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Preparatory Studies for Eco-design Requirements of EuPs

Lot 19: Domestic lighting
Part 1 - Non-Directional Light Sources

Draft final task reports
Task 3: Consumer behaviour and local infrastructure

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This is an updated draft document intended for stakeholder communication.

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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.

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 'consumer'

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

1. The responsible person for the putting into service of a new house/flat or renovation of parts of the home, e.g. 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, so here is also a service provider involved.
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 a DIY consumer.

Anyhow, ’service providers’ are having a growing influence on energy used in the domestic homes because for some domestic rooms (e.g. kitchen or bath room) lighting is an integral subcomponent of the design and installation process – the customer buys “the whole package” including lighting. In this case both service providers and the consumer take decisions that affect the quality, cost and efficiency of lighting in the home.

3.2 Real Life Efficiency and quantification of relevant parameters

3.2.1 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
- Participate 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 become 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 Lamp efficacy and sensitivity of the human eye

It is important in the context of lighting that the standard performance parameter on lamp 'efficacy' is defined taking into account the sensitivity of the human eye. The visual performance of the eye varies with people and eyes deteriorate with age. As we get older we need a higher quantity of light and in addition, more care has to be taken to avoid glare.

The colour perception is essential for visual performance. Some colours are more visible than others. Figure 3.2 shows that the visual response is at maximum in the yellow-green region of the spectrum (at luminance above 10 cd/m^2), but also contrast between colours is important. Blue contrasts strongly with yellow, as these colours are «complementary», but not as strongly with green as these colours are close in the spectrum.

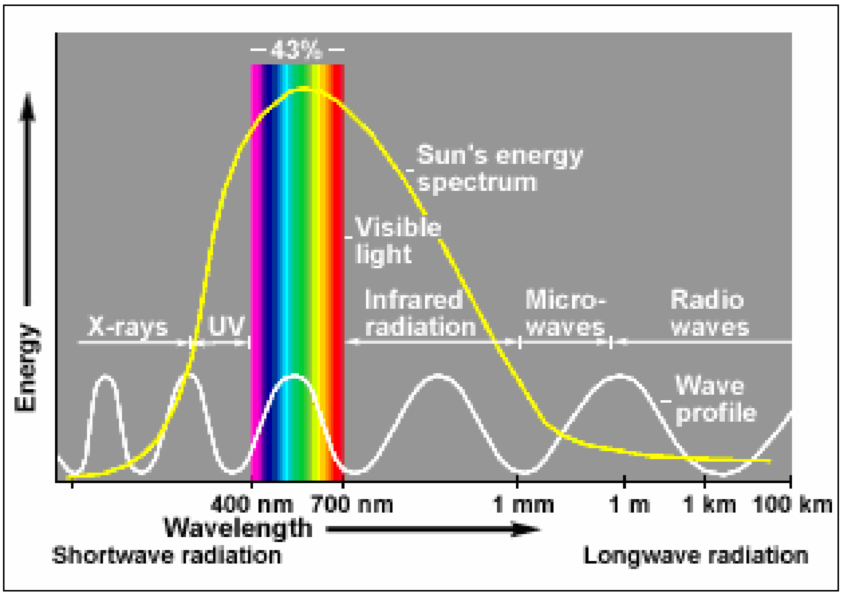

Figure 3.1: Radiation from the sun.

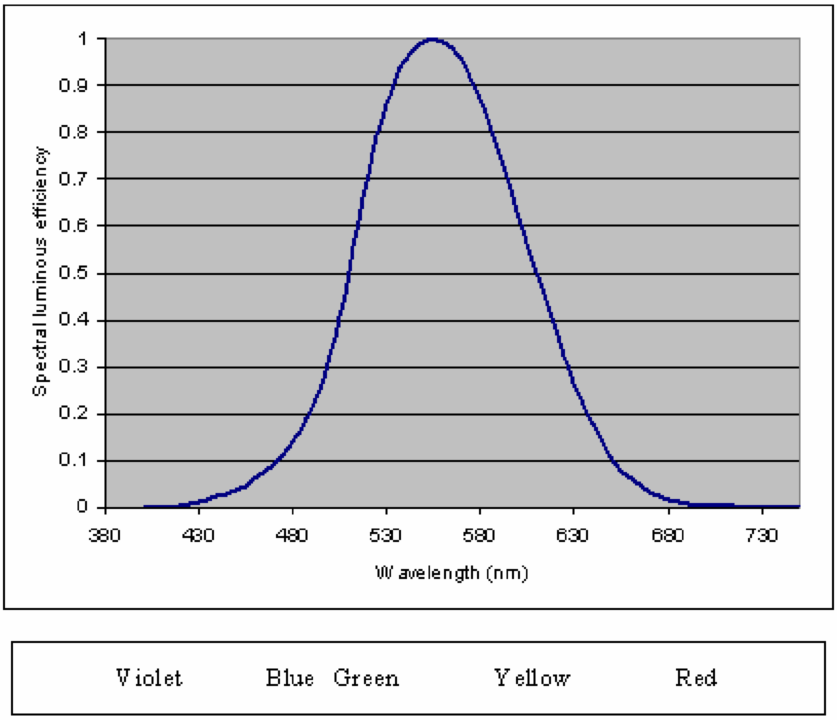

Figure 3.2: Relative spectral sensitivity of the human eye.

Lamps with a colour spectrum that match the normalised eye sensitivity will therefore have an improved lamp 'efficacy'.

To provide an indication of the **colour-rendering** properties of a light source, the general colour-rendering index Ra was introduced. The maximum value of Ra is 100. This Ra decreases with decreasing colour-rendering quality. According to standard EN 12464 for commercial working condition, lamps with a colour-rendering index lower than 80 should not be used in interiors where people stay for longer periods.

The "colour appearance" of a lamp refers to the apparent colour (chromaticity) of the light emitted. It is quantified by its correlated colour temperature (CCT). The choice of an appropriate colour appearance of a light source should largely be determined by the function of the room to be lit but it also involves psychological aspects as warmness, relaxation and clarity. The Commission Internationale de l'Eclairage specifies three different correlated colour temperature groups as shown in Table 3.1.

Table 3.1: Colour appearance groups.

Colour appearance group	Colour appearance	Correlated colour temperature
1	Warm - Could be used for relaxation spaces lit to less than 300 lux	Below 3300 K
2	Intermediate – good for blending with daylight	3300-5300 K
3	Cool – for working interiors with high lighting levels	Above 5300 K

“Good lighting conditions” is more than the quantity of lighting. The visual perception also deals with the **contours of surfaces and contrasts** between surfaces (brightness), the **direction** of light and the general lighting of the environment. Normally, the eye adapts to whatever it is viewing, but if the object or background is too bright or the contrast is too great, vision suffers either by the situation becoming visually uncomfortable (**discomfort glare**) or by the object becoming too difficult to see (**disability glare**). Disability glare refers to reduced visibility of a target due to the presence of a light source elsewhere in the field[1]. It occurs when light from a glare source is scattered by the ocular media. This scattered light forms a veil of luminance which reduces the contrast and thus the visibility of the target.

Disablity glare can be a cause for increased lighting consumption at home because an increase in the background luminance contributes to an increase in veiling luminance and as a consequence a higher luminance for the object to be perceived could be needed. For example, incorporating more decorative lighting in furniture could increase the lighting demand for general room illumination.

3.2.3 User influence on switching schemes (annual operating time)

User influence on final lighting energy consumption is primary related to presence of users in the home. It is also related to automatic systems (also domotica) that are introduced more and more:

- photocell control for outdoor lighting;
- time control lighting schemes pretending to possible burglars that there are people in the home;
- presence detection that switches lighting on with a switch-off e.g. 5 minutes after the last presence detection;
- dimming of some lighting sources.

The yearly operating time per lighting source is different depending on the family members present in the home and the activities taking place. Quantitative data about operational hours are included in chapter 2.

3.2.4 Lamp dimming

It is quite common to install lamp dimmers for some lamps in the home – typically in the living room. Lamp dimming is probably mainly applied in domestic lighting for modifying the atmosphere by either lowering the light level, changing illumination contrast or modifying the colour temperature of the lamp. In principle lamp dimming can also be used to save energy in domestic lighting but it doesn’t seem to be a real driver for installing lamp dimmers in domestic applications. Dimmed GLS or HL lamps change to a warmer colour temperature when they are dimmed (an example is shown in Figure 3.3).

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[1] Narisada K. & D. Schreuder (2004), Light pollution handbook., Springer verlag 2004, ISBN 1-4020-2665-X

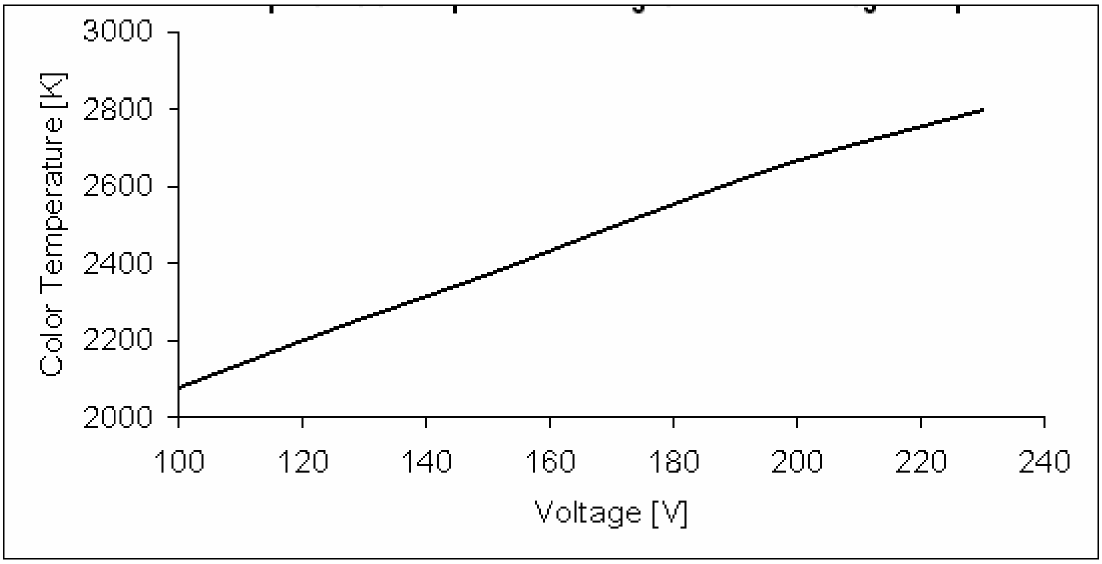

Figure 3.3: Colour temperature for dimmed halogen lamp in function of line voltage.

Dimming is also used to light a "path" dimly in the night (e.g. for elderly people or children) in new home automation solutions that are easy to build into existing homes without renovation work. The same objective can be obtained by installing small LED lights etc., but this usually requires work on the installation.

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

The power factor of an AC electric power system is defined as the ratio of the real power to the *apparent* power and is a number between 0 and 1. *Real* power is the capacity of the circuit for performing work in a particular time. Apparent power includes the *reactive* power that utilities need to distribute even when it accomplishes no useful work. Low-power-factor loads can increase losses in a power distribution system and result in increased energy costs (LRC (1995)[2]). Most utilities for electricity distribution have penalties for large consumers when the total power factor is below 0.8.

There exists inductive, reactive power as well as capacitive, reactive power in the electrical grid and both can compensate each other. Motors (e.g. refrigerators, elevators, vacuum cleaners, pumps,..) or inductors (magnetic ballasts for fluorescent or HID lamps) are typically inductive loads while many electronic sources (CFLi, PCs, TVs, ..) are capacitive. In general the grid tends to be more inductive due to the high amount of motor loads and in industry power factor compensation capacitors are frequently installed. Incandescent lamps and electronic ballasts with power levels above 25 W however have power factor 1, electronic ballasts because an active power factor compensation (PFC) circuit is needed in order to satisfy the harmonic current limits of standard EN 61000-3-2 (Basu (2004)[3]); please note that there is no direct limitation on the power factor itself in the standard but it is a consequence of

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[2] LRC (1995), Robert Wolsey, Lighting Answers: Power Quality, National Lighting Product Information Program, volume 2, number 2, February 1995.

[3] Basu (2004), Supratim Basu, T.M.Undeland, PFC Strategies in light of EN 61000-3-2, EPE-PEMC 2004 Conference in Riga, LATVIA, 1- 3 September 2004.

the harmonic current requirement and the technology used. In standard EN 61000-3-2 anno 2007 the strongest requirements are limited to lighting products above 25 W while other electronic equipment (PCs, TVs, ..) has much lower requirements, there is no public known rationale for this. Hence CFLi's that are capacitive are unlikely to create strong negative grid influences because they rather compensate inductive loads and are unlikely to dominate the total active power demand of the grid.

For CFLi's, the power factor can go down to 0,50[4]; the lower the power factor, the higher the electrical current that is needed to result in the same real power. VITO has recently measured power factors for 6 CFLi (9-17W) and the power factor was in all cases within the interval 0,62-0,66. and 0,95 for a HL-MV-IR (with integrated transformer). Neverthelesse, the lower power factor for CFLi could cause as mentioned above a higher current which again could cause around 5% more losses in the electrical grid not taking into account the existing inductive loads. Therefore a correction factor 'Lamp Wattage Factor LWFp' is introduced in order not to overestimate CFLi gains; for values see Table 3.2.

Table 3.2: LWFp correction factors for power quality used in this study

Lamp type	LWFp
GLS	1
HL types	1
CFLi	1.05

The formula for the real power and real annual energy consumption (E_{yreal}) per lamp becomes:

$$P_{real}\,[W] = Plamp \times LWFp \qquad \text{and} \qquad E_{yreal}\,[kWh] = E_y\,[kWh] \times LWFp.$$

3.2.6 Influence of voltage change

The primary cause of voltage fluctuations[5] in the medium and high voltage grid (>1000 VAC) is the time variability of the reactive power component of fluctuating loads; in the low voltage grid (e.g. 230/400VAC) it is the fluctuating load of active and reactive power. Also variations in the DER (Distributed Energy Resources) generation capacity can have an effect and because the number of such installations will increase in the future, it can be expected that voltage fluctuations will increase accordingly.

For lamps, the flicker that is generated significantly impairs vision and causes general discomfort and fatigue[6]. The permissible magnitude of light flicker is regulated by International Standards [7] [8] and was based on perception criteria related to incandescent lamps

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[4] IAEEL newsletter 3-4/95, 'Power Quality for Beginners'

[5] Power Quality Application Guide: Voltage Disturbances-Flicker, Leonardo Power Quality Initiative (LPQI), available from www.lpqi.org.

[6] Power Quality Application Guide: Voltage Disturbances-Flicker, Leonardo Power Quality Initiative (LPQI), available from www.lpqi.org.

[7] IEC 61000-3-3:1995, Electromagnetic compatibility (EMC) – Part 3: Limits – Section 3: Limitation of Voltage Fluctuations and Flicker in Low-voltage Supply Systems for Equipment with Rated Current ≤16A.

[8] IEC 60868: 1986, Flickermeter, Functional and Design Specifications

or so-called General Lighting Service (GLS) lamps. The light flicker requirements had an impact on standard EN 50160 (2007): 'Voltage characteristics of electricity supplied by public distribution networks'. For these GLS-lamps the permissible supply voltage variation (+/- 10 %) causes an incandescent lamp to deliver as little as 70% or as much as 140% of its nominal luminous flux respectively[9]. The same is trough for other filament lamps that are directly operated by the mains (e.g. mains voltage halogen lamps). Fluorescent lamps are less sensitive and will vary only +/- 20 % and even less when they are operated by inverters with power factor controllers, e.g. all electronic ballasts above 25W (see lot 8).

An increase of the voltage will also influence the lifetime of the lamps.
A major manufacturer[10] reports that an incandescent CLAS A 230V 100W lamp supplied with 240V will provide 17.5% more luminous flux, have 50% less life time and 6,6% more power consumed with the burning risk through overheating of the cap in the socket. On the contrary, an incandescent CLAS A 240V 100W lamp supplied with 230V will provide 15% less luminous flux, will convert from energy class E to F but the life time will be 80% longer.

The influence described above might explain why some customers complain about to short life time of their lamps.

3.2.7 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 lamptype (see section 1.1.3.1). Due to normal ageing and deviation of the installed lamp from standard conditions in the use fase, this efficacy can be influenced.

3.2.7.1 Due to lamp ageing

The lumen output of a lamp deteriorates during its lifetime. This decrease is not equal for all lamp types and is expressed by the Lamp Lumen Maintenance Factor (LLMF) (see section 1.1.3.1). Technical Report CIE 97: "Guide on the maintenance of indoor electric lighting systems", edited by the International Commission on Illumination, gives examples of the influence of aging, listed as shown in Table 3.3.

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[9] Power Quality Application Guide: Voltage Dips - Introduction, Leonardo Power Quality Initiative (LPQI), available from www.lpqi.org

[10] GLS Product Training, OSRAM, Munich Sep. 22nd 2008

Table 3.3: Typical examples of the lamp lumen maintenance factor (LLMF) and the lamp survival factor (LSF) data (Source: CIE 97 – 2005).

			Burning hours in thousand hours											
		Differences	**0.1**	**0.5**	**1**	**2**	**4**	**6**	**8**	**10**	**12**	**15**	**20**	**30**
Incandescent	LLMF	Moderate	1.00	0.97	0.93									
	LSF	Big	1.00	0.98	0.50									
Halogen	LLMF	Big	1.00	0.99	0.97	0.95								
	LSF	Big	1.00	1,00	0.78	0.50								
Fluorescent Tri-phospor HF ballast	LLMF	Moderate	1.00	0.99	0.98	0.97	0.93	0.92	0.90	0.90	0.90	0.90	0.90	
	LSF	Moderate	1.00	1.00	1.00	1.00	1.00	0.99	0.98	0.98	0.97	0.94	0.50	
Flourescent Tri-phospor Magn. ballast	LLMF	Moderate	1.00	0.99	0.98	0.97	0.93	0.92	0.90	0.90	0.90	0.90		
	LSF	Moderate	1.00	1.00	1.00	1.00	1.00	0.99	0.98	0.98	0.92	0.50		
Flourescent halophospate Magn ballast	LLMF	Moderate	1.00	0.98	0.96	0.95	0.87	0.84	0.81	0.79	0.77	0.75		
	LSF	Moderate	1.00	1.00	1.00	1.00	1.00	0.99	0.98	0.98	0.92	0.50		
Compact fluorescent	LLMF	Big	1.00	0.98	0.97	0.94	0.91	0.89	0.87	0.85				
	LSF	Big	1.00	0.99	0.99	0.98	0.97	0.94	0.86	0.50				
HP Mercury	LLMF	Moderate	1.00	0.99	0.97	0.93	0.85	0.82	0,78	0,75	0,72	0,70	0,65	
	LSF	Moderate	1.00	1,00	0.99	0.98	0.97	0.94	0.90	0.86	0.79	0.69	0.50	
Metal halide (250-400W)	**LLMF**	Big	**1.00**	**0.98**	**0.95**	**0.90**	**0.87**	**0.83**	**0.79**	**0.65**	**0.63**	**0.58**	**0.50**	
	LSF	Big	**1.00**	**0.99**	**0.99**	**0.98**	**0.97**	**0.92**	**0.86**	**0.80**	**0.73**	**0.66**	**0.50**	
Ceramic metal halide (50-150W)	**LLMF**	Big	**1.00**	**0.95**	**0.87**	**0.75**	**0.72**	**0.68**	**0.64**	**0.60**	**0.56**			
	LSF	Big	**1.00**	**0.99**	**0.99**	**0.98**	**0.98**	**0.98**	**0.95**	**0.80**	**0.50**			
High pressure sodium	LLMF	Moderate	1.00	1.00	0.98	0.98	0.98	0.97	0.97	0.97	0.97	0.96	0.94	0.90
	LSF	Moderate	1.00	1.00	1.00	1.00	0.99	0.99	0.99	0.99	0.97	0.95	0.92	0.50
LED	LLMF	Big	Data are changing too rapidly											
	LSF	Big	Data are changing too rapidly											

Below the average LLMF over an assumed lifetime is calculated, based on the values in this Table 3.3:

- For incandescent lamps (GLS): 0,965 (life time assumption 1000 h);
- For halogen lamps (HL-types): 0,975 (life time assumtion 2000 h);
- For compact fluorescent lamps (CFLi): 0,925 (life time assumption 10000h).

Please note that in Table 3.3 moderate and big LSF and LLMF variations are reported for most lamp types. It indicates differences in LLMF and LSF among lamps, which belong to the same lamp type category. Few test data on halogen and incadescent lamps were found in literature while for CFLi some consumer test data are available. They are included hereafter and they confirm the strong variations, hence quality requirements can be beneficial.

Warentest 3/2008 tested 20 CFLi's for reduction in lighting output after 2000 respectively 10000 hours. The results are shown in Figure 3.4.

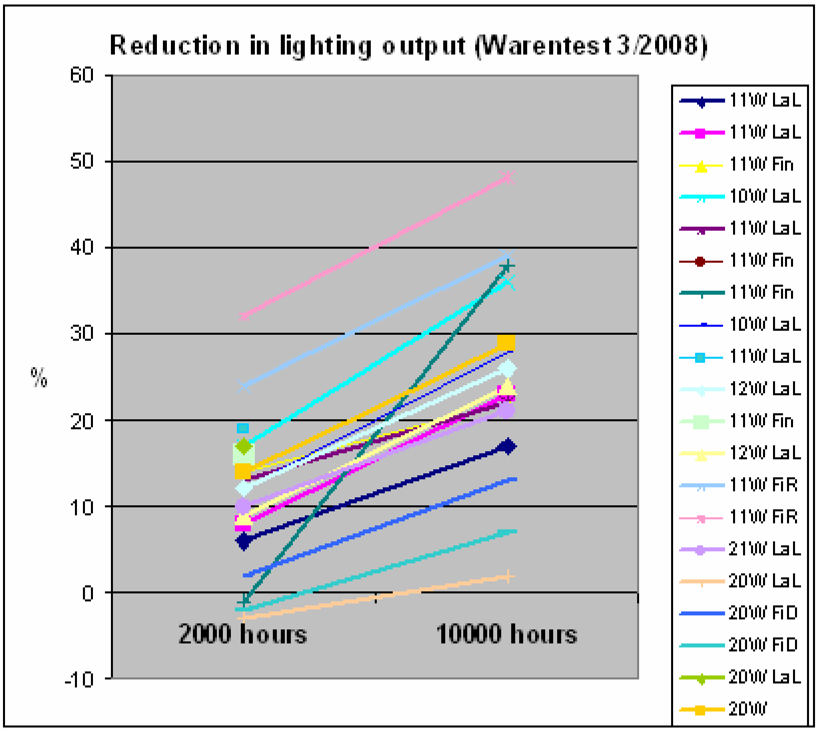

Figure 3.4: Reduction in lighting output found in test of 20 CFLi.

The average reduction after 2000 hours is already 9,6% for the 18 CFLi's excluding the very poor reflector lamps. The worst half includes both lamps from some of the large manufacturers as well as large retailers producing CFLi's. At the age of 10000 hours 3 of the 20 lamps had stopped working and the average reduction for the remaining 15 CFLi's (excluding the reflector lamps) was 21,9%. For these lamps the average LLMF is around 0,85 during the lifetime of 10000 hours.

3.2.7.2 Decrease in lumen output due to temperature or lamp position

Many CFLi's have light output claims that are only achieved at the optimum operating temperature and/or in some optimum burning position. As normal CFLi's for indoor applications have the optimal working conditions in the temperature interval 25-35 °C, lamp manufacturers are offering special CFLi's for outdoor applications.

By introducing amalgam technology (see chapter 6), manufacturers are trying to reduce as much as possible the influence of ambient temperature on light output of the lamps.
For many lamp types, the lumininous flux output is also different for base-up, horizontal and base-down position.

Because several adjustments[11] have already been developed to both the lamps and the fixtures to reduce the thermal efficiency problems and that lamp position is only dependent on luminaire design, these effects will not be taken into account in the calculations in this part 1 of the study.

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[11] Example: Fixing the Fixtures, Michael Siminovitch and Evan Mills, LBNL.

For luminaire design, part 2 of the study, these effects will be taken into account.

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

It should be noted that nearly all energy that is not converted by the light source into the defined functional unit 'light' is converted into heat. In some particular cases (e.g. winter season) this 'energy waste' is recovered as space heating and this could be considered as a useful interactive effect with the space heating needs.

This is a horizontal issue for all domestic energy using products that turn part of the electricity into heat while performing their defined function.

It should be noted that interactive effects are not the most effective way to provide indoor heating because: the installation is not optimized (e.g. the location on the ceiling can be inefficient), essential control functions are obsolete (e.g. the heating can be unnecessary in the summer period), adverse interactive effects could also occur (e.g. increased need for cooling), direct electrical heating is less effective compared to electrical heating using a heat pump (the typical Coefficient of Performance (COP) in indoor heating is 3 to 4), not all rooms need heating. Light sources installed in electrical ovens will only be discussed as exception in chapter 8. As a consequence, the wasted heat generated by lighting is considered as pure energy loss in the assessment of the performance of the lamps examined in this study.

3.2.7.4 Conclusion on correction factors used for real life lamp efficacy

In the study we have chosen to use average LLMF correction factors based on the Technical Report CIE 97: “Guide on the maintenance of indoor electric lighting systems”, edited by the International Commission on Illumination (see Table 3.3). For CFLi we are using the factor for a CFLi with lifetime 10000 hours although for the base case (see chapter 5) we assume a CFLi with a lifetime of 6000 hours.

Table 3.4: Correction factors for lumen depreciation used in this study

lamp type	LLMF (average)
GLS	0,965
HL types	0,975
CFLi	0,925

The CIE values were used despite the fact that for CFLi some new test data were available that did show lower average performance but for an equal comparison the above data source was used because there was a lack of real test data especially for GLS and HL-types.
For GLS-lamps the CIE-data also seem to be optimistic as a decrease in lumen output to 80% of the initial output can be found in litterature[12] due to the evaporation of the tungsten wire (higher resistance, lower watts and lower light output) and the deposit of this tungsten particles on the bulb.

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[12] Illuminating Engineering Society of North America: Lighting Handbook 8th edition, p.187.

3.3 End of Life behaviour related to consumers

This section discusses only the information on user behaviour related to end of life of lamps. The technical aspects of recycling at end of life are dealt with in section 4.5.

Mercury is an essential component for producing fluorescent lighting. Therefore the RoHS-directive still allows the use of mercury in discharge lamps. Although the mercury content in CFLi's is restricted to 5mg and EU lamp manufacturers supply lamps down to 1 mg, mercury remains an hazardous substance and the release to the environment has to be avoided anywhere in the society.

Many lamps also contain a lot of electronics including hazardous substances too, or precious raw materials, which we have to recover in the near future (e.g.Tantalum).

For protection of the environment and the health of its citizens, the EU has also created the WEEE-directive. This directive obliges all manufacturers from electric and electronic equipment, including discharge lamps and luminaires, to take back used products so that they can be recycled. In this way the mercury is also taken out of circulation in the mean time.

Luminaires and ballasts contain high amounts of aluminium, steel and copper and prices offered for these materials are quite high, giving the incentive to collect them after use; even rag-and-bone men are eager for buying scrap metals.

This is different for CFLi's. Notwithstanding the fact that many components (glass, metal parts, phosphors and mercury) can be recycled, recycling doesn't seem to be very profitable. As a consequence, many people don't know what to do with their used lamps, moreover they don't even know that CFLi's are containing mercury.

A new study on the rate of recovery under the WEEE directive[13] has found that on average 27,9 % of the lamps covered (category 5B) are recycled. They do not disaggregate the figure by lamp types – CFLi used in the domestic sector are less likely to be recycled than LFLs or HIDs primarily used in the non-residential sectors.

A 2006 inquiry made by a large European retailer in Sweden found that only a small fraction of the customers did bring their used CFLi's to a recycling point and that another segment threw away their lamps in the domestic waste in spite of the marking on the packaging. Table 3.3 below shows that now 75% of the lamps in Sweden are recycled which as far as we know is much better than any other European country. The data in Table 3.5 are collected by co-operation with the partners in the EU R&D project ENERLIN and on knowledge of the consultants for this study.

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[13] http://ec.europa.eu/environment/waste/weee/studies_weee_en.htm
"2008 Review of Directive 2002/96/EC on waste electrical and electronic equipment (WEEE)"

Table 3.5: Recycling of mercury containing lamps

Country	Data from	Total recycling (%)	Domestic sector recycling (5)	Commercial sector recycling (%)	More information
Baltic States					ekogaisma.lv and ekogaisma.ee
Belgium					www.recupel.be
Bulgaria		0%			
Czech Republic					www.ekolamp.cz
Denmark	2007	>50%	-	-	www.lwf.nu
France	2007	36%	-	-	Recylum.com
Germany	2006	36%	10%	90%	LightCycle
Hungary					electro-coord.hu
Poland	2007	10%			
Portugal					erp-portugal.pt
Romania					www.recolamp.ro
Sweden	2007	75%	60%	90%	Data from STEM

In the Baltic countries, Philips, Osram, GE Hungary and BLV have founded the company Ekogaisma with main headquarter currently in Latvia. Currently they are executing a campaign called "Save, but don't pollute" to raise awareness that CFLi's have to be taken to the recycling points; at present it is unknown how often people follow this advice. Experts in the countries say it would be better if people could give the used CFLi back in the shops where they have bought them.

In Belgium, the company RECUPEL was founded in 2001 by all importers and distributers of electrical and electronic equipment. Since 2004 also all discharge lamps and lighting equipment are collected. The user, professional as well as non professional, pays a recycling contribution, not a tax, at purchasing. As a consequence he can dispose of the used products at end of life free of charge. Households can dispose of their equipment in the municipal deposit park; all municipalities have set up such a deposit park. Collection rates of CFLi's are not available yet.

Bulgaria has a legislation that requires the collection for recycling of different kinds of used lamps including CFLi. A Decree states that the manufacturers and importers are responsible for the collection and that it shall be done without payment by the households. The Decree requires that no less than 45% of the weight is collected in 2006, increasing to 60% in 2007 and 80% for 2008. Anyway, the manufacturers and importers have still only come to talk about starting a WEE association to take care of fulfilling the requirements, but in reality no activities are undertaken yet.

In Denmark, the manufacturers did form in 2005 a WEE association that is taking care of collection of used LFLs and CFLs by 110 commercial collection points and 127 municipal waste collection points. The manufacturers pay for the activity through a payment per lighting source. More than 50% of the lamps (in weight) is collected. The collection is working best for the non-residential sectors while the residential sector depends on the awareness of the consumer that seems low. The handling of the lamps at the recycling stations has to be improved as you can find CFLi's thrown into a container and broken.

Since March 2006, the German law requires the manufacturers of lamps to take back used discharge lamps in order to prevent hazardous material to be exposed to the environment. On behalf of the lamp manufacturers, Lightcycle Retourlogistik has the responsibility of taking back the lamps. More than 500 disposal points have been set up all over Germany. In 2006, 40 of 110 million discharge lamps were disposed properly, which equals a rate of 36% (all lamps included - most LFLs are supposed to be properly recycled). In 2007, a broad information campaign about proper disposal of discharge lamps was executed. Also a school competition was initiated. The goal is to increase the return rate drastically. Germany seems to be ahead of most other EU27 countries.

In France, also 36% was collected. The collection is done 55% by waste collectors, 23% by lamp distributors, 15% by installation companies and the remaining 7% by municipalities and directly by customers.

In Poland, the main act related to the recycling was implemented 21st October 2005 according to the EU Directive no. 2002/96/EC. In 2006, a new body Chief Environmental Inspector (CEI) was established as the main waste management regulatory authority that keeps the record of recycling. The following professional market actors have to report to the CEI:

- Producers, importers and distributors are obliged to inform, report (quantity and weight) organize and finance collecting and recycling.
- Retail and wholesale distributors are obliged to organize in the sales-point, cost-free waste receipt if the consumer buys a new similar piece and to report quarterly (weight).
- Consumers are obliged to return worn-out electric and electronic equipment to the points of selective waste collection.

District council is obliged to adapt regulations to the district waste management plan and district authorities are obliged to organize receipt of municipal waste from immovable owners who did not draw up a waste collection agreement.

CEI's first annual report (April 2008) states that 8392 companies have registered: 2677 sales companies, 6413 collectors, 99 processing companies, 65 recycling/retrieving (other processes) companies and 5 retrievers of electronic equipment. Measured in weight, 8% of the waste is lighting equipment. In 2007, 10% of the lighting equipment was collected.

In Romania collection of used lamps started at the beginning of 2008. Recolamp association (<http://www.recolamp.ro>www.recolamp.ro) founded by Philips, Osram, Narva and General Electric is in charge of the collection. When buying a fluorescent lamp the customer pays for a green stamp tax e.g. aprox. 0.24 EUR/CFL. A national campaign has started in order to place around 1000 used-lamp-containers during 2008 at lamp retailers, at city disposal plants and companies that produce or distribute lamps.The containers are transported by local authorized operators to 4 regional points where the lamps are sorted by type and category, packed and then sent to a recycling company in Germany (several other Central-Eastern European countries are also exporting their disposed lamps as they don't have any recyling plant).

In Czech Republic, participants pay a treatment fee to Ekolamp proportional to their market share. The total collected "recycling fee" corresponds to the cost of recycling.

The general impression from contact with manufacturers and EU27 country representatives is that the recycling system for collection of mercury from lamps is in most countries not implemented properly, especially for the residential sector. A large part of the consumers don't even know that a CFLi contains mercury and that they should give back the disposed

CFLi for recycling. An easy way to dispose CFLi's seems to be a requirement that it is mandatory to be able to return disposed CFLi's to the points of purchase.

3.4 Local infra-structure and facilities

3.4.1 Influence of the physical room infrastructure

As mentioned in section 3.2.2, "good lighting conditions" is more than just the quantity of lighting. The visual perception also deals with the contours of surfaces and with contrasts between surfaces (brightness).

Local infrastructure and room design can have an important influence on the efficiency of lighting installations. In one period, dark painted walls turn into fashion while another period white or bright colours come in again. Colour and reflection of walls, ceilings and floors are very important for the visual performance as shown in Table 3.6.

Table 3.6: Reflectance values used in the previous preparatory study on office lighting.

	very bright	typical (default)	very dark
Reflectance ceiling	0.8	0.7	0.3
Reflectance wall	0.5	0.5	0.3
Reflectance floor cavity	0.3	0.2	0.1

3.4.2 Lack of skilled and informed users

A very broad range of lamps for domestic application did become available on the market in the last decades (see chapter 1). A one to one comparison with the familiar GLS 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, a CFLi can be bought in a broader product range of colour temperatures, light distribution patterns or product life time compared to GLS. 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, temperture sensivity, ..) It is also recommended that users are informed timely about the proper energy efficient retrofit solution in case certain products become obsolete.

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 indirect influence on the selection and amount of installed luminaires in modern houses. Also some energy retrofit solutions, e.g. replace a dimmable incandescent lamp by a CFL or efficient halogen solution, can benefit from professional advice in order to reduce trial and error by users resulting in negative consumer experiences.

3.4.4 Luminaire socket and space lock-in efffect

Some luminaires do not accept an energy efficient retrofit lamp due to the available space and/or socket types. Especially very compact luminaires with G9/R7s sockets will face difficulties to accept a more energy efficient lamp. In most cases a luminaire replacement should be recommended. Users of those luminaires should be informed in cases when replacement lamps will become obsolete in order to allow them to store sufficient replacements lamps in the cupboard. This cannot involve any problem because the cupboard store life time of these lamps is not limited.

It is also important to note that the introduction of amalgam technology (see chapter 6) in CFLi production enables the manufacturers to reduce the size of these lamps so that most problems with space lock-in effects has currently disappeared.

Some Edison socket luminaires (E14/E27) also reduce the real CFLi life time due to their poor thermal heat design. Nevertheless it is unsure whether users are sensitive to this reduced life time as they are already familiar with the low GLS lamp life time. In some cases a luminaire replacement should be recommended. Users should be informed about this potential occurrence.

3.4.5 Electrical wiring and control system lock-in effect

In domestic lighting two types of wiring are used:

- 'Two-wire installation' that contains only one wire between switch and lamp. In this system the switch/control product is connected in series with lamp/load and the neutral is not present in the switch (except in some countries). The advantage is the low amount of required copper wire and reduced short circuit risk during installation but the disadvantage is that no direct power supply is available for electronic control switches (e.g. dimmers). In Figure 3.5 an example of a (special) two wire installation with two three-way switches is shown. The neutral wire is directly going to the lamp, without intermediate switch.

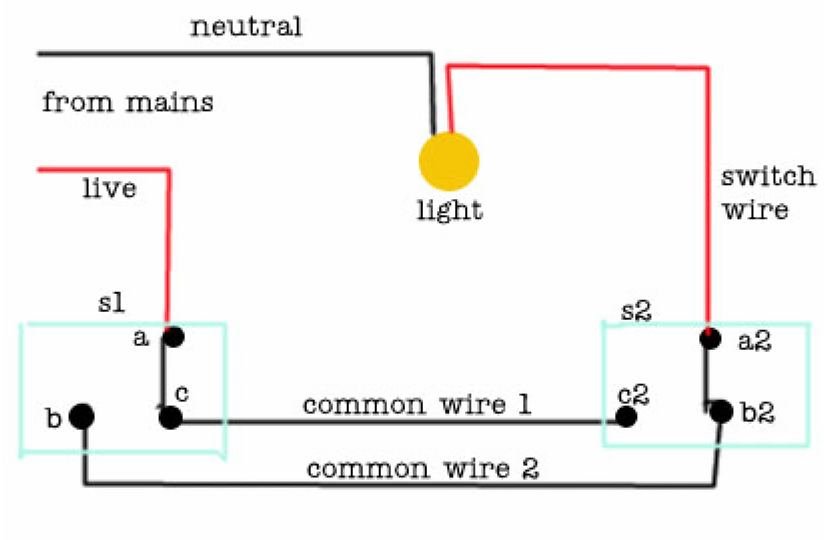

Figure 3.5: Example of a 'two wire installation'.

- 'Three wire installation' that contains both the neutral and phase wire between the switch and the lamp. The main advantage is that a power supply for the control switch can easily be obtained but it requires more copper wire for installation.

Two-wire installations with electronic control switches (e.g. dimmers, presence detectors, ..) do risk to create lock-in effect for high power incandescent lamps because they need to draw a small amount of current for their internal power supply (when no battery is used). Therefore a parasitic leakage current flows in the off state through the lamp. These systems were typically designed for incandescent lamps and require a minimum wattage. When more efficient lamps are installed below the minimum wattage they can face problems, typically:

- Although it looks alright to the user, the CFLi may draw excessive current which might cause overheating and reduce the lamp life significantly.
- The control product may not work correctly, if the supply current can't pass through the load (flashing, non-reaction or other erratic behaviour).
- The supply and the leakage current causes some CFLs to flash briefly at short intervals in off state.
- Some dimmers for two-wire installations are unable to reliably synchronise to the mains frequency when no minimum resistive load (incandescent lamp) load is connected. As a consequence they do not function properly and are unable to dim common CFLi.

Lamp manufacturers have developed lamps that do overcome this problem, they are implemented in the more expensive dimmable CFLi lamps or HL-MV lamps with integrated electronic ballast (see dimmable CFLi in chapter 6).

Standardisation is available, e.g. in "Electronic switches for households and similar use (EN 60669-2-1)" and EN 60969 for CFLi but there are currently no provisions for compatibility.

3.5 Potential barriers and restrictions to possible eco-design measures

This section, dealing with the lighting source, shall be seen as complementary to the earlier sections. Especially the CFLi is in the focus with regard to quality and questions e.g. to alleged negative health effects which have never been raised for other lamp types (GLS, HL-MV, HL-LV, LED). Anyhow, we recommend to pay more attention to quality tests of other lamp types like LED and 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. Please also note that some of these barriers related to CFLi might become irrelevant supposing that certain types of lamps (e.g. efficient halogen lamp types, low power incandescent lamps and LED's) remain on the market.

3.5.1 CFLi quality and comparison with GLS

The quality of the CFLi's has been the focus of several eco-label or quality charter initiatives. This is also the fact for the correctly correlated lamp power of a GLS and a CFLi. Despite several initiatives for the sake of quality few up-to-date market surveillance data are known. Other lamp types, such as GLS, were paradoxally enough not in the focus of such quality initiatives.

The image of CFLi's is not as good as it could be[14]. This is mainly due to the experience with the first generation of CFLi's that came on the market twenty years ago with cold light colour, poor colour rendering, fairly heavy weight and large dimensions. In the mean time, most of these disadvantages are eliminated (see chapter 6). Anyway nowadays some people also have bad experiences with CFLi's of poor quality e.g. the light output is not enough, the lifetime is less than claimed etc. Although the quality of an incandescent lamps is often also not good enough, the bad experience of CFLi's can damage the image of higher quality products and can make people afraid of buying CFLi's again.

In 1999 EC and UNIPEDE/EURELECTRIC made a voluntary CFL Quality Charter including requirements concerning safety, performance, efficacy, lumen maintenance, time to stabilised light output, fast switching life evaluation, colour rendering, guarantee and information on the packaging.

In some EU countries, lists are produced with 'good quality' CFLi's that fulfill the requirements of the European CFL Quality Charter[15]. These lists are based on information from the manufacturers as well as on independent testing.

More details about quality parameters are included in the subsequent sections.

Because few market data for CFLi are known and there is a complete lack of information about quality of other lamp types (e.g. incandescent lamps), there will be no correction factor

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[14] LRC (2003), 'Increasing Market Acceptance of Compact Fluorescent Lamps', LRC Final project report, Rensselaer Polytechnic Institute.

[15] E.g. the Danish Electricity Saving Trust list at http://application.sparel.dk/asp/a-paere/query/paerewiz/liste.asp

introduced for quality. In chapter 8, some recommendations could be proposed for quality assurance.

3.5.1.1 The need for right comparison of light output from CFLi's versus incandescent lamps

The user should know how to replace incandescent lamps by CFLi's giving the same amount of light (lumen). Unfortunately, the manufacturers generally do not give correct information about this replacement. Most manufacturers admit this but have over the years continued to claim that it is not so important. The customers often say "CFLi's don't give good lighting" while they could mean that 'they do not give enough light'. For example, an 11W CFLi lamp with 550 lamp lumen can suggest on the package to be equivalent to a 60 Watt incandescent lamp (GLS) (Figure 3.6). As can be found in chapter 4, a 60 Watt GLS lamp has a lamp lumen output of 710 lumen, which is as a matter of fact about 30 % more. Comparing the initial lumen output (after 100 hours), mathematically a 60 W incandescent lamp should be replaced by a 13 W but this wattage is not commonly available on the market.

This has been and is still giving the CFLi's a bad image and creates a barrier. Many people probably have stopped using the energy saving CFLi's because of these negative experiences. Users have the need to be correctly informed on the packaging of the CFLi.

Figure 3.6: Example of misleading information on the product packaging of CFLi lamp.

Anyhow the equivalence must also take into account the decrease in lamp efficacy in real life operation by using the correction factors for lumen depreciation (see Table 3.4); as these correction factors were calculated as an average during the entire lifetime of the lamp, they already take into account that a GLS is "refreshed" by shifting to a new 6-12 times during the life of a CFLi.

The new version of the European Quality Charter (July 2008)[16] proposes that e.g. a 60W GLS (with initial lumen output 710 lumen) is replaced by a CFLi with 850 lumen (20% more). This is equal to an easily understandable "rule of thumb" for an equivalence of 4:1 where a 60W incandescent lamp will be replaced by a 15W CFLi. This requirement compensates for the lower real life performance of the CFLi compared to GLS due to lower LLMF (ageing factor, see section 3.2.7), temperature effects, potential influence from lamp position and a compensation for the low start performance due to warm-up time.

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[16] http://re.jrc.ec.europa.eu/energyefficiency/CFL/index.htm

In the Northern part of EU, Energy Authorities and the utilities have for more than 15 years recommended the 4:1 equivalence as many lighting experts[17] in other parts of EU also have.

3.5.1.2 Warm-up time for CFLs

Energy Star defines warm-up time (also called run-up time) as the time needed for the lamp to reach 80% of its stable light output after being switched on. The new version of the European Quality Charter requires that the 80% level is reached within 60 seconds.

Figure 3.7, Figure 3.8 and Figure 3.9 show the results from three tests of warm-up for a total of 40 CFLi's. SAFE[18] did test 14 CFLi's (including both the finger type and the Look-a-Like type with external casing) and all of them had a warm-up time lower than 60 seconds.
VITO did test 7 CFLi's where 4 of them had longer warm-up times and that included CFli's distributed by large retailers as well as CFLi's produced by the 4 major manufacturers. Warentest did test 19 CFLi's where 5 of them had long warm-up times. All CFLi's coming from the 4 major manufactures had a sufficient warm-up time no matter the type of CFLi.

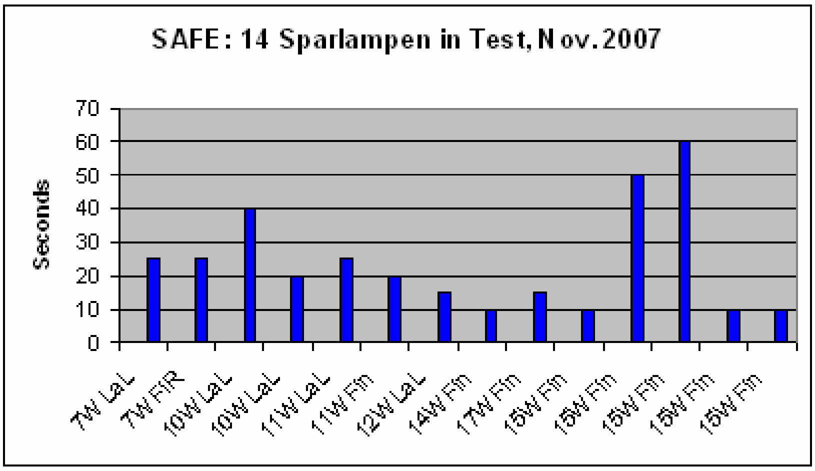

Figure 3.7: Warm-up time SAFE test.

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[17] http://lightinglab.fi/IEAAnnex45/publications/Technical_reports/On_the_substitution_of_incandescent_lamps.pdf

[18] Schweizerische Agentur für Energieeffizienz: Sparlampen_07_Schlussbericht_191107

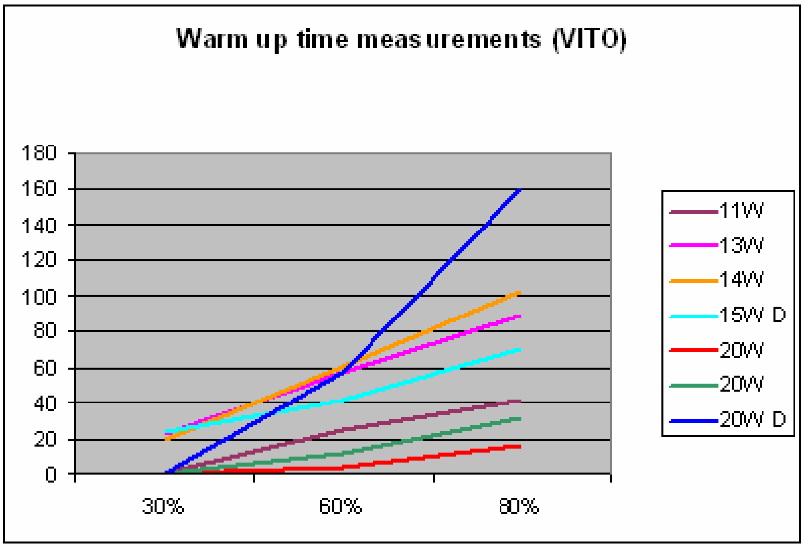

Figure 3.8: Warm-up time VITO test.

Fin=Finger, FiD=Finger Dimmable, FiR=Finger Reflector, LaL=Look-a-Like

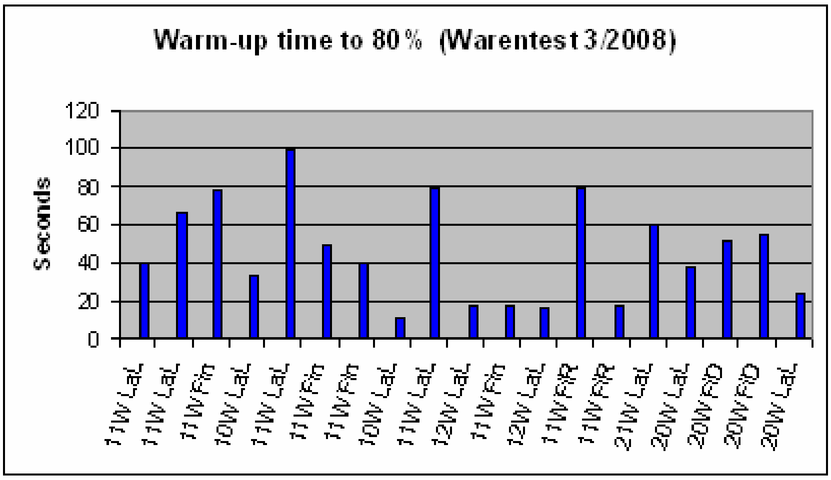

Figure 3.9: Warm-up time Warentest.

In total, 31 (77%) of the 40 CFLi's had an acceptable warm-up time and that includes all types of CFLi's: Fingertype, Look-a-Like, Finger reflector or Finger dimmable. For these 31 the warm-up time is on average 29 seconds so in the future the limit might be revised to less than 60 seconds. Anyway for the time being the EU Quality Charter requirement seems reasonable.

A barrier for reduction of the warm-up time is that manufacturers nowadays use amalgams in the CFLi's in order to reduce the influence of ambient temperature on the light output of a lamp during normal operation. This amalgam technology that is also necessary to produce the more compact types, increases the warm-up time. In chapter 6 the use and the advantage of amalgam is extensively discussed.

3.5.1.3 Colour temperature and colour rendering

As described in part 3.2.2., the different lamp types have different intensities for the spectral distribution of the emitted light. The most important visual lamp characteristics are (see section 1.1.3.1):

- the colour appearance of the lamp, defined by the correlated colour temperature CCT in [K];.
- the colour rendition of objects or surfaces illuminated by the lamp, defined by the colour rendering index CRI.

The colour temperature of an incandescent lamp is situated between 2400K (for lower wattages or dimmed high wattages) and 2800K (for high wattages).
CFLI's are available with different colour temperatures. In the Southern part of the EU the tendency is that people prefer colder light i.e. a higher colour temperature (higher content of blue lighting) while people in the Northern part of the EU prefer warmer light i.e. a low colour temperature (higher content of yellow/red lighting).

Incandescent and halogen lamps have a CRI score close to 100 while this score is lower for other lamp types. For existing CFLi's, all using 3-band phosphor, the CRI is typically between 82 and 85. In the family of LFL's, 5-band phosphor types are available with CRI from 91 up to 98. This technique could also be used for CFLi's as an alternative for the lighting points where the user sets very high requirements for colour rendering. Special attention must be paid to the fact that in this case the lumen output decreases with about 30% and the product price will be higher due to the use of more expensive phosphorous powders. At the latest Quality Charter revision meeting in October 2007, the Danish Electricity Saving Trust and other participants recommended the manufacturers to start production and sales of CFLi's with higher CRI with CRI within the same area 91-98 as seen for LFL. In the Nordic countries ,some architects and designers are demanding such high quality CFLi lamps[19].

3.5.2 Visual appearance

The visual appearance of lamps is optimal when the luminaire is designed for the lamp type used in the luminaire. Most existing luminaires in the home are designed for incandescent lamps. Use of a CFLi in a luminaire dedicated to incandescent lamps might reduce the visual appearance (e.g. by losses in light output and/or glare). Currently this problem is mostly remedied by the introduction of look-a-like CFLi's for frosted or silicated incandescent lamps. It is important that luminaire manufacturers bring luminaires on the market that are dedicated to CFLi's so the customer is aware of combining luminaire and lamp in the best way. (Part 2 of this study.)

3.5.3 Luminaire socket and space lock-in efffect

For this item, see section 3.4.4.

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[19] Dissemination in order to eliminate Barriers for use of Energy Saving Lamps in the Domestic Sector, SAVE project 4.1031/Z/97-030, December 2000, page 27 and 105.

3.5.4 Electrical wiring and control system lock-in effect

For this item, see section 3.4.5

3.5.5 Harmonic interference in the low voltage network

In many homes energy suppliers have observed network pollution by harmonic interference originating from appliances as TV and PC sets. CFLi's are also giving a little harmonic interference and some energy suppliers have discussed or claimed that the manufacturers should introduce an electronic compensation system in the CFLi's. According to the legal regulations in Europe (IEC 1000-3-2), reduction of harmonic emissions is not obligatory for appliances with an active input power less than 25 W. There is thus no regulation that requires compensation for CFLs.

A comprehensive field test study was carried out by The Community of the Austrian Electricity Suppliers including laboratory measurements and field measurements. The Austrian measurements showed that extensive use of CFLi's did not lead to negative effects on the voltage quality[20]. Computer simulations were carried out to estimate the effect of the increased use of CFLi's on the higher voltage levels. Considering the result of the calculation, the distortion factor will increase with less than 1%. Therefore it was concluded that remedial measures are not necessary.

This is in accordance with the result of an inquiry made by the German umbrella organisation ASEW including six local energy suppliers which showed that none of them had experienced any problems with harmonic interference caused by the use of CFLi's.

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

Safety requirements for electrical equipment (including lamps and luminaires) are laid down in annex I section 2 of the EU's Low Voltage Directive (LVD) 73/23/EEC (see also chapter 1). The directive requires that electrical equipment should be designed and manufactured to ensure protection against physical injury, harm or danger which may be caused by direct or indirect contact with the equipment, including radiation. All lamps and luminaires considered in this study have to comply with this directive. Any complaints related to physical injury, harm or danger caused by these products should thus be tackled under the Low Voltage Directive, and are not within the direct scope of the Ecodesign Directive and therefore of this study.

Some stakeholder groups (Lupus UK, Eclipse Support Group, Spectrum (UK) and Lupus DK)[21] have brought to the attention that some people who are light-sensitive are concerned that shifting to other lighting sources than low wattage incandescent lamps may affect their

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[20] Brauner G, Wimmer K., "Netzruckwirkungen durch konpaktleuchtsofflampen in Niederspannungsnetzen", Verband der Elektrizitätswerke Osterreich, 1995.

[21] SPECTRUM, www.spectrumalliance.org.uk, SLE/Lupus DK www.sle.dk, kirsten@lerstrom.dk

quality of life. Flickering and electromagnetic fields are also causing concern to some stakeholders.

To study these alleged effects, the European Commission (DG SANCO) has given the SCENIHR mandate; for more information see:

http://ec.europa.eu/health/ph_risk/committees/04_scenihr/docs/scenihr_q_016.pdf.

September 2008 SCENIHR has reported on light sensitivity health issues. The report is available at:

http://ec.europa.eu/health/ph_risk/committees/04_scenihr/docs/scenihr_o_019.pdf

Impact assessments on social, economic and environmental impacts of the planned measures will be done after the preparatory study and before the adoption of the measures.

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

For more info see website www.eup4light.net.