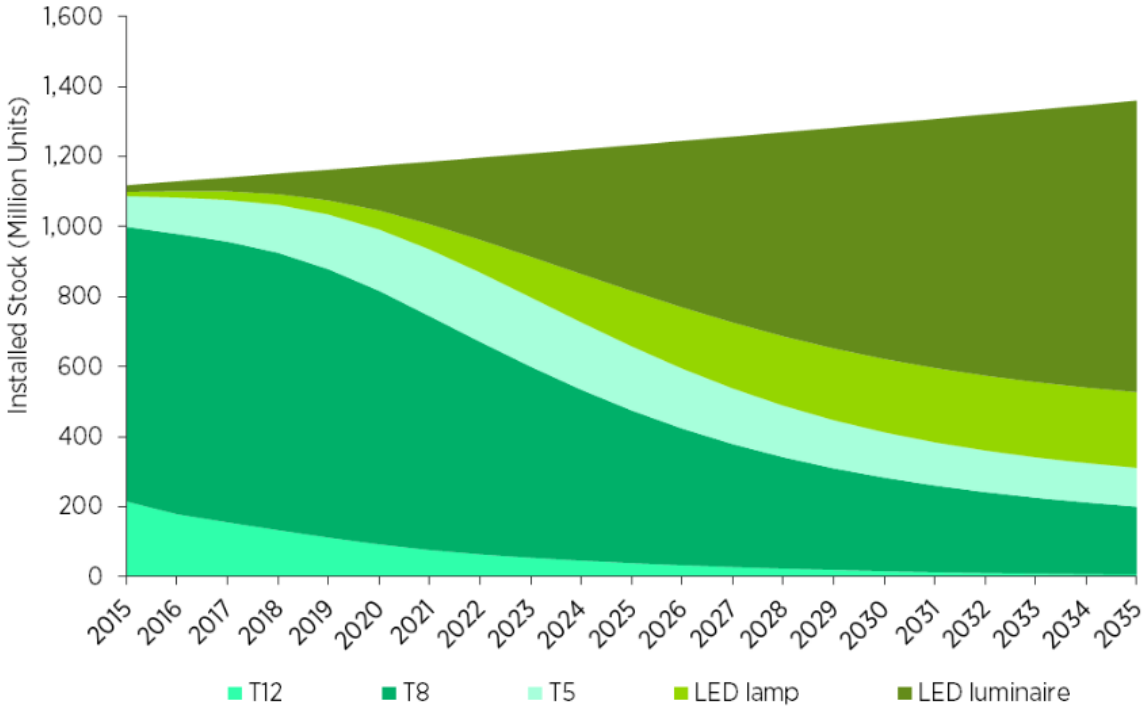


Figure 6: Linear fixture submarket stock forecast (source: US DOE report, 2016)

In terms of these trends (Figure 5, Figure 6) the current EU regulations for luminaires are not sufficient and needs to reflect these forecasts. Furthermore, the discussed removability considerations of the EU commission in the next lighting revisions for luminaires are needed since the integrated LED luminaires are gaining rapidly market share (see Figure 7).

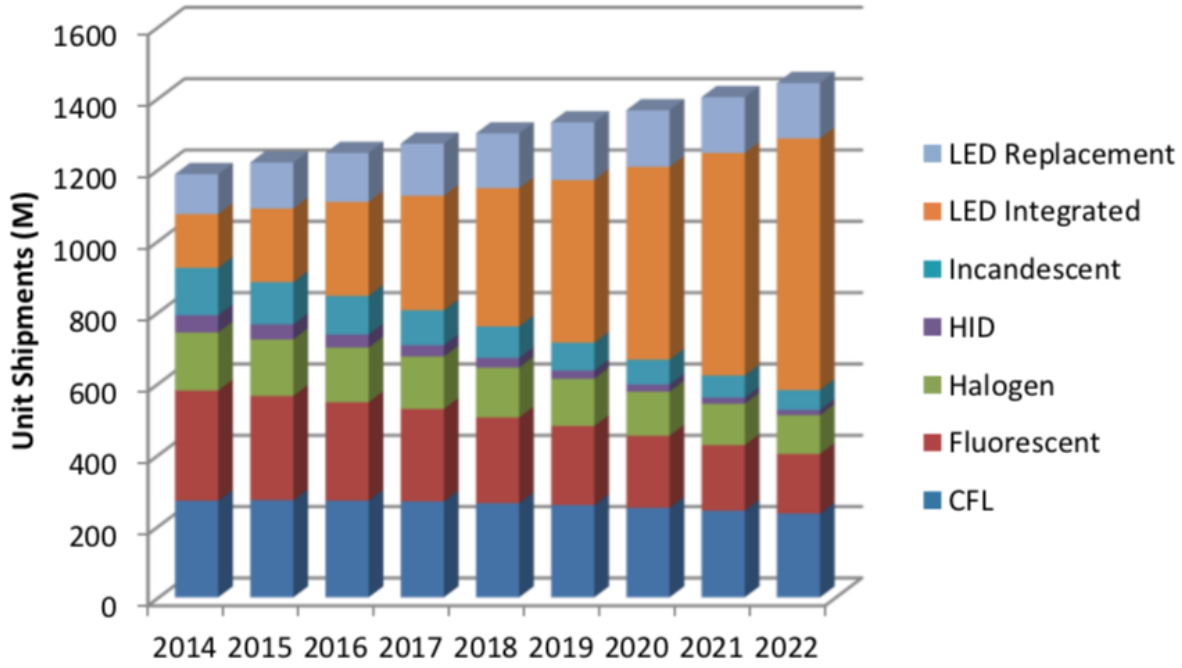


Figure 7: Global luminaires unit shipments (source: Smallwood 2016)

In accordance with the market forecasts above, Topten also observes that the market share of luminaires with integrated LED lamps is growing. The results from Topten Switzerland's ongoing luminaire measurements show that there are large saving potentials in domestic

luminaires. Luminaire efficiency ranges from 10 - 150 lumens per watt; and standby energy consumption is common and sometimes unnecessarily high. Measured colour rendering values of LED luminaires were generally good though could improve.

Since these lamps cannot be changed it is important that consumers have the best possible product information, as described in the policy section above. For these luminaires, test results show that, had the efficiency classes of luminaires been calculated in the same ways as it is done for LED lamps, then most of the luminaires would fall in class A. It's to be noted that these figures are only representativ for these subset of measured luminaires which have been preselected by Topten Switzerland. The preselection makes sure that a large share of the submitted luminaires can reach the Topten label. Measuring the entire Swiss market would be not feasible, therefore we try to maxify the number of successful measurements and identify the best avaiable products. The current best luminaires can reach the A++ class. A luminaire that really belongs to class A++ (measuring its luminous flux as it is done for LEDs) saves:

- over 80% compared to class B or C luminaires;
- over 50% compared to class A luminaires;
- over 25% compared to class A+ luminaires.

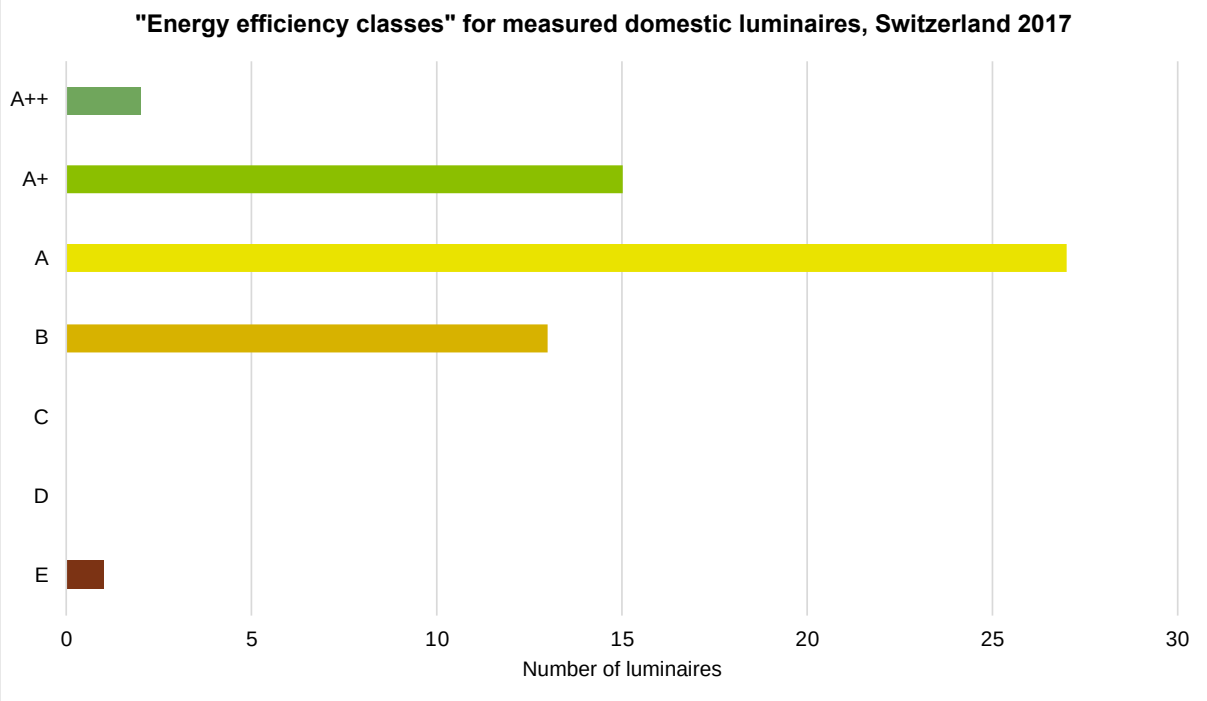


Figure 8: Distribution of measured LED luminaires per "energy efficiency class" in Topten's tests in Switzerland (source: Topten Switzerland 2018)

Finally, a last trends which needs to kept an eye on are so called smart and connected luminaires. According to Smallwood (2016) the compound annual growth rate of connected indoor lighting market is at 25% (for 2014 until 2022).

6. References and links

Useful links

Topten Criteria for Household Luminaires:

German: http://www.topten.ch/?page=auswahlkriterien_wohnleuchten&fromid=

French: http://www.topten.ch/?page=Crit-f-luminaires-d-interieur&fromid=
Italian: http://www.topten.ch/?page=Crit-lampade-casa&fromid=

Topten.eu selection criteria for office luminaires:
http://www.topten.eu/english/criteria/office_lighting_crit.html&fromid=

Topten.eu lists of selected office luminaires:
http://www.topten.eu/english/lamps/office-luminaires/ceiling-mounted.html
http://www.topten.eu/english/lamps/office-luminaires/recessed.html
http://www.topten.eu/english/lamps/office-luminaires/suspended.html
http://www.topten.eu/english/lamps/office-luminaires/floor-standing.html
http://www.topten.eu/english/lamps/office-luminaires/desk.html
http://www.topten.eu/english/lamps/office-luminaires/wall-mounted.html
http://www.topten.eu/english/lamps/office-luminaires/spots.html
http://www.topten.eu/english/lamps/office-luminaires/downlights.html

S.A.L.T., Swiss Alpine Laboratories for Testing of Energy Efficiency, http://www.salt-chur.ch

ZHAGA books for LED interface standardisation
https://www.zhagastandard.org/books/overview/

References

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

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

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://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012R1194&from=EN

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
http://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=URISERV:en0030&from=EN

Energy Star luminaires specification version 2.1 (2017)
https://www.energystar.gov/products/spec/luminaires_specification_version_2_0_pd

'Luminaire efficiency: what mandatory and voluntary labels achieve, and what they should achieve in the future' Eva Geilinger et al., August 2015.

- *Full Paper:*
  http://www.topten.eu/uploads/File/EEDAL15_Eva_Geilinger_Luminaire_efficiency.pdf
- *Slides presented at EEDAL'15 conference:*
  http://www.topten.eu/uploads/File/EEDAL15_Eva_Geilinger_Presentation_Luminaire_efficiency.pdf

Philip Smallwood, Lighting, LEDs and Smart Lighting Market Overview, February 2016

https://www.energy.gov/sites/prod/files/2016/02/f29/smallwood_mktadoption_raleigh2016.pdf

Swiss Office of Energy, Faktenblatt: Lichtmarkt Schweiz 2014, November 2015
https://www.newsd.admin.ch/newsd/message/attachments/41731.pdf

Swiss Office of Energy, Faktenblatt: Lichtmarkt Schweiz 2015, December 2016
https://www.newsd.admin.ch/newsd/message/attachments/46460.pdf

Swiss Office of Energy, Faktenblatt: Lichtmarkt Schweiz 2016, November 2017
https://www.newsd.admin.ch/newsd/message/attachments/50236.pdf

US Departement of Energy: Energy Savings Forecast of Solid-State Lighting in General Illumination Applications, September 2016,
https://www.energy.gov/sites/prod/files/2016/09/f33/energysavingsforecast16_2.pdf