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(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 6: Technical Analysis BAT And BNAT

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2007/ETE/R/

VITO

May 2009

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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.

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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.

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

For more info see website www.eup4light.net.

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

Scope: This entails a technical analysis and description of the Best Available Technology (BAT) and Best Not yet Available Technology (BNAT) that can be implemented on product or component level. The described BAT is in many cases already available on the market, but is less frequently used because of the purchase price. It partly provides the input for the identification of part of the improvement potential (task 7), i.e. especially the part that relates to the best available technology. In chapter 7, also cost, intellectual property and availability are taken into account for the selection of options. This is not the case in this chapter and many of the presented technologies are intellectual property or linked to individual companies. The input of this chapter is partially the result of an organised visit to the Light and Building trade fare in Frankfurt 2008 (see also chapter 9 stakeholder consultation). Additional information was collected by consulting manufacturer's catalogues and technical publications. Much research is ongoing and information is not always publicly available, therefore this chapter can never claim to be complete but aims to give a general overview. For commercial reasons brand names are avoided in the text as far as possible.

This chapter also focusses on technical data[1] that influence the use phase i.e. the energy consumption. As demonstrated in the eco-reports in chapter 5, this phase is much more important than the production phase. For the BOMs, no significant differences with the base case lamps can be noticed. The production phase (including the BOM's) will be examined only for LEDs; the eco-reports for these light sources will be calculated in chapter 7.

6.1 BAT State-of the art

6.1.1 Mains voltage halogen lamps with Edison (E27/E14) or Swan (B22d/B15d) cap

Improvements for the efficacy of blown reflector halogen lamps type R50, R63, R80 etc. can be classified in:

- improvement of the reflector by changing to a PAR reflector,
- improvement of the reflector by changing to a dichroic PAR reflector,
- improvement of the efficacy by xenon gas filling,
- improvement of the efficacy by optimized filament wire design,
- Incorporating a transformer in a PAR lamp and using low voltage halogen bulb.

[1] Technical data in this chapter were collected from different sources e.g. www.olino.org , ELC-members, …

Figure 6.1: Blown reflector R63, PAR20 and PAR20i lamp.

6.1.1.1 Halogen lamps with PAR reflector

Compared to the blown reflector base case lamps R63, GLS-R as well as HL-MV-R, the efficacy of halogen PAR20 reflector lamps is much higher. The reason for this is the poor optical matching of a MV halogen bulb in the blown reflector. A PAR reflector is a pressed glass reflector and has the following advantages compared to a blown reflector:

- better beam control by the facetted reflector,
- no use of satinated front cover and therefore a higher % of the luminous flux in the 90° cone,
- much less (spilled) light backward.

Blown reflector lamps R63 can easily be replaced by PAR20 halogen lamps without changing the luminaire.
These lamps have an excellent colour rendering (CRI=100) and can easily be dimmed as long as the wattage is above the minimum required wattage of the dimmer.

The technical data for these lamps are shown in Table 6.1.

6.1.1.2 Halogen reflector lamps with xenon gas filling

As already explained in part 1 of the study, efficacy of halogen lamps can be improved by replacing the normal halogen gas filling of the bulb by xenon gas. This is of course also the case for halogen reflector lamps.
These improved lamps are already available on the market for the blown reflector base case lamps and even for the PAR lamps.
These lamps have the same properties as all halogen lamps: excellent colour rendering and normal dimmability.

The technical data for these lamps are shown in Table 6.1.

Important remark:
It must be stated that the improvement due to xenon can not be concluded from the measurements that were performed on market samples for R63 halogen lamps. This mainly confirms the earlier statement that the optimal position of the halogen bulb in a blown reflector lamp can not be guaranteed in normal, continuous production.

6.1.1.3 Halogen PAR reflector lamps with dichroic reflector

The evaporated aluminium coating of the reflector can be replaced by a special dichroic multi-layer coating as it is already common practice with low voltage halogen reflector lamps.

This dichroic reflector causes an improved reflection[2] for visible light compared to a normal aluminized reflector and gives also a cool beam. A cool beam means that it contains less infrared radiation or heat. These dichroic reflectors that are common practice for low voltage halogen reflector lamps are also on the market with GZ10 cap as improvement for GU10 capped halogen lamps. In the range of PAR lamps with Edison or Swan cap, they are BNAT.
A possible problem with dichroic reflectors could be the heat that escapes backward. If the existing luminaire is not designed for this changed heat transfer, these lamps can cause damage and maybe fire risk. Dirchroic coating is a multilayer coating which selectively transmits portions of the spectrum[3] (in this case IR); the technology is based on interference filters. High efficiency in visible light can be obtained. Similar technology is used for 'infrared coated lamps', see also 6.1.3.

All the properties from halogen lamps are maintained.

The technical data for these lamps are shown in Table 6.1.

6.1.1.4 Mains voltage halogen reflector lamps with optimized filament wire design

The design of the filament wire has a strong influence on the light output and light distribution of a mains voltage halogen reflector lamp. The more compact the filament is, the more homogeneous and better the light output of a reflector lamp is.
Compared to a low voltage halogen lamp, the filament of a mains voltage halogen lamp is much longer and focussing this wire in a reflector is not easy. By optimizing the design of the filament, an improved efficacy can be obtained.
All the properties from halogen lamps are maintained.

The technical data for these lamps are shown in Table 6.1.

6.1.1.5 Mains voltage halogen reflector lamps with an integrated electronic transformer, using a low voltage halogen bulb

These lamps use the same technology that was explained in part 1 of the study. A low voltage halogen bulb is mounted in the housing of an halogen PAR 20 lamp where also an electronic transformer is incorporated. The E27/B22d cap allows a one to one retrofit with a similar incandescent lamp and the energy consumption reduces to about half of it.
If the halogen bulb should be coated with an IRC reflective layer, and the reflector should be dichroic, efficacy could still raise. Altough IRC technology and dichroic reflectors are common practice in different lamp applications, the application for this specific lamp is not yet available on the market.

The technical data for these lamps are shown in Table 6.1.

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[2] In literature, values of 5 till 10% are given (to be completed).
[3] (IESNA(1993)): 'Lighting handbook' (ISBN 0-87995-102-8).

6.1.1.6 *Summary of technical data for Edison or Swan capped mains voltage halogen lamps*

Table 6.1 summarizes the main improvement data for Edison or Swan capped reflector lamps.

As already written in part 1 of the study, it must be taken into account that efficacy of lamps in the same family raises with the wattage i.e. a lamp of 50W will have a higher efficacy as his family member of 35W with the same technology. Please note that the lamps are available with different life times and as mentioned in part 1 there is a trade off between lamp life and lamp efficacy[4]. Some lamps are indicated as BNAT, they are not on the market due to current low market demand however their production is technical obvious and feasable.

Table 6.1: Data for lamp efficacy, cost and life time of Edison or Swan capped halogen lamps (source: ELC members)

Lamp type **Acronym**	**Wattage**	**LWFt[5]**	**Beam angle**	**Intensity**	**Functional lumens in an angular beam of 90°**	**ηlamp(90°) @25 °C**	**Life time**	**Unit price (for end user)**
	[W]		**[°]**	**[cd]**	**[lm]**	**[lm/W]**	**[h]**	**[€]**
Halogen reflector lamp, PAR20, E27 (B22d) **HL-MV-R**	50	1	30	1056	353	7.1	2000	12
Halogen reflector lamp, R63, E27 (B22d), xenon **HL-MV-R**	42	1	30	629	247	5.9	2000	3.0
Halogen reflector lamp, PAR20, E27 (B22d), xenon **HL-MV-R**	50	1	30	1161	388	7.8	2000	14
Halogen reflector lamp, PAR20, E27 (B22d), xenon +optimized filament wire design **HL-MV-R**	40	1	30	1042	296	7.4	2000	14
BNAT[6] Halogen reflector lamp, PAR20, E27 (B22d), xenon +optimized filament wire design + dichroic **HL-MV-R**	40	1	30	1094	311	7.8	2000	15
BNAT Halogen reflector lamp, PAR20, E27 (B22d) transfo inc + +Xenon+ IRC+dichroic **HL-MV-R**	21	1	36	1110	305	14.4	5000	26

[4] (IESNA(1993)): 'Lighting handbook' (ISBN 0-87995-102-8) p. 186
[5] LWFt = Total Lamp Wattage Factor = LWFp x LWFe (see chapter 4).
[6] Intensity, functional lumen and efficacy are only calculated, based on an improvement of 5%.

6.1.2 Mains voltage halogen reflector lamps with GU10 cap

Three similar improvements as for Edison or Swan capped lamps can be considered for GU10 capped lamps (GU10 capped halogen lamps already use PAR/MR reflectors):

- xenon gas filling,
- improved filament wire design,
- dichroic reflector.

The description of these improvements were already given in the preceding section.

Important remark for dichroic reflector lamps (see also 6.1.1.3):
Because a dichroic reflector evacuates the heat backward, this lamp has a specially adapted cap, the GZ10 cap. Interchangeability with a GU10 cap in the same luminaire is not always possible. If the luminaire has a GZ10 holder, a GU10 capped as well as a GZ10 capped lamp can be placed but if the luminaire is fitted with a GU10 holder, no GZ10 capped lamp can be placed. By this measure, the risk for damage and fire is eliminated.

All properties of halogen lamps are also maintained for these lamps.

The technical data for these lamps are shown in Table 6.2.
It must be noted that nearly all lamps have a relative short life time of 2000 h. Lamps with longer life time are probably not brought on the market due to negative impact on lamp efficacy[7]. Some lamps are indicated as BNAT, they are not on the market due to current low market demand however their production is technical obvious and feasable.

[7] (IESNA(1993)): 'Lighting handbook' (ISBN 0-87995-102-8) p. 186 relation between lamp efficacy and life time

Table 6.2: Data for lamp efficacy, cost and life time of GU10/GZ10 capped halogen lamps (source: ELC members)

Lamp type **Acronym**	**Wattage**	**LWFt**[8]	**Beam angle**	**Intensity**	**Functional lumens in an angular beam of 90°**	**ηlamp(90°) @25 °C**	**Life time**	**Unit price (for end user)**
	[W]		**[°]**	**[cd]**	**[lm]**	**[lm/W]**	**[h]**	**[€]**
Halogen reflector lamp, MR16, GU10, xenon **HL-MV-R**	42	1	30	826	284	6.8	2000	6.5
Halogen reflector lamp, MR16, GU10, xenon + optimized filament wire design **HL-MV-R**	35	1	40	500	251	7.2	2000	6.5
Halogen reflector lamp, MR16, GU10, xenon + optimized filament wire design **HL-MV-R**	50	1	40	900	427	8.5	2000	6.5
BNAT[9] Halogen reflector lamp, MR16, GZ10, xenon + opt filament wire design + dichroic **HL-MV-R**	35	1	40	525	264	7.5	2000	7.5
BNAT[10] Halogen reflector lamp, MR16, GZ10, xenon + opt filament wire design + dichroic **HL-MV-R**	50	1	40	945	448	9.0	2000	7.5

6.1.3 Low voltage halogen reflector lamps with infrared coating and/or xenon gas filling

This is again an improvement option that was explained in part 1 of the study, but now implemented on low voltage halogen reflector lamps. Also these lamps are already available on the market. It is important to note that efficacy of low voltage halogen lamps also can be improved if lifetime is shortened[11].
Currently lamp manufacturers are bringing low voltage halogen reflector lamps on the market with only xenon filling and almost the same efficacy of the ones with xenon and IRC, however with lifetimes of 2000h instead of 5000h.

[8] LWFt = Total Lamp Wattage Factor = LWFp x LWFe (see chapter 4).
[9] Intensity, functional lumen and efficacy are only calculated, based on an improvement of 5%.
[10] Intensity, functional lumen and efficacy are only calculated, based on an improvement of 5%.
[11] Lifetime and efficacy, see IESNA, Lighting Handbook p. 186.

All these lamps only differ from the normal low voltage halogen reflector lamps by the form of the halogen bulb, the thin layer of the infra-red reflecting coating and the filling gas.
There are no differences with the base case lamps neither regarding the reflector that is already a multi-facetted dichroic reflector nor regarding the filament wire that has the same compact dimensions that optimally fits in a reflector.
As a consequence the BOM's will not noticeably change compared to the BOM's showed in chapter 4.

Price and efficacy data about these lamps are included in Table 6.3 hereafter. These data will also be used for the improvement options assessment in chapter 7.

Table 6.3: Data for lamp efficacy, cost and life time of HL-LV-R with IRC-coating and/or xenon. (source: ELC members)

Lamp type / Acronym	Wattage	LWFt[12]	Beam angle	Intensity	Functional lumens in an angular beam of 90°	ηlamp(90°) @25 °C	Life time	Unit price (for end user)
	[W]		[°]	[cd]	[lm]	[lm/W]	[h]	[€]
Halogen reflector lamp, MR16, 12V, GU5.3, IRC + xenon **HL-LV-R**	20	1.06	36	1110	305	15.2	5000	7.5
Halogen reflector lamp, MR16, 12V, GU5.3, IRC + xenon **HL-LV-R**	45	1.06	36	2530	853	19.0	5000	7.5
Halogen reflector lamp, MR16, 12V, GU5.3, xenon **HL-LV-R**	25	1.06	36	862	371	14.8	2000	7.0

Remark: The LFWt for the improvement options takes into account that the EuP study on External power supplies proposes as BAT a value of 1.06.

6.1.4 LED retrofit lamps for replacing incandescent and halogen reflector lamps

White-light emitting diode (WLED) solid state lighting (SSL) lamps have been recently becoming available on the market with increasing efficacy (up to 94 lumen/W ((Härle (2007)) and increasing life time as a result of decades of semiconductor research and progress. Anyhow, WLEDs that actually could serve as retrofit solutions in this study have much lower efficacy but the rate of improvements is very high.
Also applications where coloured light is required benefit from LED's, e.g. traffic and other signs (applications with a low power density). LED's can be dimmed easily if the power supply is adapted for this function. WLED's are available in a wide range of lamp efficacies

[12] LWFt = Total Lamp Wattage Factor = LWFp x LWFe (see chapter 4).

from the same manufacturing production line, these LEDs were sorted during manufacture by their actual efficacy. This efficacy sorting is also called 'efficacy binning'.

WLED's that are nowadays on the market are mainly Solid State Lighting (SSL) devices, that rely on semiconductor material. For this SSL technology, efficacy and life time rapidly decrease with ambient temperature, therefore no high power densities or compact light sources can be obtained. SSLs are therefore primarily produced as discrete devices they are mainly available in low wattages (typical 1 to 5 Watt) and the main market products nowadays are mobile appliances (48 % in 2006, Steele (2007)). They are also sold as LED replacement lamps for existing reflector lamps.

Dr. Shuji Nakamura of Nichia of Japan is the inventor of the white LED which took a composite YAG phosphor coating on top of a blue LED and converted it to white light. This technique is nowadays nearly used by all WLED manufacturers. A theoretical limit in efficacy can be expected in the range of 135-150 lm/W with lens and without power supply losses (Härle (2007). The spectrum of some white LEDs differs significantly from incandescent light. There is a strong dependency of maximum efficacy on colour temperature colour coordinate (up to 20% increase) (Härle (2007)). The most efficient WLEDs appear blue (e.g. CT 6000 K) and do not meet the CRI > 80 colour rendering requirement for office lighting (EN 12464-1).

The SSL dependence on solid state semiconductor material could keep the price relatively high for these sources and the environmental impact of the production should be followed up in the near future. WLED semi-conductors are crystals comprised of combinations of typically two or tree inorganic elements, such as gallium phosphide (GaP), gallium nitride (GaN), gallium indium nitride (GaInN) or gallium indium phosphide (GaInP). It should be noted that LEDs in general, thus not only WLED, are included in the environmental impact unit indicators in the MEEUP methodology report (table 29 material 48) and herein the production energy requirement or GWP per kg is very high compared to other materials. This can be explained by the high energy (GWP) and environmental impact that is typical for the production of semiconductor material, see also material 47 (ICs SMD) in table 29 in the MEEUP methodology report. The WLEDs in particular make use of the rare raw materials gallium and indium that are used in many other high tech applications (PV panels, monitors, LCD displays with coatings of indium tin oxide) ('Only united are we strong: supply problems await areas other than silicon', Photon International, July 2006). The world annual indium production was estimated(2005) at 455 ton at 650 €/kg with about 6000 ton global reserves only(US Geological Survey, Mineral Commodity Summaries, January 2006). The indium price did rise with a factor 8 from 2002 to 2005. The world annual gallium production is estimated in 2005 at 208 tons at 410 €:kg and the global reserve is more difficult to estimate. Gallium occurs in very small concentrations in ores of other metals and is produced as a byproduct (e.g. bauxite). Based on the world resource of bauxite the reserve exceeds 1 million ton but probably only a small percentage of this metal is economically recoverable (US Geological Survey, Mineral Commodity Summaries, January 2006). The required energy (GWP) and material for the particular high efficacy WLEDs can only be modelled very approximate nowadays because it is unclear how many % of the production reach the high efficacy rating and there are many different and new production processes involved from which no data is made available due to intellectual property concerns. In this study the environmental impact will be modelled with the unit indicator (material 48 'SMD/LED's Avg per kg') from the MEEUP methodology (table 29). It must be noted that also GaAs and AlGaAs semiconductor is used for LEDs (Schurbert (2003), pp.4-7)[13], the are mainly used for

[13] Schubert (2003): 'Light-Emitting Diodes', second edition, ISBN-13 978-0-51-86538-8

red or infrared LEDs. Arsenic is a well known toxic material. For visisble red/orange light currently AlGaInP/GaP is used (Schurbert (2003), p. 213)[14], Infrared LEDs can still rely on these materials however they are not used for products in the focus of this study. Due to the high rate of innovation it cannot be excluded that arsenic compounds will reappear in LEDs for general lighting. (If stakeholders have more accurate information please provide it). It is also clear from the unit indicator in the MEEUP methodology that environmental impact from the production may not be neglected in future assessments.

The rate of innovation is still very high and results in a significant amount of intellectual property (IP). A query for ‘LED’ in the European patent database[15] results in 1320 filed European patent claims and 9 patent claims were filed in the first trimester of 2009.

At the moment, different suppliers are offering LED retrofit solutions to replace the currently available incandescent and halogen reflector lamps. The quality and the lifetime still stay problematic for many of these solutions and although the efficacy is improving, the provided functional lumens still stay far below the lumens provided by halogen lamps. Finally, all measured LED retrofit lamps have a very poor power factor <0.5.

Even though this part of the study does not look in detail into retrofit LED NDLS lamps that appeared as replacement lamps for NDLS incandescent bulbs since the completion of part 1 of the study, these statements relating to the efficacy, quality and BOM of retrofit LED DLS lamps as compared to other DLS lamp technologies are also largely valid for retrofit LED NDLS lamps compared to other NDLS lamp technologies.

In this chapter, three retrofit lamp types are studied:

- a LED-retrofit lamp for the R63-E27 5B22d) incandescent and halogen reflector lamps
- a LED-retrofit lamp for the MR16-GU10 halogen mains voltage reflector lamps
- a LED-retrofit lamp for the MR16-GU5.3 halogen low voltage lamps.

Price and efficacy data can be found in Table 6.4 and de BOM data in Table 6.5.

Lamps with a correlated colour temperature (CCT) of 2700 K were chosen because this is similar to incadescent lamps, 2700 K is also referred as ‘warm white’. Nevertheless it should be noted that 4000 K LEDs are about 50 % more efficient compared to 2700 K LEDs, as can be concluded from manufacturers catalogue data.

Figure 6.2: Some examples of LED retrofit lamps

[14] Schubert (2003): ‘Light-Emitting Diodes’, second edition, ISBN-13 978-0-51-86538-8

[15] http://be.espacenet.com/

Table 6.4: Data for lamp efficacy, cost and life time of LED retrofit reflector lamps (data source: Olino[16])

Lamp type Acronym	Wattage	LWFt[17]	Beam angle	Intensity	Functional lumens in an angular beam of 90°	ηlamp(90°) @25 °C	Life time	Unit price (for end user)
	[W]		**[°]**	**[cd]**	**[lm]**	**[lm/W]**	**[h]**	**[€]**
LED retrofit reflector lamp, R63, E27 (CCT 2700 K) **LEDi-R**	7.4	1.05	45	360	247	33.4	30000	40
LED retrofit reflector lamp, MR16, GU10 (CCT 2700 K) **LEDi-R**	4.7	1.05	32	382	170	36.1	30000	30
LED retrofit reflector lamp, MR16, GU5.3 (CCT 2700 K) **LEDi-R**	4.4	1.17	29	405	136	31	30000	30

[16] www.olino.org
[17] LWFt = Total Lamp Wattage Factor = LWFp x LWFe (see chapter 4).

Table 6.5: Input data for the materials extraction and production of the lamps (expressed in g)

MATERIALS Extraction & Production	LED retrofit reflector lamp, R63, E27 – **7.5W**		LED retrofit reflector lamp, MR16, GU10 – **4W**		LED retrofit reflector lamp, MR16, 12V, GU5.3 – **4W**	**Category**	**Material or Process MEEUP**
Description of component							
Glass for lens	10.1		10.1		10.1	7-Misc.	**54-Glass for lamps**
Aluminium body for cooling	140		27.3		27.3	4-Non-ferro	**27-Alu die-cast**
Aluminium for caps	1.5					4-Non-ferro	**26-Al sheet/extrusion**
Copper for caps / connector pins			1.5		1.5	4-Non-ferro	**30-CU tube/sheet**
LED	1		0.7		0.7		**48-SMD/LED's avg**
Copper plate (heat transfer)	10		9		9		**30-CU tube/sheet**
Plastic insulation plate	10		2.2		10		**8-PVC**
Porcelain housing			16				
Printed circuit board, assembled	10		7.5		7.5		**53-PWB assembly**
Total weight							

6.1.5 Compact fluorescent reflector lamps (CFLi-R) with integrated electronic ballast

As can be concluded from the technical analysis and the data in chapter 4, most CFLi-R on the market can not be considered as a DLS. Only in the range of lamps with big dimensions, some lamps match the definition of a DLS. Moreover, their efficacy is very low, compared to non directional CFLi. The reason for this lower efficacy and the non conformity with the DLS criterion is caused by the dimensions of the light emitting discharge tube which makes it necessary to lay the folded tube in layers. The upper layer of the folded tube shields the light from the underlying. As a consequence, there is no optical control in small size reflectors.

The lamps with big dimensions are rarely used in domestic lighting and for the normal dimensioned CFLi-R's no improvement can be expected. The techical and economical data for the improvement options in chapter 7 (if any) were included in chapter 4.

6.1.6 Cold Cathode Compact Fluorescent Reflector Lamps (CCFLi-R) with integrated electronic ballast

Cold cathodes fluorescent lamps (CCFL) are fluorescent lamps that do not employ a cathode heater. Nowadays, miniature CCFL's are extensively used as backlights for computer liquid crystal displays or flat screen television sets. More recently reflector lamps for general illumination appeared on the market. Their manufacturers claim a longer life time, dimmability and improved light distribution. Compared to a normal CFLi-R it can be said that the smaller light emitting discharge tube could have as a consequence that the light output is higher in the 90° cone angle. It must also be stated that these lamps contain mercury. More technical information can be found in the final report of preparatory study for ecodesign of EuP products lot 5 for television sets[18].

Stakeholders are invited to provide more input.

6.1.7 White light HIDi-R lamps to retrofit high wattage reflector lamps

High wattage incandescent or halogen reflector lamps can be replaced by more efficient HID reflector lamps with integrated control gear (HIDi-R).

The main advantage compared to CFLi-R is that an HID burner is a point source that performs better when the light needs to be focused by optics, e.g. in reflector lamps or a luminaire. Normal HID lamps are mainly available in high lumen output versions (> 1000 lm) and hence users are also forced to use luminaires to prevent glare and distribute the light.
There currently exist HIDi-R lamp versions that directly offer cost effective integrated solutions for replacing high wattage PAR38 incandescent or halogen reflector lamps with E27 cap. These lamps are rarely used in indoor domestic applications. In outdoor applications (e.g. garden lighting) they are a good alternative. Compared to an incandescent reflector lamp PAR 38-120W the equivalent HIDi-R only needs 25W, with a high colour rendering Ra = 87 and a warm, suitable colour temperature of 3000K.
These HIDi-R lamps have of course the same warm up and restrike times of several minutes as the normal HID lamps that were discussed in the street lighting study; also dimming is not possible. This makes them not very suitable for indoor domestic applications with regular switch-on's and –off's. Nevertheless, for horeca and outdoor applications they provide an energy efficient, retrofit alternative without need to change the luminaire.
It is unlikely that much lower lumen output HIDi-R lamps will appear on the market in the near future. It is a strong technological challenge. Simply downscaling can compromise life expectancy. Obstacles are the thermal conduction losses from the arc and the electrode losses that become more important for low wattages
Also here must be stated that white HIDi-R lamps also contain mercury; for more information on HID lamps see the preparatory EuP-study on street lighting lot 9.

[18] www.ecotelevision.org

Figure 6.3: HID-reflector lamp with integrated control gear.

The efficacy data for these lamps are shown in Table 6.6

Table 6.6: Data for HIDi-R lamps

Lamp type Acronym	Wattage	LWFt[19]	Beam angle	Intensity	Functional lumens in an angular beam of 90°	Luminous flux in a solid angle of 2π	ηlamp(90°) @25 °C	Life time	Unit price (for end user)
	[W]		[°]	[cd]	[lm]	[lm]	[lm/W]	[h]	[€]
HID retrofit reflector lamp, PAR38, E27 **HIDi-R**	25	1.05	10	26000	*1025*	1275	*41*	9000	40
HID retrofit reflector lamp, PAR38, E27 **HIDi-R**	25	1.05	25	5000	*1025*	1275	*41*	9000	40
HID retrofit reflector lamp, PAR38, E27 **HIDi-R**	25	1.05	40	2100	*1025*	1275	*41*	9000	40

6.1.8 DLS LED luminaire as improvement option to DLS luminaire + DLS lamps

Following the logic of Regulation 244/2009, integrated DLS LED luminaires would be considered as lamps and will have to comply with the requirements applicable to DLS lamps. Indeed, because of their integrated nature, they are an improvement option not only to luminaires (as discussed in section 6.1.9) but also to lamps, in the series of lamp improvement options started above. As the price is higher for retrofit the consumer might choose to replace the complete luminaire.

Compared to the use of DLS lamps (other than retrofit LEDs) in DLS luminaires, LED luminaires could bring the benefit of higher energy efficiency, reduced maintenance (lamps do not need to be changed) and as a consequence, reduced waste production.

Compared to the use of retrofit LED lamps in DLS luminaires, the main improvement through LED luminaires is brought by higher energy efficiency, thanks to an improved thermal design

[19] LWFt = Total Lamp Wattage Factor = LWFp x LWFe (see chapter 4).

with LED modules and more efficient power supplies because they do not suffer from space limitations that similar retrofit LED lamps encounter.
A typical example is a downlighter luminaire, see Figure 6.4. The functional performance parameters are included in Table 6.7 and the estimated BOM (extra functional elements) in Table 6.8. Dimmable power supplies are available. As can be seen from Table 6.7 the approach of quantifying functional lumens in a 90 ° solid angle is less suitable compared to functional lumens in a 120 ° for luminaires with LED modules (see also chapter 1).

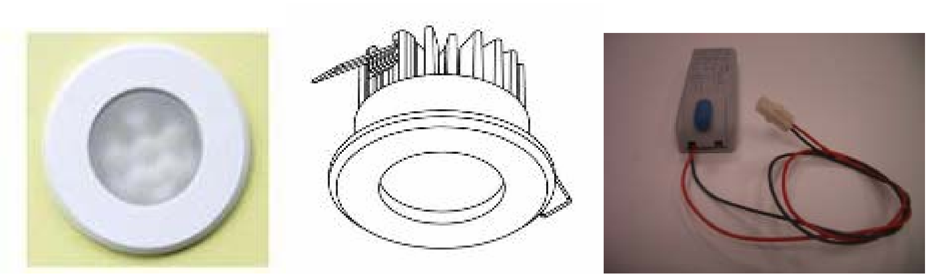

Figure 6.4: Sample LED downlighter incorporating an LED module and its dimmable external power supply

Table 6.7: Data for lamp efficacy, cost and life time of LED retrofit reflector lamps (source: manufacturer catalogue data)

Lamp type **Acronym**	**Wattage LED module (ecl. Power supply)**	**LWFt[20]**	**Beam angle**	**Intensity**	**Functional lumens in an angular beam of 180°**	**Functional lumens in an angular beam of 120°**	**Functional lumens in an angular beam of 90°**	**ηlamp(90°) @25 °C with power supply losses**	**Life time (as used in this study)**	**Unit price luminaire (for end user) (excl. power supply)**	**Unit price dimmable power supply (for end user)**
	[W]		**[°]**	**[cd]**	**[lm]**	**[lm]**	**[lm]**	**[lm/W]**	**[h]**	**[€]**	**[€]**
LED downlighter luminaire (CCT 3000 K) (32° beam angle) **LED module**	6.7	1.19	32	866	450	435	409	51	30000	99	44
LED downlighter luminaire (CCT 3000 K) (70° beam angle) **LED module**	6.7	1.19	32	866	450	395	309	38	30000	99	44

[20] LWFt = Total Lamp Wattage Factor = LWFp x LWFe (see chapter 4).

Table 6.8: Input data for the materials extraction and production of the LED module luminaire (expressed in g) (stimated)

MATERIALS Extraction & Production ***Description of component***	LED retrofit reflector lamp, R63, E27 – **7.5W**		**Category**	**Material or Process MEEUP**
Glass for lens	15		7-Misc.	**54-Glass for lamps**
Aluminium body for cooling	300		4-Non-ferro	**27-Alu die-cast**
LED	1.5			**48-SMD/LED's avg**
Copper plate (heat transfer)	15			**30-CU tube/sheet**
Plastic insulation plate	10			**8-PVC**
Printed circuit board, assembled	10			**53-PWB assembly**

6.1.9 Luminaires with reduced energy consumption (system level)

The **average luminaire** was defined in chapter 4.

The purpose of this section to evaluate how much energy can be saved with a particular improvement option taking into account that the compared luminaires should have an equal lumen output and luminance or shape of the decorative ornaments. The sole exception is dimming, where lumen output and/or and luminance of the decorative ornaments is changed.

It is hard to find sufficient data for luminaires sold on the market, therefore all stakeholders are invited to provide data. Aferwards this data will be processed and at the stakeholder meeting the quality of this data will be discussed. Stakeholder can also present improvement options if they are not listed hereafter. The proposed format for providing data is included in Table 6.9 and the corresponding spreadsheet can be found on the website. Any other data or format is also welcome. The luminaire categories used in Table 6.9 are defined in chapter 4. Please fill in a separate table for each improvement option.

Table 6.9: Suggested, additional improvement options (Table can be found as spreadsheet on the website)

Option:	?							
Your country:	?							
Saving method description	?							
Sample picture best practice	?	**Sample picture worst practice**	?					
Category of luminaires (defined in chapter 4)	**Is this option applicable to this category or not**	**How big is the market share [EU27 sales] of improvable luminaires in its category**	**What proportion of the energy can be saved comparing worst to best practice**	**How many luminaires [EU27 sales] are among the worst 30 % performers in the category**	**How many luminaires [EU27 sales] are among the best 30% performers in the category**	**What proportion of the energy can be saved on average assuming all luminaires sold are in the range of 30 % best performers**	**Chararacteristic parameter best performer**	**Chararacteristic parameter worst performer**
	Y/N	**%**	**%**	**%**	**%**	**%**	***?***	***?***
Downlights (recessed mounted)	?	?	?	?	?	?	?	?
Suspension (chandeliers)	?	?	?	?	?	?	?	?
wall&ceiling	?	?	?	?	?	?	?	?
Desk	?	?	?	?	?	?	?	?
Table	?	?	?	?	?	?	?	?
Floor	?	?	?	?	?	?	?	?
Spotlights	?	?	?	?	?	?	?	?
Outdoor	?	?	?	?	?	?	?	?

The proposed improvement options for luminaires are:

Avoid the lock-in effect into low efficient lamps class C.
This is obvious from the lamp data, as a consequence this option does not need to be documented.
Example: HL-MV lamps, luminaires that recommend frosted lamps that have no direct light output, ..

Use material with increased light transmittance for visible parts that are transparent / translucent.
Example: Opal glass can have a significant lower light transmittance compared to surface treated glass (e.g. sand blasted).

Use materials with increased reflectance for invisible parts that are not transparent/translucid.
Example: Using a lamp shade with white internal surface compared to a black one.

Increase overall LOR for the luminaire
Example: Design the luminaire to the extent possible in such a way that its elements do not block or filter out the light coming from the lamp(s).
The worst and the best practice cases to be compared should both have the same room illumination function in parallel to the decorative function. This means that you should not compare a purely decorative black box-type fashion luminaire to a bare lamp hanging at the end of wire, but for example two suspended NDLS luminaires that are meant to provide the main illumination in a living room but are also supposed to be decorative. In that case, the energy saving for Table 6.7 is proportionate to the difference in LOR, as in order to achieve the same light output the best luminaire will need lower wattage lamps than the worst. In this case LOR is the characteristic parameter.

.
Reduce power supply losses.
Example: improving the energy effiency of the power supply (including in standby mode, if it cannot be switched off by the luminaire switch).

Eliminate standby losses.
Example: Install the switch before an incorporated lower voltage power supply instead of after the power supply.

Incorporate presence and/or daylight detector switch.
Example: outdoor luminaire with presence detector and daylight sensor.

Incorporate dimmers.
Example: uplighter with dimmer.

Design the luminaire in a way that it can be cleaned.

Example: some luminaires trap flies and if they cannot be cleaned the light output will decrease.
When reflectors are used to create a directional light with NDLS lamps, they should be more efficient compared to equivalent DLS lamps.
Example: an inefficient reflector luminaire for HL-LV lamp could be better replaced by a HL-LV-R lamp luminaire.

For complicated light distributions, consider LED modules or high performing LOR.
Example: wall mount luminaire with low LOR could be replaced by LED luminaire.

Use coloured LED's to create directly the desired colour instead of filtering white light using a lamp shade.
Example: to be completed

For luminaires that rely on LED's, one can consider to use LED modules incorporating an appropriate cooling, compared to luminaires that rely on retrofit LED lamps.
Example: LED downlighter (see 6.1.8)

Any other (stakeholder please sent suggestions and complement Table 6.9.

6.2 State-of the art of best existing product technology outside the EU

The EU has premises of leading international companies in the field of lighting with also important R&D related to office lighting within the EU. For the cited BAT above, similar technology exists around the world, mainly in the US and in Asia. Many European companies are also internationally active and it is difficult to allocate their activities and achievements exclusively to the EU. The production of CFL is often located in China.
On the longer term (above 5 years), the proliferation of more advanced electronic lamp technology and solid state lighting such as LED's could be allocated to technology resulting from Asian technological developments.

6.3 BNAT in applied research

6.3.1 OLED lamps

OLED's (Organic LED) are a new upcoming technology but they are not intended to give directional light. The reason for this is that the light producing element has typically a flat surface and the amount of generated lumens per m² is rather low. Due to the dimensions, a directional light source based on this technology is unlikely. The future of OLED's can mainly be found as backlights in flatscreens and mayby also as a NDLS in general room illumination. As a consequence they will not be discussed in this part 2 of the study.

6.3.2 The road map for WLED development

As mentioned before LEDs are under contineous development and LED efficacy is expected to furher increase.

Stakeholders are invited to provide input.

6.3.3 Theoretical maximum lamp efficacy

It is important to note that the lamp efficacy has a physical upper limit; this is when all light is converted into visible electromagnetic radiation.
This maximum lamp efficacy is related to the colour due to the definition of lumen and the relative spectral sensitivity of the human eye that was taken into account.
The maximum lamp efficacy for a perfect cool white light source is 348 lm/W and the absolute maximum for monochromatic yellow-green light (555 nm) sources is 683 lm/W (IESNA (1993), p. 204).

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.