Öko-Institut e.V.
Institut für angewandte Ökologie
Institute for Applied Ecology

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Innovation goals LED lamps

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Authors:

Stéphanie Zangl

Dietlinde Quack

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Öko-Institut e.V.
Freiburg Head Office
P.O. Box 50 02 40
79028 Freiburg, Germany
Street Address
Merzhauser Str. 173
79100 Freiburg, Germany
Tel. +49 (0) 761 – 4 52 95-0
Fax +49 (0) 761 – 4 52 95-88

Darmstadt Office
Rheinstr. 95
64295 Darmstadt, Deutschland
Tel. +49 (0) 6151 – 81 91-0
Fax +49 (0) 6151 – 81 91-33

Berlin Office
Novalisstr. 10
10115 Berlin, Deutschland
Tel. +49 (0) 30 – 28 04 86-80
Fax +49 (0) 30 – 28 04 86-88

www.oeko.de

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1 Status quo

Because of the long tradition of using filament light bulbs as universal lighting source in households – together with the technologically similar halogen bulbs – new and more efficient light sources have been developed primarily for existing fixtures and luminaires. These are commonly called "retrofit lamps" as they are intended to replace filament and halogen light bulbs. As such, energy saving lamps are available in different shapes and types to be used in many of the commonly used sockets. This is similar for LED lamps that now enter the market as household lamps.

Both technologies – compact fluorescent lamps and LED lamps – are much more efficient than conventional filament and halogen light bulbs. However, due to their technology they have some specific disadvantages. Especially LED retrofit lamps are technologically not yet mature enough to be placed on the market with the same economic and energy efficiency viability as energy saving lamps (this is due to still high purchase prices and quality issues).

Gasser 2009 summarises the technological challenges of LED lamps as follows:

- Often a lifetime of 50.000 h is declared - this can only be reached if the heat dissipation is ensured and if the quality of the necessary control equipment can also fulfil the high lifetime of the LED lamp.
- Due to high production tolerances colour temperatures and hence also efficiency are subject to too large variances. Or on the contrary, LED lamps with low production tolerances and reliable energy efficiency are still too expensive to be used widely in households as economically viable light source.
- Using LED lamps in specifically designed luminaires has the advantage that the heat can be dissipated over the metallic housing. Further development of such complete systems increases the probability of a better efficiency beyond the already achieved level of energy saving lamps. This is especially due to the fact that LED lamps indeed need an anti-glare provision but do not need reflectors within the luminaire.

Further LED specific challenges include lacking declaration which itself is related to missing normative and quality standards. Only once reliable statements on efficiency and lifetime can be given can LED lamps be considered an equivalent replacement for lamps in households.

In addition, it has to be stated that not every lamp technology is suited for each type of application. While halogen lamps are suited for specific uses where good colour rendering is important LED lamps can be the better alternative for directional lighting if they have equivalent colour rendering properties but higher efficiency and lifetime.

Energy saving lamps can rather be used as general light source with fair colour rendering as for this type of use they are the more cost-effective alternative. Furthermore, the absence of necessary cooling meanwhile also allows aesthetically variable uses.

2 Future developments

From a technological point of view the rather mature energy saving lamps will rather be further developed with regard to switching cycles and start-up time. Nevertheless, they will remain best suited for efficient general indoor lighting even though directional types are available.

For LED lamps further development will focus on the issue of ensuring sufficient cooling, prevent glare and extend lifetime of all components. Furthermore, the currently reached efficiency of 60 lm/W is to be doubled in the next years (Gasser 2009).

The area of organic light emitting diodes (OLED) is a relatively new domain of lighting technology development. It will still need some years before OLED applications are available that can be used for general lighting. Their advantage will be that they can generate light very efficiently. However, these light sources are only suited as plane and not as point sources nevertheless making them more comfortable for the human eye due to reduced glare. Therefore, OLEDs will rather to be used in “light wall paper” and not as a full replacement of common light sources (BMBF 2010).

3 Deduction of innovation goals

In order to further support the development of efficient LED lamps and to improve their market acceptance innovation goals are set in the following. They are intended to offer product developers and producers the possibility for better prioritisation as well as to offer users good quality and at the same time efficient products. The innovation goals were discussed with a group of lamp manufacturers and experts in lighting technology (cf. attached minutes).

3.1 Doubling energy efficiency

Currently available LED lamps have an energy efficiency during use of between 50 and 70 Lumen per watt and are therefore comparable to energy saving lamps. Experts assume that this will double within the next 5 years (Gasser 2009).

This is to be achieved inter alia with putting together bigger modules into lamps with higher wattages in order to reduce the influence of power supply losses onto energy efficiency compared to lamps with lower wattages[1]. Furthermore, this goal can only be achieved in combination with efficient thermal management.

During discussion with experts, it appeared that formulating a general goal of doubling energy efficiency in the context of the Euro Top Ten approach does not seem a feasible innovation goal. Rather consumer should be informed about lumen equivalences, interaction of colour rendering and efficiency as well as the best suited applications for LED replacement lamps. This is due to the fact that there is always a trade-off between high colour rendering and high efficiency. Also, doubling the energy efficiency for non-directional LED lamps seems very ambitious since there are constructive limitations to thermal management (heat dissipation can only be guaranteed to a certain degree). Possibly LED lamps are not suited as retrofit technology for incandescent light bulbs whereas as retrofit for halogen light bulbs they have the potential to be used in their optimal area of application. Thus, for directional LED lamps an increase in energy efficiency could be possible.

3.2 Good thermal management

Retrofit LED lamps currently still have non aesthetical cooling devices due to their construction shape: heat here needs to be dissipated over the circuit board or the module and not over the housing. Hence they are currently only offered with low voltages. Cooling is necessary because in LED lamps heat is generated as energy loss at the back end (75%) and not in the light beam. When the junction temperature (temperature on the chip) gets too high light output and lifetime are highly reduced. In case of overheating the chip is destroyed since it should not exceed a temperature of 80°C (depending on the type) (Gasser 2009).

Discussion on this point with experts led to the conclusion that a recommendation for Euro Top Ten could be to inform consumers about the necessity of a good thermal management which also includes the use of a LED lamp in a luminaire that should not increase the temperature of the lamp. Also, here again, users should be made aware of the fact that using LED lamps as light bulb replacement has wattage and lifetime limitations due to the need of heat dissipation.

This resulted from the fact that thermal management for non-directional LED lamps offers no optimisation potential since there are design limitations due to the bulb shape that needs to fit in existing sockets and luminaires. On the contrary, thermal management is less an issue for complete lighting systems (lamp + luminaire) since heat can be dissipated over large surface area. For example new materials such as plastics, metals other than aluminium, ceramics etc. can be used for nicely designed cooling elements. In this area there is still development potential.

[1] A power supply has at least 0,5 W own energy consumption making its proportion for a 1 W LED lamp very high (Gasser 2009).

3.3 High power factor

Alike energy saving lamps LED lamps need mains voltage transformation which is located in the control circuit. This has a certain loss and good quality products have an efficiency rate of around 90%. The power factor on the contrary is determined through the quality of the power supply and gives an indication on the relation between the used active power and the apparent power transported through the electricity grid (Gasser 2009).

The EuP implementing measure for non directional household lamps (244/2009/EC) provides for a power factor of > 0,5 for energy saving lamps below 25 W. Draft criteria for the German ecolabel Blue Angel sets a power factor of > 0,75, the US Energy Star set one of 0,7 and the British Energy Saving Trust of 0,65. Measurements of the Swiss Chur university of technology (HTW) have shown that out of 11 tested retrofit lamps only 6 could reach just above 0,5 (Gasser 2009).

Legally binding values do not yet exist for directional lighting.

During discussion with experts no consensus could be reached on whether a high power factor really is a quality criteria for lamps and from what wattage on a PFC (Power Factor Corrector) switch would make sense. In general it was pledged not to set a criteria for the power factor but to mention it for information purposes. Also, the power factor is irrelevant for users as it merely gives an indication on the influence the electrical equipment has on the power grid. Minimum legal requirements should thus be sufficient here.

3.4 Proof of long lifetime for all components

A high LED lamp lifetime depends on whether the built-in components and here particularly the control circuit are capable of reaching the same lifetime as the diode itself. Furthermore it is largely influenced through the thermal management of the lamp.

A real time proof of a very long lifetime – as it theoretically is the case for LED lamps – cannot be provided through tests since these would last much too long. For a qualified proof the only remaining possibility is thus an extrapolation based on more short term measurements. However, this approach is not yet standardised and no commonly agreed method exists either. The goal would thus be to develop such a method and to internationally standardise it. Different proposals exist but there is no clear directional reliability as to where the agreement could be. This leads to the fact that there is no possibility for third-party certified and independent verification of producer specifications.

As stated above testing long lamp lifetimes is not practicable since a test of 50.000 h lifetime based on a switching cycle of 2 h 45 min „on“ and 15 min „off“ (corresponds to a 3h daily use cycle) would last for 6 years. By then products would maybe not be on the market anymore or would be outdated. Against this background Philips has brought forward a proposal for an accelerated verification of LED lamp lifetime (Philips LED lifetime). It is assumed that LED lamps – just as energy saving lamps – loose light output over time. Hence, firstly a lifetime definition depending on the decrease in light output has to be defined. According to industry statements a decrease in light output of 30% (Lamp Luminance Maintenance Factor LLMF = 70) is close to the possibility for detection of the human eye. It thus appears sensible to define the end of the lifetime at the point of time where this 30% decrease has been reached. In addition the average lifetime of a lamps is already commonly defined as the point of time where 50% of the lamps are out of function (Lamp Survival Factor LSF = 50). It thus appears sensible to define the useful lifetime of a lamp against both parameters (e.g. the useful lifetime is reached at LSF_{50} and $LLMF_{70}$).

In its "Technology White Paper – Understanding LED lifetime analysis" (Philips LED lifetime) Philips moreover points out the influence of the junction temperature and of the operating current on the LED lamp lifetime whereas a low junction temperature and a low operating current lead to a higher lamp lifetime. These two parameters are particularly relevant for building-in LED lamps and thus rather interesting for light designers and planners. Philips has consequently decided to publish lamp specifications as LSF_{10} / $LLMF_{70}$ and LSF_{50} / $LLMF_{70}$ together with the interaction on junction temperature and operating current (cf. Figure 1).

The paper furthermore contains a proposal on the prediction of LED lamp lifetime based on the application of the Weibull distribution function – a commonly agreed statistical method - on empirical data. Thereby measured data is extrapolated in order to predict the behaviour of lamps over a longer period than the measurement. According to Philips it is possible to give sufficiently exact estimations of up to 60.000 h using available measurement data. However, as stated above, this is only one of the currently discussed proposals.

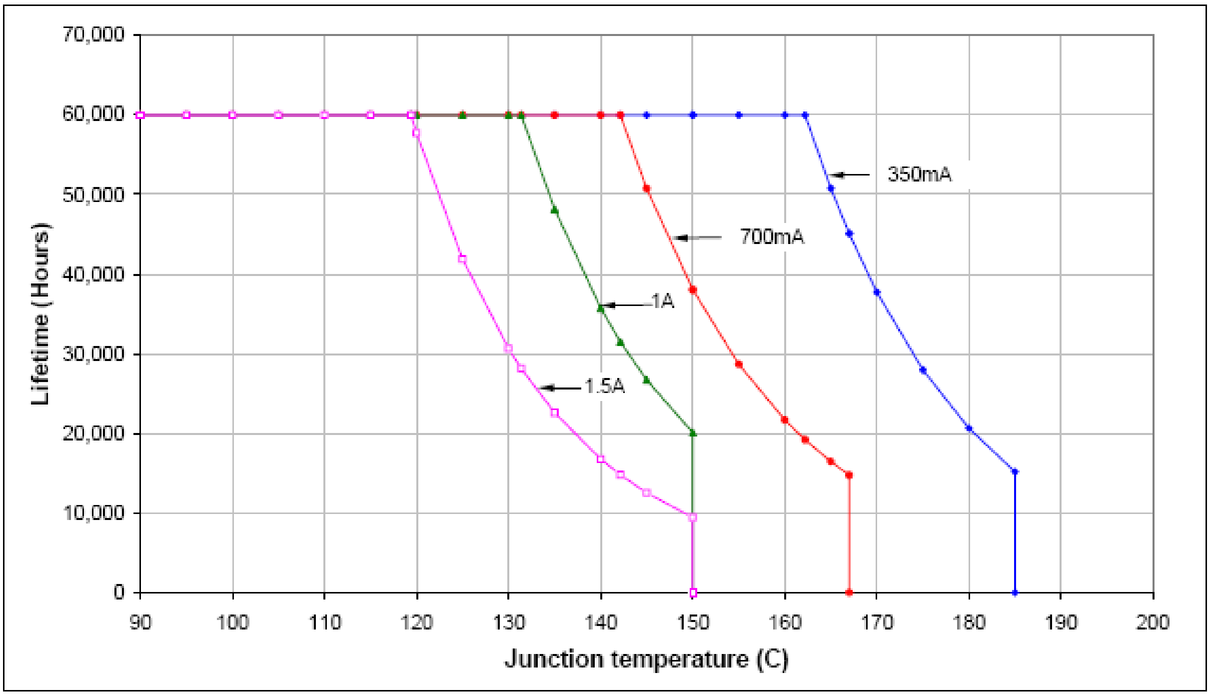

Figure 1 LSF_{50} / $LLMF_{70}$ lifetime data against junction temperature and operating current for Philips K2 LED lamp (Philips LED lifetime)

As a result from discussion with experts, it came out that a minimum requirement of e.g. 10.000 hours (in order to be comparable with CFLs) should be set. However, no verification is possible and thus manufacturer data has to be taken for granted. Nevertheless, lifetime needs to be equally defined and corresponding information has to be published and explained on topten.info. This means that it has to be agreed whether lifetime is defined at a lamp survival factor of e.g. 50% in connection with a certain lumen maintenance and the meaning of these figures has to be explained to users.

Furthermore, concerning the issue whether or not a long product warranty could solve the problem of proving long lifetimes, experts stated that it is requested not to set a long warranty as a criteria but rather to inform about how „correct“ lamp use can lead to a long lifetime. This is due to the fact that giving higher warranties than legally necessary is problematic due to the fact that LED lamps can be used in so many different ways that the operating conditions can be very bad or wrong resulting in lamp failure. Therefore manufacturers are very reluctant to giving higher warranties in the b2c area. For LED lamps sold in the b2b area this might be different since here individual contractual negotiations allow for higher warranties.

3.5 Reduction of blue light hazard

A certain hazard through optical radiation is assumed for blue and white LEDs. The reasons for this lie in a photo-chemical reaction on the retina. This phenomenon is currently being further investigated (Gasser 2009) and thus no innovation goal can currently be derived.

3.6 Quality standards

It has to be considered that for all current light sources usual measurements are done at warm operating condition whereas LED component manufacturers carry out measurements in cold condition. EU and US standardisation bodies are currently developing the grounds for LED measurement standards (Gasser 2009).

In the US standards of the Illuminating Engineering Society of North America (IESNA) already exist for LED lamps which are however not yet considered commonly agreedd in Europe. The two standards LM 79 and LM 80 contain measurement standards for the determination of inter alia lamp efficiency, lamp luminance maintenance and lifetime (here however without statements on the transferability of measurement results into estimations on real lifetime).

On international level a standard for the operation of LED lamps with integrated ballast for general lighting purposes exists as so-called Committee Draft (IEC 62612 from July 2009). According to the responsible officer at the German Commission Electrical Engineering within the standardisation bodies (DIN and VDE) it can however still take up to 3 – 4 years until the standard is published and thus commonly recognised[2].

The draft standard defines terms, sets requirements on labelling, verification conditions, lamp performance, light output, colour properties, lamp lifetime, lamp luminance and defines a stress test for the electronic circuit as well as measurement procedures for lamp characteristics. Concerning the terms it should be mentioned that in parallel there is a further draft standard (IEC 62504) which includes terms and definitions for LEDs and LED modules.

The goal of the next years is thus to foster and continue ongoing activities in such a way that commonly agreed quality standards can be adopted that allow producers of good quality products to have an outstanding position on the market and thus also to label their products with standardised parameters and specifications.

This was confirmed in the expert discussion: setting quality standards seems too early in the process as experts and lighting industry themselves have not yet agreed on a set of relevant and verifiable criteria. While quality is very important for market penetration of LED lamps

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[2] After the current Committee Draft, a Committee Draft for Voting is agreed which takes supplied comments into account and is in parallel dealt with by the responsible European standardisation body CENELEC. After voting a final draft international standard is circulated before the final version is published.

consumers should be made aware of the fact that choosing good quality LED lamps using commonly agreed quality criteria is currently not feasible.

3.7 New lighting systems

Currently lighting systems are characterised through so-called lock-in effects. This means that retrofit lamps are designed for existing luminaires and can thus not fully exploit their efficiency potential. While on the one hand an average luminaire has a degree of efficiency of 60% which can be enhanced over 80% by the use of LED lamps, on the other hand the maximum light output of retrofit lamps lies at around 400 lumen (Gasser 2009).

Developing new lighting systems that are specifically designed for LED lamps could thus improve further efficiency, quality and application diversity of lamps.

As an outcome of discussions with experts, it was agreed that new lighting systems cannot yet be recommended to consumers since it would require a re-design and installation of light sources in households. However, for professional lighting applications recommending complete lighting systems on the basis of LED lamps is a possible area of improvement for Euro Top Ten.

It is perceived by the experts that the market is ready for a technological changeover. Especially there is a general change: in the past luminaire, lamp and control gear manufacturers existed. Today all manufacturers want to offer complete systems consisting of luminaires and lamps and semiconductor business is entering the lighting market. In the long run, LED lamps will be sold together with luminaires that have been designed to take advantage of the possibilities of this technology.

Concerning market presence of retrofit lamps designed to fit into existing sockets and luminaires there was no consensus among experts: while on the one hand retrofit lamps offer advantages for consumers (security of supply, replacement with more efficient technology involves least efforts) on the other hand they have technological limitations for optimum heat dissipation.

4 Conclusions and general recommendations for topten.info

The expert discussions led to the following conclusions:

- Setting clear and ambitious innovation goals for LED lamps seems to be a difficult task at the moment as the technology is still under development and reliable and verifiable data and information is missing.
- The aim of topten should in the short term thus rather be to publish information for consumers and public procurers on how to “read” LED lamp parameters currently

published and available. A proper understanding of the technology's limitations and best possible applications is currently very important.

- Otherwise, further recommendations should only be given once commonly agreed quality criteria are available – be it through a voluntary manufacturer's label, eco-labels like e.g. the German Blue Angel or the European eco flower or at least through existing legal minimum requirements as they are expected to enter into force through the EuP implementing measure sometime in 2011.
- The one innovation goal that seems the most promising one in the mid and long term is the introduction of new lighting systems that are specifically designed to accommodate the advantages of LED lamps. However, this will first have to be introduced in the area of professional lighting applications before becoming available and interesting for consumers. Topten could thus create a new product section destined at these professional LED lighting systems.

As another outcome of expert discussions, some improvement options for the current online presence of topten.info were mentioned: participants pointed out that it is absolutely necessary to mention the measurement method which should be used for generating data requested under topten.info. Measurement is requested to be done at a certified laboratory which is however not sufficient for unambiguously identifying the necessary measurement method.

This is especially valid for LED lamps as here standards are still under development. The question is whether for example the newly issued „Minergie" measurement rule (Stefan Gasser leads the „Minergie" light certification unit) should be used for orientation. It should furthermore be made very clear that data requested and then published under topten.info refers to entire LED lamps and not LED modules.

5 References

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