Free dissemination

(ContractTREN/07/D3/390-2006/S07.72702)
Preparatory Studies for Eco-design Requirements of EuPs

Lot 19: Domestic lighting – Part 2
Directional lamps and household luminaires

Interim Task Report

Task 3: Consumer behaviour and local infrastructure

Study for European Commission DGTREN unit D3, contact: Andras Toth

Contractor:

Project performed in cooperation with:

Contact Vito: Paul Van Tichelen, info@eup4light.net

2007/ETE/R/

VITO

March 2009

Project team

Vito:
Paul Van Tichelen
Bart Jansen
An Vercalsteren
Bio Intelligence Service:
Shailendra Mudgal
Lea Turunen
Benoît Tinetti
Energy Piano:
Casper Kofod
Kreios:
Lieven Vanhooydonck
Laborelec (reflector lamp tests):
Jean-Michel Deswert

Important note:
This report contains the updated draft results of research by the authors and is not to be perceived as the opinion of the European Commission.
This is an updated draft document intended for stakeholder communication.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

0 PREFACE

VITO and its partners are performing the preparatory study for the new upcoming eco-design directive for Energy Using Products (EuP) related to domestic lighting, on behalf of the European Commission (more info http://ec.europa.eu/enterprise/eco_design/index_en.htm).

The environmental impacts of Energy-using Products such as domestic lighting take various forms, including: energy consumption and the related negative contribution to climate change, consumption of materials and natural resources, waste generation and release of hazardous substances. Eco-design, which means the integration of environmental considerations at the design phase, is arguably the best way to improve the environmental performance of products.

The creation of a coherent framework for environmental product policy avoids the adoption of uncoordinated measures that could lead to an overall negative result; for example eliminating a toxic substance from a product, such as mercury from lamps, might lead to increased energy consumption, which could in total have a negative impact on the environment. A Community framework also ensures that divergent national or regional measures, which could hinder the free movement of products and reduce the competitiveness of businesses, are not taken. It is not the intention to decrease the quality of domestic lighting.

The objective of this interim draft document is to present preliminary data for discussion with stakeholders related to the EuP preparatory study for the lot 19.
You can follow the progress of our study and find general information related to lot 19 on the project website when you register as stakeholder: http://www.eup4light.net
Please, also consult the website for timing and organisation of the tasks.

Important remark:
It must be clearly stated that this part 2 of the study relies on the draft regulation resulting from part 1 of the study on non-directional light sources. Specific items on non directional lamps that were discussed in part 1 will not be repeated in this part 2. Items that are related to all light sources can be repeated, only to improve the readability, not for new discussion.

1 PRODUCT DEFINITION

For more info see website www.eup4light.net.

2 ECONOMIC AND MARKET ANALYSIS

For more info see website www.eup4light.net.

3 CONSUMER BEHAVIOUR AND LOCAL INFRASTRUCTURE

Consumer behaviour can -in part- be influenced by product-design but overall it is a very relevant input for the assessment of the environmental impact and the Life Cycle Cost of a product. The scope of this chapter is to identify barriers and restrictions to possible eco-design measures, due to social, cultural or infra-structural factors. A second aim is to quantify relevant user-parameters that influence the environmental impact during product-life and that are different from the Standard test conditions as described in section 1.2.

3.1 Definition of the Consumer and context

For domestic lighting it is important to discriminate two main types of consumer:

1. The person responsible for the putting into service of a new house/flat or renovation of parts of the home, e.g. interior designers, property developers, kitchen and bathroom designers and installers, hereafter called the *'service providers'*. Please note also that more and more appliances are including lighting, e.g. extractor fans in the kitchen in which case a service provider is also involved. Interior designers and/or lighting architects are thus having a growing influence and some decisions are taken in the same as in some parts of the tertiary sector.
2. The consumer who lives in the home and makes use of the lighting equipment, hereafter called the *' user'*.

In the domestic lighting market the 'service provider' and 'user' can be the same, especially when Do-It-Yourself (DIY) equipment is bought and put into service by the user as a DIY consumer.

Nevertheless, the ’service providers’ is often not the user. They have a growing influence on energy used in the domestic homes because with growing welfare, many people install new kitchens, bathrooms, corridor, adding a veranda etc.. In this process, the designers, home decorators, installers or qualified electrician have a large influence by including lighting solutions that are typically outdoors, installations in the ceiling, and sometimes even more. Some of those furniture and appliance manufacturers include lighting in their products, and this market is dominated by a multitude of down lighting by reflector lamps actually mainly of the halogen type. The lighting is an integral subcomponent of the design and installation process where the customer buys “the whole package” including lighting. In this case both service providers and the consumers take decisions that affect the quality, cost and efficiency of lighting in the home.

It should be noted that the lamps and luminaries within the scope of this study are also used in lighting for the tertiary sector (e.g. Horeca sector, shops). In this sector, service providers are typically involved and often also lighting designers performing calculations. The process is similar to what is described in the preparatory study concerning office lighting (Lot 8). Please see this study[1] for description of this service approach – in contrary to domestic circumstances photometric data for ‘architectural lighting luminaires’ for offices is available for the service provider and lighting designer.

3.2 Real Life Efficiency and quantification of relevant parameters

3.2.1 Background info on lighting design criteria

The concept of energy-efficient lighting is meaningless unless the lighting system provides the conditions necessary to perform the task. The goal in designing a lighting system is to provide a suitable visual environment that provides “right light at the right time at the right place”.

The main objectives for installing electric lighting systems are:

- Facilitating the performance of visual tasks
- Promoting safety and security
- Attractively revealing the environment – create atmosphere
- Participating in the interior design of the household by attractive design of lamp or luminaire.

The priority of the above objectives in the design process depends on the specific situation and the preference of the user. Moreover, if the object is three-dimensional or coloured, the direction of the incident light or its colour-rendering properties becomes important determinants of visibility.

In the domestic sector all the design is up to the consumer in contrast to the commercial sector using lighting codes and standards for satisfactory visual performance.

3.2.2 Lumen losses within luminaries

For *luminaires with DLS lamps* nearly all luminaires found on the market do not obstruct the functional lumen output from the lamp as defined in Task 1 (functional unit) (see Figure 3.1). Hence for these luminaires there is simply no improvement potential related to lumen losses. Please note that this might to some extent explain the popularity of those DLS lamps (see chapter 2). The LOR of those luminaires is 1.

[1] VITO EuP Lot 8, Office Lighting, Final Report, April 2007.

Figure 3-1 DLS luminaires have most often LOR=1

For luminaires with NDLS lamps there is a broad spread on lumen losses within luminaires (LOR) (See Figure 3.2). The LOR for these luminaires can vary from below <0.1 up till 1 (bare lamp holder).

Figure 3-2 Domestic luminaire for NDLS: left with LOR <0.1, middle[2] LOR > 0.5, left >0.99

[2] Lesslamp by Jordi Canudas (b. 1975 Barcelona, Spain): The Less Lamp is a sealed lamp shade that needs to be broken in order to release the light trapped within. The shell is cracked using a specially designed hammer. The user decides the appearance and position of the hole depending on how much light is required and where it is to be directed.

Notes on luminaire LOR (Light Output Ratio):

- Both the visual appearance and the lumen losses within luminaires are optimal when the luminaire is designed for the lamp type used in the luminaire. It is therefore important that luminaire manufacturers bring luminaires on the market that are dedicated to the lamp type so the customer is aware of combining luminaire and lamp in the best way. Hence LOR can vary in real life if another lamp type or shape is used in the luminaire.
- The right energy efficient luminaire will balance: maximum light output ratio, glare control, light distribution and amount of decorative ornaments that absorb light.
- It should be noted that the LOR improvement potential for functional luminaires that are used in the tertiary lighting sector were assessed in preparatory studies on office and street lighting (lot 8 and 9). All those luminaires have an optical system to control the light distribution. This information and approach will not be repeated in this study.
- In case of LED luminaires with integrated lamps, only LER can be used (see chapter 1 for definition of LER).
- The main parts (e.g. lamp cap) that influence LOR and light distribution are often sold separately (see Figure 3-3).

Figure 3-3 Domestic NDLS luminaire (LOR=1) that optionally can be quipped with a lampshade (LOR<1). The lampshade prevents glare and influences light distribution.

3.2.3 Illumination losses in the task area by lack of lighting design

For performing the visual task maintaining a minimum illumination level in the task area is essential, moreover glare should be prevented and the uniformity should be kept within acceptable limits. This is typically done when a professional lighting designer is involved and the approach is identical to what explained in the preparatory study on office lighting (lot 8)

Nevertheless, professional lighting designers are seldom involved in domestic lighting and many common practices found in domestic lighting cause a loss of illumination. Below please some examples of domestic use of reflector lamps in order to illustrate the improvement potential in this area.

Example 1 Wrong usage of reflector lamp (DLS):

Many reflector lamps are used for general lighting (as NDLS) where the user often don't make use of the lighting is limited to a specific beam angle. On the contrary, there might be areas not lit properly where the users thus install extra lighting.

Example 2 Optimum use of reflector lamps (DLS):

In this case a series of spot lamps with turnable socket are installed in the ceiling. This allows the user to control and fine tune the light in the desired direction e.g. towards the sofa and table and away from the TV set. This is a very common practice in the modern living room and is part of the explanation for the growth in use of DLS (see chapter 2).

3.2.4 Room surface reflection

The room surface reflection can have a significant influence on the illumination level in the task area, for more information see the preparatory study on office lighting (Lot 8)[1]. The improvement potential (e.g. using white painted walls) is outside the product scope of this study.

3.2.5 Lamp efficacy and sensitivity of the human eye

Please see chapter 3 in the final report for part 1 of the study.

3.2.6 User influence on switching schemes (annual operating time)

Please see chapter 3 in the final report for part 1 of the study.

3.2.7 Lamp dimming

Please see chapter 3 in the final report for part 1 of the study.

3.2.8 Influence of the power factor and harmonic currents of a light source

Please see chapter 3 in the final report for part 1 of the study.

3.2.9 Influence of voltage change

Please see chapter 3 in the final report for part 1 of the study.

[1]

3.2.10 Decrease in lamp efficacy in real life operation compared to standard conditions

The lamp efficacy that is announced by manufacturers is measured after an ageing period of a number of hours burning in standard conditions as defined in the specific European standard on performance requirements for the lamp type (see chapter 1).

Due to normal ageing and deviation from lamp specification conditions when placed in a luminaire, the efficacy might be influenced – this is certainly the case for a LED luminaire.

3.2.10.1 Lamp ageing

For all lamps except LED please see chapter 3 in the final report for part 1 of the study.

WLED retrofit lamp

For most light sources, the lamp fails before significant lumen depreciation occurs while LEDs continue to operate also at very low light levels. Therefore LED lifetime is usually defined as lumen depreciation to a certain level e.g. 70% of initial lumens (abbreviated as L70 or L_{70}) together with a particular typically F50 (50% failure rate, see also chapter 1 and figure 3.7).

The LED industry group ASSIST[3] (Alliance for Solid-State Illumination Systems and Technologies); stated that 70% lumen maintenance is close to the threshold at which the human eye can detect a reduction in light output. LED manufacturers publish lumen depreciation curves based on testing of their products, extrapolating lumen depreciation to the 70% level because it takes to measure.

Depending on the application, other depreciation levels may be appropriate as end of life limits, such as L_{50} or L_{80}.

The standard IESNA LM-80-08 – Approved Method for Measuring Lumen Maintenance of LED Light Sources (released 2008) applies to LED arrays, packages and module but **not** luminaires. It includes a test method for $L_{70,}$ including photometric measurements at three temperatures 55°C, 85°C and XX°C (the manufacturers own choice) and a test duration of minimum 6,000 hours with measurements at 1,000 hour intervals. This standard does **not** provide guidance regarding predictive estimations or extrapolation. IES TM-21-xx which is currently under development will address this topic.

Figure 3.4 shows an example of a LED lamp **predicted** lumen maintenance curve for a warm white LED[4] in operation at drive current 700 mA with junction temperature at or below 120°C where the lumen depreciation starts right from the start and 80% depreciation occurs already around 1100 hours and 70% occurs around 25,000 hours!

[3] Details about ASSIST can be found at www.lrc.rpi.edu/programs/solidstate/assist/index.asp
[4] Atlas Lamina Series LED Light Engines, FM-0167, rev. 02.14.2007.

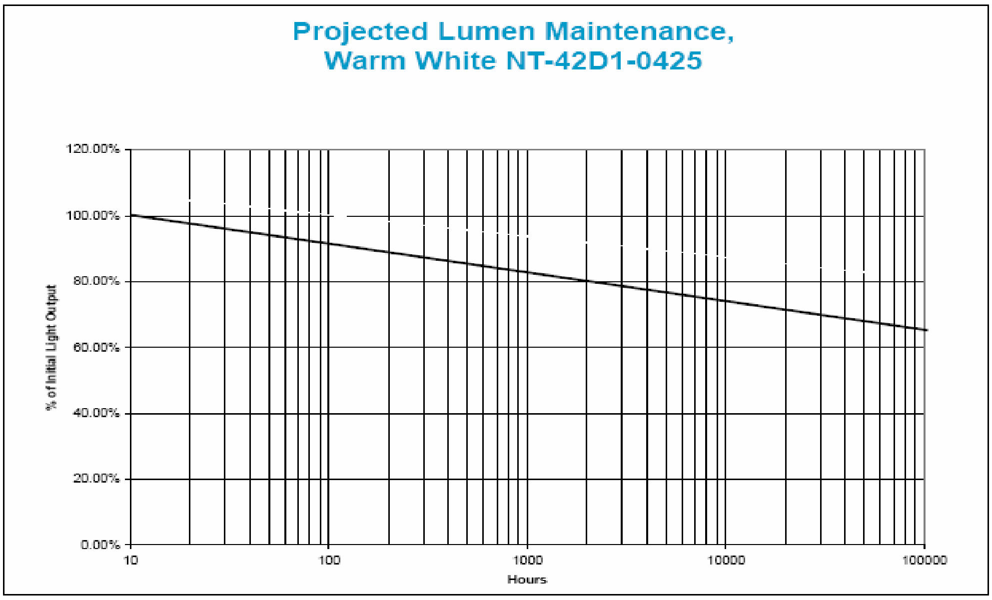


Figure 3.4: LED Lamp lumen maintenance curve for a warm white LED Source: Atlas LED Light Engines, www.laminalighting.com.

Figure 3.5 shows a **measured** LED lamp lumen maintenance curve for the first 6000 hours provided by one of the large manufacturers[5] where 92% depreciation occurs at 6000 hours

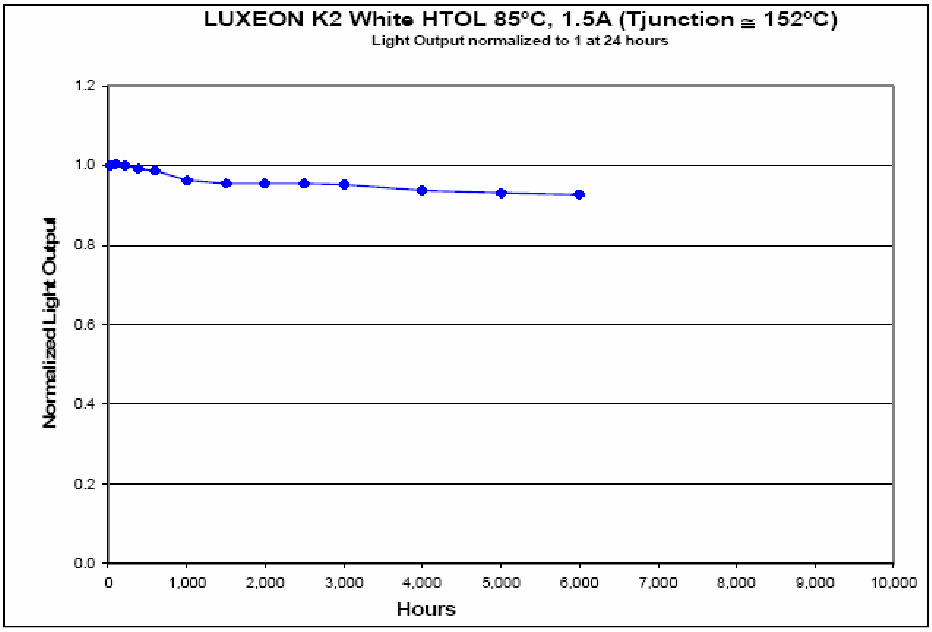


Figure 3.5: LED Lamp lumen maintenance curve for Philips Lumileds K2 LED.

The LED lamp depreciation varies a lot depending on the quality of the product.

Conclusion

An average lamp depreciation factor 0.95 for the first 6,000 hours and 0.85 for the first 25,000 hours is good quality. Stakeholders are welcome to provide more data and suggestions.

[5] PHILIPS Technology White paper: Understanding power LED life analysis, *www.philipslumileds.com/pdfs/WP12.pdf*

Integrated LED luminaires

Rated output for LED lamps is often quoted at a temperature of 25°C which is very different from operation in a LED luminaire where the junction temperature typically will be in the interval 60-150°C.

The DOE CALiPER program[6] began reliability testing on LED luminaires in August 2007. Figure 3.6 summarize lumen depreciation interim testing results for 13 LED products. The lumen depreciation testing is not completed for these samples, but these interim results already provide insight. The two white lines in the plot are provided as reference curves: the horizontal white line indicates 70% of the initial output, and the descending white curve represents a typical logarithmic decay that would reach L70 at 50,000 hours.

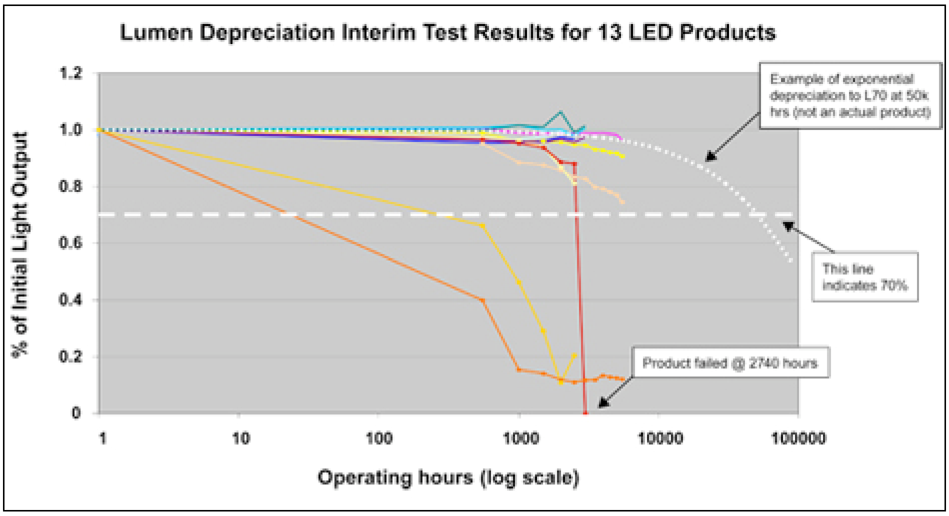


Figure 3.6: Interim results from CALIPER lumen depreciation testing. May 2008, source: CALIPER Round 5 Summary Report.

Some luminaires maintain output levels over the first 6,000 hours of operation (7 of 13 products are producing over 96% of their initial output), while others exhibit rapid lumen depreciation within the first 1,000 to 2,000 hours, and some products exhibit significant color shift over the first 6,000 hours of operation. No general patterns can be observed yet.

These 13 products cover a range of LED configurations, including task lamps, replacement lamps, retrofit lamps, and outdoor area luminaires. At this point of testing, and given the small sample size, one cannot draw conclusions about the lumen depreciation performance of any particular category of products (based on size or application). The CALiPER program will continue to collect lumen depreciation and chromaticity maintenance data on a range of products, and to make those testing results publicly available.

At this time, there is not a standard reporting format for LED lifetime or lumen depreciation curves. A test procedure currently is in development by the Illuminating Engineering Society of North America (designated LM-80, IESNA Approved Method for Measuring Lumen Maintenance of LED Light Sources). The US Lighting Research Centre also reports[7] that their preliminary test results indicate significant performance variations among different

[6] U.S. Department of Energy - Energy Efficiency and Renewable Energy, Solid-State Lighting, http://www1.eere.energy.gov/buildings/ssl/reliability_points.html
7 http://www.lrc.rpi.edu/programs/solidstate/cr_highfluxleds.asp

manufacturer's products and they mention that researchers are developing alternate lifetime prediction methods to avoid long-term product testing.

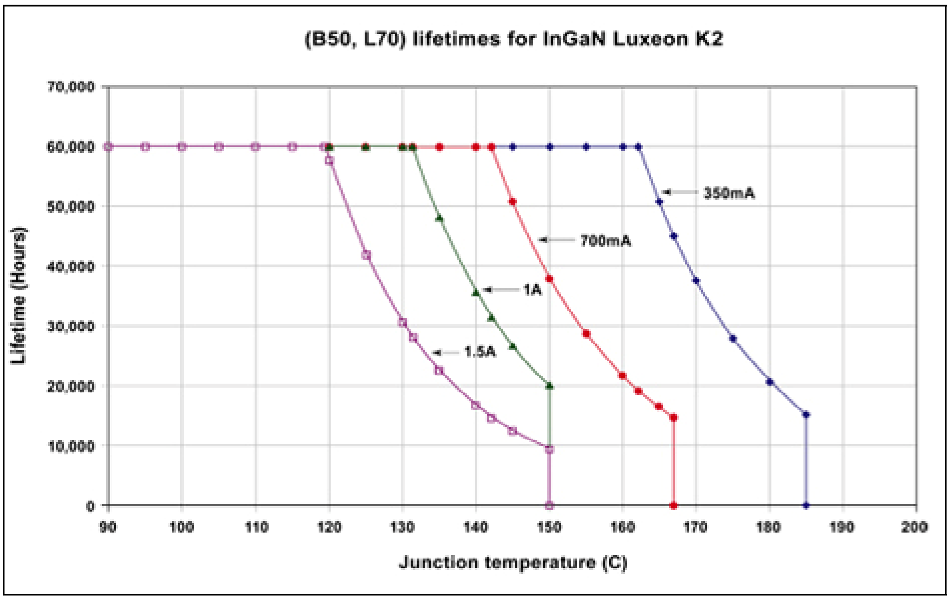
The EPA Residential Light Fixture program is under development and has expanded it scope to include decorative LED fixtures[8].

3.2.10.2 Decrease in lumen output due to temperature

Concerning, CFLi/CFLi-R please see chapter 3 in the final report for part 1 of the study.

For LED, the rated output and nominal output is often quoted at a temperature of 25^{o}C. This bear little relation to the actual light output in a LED fitting or luminaire where the junction temperature typically will be between 60 and 150^{o}C. At these temperatures, the light output and efficiency will be significantly less. It is therefore necessary to test LEDs in a complete system.

The LED lumen maintenance is dependent on drive current and junction temperature. Figure 3.7 shows published lifetime curves from a large manufacturer for their K2 LED package. According to this graph the lifetime decreases with higher junction temperature and the junction temperature has to be decreased in case the drive current is increased, e.g. to obtain a lifetime of 60,000 hours the junction temperatures has to be lower than 140^{o}C with at drive current 700 mA where it could be up to 160^{o}C with a drive current at 350 mA.



B50, L70 means 50% of the products have at least 70% lumen maintenance for the projected number of operating hours.

Figure 3.7: Expected LED lifetime as a function of drive current indicated by each colored line and target LED junction temperatures. Source: Philips Lumileds.

Accurate measurements of the LED junction temperature in a fitting or luminaire will help in designing optimal thermal management of lumen output, energy efficiency and lifetime, and at the same time it will reduce the number of LEDs needed to obtain a specific lumen output.

[8] http://www.energystar.gov/index.cfm?c=revisions.fixtures_spec

Some new standards are under development: CIE TC-xx addressing test methods to evaluate the junction temperature and IESNA LM-xx concerning approved methods for electrical and photometric measurements of high-power LED's.

With high-power LEDs it is essential to remove heat from the LED through efficient thermal management by use of materials with high thermal conductivity. Unfortunately, some high thermal conductivity materials such as copper are relatively expensive, and there is a trade/off between cost, performance, manufacturability and other factors.

3.2.10.3 Interactive effects of the light source on heating or cooling needs

Please see chapter 3 in the final report for part 1 of the study.

3.2.10.4 Conclusion on correction factors used for real life lamp efficacy

Please see chapter 3 in the final report for part 1 of the study.

3.2.10.5 Luminaire maintenance factor (LMF)

This factor takes into account the luminaire pollution. For more information about this topic please see the preparatory study on office lighting (lot 8)[1].
Please note that household luminaires are used in a higher variety of circumstances than office luminaires compared to the ceiling of a relatively clean office. Table, wall-mounted, floor-standing, furniture-integrated (e.g. kitchen) luminaires are likely to get dirty faster. Not to mention outdoor household luminaires. This could lower LMF.
When reflector lamps (DLS) are used luminaire pollution is not a problem, because the complete optic system is within the lamp and replaced with the lamp. Cleaning of domestic luminaires is a common practice and in many cases straightforward. This raises LMF.
As a conclusion:
For luminaires with DLS lamps LMF will not be used (LMF=1).
For luminaires with NDLS the benchmark value of office lighting can be used (LMF =0.95).

3.3 End of Life behaviour related to consumers

Please see chapter 3 in the final report for part 1 of the study.

3.4 Influence of local infra-structure and facilities

3.4.1 Influence of the physical room infrastructure

Please see chapter 3 in the final report for part 1 of the study.

3.4.2 Lack of skilled and informed users

A very broad range of DLS lamps for domestic application is available on the market (see chapter 1). A one to one comparison of lamp types is not always straightforward and could create a user barrier as will be discussed in more detail in 3.5. The new lamp types often have very different selection parameters that, when applied correctly, could offer more comfort and user satisfaction. For example, CFLi-R and LED might be bought in a broader product range of colour temperatures, light distribution patterns or product lifetime compared to GLS or halogen lamps. However this is often unknown and wrong product choices can lead to unsatisfied users. Users should therefore be clearly informed about correct lamp selection parameters (start up time, light colour, light distribution, light output, dimming method, life time, temperature sensitivity...) It is also recommended that users are informed timely about the proper energy efficient retrofit solution in case certain products become obsolete.

Designers and their organisation note that great many reflector lamps are being used inappropriately in the domestic settings when a number of down-light reflector lamps are used for general illumination of kitchen, bathroom, corridor, hall, bed rooms and even living room although reflector lamps are not made for this purpose.. In many circumstances, directional lighting typically with 24 degree beam angle might provide inadequate lighting and therefore additional lamps with more distributive characteristics are added resulting in the total electrical lighting consumption becomes unreasonable. Frequently dimmers are used to be able to reduce the light output from the down lighters that often cause discomfort glare. Use of a multitude of halogen down lighters in the kitchen often also causes thermal discomfort by emitting heat. It appears as there is a large potential for energy efficient lighting.

The down lighters cause discomfort glare because of the brightness of halogen lamps and that the eye look up directly at the lamps without any kind of shielding – the higher wattage the larger discomfort glare. Disability glare might also occur and might cause increased lighting consumption when an increase in the background luminance contributes to an increase in veiling luminance. Consequently, a higher luminance for the object to be perceived could be needed.

The brightness of the lamps might be adjusted with appropriate fixtures and dimmers. However, the color temperature changes significantly when the lamp is dimmed. The lamps are anyway still giving glare but this problem can be reduced by buying lamps with smooth reflectors, resulting in a sharper fall-off to the illuminated area.

In many cases consumers want to install a luminaire that provides functional illumination and that is good looking (decorative). However the knowledge to provide sufficient illumination often fails and otten the selection is only based on good looking luminaires. In that case the consumer ends up by retrofitting a stronger lamp or more luminaires in the room.. More information on the optical efficiency of the luminaire and their standard performance in combination with a recommended lamp at the moment of purchase could help in this situation.

3.4.3 Lack of skilled service providers

This is especially important for furniture-integrated luminaires (e.g. kitchens, bathrooms...) as sales people could have a strong influence on the selection and the amount of installed luminaires in modern houses. Service providers do in many cases also install reflector lamps in down-lights for general illumination. The user often experiences that the directional light provided is inadequate to make the room feel “lit”, install additional lamps and increase the electricity consumption.

Some energy retrofit solutions, e.g. replacing a dimmable GLS or halogen lamp by a CFLi-R or LED can benefit from professional advice in order to reduce trial and error by users and possible negative consumer experiences.

3.4.4 Luminaire socket and space lock-in effect

Please see chapter 3 in the final report for part 1 of the study.

3.4.5 Electrical wiring and control system lock-in effect

Please see chapter 3 in the final report for part 1 of the study.

3.5 Potential barriers to possible eco-design measures

This section, dealing with the lighting source, shall be seen as complementary to the earlier sections. Particularly, the CFLi-R and the LED is in the focus with regard to quality and raised questions. Anyhow, there should also be attention paid to quality tests of halogen lamps, e.g. the lumen maintenance for halogen lamps appears to be low in some cases but there is a lack of test data. It should be noted, that some of the barriers related to CFLi might become irrelevant supposing that certain types of lamps (e.g. efficient halogen lamp types and LED’s) remain on the market.

3.5.1 CFLi-R quality

Please see chapter 3 in the final report for part 1 of the study.

3.5.2 LED quality

The performance of WLED products (White LED called LED further on) available at the market varies within a very wide range. One large performance test[9] found the efficacy range from 12-60 lumens/W. They also found that the performance within individual batches of identical sources varied as much as 40%. That indicates that the actual manufacturer has not performed a proper binning. This may be caused by downward pressure on pricing increase the temptation for manufacturers to "cut corners".

Both the colour appearance (CCT) and the colour rendering vary within large intervals.

There is a high risk of "market-spoiling" if some manufacturers claims overstate their LED performance. Consumers unlucky enough to purchase a low performing LED (not performing as claimed by the manufacturer) can be very dissatisfied and they may reject the technology, and the overall reputation of LED systems could suffer. This has already been experienced when the CFLi product was introduced at the market and it took many years and a lot of work to overcome the barriers created during the first years at the market. It is very important not to repeat this failure when the LED is introduced at the market.

LED luminaires and replacement lamps available today often claim a long lifetime, usually 50,000 hours. These claims are based on the estimated lumen depreciation of the LED used in the product and often do not account for other components or failure modes. Lifetimes claimed by LED luminaire manufacturers should take into account the whole lighting system, not just the LEDs. One of the key lessons learned from early market introduction of CFLi[10] is that long life claims need to be credible and backed-up with appropriate manufacturer warranties.

Another important aspect is that LED's are often integrated permanently into the fixture/luminaire, making their replacement difficult or impossible.

Formalisation of product quality and a performance testing process is needed urgently. I
Independent testing has to start as soon as possible and the results have to reach the key audiences. The availability of standard test procedures can support manufacturers' product development efforts, evaluation of progress towards achieving higher quality (comparison to established benchmarks) and competitive analysis.

On the other hand, it is important to ensure the cost of testing is not overly burdensome to manufacturers. High-cost testing can be less successful than a more moderate approach because small firms might be unable to afford the entry cost to high-cost testing and some manufacturers might avoid markets where quality assurance is required. Another strong argument is that LED

[9] "The Need for Independent Quality and Performance testing of Emerging Off-grid White-LED Illumination systems for Developing Countries", Evan Mills, LBNL and Arne Jacobsen, Schatz Research Center, Technical report 1, The Lumina project, August 2007, http://light.lbl.gov.
[10] US DOE. "Compact Fluorescent Lighting in America: Lessons Learned on the Way to Market". 2006.

products have such long lives that lifetime testing and acquiring of real application data on long-term performance becomes problematic as new versions of products are available before current ones can be fully tested.

An overview of measurements including a number of LED lamps can be found at the Renewable Energy OliNo web site[11] including different kind of fittings. Unfortunately, most of the lamps don't fulfil the quality requirements to either efficacy, CCT and/or CRI.

3.5.2.1 Most important LED lighting parameters

When buying LED's, LBNL and others [10] stress that it is important to focus at:

1. Lumens, measurements of total luminous flux e.g. by use of goniometer allows for characterization of the light-distribution pattern. Rated output for LEDs is often quoted at a temperature of 25^{o}C which is very different from operation in a LED luminaire where the junction temperature will typically be in the interval 60-150^{o}C.
2. Lamp efficacy in lumens/W
3. Lamp efficacy as a function of time. High-quality LED can maintain high lighting levels for tens of thousands of hours, while the output of low quality products declines much more rapidly. These long-term measurements can require 12+ months so it is important to find a short-term approach.
4. Colour: CCT (Correlated Colour Temperature), CRI (Colour Rendering Index) and CQS (Colour Quality Scale).
5. Glare: Measurement of the intensity of light from the source itself. This is important given the small size of LED lights and their corresponding brightness, which can cause discomfort glare as well as injury if users look directly into the light. A very recent test [12] reports glare varied by a factor 1.4 and that it was above the acceptable threshold in most cases.

The standard CIE 127:2007 addresses some of the above measurement of individual LEDs.

3.5.2.2 ENERGY STAR Qualified LED lighting

Please note that most of this information will be moved to chapter 1 in the final version.

On September 30, 2008, the ENERGY STAR Solid-State Lighting (SSL including LEDs, OLEDs and PLEDs) Criteria program went into effect. Manufacturers who are ENERGY STAR partners can begin submitting products for qualification, retailers can begin promoting these qualified products in their stores and showrooms, utilities and energy efficiency organisations can begin implementing incentive programs for these efficient products, and consumers can start looking for the ENERGY STAR on quality products. The ENERGY STAR label on SSL luminaires provides consumers with the confidence that these products meet efficiency and performance criteria established by DOE in collaboration with industry stakeholders.

---

[11] http://www.olino.org/

[12] "Measured off-grid lighting system performance", Evan Mills, LBNL and Arne Jacobsen, Schatz Research Center, Technical report 4, The Lumina project, December 2008, http://light.lbl.gov.

The rapid pace of the technology advances led DOE to select a two-phase approach:

1. First phase allows for early participation of a limited range of market-ready products
2. Second phase sets out more rigorous performance targets for future products. The criteria are continually updated to keep pace with the technology advances.

The released requirements for obtaining to be ENERGY STAR qualified LED lighting include:

1. **Energy consumption** at least 75% less energy than incandescent (GLS) lighting for the same quantity of lighting (lumens).
2. **Reduces maintenance costs** by lasting 35 - 50 times longer than incandescent (GLS) lighting and about 2 - 5 times longer than fluorescent lighting. No bulb-replacements, no ladders and no ongoing disposal program.
3. **Reduces cooling costs** by LEDs.
4. **Minimum three-year warranty** which is far beyond the industry standard.
5. **Offers convenient features** by being available with dimming on some indoor models and automatic daylight shut-off plus motion sensors on some outdoor models.
6. **Durable** - not breaking like a bulb.
7. **Brightness equal to or greater than existing lighting technologies** (incandescent or fluorescent) and the light must be well distributed over the area lighted by the fixture.
8. **Light output remaining constant over time**, only decreasing towards the end of the rated lifetime (at least 35,000 hours or 12 years based on 8 hours use per day).
9. **Excellent color quality**. The shade of white light must appear clear and consistent over time.
10. **Efficiency as good as or better than fluorescent lighting**.
11. **Light coming on instantly** when turned on.
12. **No flicker** when dimmed.

In the DOE Caliper testing program[13] was found power factors within the interval 0.52-0.99 so power factor could also be a quality parameter.

3.5.2.3 Integrated LED luminaires

LED luminaire lifetime is not identical to estimated LED lamp lifetime. LED luminaire lifetime is also a function of the power supply, operating temperatures, thermal management, materials, and electrical and material interfaces. DOE[14] reports that definitive lifetime ratings will not be possible until more experience is logged with a wide range of LED luminaires in the field. They recommend looking for:

---

[13] Caliper Summary Report, January 2009, Round 7 of products testing (prepared for DOE), http:apps1.eere.energy.gov/buildings/publications/pdfs/ssl/calliper round 7 summary final.pdf

[14] http://www1.eere.energy.gov/buildings/ssl/reliability_points.html

- High-quality LEDs from manufacturers who publish reliability data.
- Luminaire warranty offered by the manufacturer – should be at least comparable to traditional luminaires used for the application under consideration.
- Luminaire photometric report, based on LM-79-08 test procedure, from an independent testing laboratory.
- Temperature data (for example, board, case, or solder joint temperature) for the LEDs when operated in the luminaire in the intended application; and information about how the measured temperature relates to expected lifetime of the system.
- Any test data available about longer term performance of the LED luminaire, such as DOE CALiPER testing, manufacturer in-house testing, or field tests conducted by DOE, utilities, or other parties.

3.5.3 Luminaire socket and space lock-in effect

For this item, see section 3.4.4.

3.5.4 Electrical wiring and control system lock-in effect

Please see chapter 3 in the final report for part 1 of the study.

3.5.5 Harmonic interference in the low voltage network

Please see chapter 3 in the final report for part 1 of the study.

3.5.6 Alleged negative health effects due to optical and electromagnetic radiation from certain light sources

Please see chapter 3 in the final report for part 1 of the study.

3.5.7 Luminaire photometric data is usually not measured

Few luminaires within the scope of this study are provided with photometric data, the requirement for having a minimum LOR or LER performance or providing data about it could create additional cost and administration. In decorative luminaires such a requirement could limit the amount and light absorption of the ornaments sold with the luminaire.

Basic design rules rather than LOR requirements could avoid cost and administration but there are no public known examples so far. (Stakeholders are strongly invited to provide input)

4 TECHNICAL ANALYSIS EXISTING PRODUCTS

For more info see website www.eup4light.net.

5 DEFINITION OF BASE-CASE

For more info see website www.eup4light.net.

6 TECHNICAL ANALYSIS BAT

For more info see website www.eup4light.net.

7 IMPROVEMENT POTENTIAL

For more info see website www.eup4light.net.

8 SCENARIO- POLICY- IMPACT- AND SENSITIVITY ANALYSIS