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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 5: Definition of Base-Case

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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.

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

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

<u>Important remark</u>*: This chapter 5 only discusses part 1 of the study and does not yet discuss directional light sources such as reflector lamps. Those products are being analysed in the second part 2 of the lot 19 study.*

Chapter 5 comprises of an assessment of average EU products, the so called "base cases".

A base-case is "a conscious abstraction of reality". The description of the base-cases is the synthesis of the results of tasks 1 to 4. The environmental and life cycle cost analysis are built on these base-cases throughout the rest of the study and it serves as the point-of-reference for chapter 6 (technical analysis of BAT), chapter 7 (improvement potential), and chapter 8 (policy analysis).

According to the MEEuP methodology, the scope of a preparatory study should be covered by one or two base-cases in chapter 5. Nevertheless, as discussed in chapter 1, a wide range of lamps are available and chapter 2 highlighted that their sales amounts are significant. Therefore, it was decided to analyse a larger number of base-cases to portray the market reality in a comprehensive manner. Detailed analysis of several base-cases will also allow a more realistic assessment of improvement potentials in the subsequent tasks and EU-27 total environmental impact.

In this first part of the study, related to non-directional lighting sources, 6 base-cases were considered to be representative of the current European market:

- **Incandescent lamp, clear (GLS-C): 54 W**
- **Incandescent lamp, frosted (GLS-F): 54 W**
- **Halogen lamp, low voltage (HL-LV): 30 W**
- **Halogen lamp, mains voltage, low wattage (HL-MV-LW): 40 W**
- **Halogen lamp, mains voltage, high wattage (HL-MV-HW): 300 W**
- **Compact fluorescent lamp, with integrated ballast (CFLi): 13 W**

The average yearly use times are different for all base-cases and figures presented in chapter 2 (see section 2.2.5) are used in this chapter:

- Incandescent lamp, clear (GLS-C and GLS-F): 400 hours/year
- Halogen lamp, mains voltage (HL-MV): 450 hours/year
- Halogen lamp, low voltage (HL-LV): 500 hours/year
- Compact fluorescent lamp, with integrated ballast (CFLi): 800 hours/year

The choice of the wattage of the base-cases was based on the outcomes of the EU R&D project EURECO (see chapter 2, section 2.2.4) which provided information about the use of lighting sources by wattage groups for several European countries.

As already mentioned in chapter 4 (section 4.1.3), neither ballasts for LFL and CFLni, nor transformers and power supplies for low voltage halogen lamps will be discussed in detail in this study as they were already detailed in the study on office lighting[1] and on external power supplies[2].

The environmental impacts of the base-cases are evaluated with the EuP EcoReport tool as specified in the MEEuP methodology. This allows identifying the significance of the different phases of the life cycle in terms of environmental impacts.

Inputs used in this chapter were defined in previous chapters. Chapter 4 provides the required technical data, viz., Bill of Materials (BOM), packaging and packaged volume, energy consumption during the use phase and considerations regarding the end-of-life of materials for existing products. Economic data (sales and stocks in EU-27, as well as product price and electricity tariff) were established in chapter 2.

For each of the 6 base-cases, the electricity consumption used in chapter 5 is for real life conditions. Thereby, the correction lamp wattage factors, namely LWFp and LWFe, presented in section 4.3.2 have been taken into consideration. Further, the average lamp lumen maintenance factor (LLMF), as discussed in chapter 3, is used to calculate the lamp efficacy of the base-case.

5.1 Product-specific inputs

5.1.1 Base-case GLS (General Lighting Service)

Technical data for the two base-cases GLS-C and GLS-F are assumed to be the same as the wattages are equal. For the definition of the BOM and of the packaged volume of the base-cases, it was assumed that these parameters were equal to the ones defined for a GLS 50 W with an arithmetic mean of the product-cases GLS 40 W and GLS 60 W presented in chapter 4.

- **Bill of Material**

The BOM of these base-cases is derived from the products presented in chapter 4 (section 4.1.2) for the incandescent lamps 40 W and 60 W (see Table 5.1).

For the base-case GLS-C, data related to the product case 200 W presented in chapter 4 were not taken into account. This assumption will be discussed in the conclusion of this chapter after the analysis of environmental impacts due to the production phase.

[1] Preparatory Studies for Eco-design Requirements of EuPs, Lot 8: Office lighting, Final Report (April 2007).
[2] Preparatory Studies for Eco-design Requirements of EuPs, Lot 7: External power supplies and battery chargers (January 2007).

Table 5.1: EcoReport material input table for base-cases GLS-C & GLS-F

Nr	Product name		Date	Author
	Base-Case GLS-C			**BIO**

Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
1	**Glass**	**19.75**	7-Misc.	**54-Glass for lamps**
2	**Aluminium for caps**	**1.25**	4-Non-ferro	**26-Al sheet/extrusion**
	TOTAL	**21.00**		

- **Primary scrap production during sheet metal manufacturing**

It was assumed that the production of 1 kg sheet metal for lamps required 1.25 kg sheet metal, which leads to 20 % of sheet metal scrap.
This assumption is valid for the 6 base-cases.

- **Volume and weight of the package volume**

The weight of the base-case is 21 g and it has a packaged volume of 0.24 dm^3.

- **Annual resource consumption and lamp efficacy**

The power rating of the two base-cases GLS-C and GLS-F is 54 W as the correction factors are equal to 1, with a lamp lifetime of 1000 hours. With a yearly use of 400 hours, the lifespan of a typical incandescent lamp (both clear and frosted) is 2.5 years.

Despite having the same power output, the two base-cases have different ‘functional’ lumen output. As discussed in chapter 4 (section 4.3.1.3), the luminous efficacy (ηlamp) of a clear incandescent lamp is higher than a frosted incandescent lamp for the same wattage: the luminous efficacy (at 100 hours) of a typical 54 W clear incandescent lamp is 11.4 lm/W, whereas it is 11 lm/W for a typical 54 W frosted incandescent lamp (figures defined considering that the luminous efficacy wattage relationship is linear between 40 W and 60 W). Further, in contrast to the interim report published in November 2007, lamp lumen maintenance factor (LLMF) needs to be taken into consideration in order to characterise the decrease in lamp efficacy with the lamp lifetime. This parameter is equal to 0.965 for GLS as presented in chapter 3, section 3.2.6.1.
Therefore, **the effective luminous efficacy of a typical 54 W GLS-C is 11.0 lm/W, whereas it is 10.6 lm/W for a typical 54 W GLS-F.**

- **Disposal and Recycling**

For incandescent lamps, 100 % of the product is assumed to be disposed in landfills.

5.1.2 Base-case HL-MV-LW (Halogen Lamp – Mains Voltage (230 V) – Low Wattage)

Chapter 4 presented one type of HL-MV-LW: a clear lamp with a G9 socket and a power of 40 W and the characteristics of this lamp are used to define the base-case HL-MV-LW.

- **Bill of Material**

The BOM of the base-case HL-MV-LW is presented in Table 5.2. As mentioned in chapter 4, about 98% of the weight of the lamp is modeled with the glass. The remaining 2% (i.e. about 0.04g) are negligible both in weight and in environmental impacts.

Table 5.2: EcoReport material input table for base-case HL-MV-LW

Nr	Product name			Date	Author
	Base-Case HL-MV-LW				BIO
Pos nr	**MATERIALS Extraction & Production Description of component**	**Weight in g**	**Category Click &select**	**Material or Process select Category first !**	
1	Glass	2	7-Misc.	54-Glass for lamps	
	TOTAL	2			

- **Volume and weight of the package volume**

The weight of the base-case HL-MV-LW is 2 g and it has a packaged volume of 0.05 dm^3.

- **Annual resource consumption and lamp efficacy**

The electricity consumption of the base-case HL-MV-LW is 40 Wh/h, as the total Lamp Wattage Factor (LWFt) is equal to 1 (see section 4.3.1.3). The lamp lifetime is 1500 hours with an average use of 450 hours per year resulting in a lifespan of 3.33 years.

Based on the luminous efficacy of the product-case presented in chapter 4 and an average LLMF of 0.975, it can be assumed that **the luminous efficacy of the base-case HL-MV-LW is about 12.0 lm/W.**

- **Disposal and Recycling**

Similar to incandescent lamps, 100 % of the halogen lamp is assumed to be placed in landfill.

5.1.3 Base-case HL-MV-HW (Halogen Lamp – Mains Voltage (230 V) – High Wattage)

Chapter 4 presented only one type of HL-MV-HW; a clear linear bulb with a power of 300 W and a R7s socket. The technical parameters presented in chapter 4 were used to define the base-case HL-MV-HW.

■ **Bill of Material**

The BOM of the base-case HL-MV-HW presented in the table below (Table 5.3) is based on the data presented in chapter 4. Only the glass is taken into consideration, as the weight of other components is negligible (maximum of 2% according to chapter 4, i.e. 0.18g). Further, when the neglected materials are measured in the environmental impact weighing system of the EcoReport (e.g. by assuming that the material neglected is aluminium for caps), differences are insignificant for all environmental indicators.

Table 5.3: EcoReport material input table for base-case HL-MV-HW

Nr	Product name		Date	Author
	Base-Case HL-MV-HW			**BIO**

Pos nr	**MATERIALS Extraction & Production Description of component**	**Weight in g**	**Category Click &select**	**Material or Process select Category first !**
1	Glass	9	7-Misc.	**54-Glass for lamps**
	TOTAL	9		

■ **Volume and weight of the package volume**

The weight of the base-case HL-MV-HW is 9 g and it has a packaged volume of 0.15 dm^3.

■ **Annual resource consumption and lamp efficacy**

The electricity consumption of the base-case HL-MV-HW is 300 Wh/h, as the total Lamp Wattage Factor (LWFt) is equal to 1 according to chapter 4 (section 4.3.1.3). The lamp lifetime is 1500 hours with an average use of 450 hours per year. Therefore, the lifespan of a typical HL-MV-HW is 3.33 years, as for the base-case HL-MV-LW.

Furthermore, it is assumed that **the luminous efficacy of the base-case HL-MV-HW is about 17.3 lm/W**, on the basis of an initial lamp efficacy of 17.7 lm/W and average LLMF of 0.975.

■ **Disposal and Recycling**

100 % of the HL-MV-High Wattage is assumed to be disposed in landfill.

5.1.4 Base-case HL-LV (Halogen Lamp – Low Voltage (12 V))

■ **Bill of Material**

The bill of material of the base-case HL-LV (see Table 5.4) derives from the BOMs of two product-cases presented in chapter 4 (35 W and 50 W) for which only the glass is taken into account, as it represents about 98% of the total weight of the lamp. Further, even if the neglected 2% were modelled with aluminium for the cap, it would not influence environmental impacts of the base-case over its whole life cycle.

Table 5.4: EcoReport material input table for base-case HL-LV

Nr	Product name	Date	Author
	Base-Case HL-LV		BIO

Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
1	Glass	2	7-Misc.	54-Glass for lamps
	TOTAL	2		

- **Volume and weight of the package volume**

The weight of the base-case HL-LV is 2 g and it has a packaged volume of 0.15 dm^3.

- **Annual resource consumption and lamp efficacy**

The power of the base-case HL-LV is 30 W, and the total Lamp Wattage Factor (LWFt) is equal to 1.11 (see section 4.3.1.3) due to the electrical losses in the transformer required to connect this type of lamp to the domestic electric grid. Thus, the 'real' electricity consumption of this base-case is 33.3 Wh/h.

The lifetime of an HL-LV lamp is assumed to be 3000 hours with an average use of 500 hours per year. Therefore, the lifespan of a typical HL-LV is 6 years.

By considering that the luminous efficacy wattage relationship is linear between 30 W and 50 W and that the average LLMF of this lamp type is 0.975, **the luminous efficacy of the base-case HL-LV 30 W is 14.5 lm/W**.

- **Disposal and Recycling**

100 % of the halogen lamp is assumed to be placed in landfill.

5.1.5 Base-case CFLi (Compact Fluorescent Lamp with integrated ballast)

- **Bill of Material**

Chapter 4 presented technical data for 4 compact fluorescent lamps with integrated ballast. A simple arithmetic mean of these product-cases was taken as the bill of material of the base-case CFLi 13 W (see Table 5.5). Moreover, the plastic used for the housing (PBT: PolyButylene Terephtalate) cannot be modelled in the EcoReport, and only its weight was taken into account without specifying the plastic type. It is assumed not to impact the comparison of base-cases, as the environmental impacts during the production phase can be expected to be negligible compared to the use phase. This assumption will be further discussed in the sensitivity analysis of chapter 8, where the PBT will be modelled with LDPE, as PBT derives from polyethylene.

Table 5.5: EcoReport material input table for base-case CFLi

Nr	Product name		Date	Author
	Base-Case CFLi			**BIO**

Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
1	Glass	**21.25**	7-Misc.	**54-Glass for lamps**
2	Aluminium for caps	**1.25**	4-Non-ferro	**26-Al sheet/extrusion**
3	Metal mercury	**0.004**		
4	Plastic housing (PBT)	**20.25**		
5	Lamp enveloppe	**10**	7-Misc.	**54-Glass for lamps**
6	Printed circuit board, assembled	**18.25**	6-Electronics	**51-PWB 6 lay 2 kg/m2**
	TOTAL	**71.004**		

- **Volume and weight of the package volume**

The weight of the base-case CFLi is about 71 g and it has a packaged volume of 0.5175 dm^3.

- **Annual resource consumption and lamp efficacy**

The power rating of the base-case CFLi is 13 W and the total Lamp Wattage Factor (LWFt) is equal to 1.05 (see section 4.3.1.3) due to electrical losses in the ballast. Thus, the 'real' electricity consumption of this base-case is assumed to be 13.65 Wh/h.

The lifespan of a typical CFL with integrated ballast is 7.5 years (i.e. life time of 6000 hours with an average use of 800 hours per year).

Two types of CFLi are investigated in chapter 4: bare CFLi and enveloped CFLi. They have different luminous efficacy for a same wattage due to the use of the envelope which reduces the luminous efficacy. In order to calculate the luminous efficacy of the base-case (13 W), it was first defined separately for a bare and enveloped CFLi 13 W (considering in both cases that the efficacy is linear between 10 W and 15 W). Then, an arithmetic mean of the two values was made (50 lm/W for a bare CFLi and 43 lm/W for an enveloped CFLi) and finally multiplied by the average LLMF of 0.925 for a CFLi (see section 3.2.6.1).
Thereby, **the luminous efficacy of a typical CFL 13 W with integrated ballast is assumed at 43.0 lm/W**.

- **Disposal and Recycling**

As CFL lamps should be collected separately, it was assumed that 5 % of the materials go to landfill and 95 % of the metals and glass is recycled. Furthermore, regarding the mercury contained in compact fluorescent lamp (0,004 g), it was assumed that 80 % (i.e. 3.2 mg) was emitted to air during the end-of-life processing, as mentioned in chapter 4. This value was obtained based on information related to recycling practices from different Member States, although according to the WEEE Directive, all CFLi have to be recycled.

5.2 Base-case Environmental Impact Assessment

5.2.1 Base-case GLS

Table 5.6 presents the results of the environmental impact assessment of both base-cases GLS-C and GLS-F.

It is clearly visible that for each of the 15 environmental impact indicators, the use phase is the most impacting stage over the whole product life cycle. The total energy consumption for the whole life cycle of the 54 W GLS base-case is 621 MJ of which about 91 % is consumed during the use phase.

Table 5.6: Environmental assessment results from EcoReport (base-case GLS)

Base-Case GLS — 0 BIO

Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
Resources Use and Emissions		Material	Manuf.	**Total**	**BUTION**		Disposal	Recycl.	**Total**	
Materials	**unit**									
Bulk Plastics	g			**0**			0	0	**0**	**0**
TecPlastics	g			**0**			0	0	**0**	**0**
Ferro	g			**0**			0	0	**0**	**0**
Non-ferro	g			**1**			1	0	**1**	**0**
Coating	g			**0**			0	0	**0**	**0**
Electronics	g			**0**			0	0	**0**	**0**
Misc.	g			**20**			20	0	**20**	**0**
Total weight	g			**21**			21	0	**21**	**0**
								see note!		
Other Resources & Waste							debet	credit		
Total Energy (GER)	MJ	1	0	**1**	**52**	**567**	1	0	**1**	**621**
of which, electricity (in primary MJ)	MJ	0	0	**0**	**0**	**567**	0	0	**0**	**567**
Water (process)	ltr	0	0	**0**	**0**	**38**	0	0	**0**	**38**
Water (cooling)	ltr	0	0	**0**	**0**	**1512**	0	0	**0**	**1512**
Waste, non-haz./ landfill	g	5	0	**5**	**52**	**657**	26	0	**26**	**740**
Waste, hazardous/ incinerated	g	0	0	**0**	**1**	**13**	0	0	**0**	**14**
Emissions (Air)										
Greenhouse Gases in GWP100	kg CO2 eq.	0	0	**0**	**5**	**25**	0	0	**0**	**29**
Ozone Depletion, emissions	mg R-11 eq	negligible								
Acidification, emissions	g SO2 eq.	0	0	**0**	**12**	**146**	0	0	**0**	**158**
Volatile Organic Compounds (VOC)	g	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Persistent Organic Pollutants (POP)	ng i-Teq	0	0	**0**	**0**	**4**	0	0	**0**	**4**
Heavy Metals	mg Ni eq.	0	0	**0**	**3**	**10**	0	0	**0**	**13**
PAHs	mg Ni eq.	0	0	**0**	**3**	**1**	0	0	**0**	**4**
Particulate Matter (PM, dust)	g	0	0	**0**	**1**	**3**	2	0	**2**	**6**
Emissions (Water)										
Heavy Metals	mg Hg/20	0	0	**0**	**0**	**4**	0	0	**0**	**4**
Eutrophication	g PO4	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

Figure 5.1 and Figure 5.2 show the contribution of each of life cycle phases to two main environmental indicators: gross energy requirement (GER) and global warming potential (GWP). As previously mentioned, the use phase is the highest contributor of these impacts. It represents about 91 % of the total energy consumption and about 84 % of the GWP over product's lifetime.

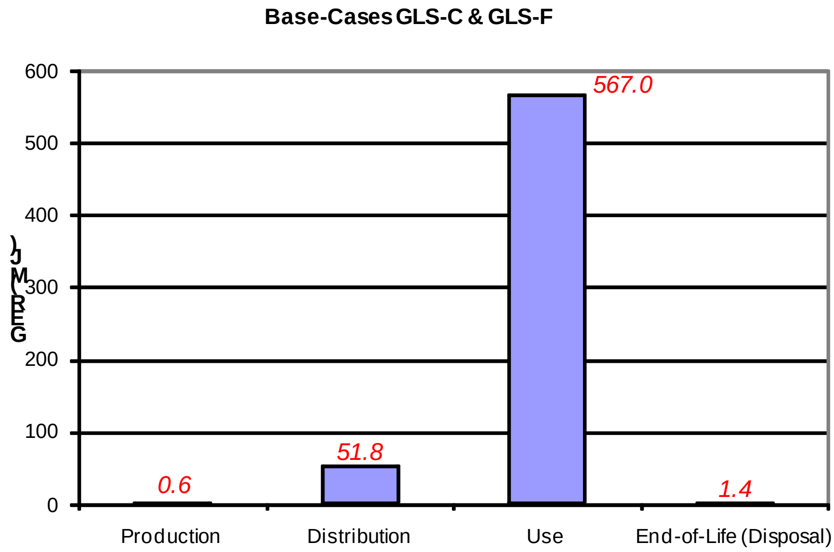

Figure 5.1: Total energy consumption during all life cycle phases

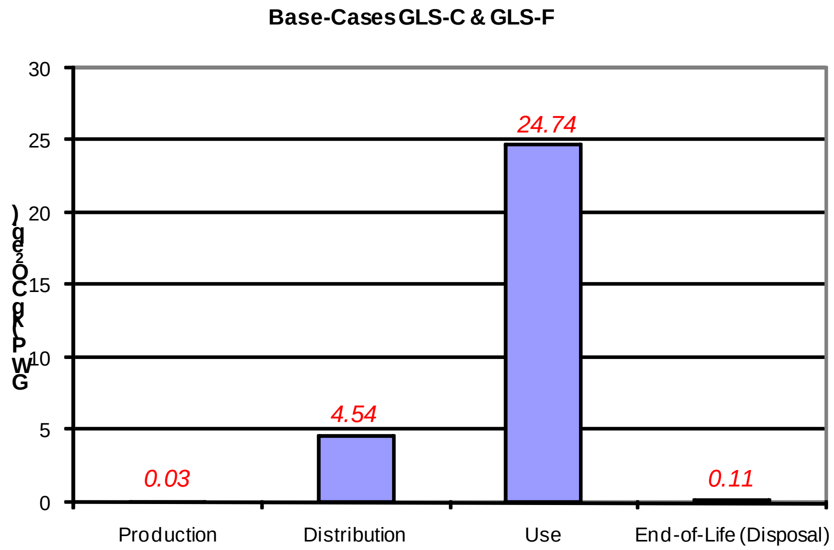

Figure 5.2: Total Global Warming Potential during all life cycle phases

Figure 5.3 presents the contribution of the life cycle phases for each of the 15 environmental impact indicators.

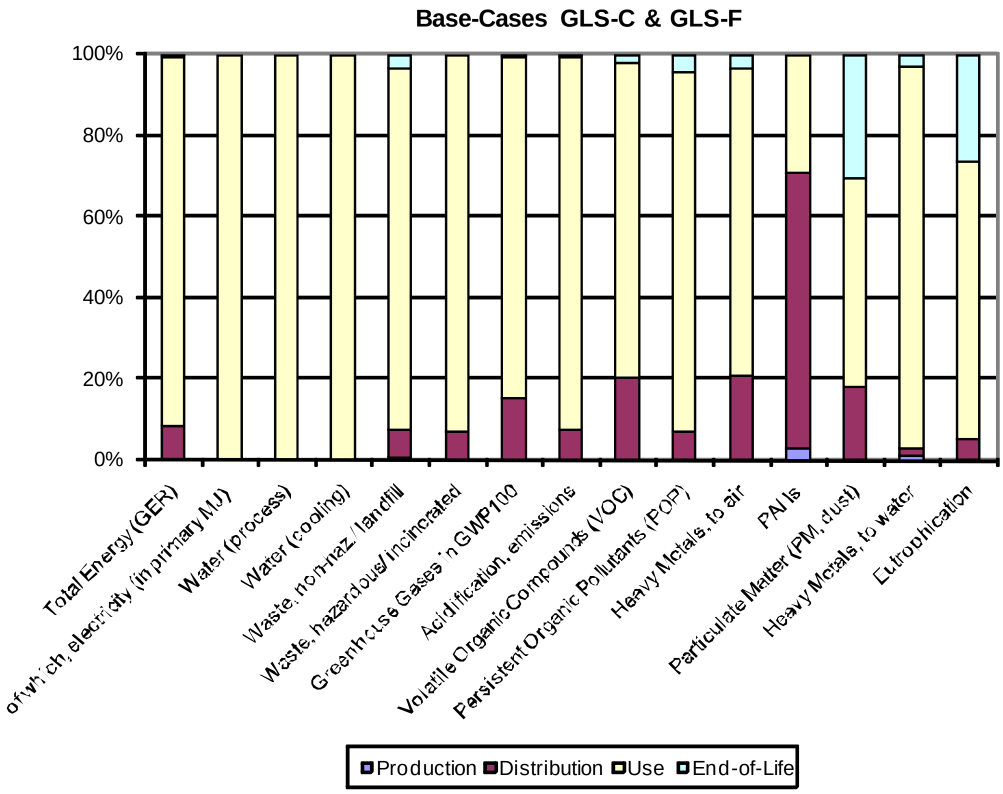

Figure 5.3: Distribution of environmental impacts per life cycle phase

Several observations can be made from this analysis:

- The production phase is negligible for all environmental impact indicators. Its highest contribution is 3 % to the emissions of Polycyclic Aromatic Hydrocarbons (PAHs) to air, due the use of aluminium for the caps of the lamps. Therefore, taking into consideration the BOM of the GLS-C 200 W when establishing the BOM of the base-case would have negligible effect on the present environmental assessment even if it contains copper which has more significant impacts than aluminium.
- The distribution phase contributes more than 5 % of the life cycle impacts for 11 of the 15 environmental impact indicators. Impacts of this phase are the highest for the emission of PAHs (69 %), heavy metals (22 %), volatile organic compounds (VOC) (21 %), and particulate matter to air. This can be explained by the assumption related to transport in trucks from the retailer's central warehouse to the shop. Nevertheless, although the distribution phase has a high contribution to these indicators, their total values over the life cycle remain low. The EcoReport tool does not allow specifying means of transport ant distances between the production place of the lamp and retailer's central warehouse; only the volume of the product is taken into consideration to assess environmental impacts of the transport. Nevertheless, according to the MEEuP methodology (section 5.3.6, page 96), a mix of means of transport (trucking, rail, sear freight and air freight) with assumptions on distances was used for all base-cases. This assumption could be considered as disadvantageous for lamps mainly produced in Europe (e.g. GLS-F and GLS-C) and advantageous for lamps produced in Asia (e.g. CFLi). However, as mentioned previously, the contribution of the

distribution phase to the environmental impacts is either low in relative terms compared to other life cycle phases (e.g. for energy consumption or GWP), or low in absolute terms as total values over the whole life cycle are not significant compared to other products (e.g. for PAHs or VOC).

- The contribution of the use phase to environmental impact varies between 29 % (for the emissions of PAHs to air) and 100 % (for the use of cooling water). For 10 environmental impact indicators, the use phase contributes to more than 80 %.
- For incandescent lamps, the whole product is disposed of into landfill and no benefit is possible with recycling. The end-of-life phase is significant for the emissions of particulate matter to air (32 %) due to the transport to the landfill, and for eutrophication (28 %). However, the eutrophication potential due to the life cycle of an incandescent lamp is very low (less than 0,03 g PO_4) compared to, for example a typical 32" LCD TV (about 15 g PO_4)[3].

One has to keep in mind that although the two base-cases have the same electricity consumption, their luminous efficacy differs. Therefore, with a reference of 594 functional lumen output (54 W x 11 lm/W for the base-case GLS-C) environmental impacts related to the use phase should be multiplied by a correctional factor for the base-case GLS-F. This correctional factor is approximately 1,038 (= 11/10,6). A comparison of these two base-cases is further detailed in section 5.5.

Power generation based on coal implies emissions of mercury to air. According to the DG Joint Research Centre, **the generation of 1 kWh emits 0.016 mg of mercury to air**, with a EU fuel mix of 31 % coal, 22 % gas and oil, and 47 % non-fossils fuels (of which 32% of nuclear)[4]. This assumption will be used for all base-cases.

Therefore, the total electricity consumption of both base-cases GLS-C and GLS-F during the use phase over the product lifetime being 54 kWh (54 Wh during 1000 hours), **0.86 mg of mercury is emitted to air over the whole life cycle** (mercury emissions in other phases than the use phase are assumed to be negligible for this lamp type).

5.2.2 Base-case HL-MV-LW

Table 5.7 presents the outcomes of the "life cycle assessment" of the base-case HL-MV-LW using the EcoReport tool.

[3] Source: EuP Preparatory Study on Television (Lot 5)
http://www.ecotelevision.org/docs/Lot%205_T5_Final_Report_02-08-2007.pdf

[4] Source: http://lca.jrc.ec.europa.eu/lcainfohub/datasets/html/processes/Power_grid_mix_UCTE__83c1f02c-f2ef-4ac4-9a57-ac2172c38D15__01.00.001.html

Table 5.7: Environmental assessment results from EcoReport (base-case HL-MV-LW)

Life cycle Impact per product:										Date	Author
Base-Case HL-MV-LW										0	BIO

Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
Materials	**unit**									
Bulk Plastics	g			**0**			0	0	**0**	**0**
TecPlastics	g			**0**			0	0	**0**	**0**
Ferro	g			**0**			0	0	**0**	**0**
Non-ferro	g			**0**			0	0	**0**	**0**
Coating	g			**0**			0	0	**0**	**0**
Electronics	g			**0**			0	0	**0**	**0**
Misc.	g			**2**			2	0	**2**	**0**
Total weight	g			**2**			2	0	**2**	**0**
								see note!		
Other Resources & Waste							debet	credit		
Total Energy (GER)	MJ	0	0	**0**	**52**	**630**	0	0	**0**	**682**
of which, electricity (in primary MJ)	MJ	0	0	**0**	**0**	**630**	0	0	**0**	**630**
Water (process)	ltr	0	0	**0**	**0**	**42**	0	0	**0**	**42**
Water (cooling)	ltr	0	0	**0**	**0**	**1680**	0	0	**0**	**1680**
Waste, non-haz./ landfill	g	0	0	**0**	**51**	**730**	2	0	**2**	**784**
Waste, hazardous/ incinerated	g	0	0	**0**	**1**	**15**	0	0	**0**	**16**
Emissions (Air)										
Greenhouse Gases in GWP100	kg CO2 eq.	0	0	**0**	**5**	**27**	0	0	**0**	**32**
Ozone Depletion, emissions	mg R-11 eq	negligible								
Acidification, emissions	g SO2 eq.	0	0	**0**	**12**	**162**	0	0	**0**	**174**
Volatile Organic Compounds (VOC)	g	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Persistent Organic Pollutants (POP)	ng i-Teq	0	0	**0**	**0**	**4**	0	0	**0**	**4**
Heavy Metals	mg Ni eq.	0	0	**0**	**3**	**11**	0	0	**0**	**13**
PAHs	mg Ni eq.	0	0	**0**	**3**	**1**	0	0	**0**	**4**
Particulate Matter (PM, dust)	g	0	0	**0**	**0**	**3**	0	0	**0**	**4**
Emissions (Water)										
Heavy Metals	mg Hg/20	0	0	**0**	**0**	**4**	0	0	**0**	**4**
Eutrophication	g PO4	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

Figure 5.4 and Figure 5.5 highlight the importance of the use phase for two main environmental impact indicators (total energy consumption and global warming potential). The production phase is negligible for all the indicators as shown in Figure 5.6 since the BOM of the base-case HL-MV-LW contains only 2 grams of glass. This also explains why the end-of-life phase is negligible.

Regarding the distribution phase, its contribution to the environmental impacts does not surpass 19 % except for the emission of PAHs to air (68 %), which is, as for incandescent lamps, due to the assumed transport by trucks.

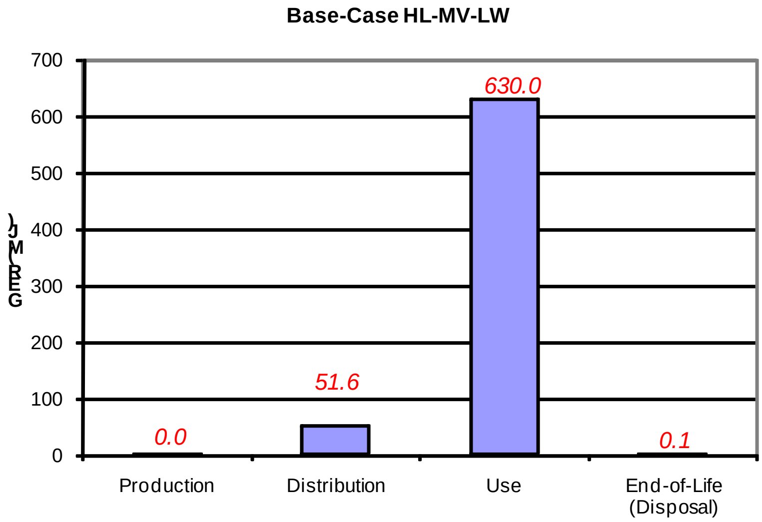

Figure 5.4: Total energy consumption during all life cycle phases

The use phase represents about 92 % of the total energy required by a typical HL-MV-LW 40 W over its whole life cycle, and about 86 % of its global warming potential.

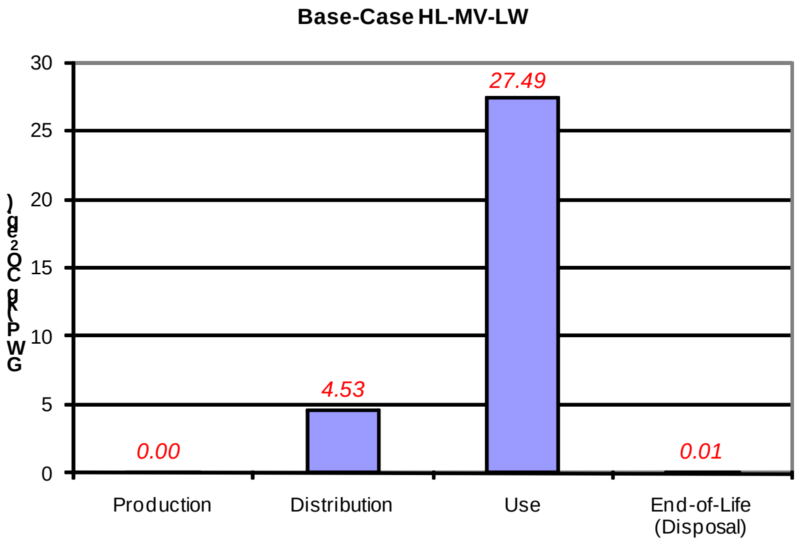

Figure 5.5: Total Global Warming Potential during all life cycle phases

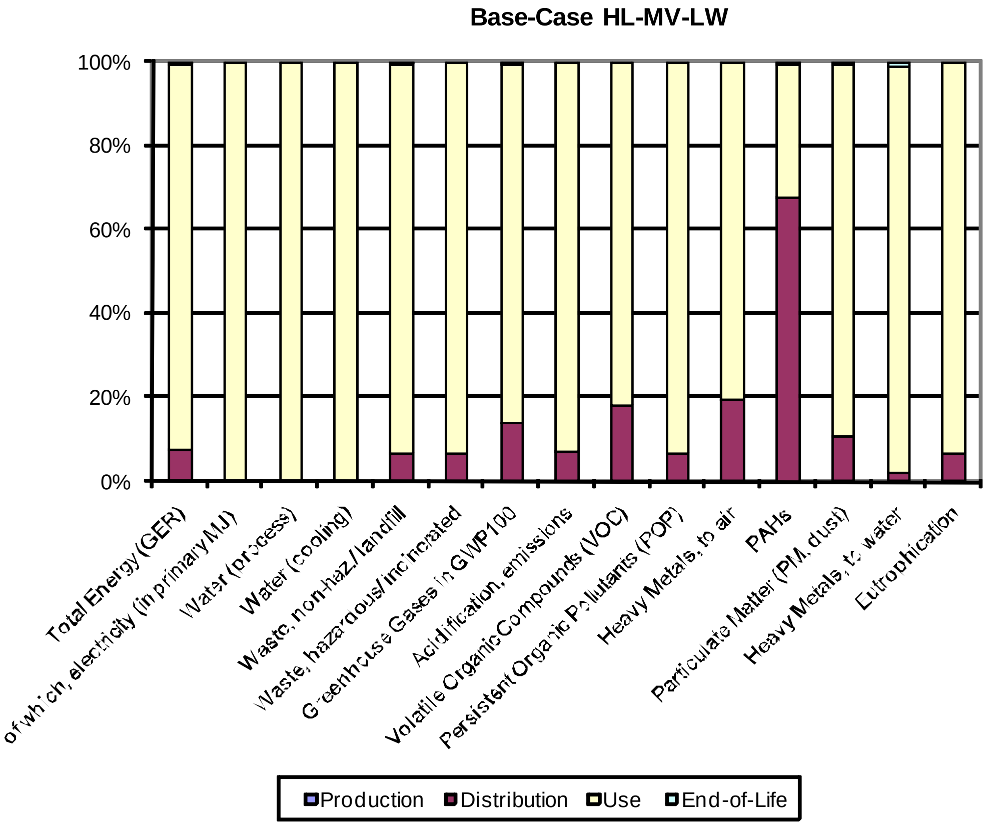

Figure 5.6: Distribution of environmental impacts per life cycle phase

As expected, the three previous figures confirm that the use phase is predominant with at least 80 % of the environmental impacts (except for the emissions of PAHs and of Particulate Matter).

Over its entire life cycle (1500 hours), the base-case HL-MV-LW (40 W) emits 0.96 mg of mercury to air, due to electricity generation. Mercury emissions in other phases than the use phase are assumed to be negligible for this lamp type.

5.2.3 Base-case HL-MV-HW

The outcomes of the "life cycle assessment" of the base-case HL-MV-LW carried out with the EcoReport tool are presented in Table 5.8 below.

Table 5.8: Environmental assessment results from EcoReport (base-case HL-MV-HW)

Life cycle Impact per product:	Date	Author
Base-Case HL-MV-HW	0	BIO

Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
Resources Use and Emissions		Material	Manuf.	**Total**	**BUTION**		Disposal	Recycl.	**Total**	
Materials	**unit**									
Bulk Plastics	g			**0**			0	0	**0**	**0**
TecPlastics	g			**0**			0	0	**0**	**0**
Ferro	g			**0**			0	0	**0**	**0**
Non-ferro	g			**0**			0	0	**0**	**0**
Coating	g			**0**			0	0	**0**	**0**
Electronics	g			**0**			0	0	**0**	**0**
Misc.	g			**9**			9	0	**9**	**0**
Total weight	g			**9**			9	0	**9**	**0**
								see note!		
Other Resources & Waste							debet	credit		
Total Energy (GER)	MJ	0	0	**0**	**52**	**4725**	1	0	**1**	**4777**
of which, electricity (in primary MJ)	MJ	0	0	**0**	**0**	**4725**	0	0	**0**	**4725**
Water (process)	ltr	0	0	**0**	**0**	**315**	0	0	**0**	**315**
Water (cooling)	ltr	0	0	**0**	**0**	**12600**	0	0	**0**	**12600**
Waste, non-haz./ landfill	g	0	0	**0**	**51**	**5478**	11	0	**11**	**5541**
Waste, hazardous/ incinerated	g	0	0	**0**	**1**	**109**	0	0	**0**	**110**
Emissions (Air)										
Greenhouse Gases in GWP100	kg CO2 eq.	0	0	**0**	**5**	**206**	0	0	**0**	**211**
Ozone Depletion, emissions	mg R-11 eq	negligible								
Acidification, emissions	g SO2 eq.	0	0	**0**	**12**	**1217**	0	0	**0**	**1229**
Volatile Organic Compounds (VOC)	g	0	0	**0**	**0**	**2**	0	0	**0**	**2**
Persistent Organic Pollutants (POP)	ng i-Teq	0	0	**0**	**0**	**31**	0	0	**0**	**31**
Heavy Metals	mg Ni eq.	0	0	**0**	**3**	**81**	0	0	**0**	**84**
PAHs	mg Ni eq.	0	0	**0**	**3**	**9**	0	0	**0**	**12**
Particulate Matter (PM, dust)	g	0	0	**0**	**1**	**26**	1	0	**1**	**28**
Emissions (Water)										
Heavy Metals	mg Hg/20	0	0	**0**	**0**	**30**	0	0	**0**	**31**
Eutrophication	g PO4	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

The total energy consumption (GER) and the Global Warming Potential (GWP) of the base-case HL-MV-HW are presented in Figure 5.7 and Figure 5.8 for each stage of the entire life cycle of the product. It is clearly visible that the use phase is predominant for both environmental indicators. As the BOM of this base-case only contains 9 g of glass, the production and end-of-life phases have negligible environmental impacts.

The distribution phase (assumed transport by trucks) is only significant for the emission of PAHs to air (22 %) and does not exceed 3 % for the other environmental impacts.

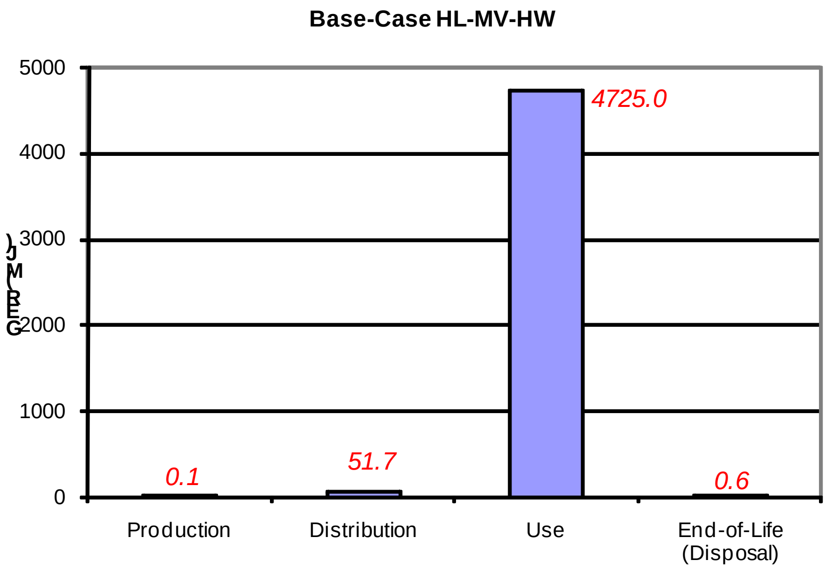

Figure 5.7: Total energy consumption during all life cycle phases

The use phase represents about 99 % of the total energy required by a typical HL-MV-HW 300 W over its whole life cycle and about 98 % of its global warming potential.

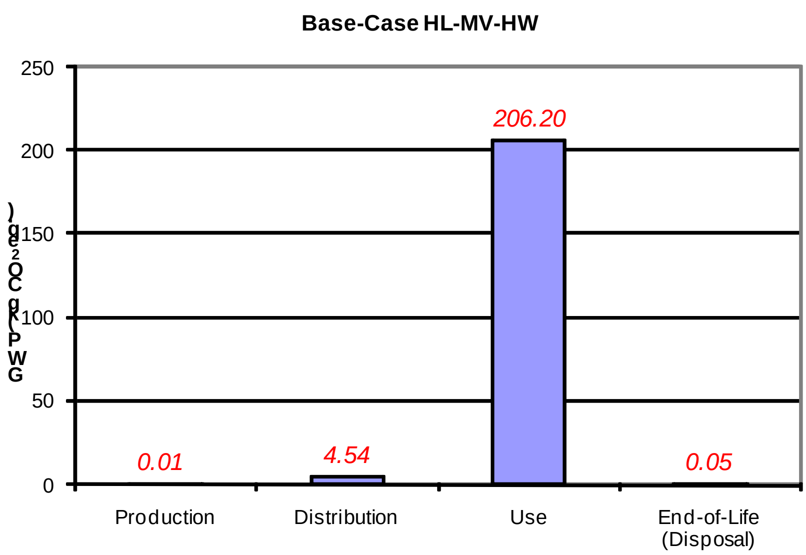

Figure 5.8: Total Global Warming Potential during all life cycle phases

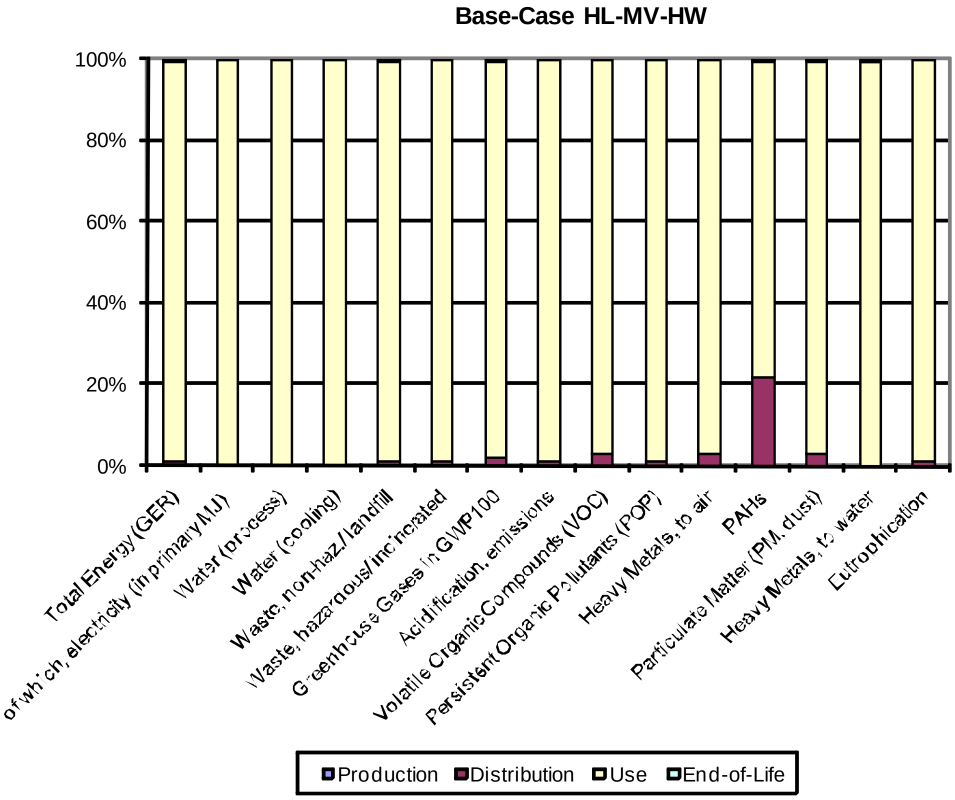

Figure 5.9: Distribution of environmental impacts per life cycle phase

Over its entire life cycle (1500 hours), the base-case HL-MV-HW (300 W) emits 7.20 mg of mercury to air, due to electricity generation. Mercury emissions in other phases than the use phase are assumed to be negligible for this lamp type.

5.2.4 Base-case HL-LV

Environmental impacts of the base-case HL-LV 30 W are presented in Table 5.9 for 15 environmental impact indicators. Two of them are shown in Figure 5.10 and Figure 5.11. As for the previous base-cases, the use phase is clearly the most impacting stage of the life cycle, except for the emissions of PAHs to air. Nevertheless, in the absolute terms, the total PAHs emissions over the whole life cycle are low (less than 4 mg Nickel equivalent).

Table 5.9: Environmental assessment results from EcoReport (base-case HL-LV)

Life cycle Impact per product:		Date	Author
Base-Case HL-LV		0	BIO

Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
Resources Use and Emissions		Material	Manuf.	**Total**	**BUTION**		Disposal	Recycl.	**Total**	
Materials	**unit**									
Bulk Plastics	g			**0**			0	0	**0**	**0**
TecPlastics	g			**0**			0	0	**0**	**0**
Ferro	g			**0**			0	0	**0**	**0**
Non-ferro	g			**0**			0	0	**0**	**0**
Coating	g			**0**			0	0	**0**	**0**
Electronics	g			**0**			0	0	**0**	**0**
Misc.	g			**2**			2	0	**2**	**0**
Total weight	g			**2**			2	0	**2**	**0**
								see note!		
Other Resources & Waste							debet	credit		
Total Energy (GER)	MJ	0	0	**0**	**52**	**1049**	0	0	**0**	**1101**
of which, electricity (in primary MJ)	MJ	0	0	**0**	**0**	**1049**	0	0	**0**	**1049**
Water (process)	ltr	0	0	**0**	**0**	**70**	0	0	**0**	**70**
Water (cooling)	ltr	0	0	**0**	**0**	**2797**	0	0	**0**	**2797**
Waste, non-haz./ landfill	g	0	0	**0**	**51**	**1216**	2	0	**2**	**1270**
Waste, hazardous/ incinerated	g	0	0	**0**	**1**	**24**	0	0	**0**	**25**
Emissions (Air)										
Greenhouse Gases in GWP100	kg CO2 eq.	0	0	**0**	**5**	**46**	0	0	**0**	**50**
Ozone Depletion, emissions	mg R-11 eq				negligible					
Acidification, emissions	g SO2 eq.	0	0	**0**	**12**	**270**	0	0	**0**	**282**
Volatile Organic Compounds (VOC)	g	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Persistent Organic Pollutants (POP)	ng i-Teq	0	0	**0**	**0**	**7**	0	0	**0**	**7**
Heavy Metals	mg Ni eq.	0	0	**0**	**3**	**18**	0	0	**0**	**21**
PAHs	mg Ni eq.	0	0	**0**	**3**	**2**	0	0	**0**	**5**
Particulate Matter (PM, dust)	g	0	0	**0**	**1**	**6**	0	0	**0**	**7**
Emissions (Water)										
Heavy Metals	mg Hg/20	0	0	**0**	**0**	**7**	0	0	**0**	**7**
Eutrophication	g PO4	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Persistent Organic Pollutants (POP)	ng i-Teq				negligible					

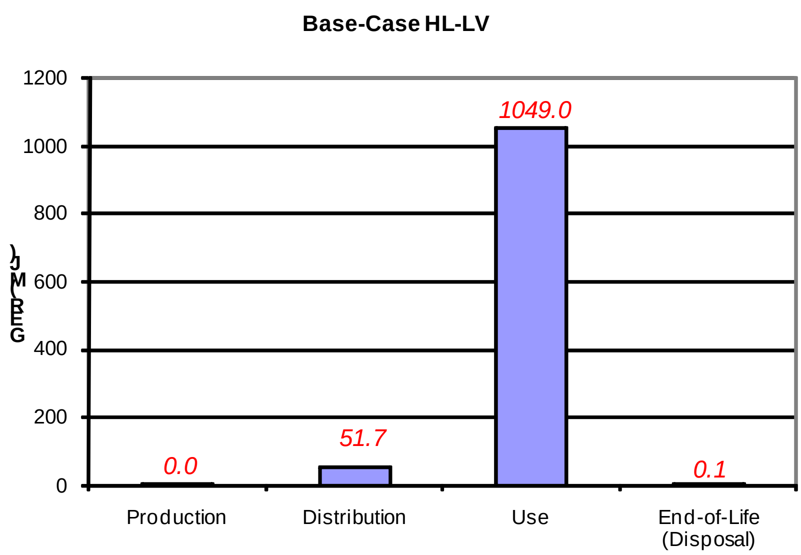

Figure 5.10: Total energy consumption during all life cycle phases

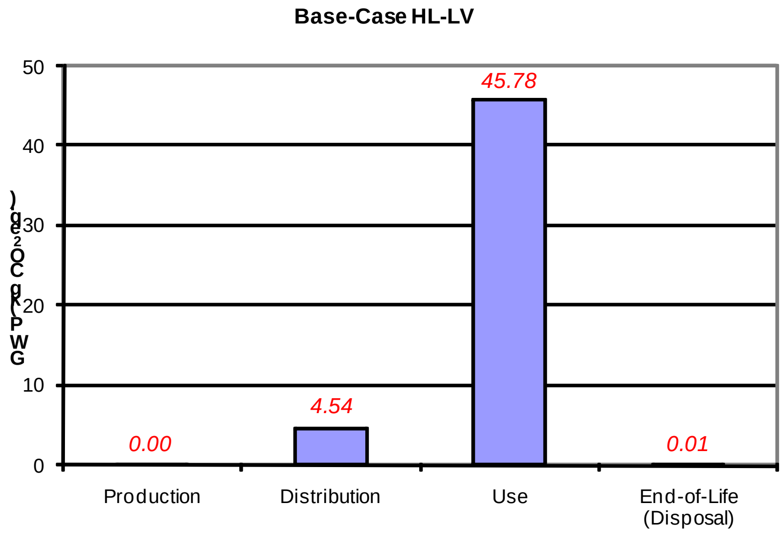

Figure 5.11: Total Global Warming Potential during all life cycle phases

The production and end-of-life phases have negligible environmental impact as pointed out by Figure 5.12 since the bill of material of the base-case HL-LV contains only 2 grams of glass. Taking tungsten wire and the caps into account could slightly increase the impact of these phases, but from the life cycle perspective, the impact of production and end-of-life would remain insignificant.

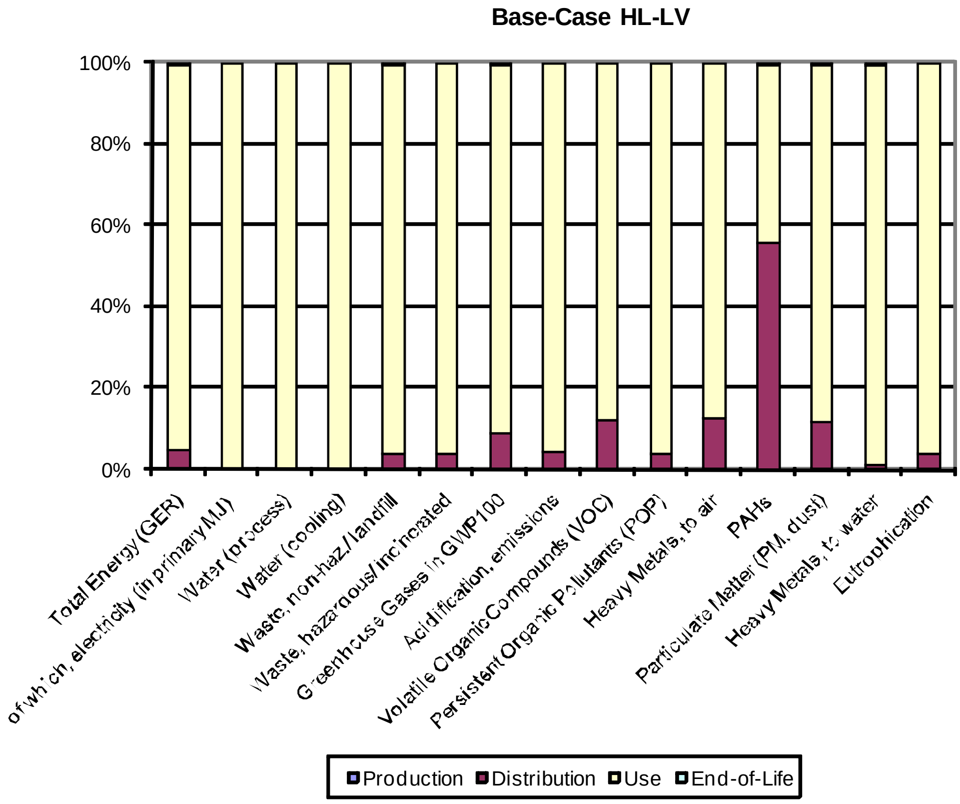

Figure 5.12: Distribution of environmental impacts per life cycle phase

As the electricity consumption of the base-case HL-LV during its entire life cycle is about 99.9 kWh and assuming that mercury emissions in other phases than the use phase are negligible for this lamp type, about 1.60 mg of mercury is emitted to air over its whole life cycle.

5.2.5 Base-case CFLi

As for the previous base-cases, an environmental assessment was carried out for the base-case CFLi 13 W with the EcoReport tool. Results of this analysis are presented in Table 5.10. Compared to the other base-cases one can notice that the column “End-of-Life Recycling” is not equal to zero, as 95 % of the metals and glass is recycled. The total of this stage of the life cycle is the difference between “disposal” and “recycling”.

Table 5.10: Environmental assessment results from EcoReport (base-case CFLi)

Life cycle Impact per product:	Date	Author
Base-Case CFLi	0	BIO

Life Cycle phases -->		**PRODUCTION**			**DISTRI-**	**USE**	**END-OF-LIFE***			**TOTAL**
Resources Use and Emissions		Material	Manuf.	**Total**	**BUTION**		Disposal	Recycl.	**Total**	
Materials	**unit**									
Bulk Plastics	g			**0**			0	0	**0**	**0**
TecPlastics	g			**0**			0	0	**0**	**0**
Ferro	g			**0**			0	0	**0**	**0**
Non-ferro	g			**1**			0	1	**1**	**0**
Coating	g			**0**			0	0	**0**	**0**
Electronics	g			**18**			14	5	**18**	**0**
Misc.	g			**31**			2	30	**31**	**0**
Total weight	g			**51**			15	35	**51**	**0**
								see note!		
Other Resources & Waste							debet	credit		
Total Energy (GER)	MJ	10	2	**12**	**53**	**860**	1	1	**0**	**925**
of which, electricity (in primary MJ)	MJ	6	0	**7**	**0**	**860**	0	1	**-1**	**866**
Water (process)	ltr	8	0	**8**	**0**	**57**	0	0	**0**	**65**
Water (cooling)	ltr	2	1	**3**	**0**	**2293**	0	0	**0**	**2296**
Waste, non-haz./ landfill	g	48	2	**50**	**52**	**998**	4	2	**3**	**1103**
Waste, hazardous/ incinerated	g	78	0	**78**	**1**	**21**	5	1	**4**	**103**
Emissions (Air)										
Greenhouse Gases in GWP100	kg CO2 eq.	0	0	**1**	**5**	**38**	0	0	**0**	**43**
Ozone Depletion, emissions	mg R-11 eq					negligible				
Acidification, emissions	g SO2 eq.	4	1	**5**	**12**	**221**	0	0	**0**	**239**
Volatile Organic Compounds (VOC)	g	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Persistent Organic Pollutants (POP)	ng i-Teq	0	0	**0**	**0**	**6**	0	0	**0**	**6**
Heavy Metals	mg Ni eq.	1	0	**1**	**3**	**15**	0	0	**0**	**18**
PAHs	mg Ni eq.	0	0	**0**	**3**	**2**	0	0	**0**	**5**
Particulate Matter (PM, dust)	g	0	0	**0**	**1**	**5**	1	0	**1**	**7**
Emissions (Water)										
Heavy Metals	mg Hg/20	6	0	**6**	**0**	**6**	0	0	**0**	**11**
Eutrophication	g PO4	0	0	**0**	**0**	**0**	0	0	**0**	**0**
Persistent Organic Pollutants (POP)	ng i-Teq					negligible				

Figure 5.13 and Figure 5.14 show the contribution of each of the life cycle phases for the GER (Gross Energy Requirement) and the GWP (Global Warming Potential). As expected, the use phase is the major contributor of these environmental impact indicators.

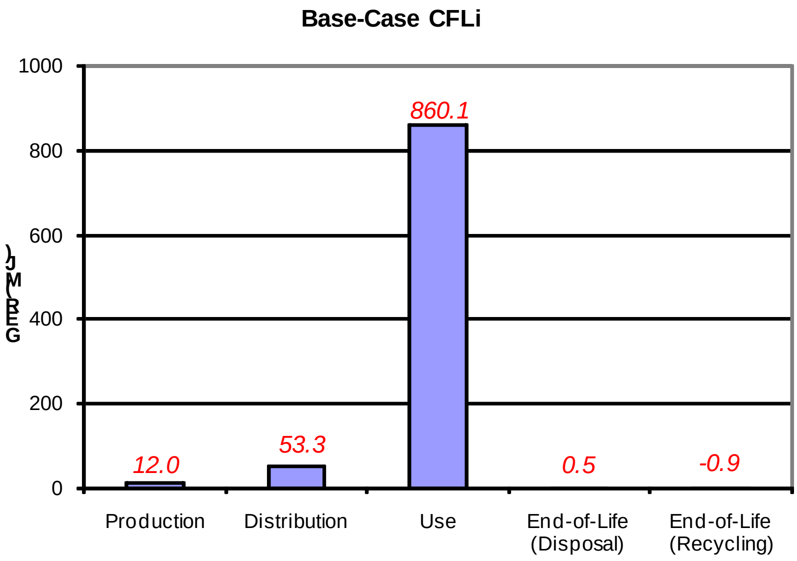

Figure 5.13: Total energy consumption during all life cycle phases

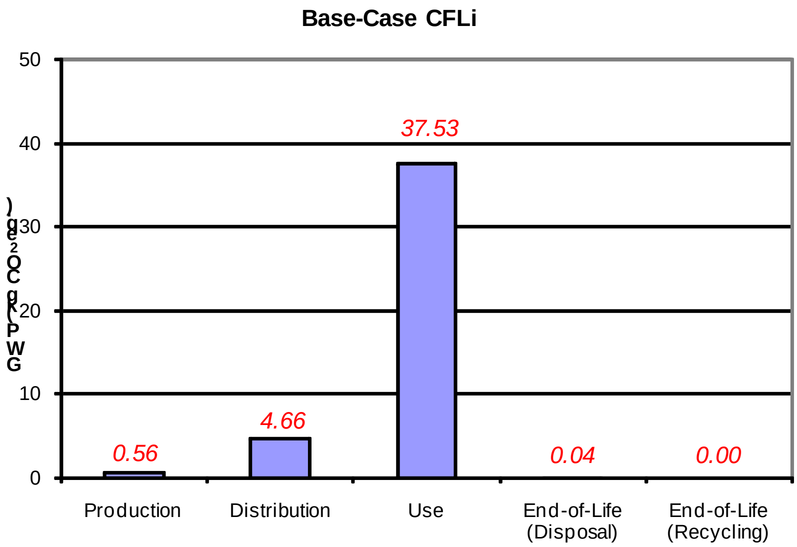

Figure 5.14: Total Global Warming Potential during all life cycle phases

Figure 5.15 shows that the production phase also contributes to the environmental impacts. This difference compared to other base-cases, where production phase has negligible impact, can be explained by two factors:

- The BOM of the base-case CFLi contains electronics (PWB: Printed Wiring Board) due to the integrated ballast, which has a greater environmental impact than glass or aluminium, especially for the emissions of heavy metals to water.
- A share of the materials is not recycled. Thus, the production phase represents 75 % of the indicator “waste, hazardous/incinerated”.

Once again, the environmental indicator “eutrophication” is negligible over the life cycle of the base-case CFLi even if the production phase represents about 71 % of the total.

The relatively high impacts of CFLi in the production phase for the three indicators “hazardous waste“, “eutrophication” and “emissions of heavy metals to water” are due to the integrated electronic ballast (modelled with a PWB in the EcoReport). The inventories for the electronic components are characterised by relatively high environmental impacts compared to “basic” materials such as glass and metal. This is a typical example of a case where adding electronics can improve efficiency, but this may create more impacts in the production phase. But thanks to the life cycle approach, using a common functional unit (lumen per hour), it can be concluded that despite this trade-off in production, the CFLi has the best performance over the life cycle (see section 5.6 for the comparison of the base-cases).

Of course, it could be possible to focus on the ballast in order to reduce the impacts on the three indicators. However, the improvement options are limited. In theory, one option would be to reduce the weight of the ballast, but technically this seems difficult. The bulky ballasts already cause problems e.g. in retrofitting some existing luminaires with CFLi, and if it was possible to make smaller ballasts they would surely exist already. Another possibility in real life is to improve the production process itself, in order to reduce the quantity of hazardous waste created in production of electronic components. Such real-life changes in production are, however, out of the scope of eco-design of lamps and cannot be taken into account in the context of the MEEuP.

Regarding the distribution phase, its environmental impacts concern the impact categories related to the transport of the product by trucks (PAHs, VOC and particulate matter).

According to the EcoReport tool, emissions of heavy metals to air at the end-of-life due to the mercury contained in the base-case CFLi (4 mg) represents a negligible share of the total of this impact over the whole life cycle (about 1.2 %) with the assumption that 80 % of CFLi are not recycled (based on data provided by various EU countries) and thus emitted mercury to air at the end-of-life (as explained in chapter 4, section 4.5). Indeed, heavy metals emissions to air, including mercury, during the production of electricity (i.e. during the use phase) has the most significant impact (about 81 % over the whole life cycle).

However, if the focus is only on mercury emissions, 3.20 mg is emitted to air at end-of-life (i.e. 80 % of 4 mg), whereas 1.31 mg is emitted during the use phase as the base-case CFLi consumes 81.9 kWh during this stage (and as the production of 1 kWh emits 0.016 mg of mercury to air).
Thereby, over the entire life cycle of the base case CFLi , 4.51 mg of mercury is emitted to air.

The production phase is predominant for the three indicators “hazardous waste”, “eutrophication” and “emissions of heavy metals to water”. As mentioned, we consider that the eutrophication impact is negligible compared to other products such as a 32’’ LCD TV (cf. EuP Lot 5). Furthermore, when comparing per lumen and per hour, a CFLi is ‘better’ than an incandescent lamp and even better than a halogen lamp (except for eutrophication).

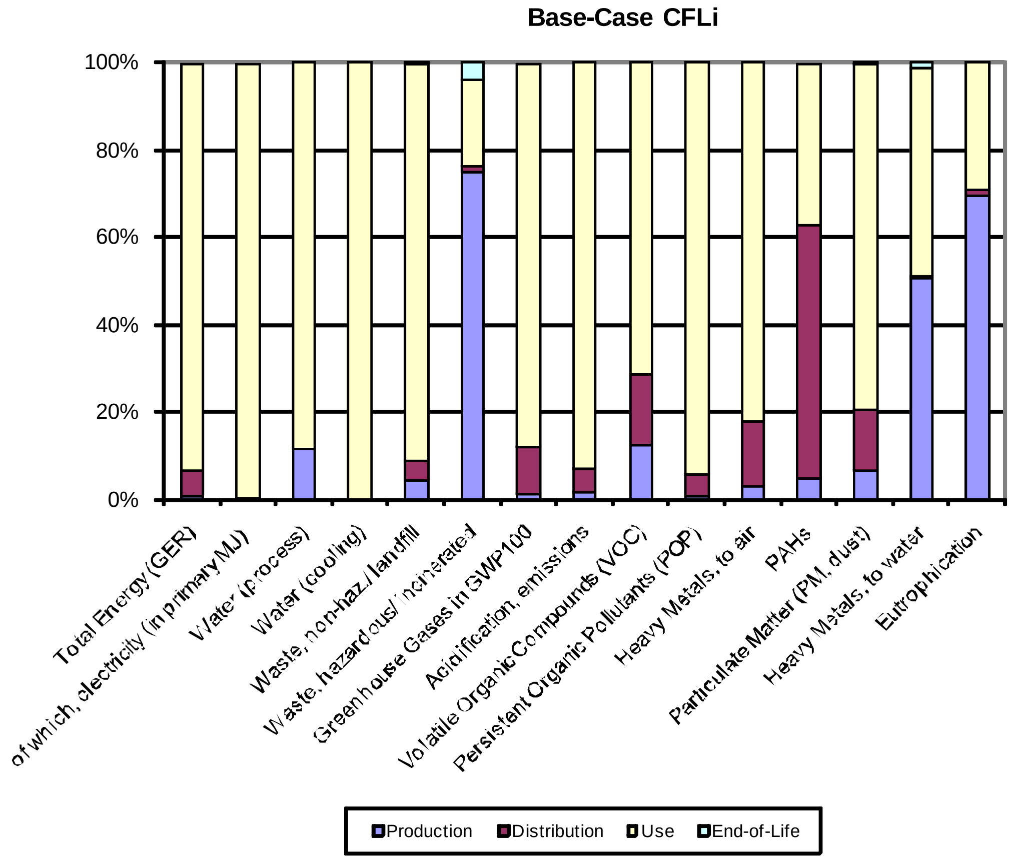

Figure 5.15: Distribution of environmental impacts per life cycle phase

5.3 Base-case Life Cycle Costs

Economic data used for the calculation of the Life Cycle Costs (LCC) were elaborated in chapters 2 and 4. Table 5.11presents the summary of the LCC input data and results for the 6 base-cases. Electricity tariff, discount rate, and overall improvement ratio are common inputs for all base-cases, of which the parameter "overall improvement ratio" equal to 1 reflects the fact that there have not been improvements related to energy efficiency of the average European lamp types in the recent years (i.e. the average products in 2004/2005 and in 2007 are quite similar in terms of energy efficiency).

Table 5.11: Inputs and outcomes of the calculation of the LCC

	GLS-C	GLS-F	HL-MV-LW	HL-MV-HW	HL-LV	CFLi
Lamp lifespan (years)	2.50	2.50	3.33	3.33	3.00	7.50
Lamp wattage (W)	54	54	40	300	30	13
Lumen output per lamp (lm)	594.0	572.4	480.0	5177.3	435.0	559.0
Electricity tariff (€/kWh)	0.1528					
Discount rate	1.8%					
Overall improvement ratio	1.00					
Product price	0.60 €	0.60 €	5.50 €	3.00 €	3.00 €	4.63 €
Electricity	8.00 €	8.00 €	8.82 €	66.16 €	14.35 €	11.61 €
Life Cycle Cost	**8.60 €**	**8.60 €**	**14.32 €**	**69.16 €**	**17.35 €**	**16.23 €**

For the base-cases GLS-C and GLS-F, life cycle costs are equal as their electricity consumption and the product prices are assumed to be same for both base cases.
One has to keep in mind that lifespan, lamp wattage and lumen output vary for different lamp types, thus a straightforward comparison with the outcomes of Table 5.11 has to be made with caution. The comparison of the LCC of the 6 base-cases is provided in section 5.5, Table 5.22.

5.4 EU Totals for the domestic sector

This section provides the environmental assessment of the base-cases at the EU-27 level using stock and market data from chapter 2. The reference year for the EU totals is 2007 for environmental impacts.
The term 'EU' is synonymous to 'EU-27'. The total impacts cover:

- The life cycle environmental impact of the new products designed in 2006 (this relates to a period of 2007 up to 2007 + product life) (i.e. impacts of the sales).
- The annual (2007) impact of production, use and (estimated) disposal of the product group, assuming post-RoHS and post-WEEE conditions and the total LCC (i.e. impact and LCC of the stock).

■ Environmental impacts of the domestic stock in 2007

Table 5.12 shows the total environmental impact of all products in operation in EU-27 in 2007, assuming that all the products have the same impacts as the base-case of their category. These figures come from the EcoReport tool by multiplying the individual environmental impacts of a base-case with the domestic stock of this base-case in 2007.

Table 5.12: Environmental impacts of the EU domestic stock in 2007

		GLS-C	GLS-F	HL-MV-LW	HL-MV-HW	HL-LV	CFLi	TOTAL
main environmental indicators	unit	Value	value	value	value	value	value	value
Total Energy (GER)	PJ	124.678	407.087	27.700	161.336	86.827	138.775	946.404
of which, electricity	TWh	10.962	35.785	2.262	15.094	7.827	11.234	83.163
Water (process)	mln.m3	7.700	25.139	1.585	10.570	5.480	10.331	60.805
Waste, non-haz./ landfill*	kton	148.161	483.786	31.650	187.157	100.114	171.431	1122.300
Waste, hazardous/ incinerated*	kton	2.835	9.257	0.625	3.708	1.985	31.988	50.398
Emissions (Air)								
Greenhouse Gases in GWP100	mt CO2eq.	5.858	19.129	1.383	7.166	3.994	6.893	44.423
Acidifying agents (AP)	kt SO2eq.	31.846	103.979	7.035	41.470	22.242	35.907	242.479
Volatile Org. Compounds (VOC)	kt	0.054	0.178	0.013	0.063	0.036	0.089	0.432
Persistent Org. Pollutants (POP)	g i-Teq.	0.840	2.742	0.179	1.059	0.566	0.896	6.282
Heavy Metals (HM)	ton Ni eq.	2.521	8.234	0.611	2.872	1.649	3.203	19.089
PAHs	ton Ni eq.	0.718	2.349	0.247	0.455	0.397	1.223	5.389
Particulate Matter (PM, dust)	kt	1.164	3.803	0.177	0.957	0.537	1.320	7.957
Emissions (Water)								
Heavy Metals (HM)	ton Hg/20	0.786	2.565	0.160	1.029	0.538	2.814	7.892
Eutrophication (EP)	kt PO4	0.005	0.016	0.001	0.005	0.003	0.026	0.057

Summary of environmental impacts of base-cases as a % of total impact for these lamp types, as well as the lot 19 (part 1) totals are presented in Figure 5.16.
For most of the environmental indicators presented in this figure, the share of the incandescent lamps (both clear and frosted) is about 56 %.

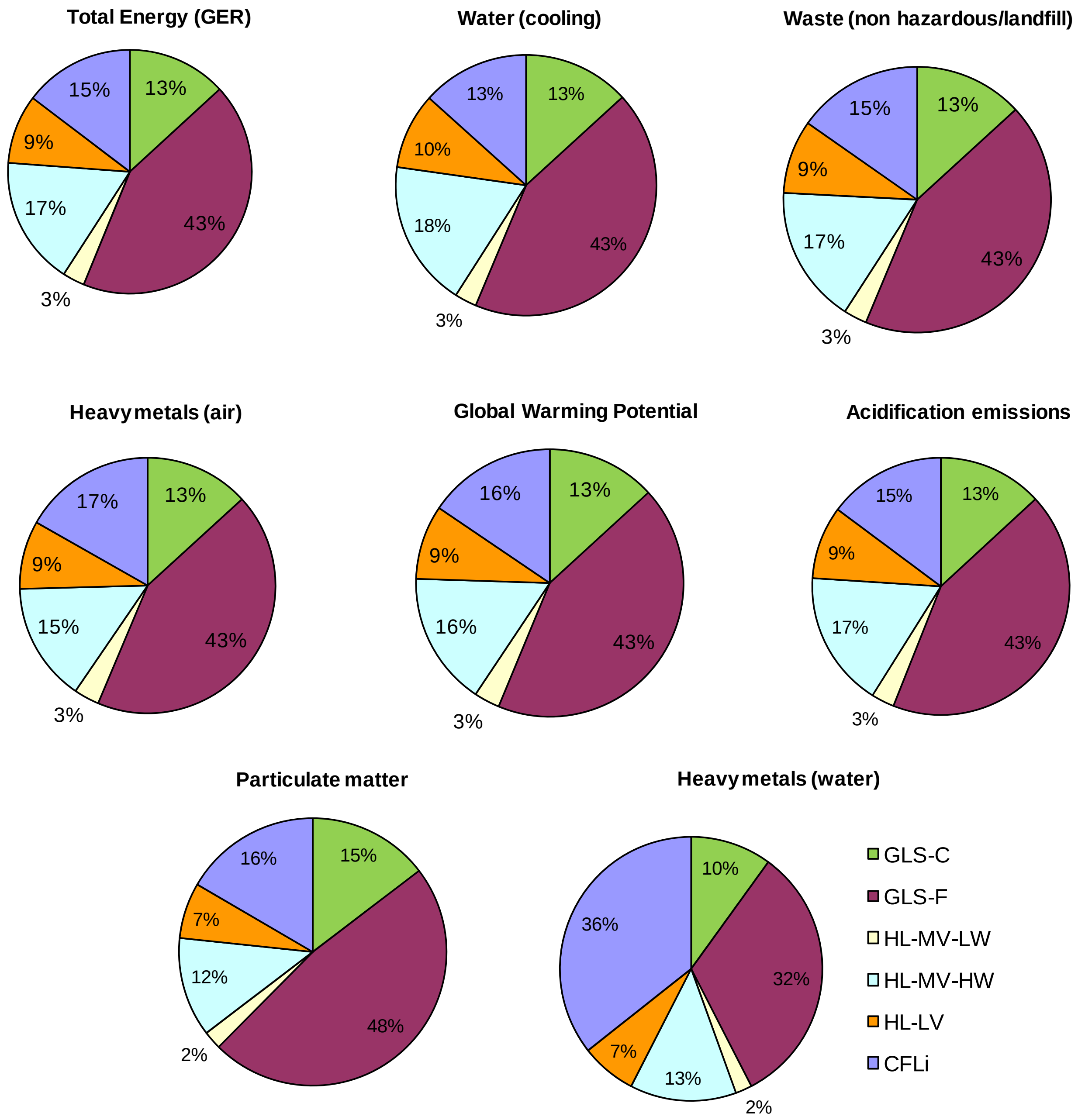

Figure 5.16: Base-cases' share of the environmental impacts of the 2007 stock

Table 5.13 summarises the total electricity consumption (during the use phase) of each base-case, assuming that the whole stock is composed of base-cases. Therefore, the total electricity consumption in 2007 of domestic non-directional lighting sources which are in the scope of this study (part 1) is about 83.16 TWh (1 TWh = 1 million MWh). This represents about 2.95 % of the EU-27 total electricity consumption[5].

[5]Source Eurostat: EU-27 electricity consumption in 2006 = 242 million toe = 2,815 TWh
http://epp.eurostat.ec.europa.eu/portal/page?_pageid=1996,39140985&_dad=portal&_schema=PORTAL&screen=detailref&language=en&product=Yearlies_new_environment_energy&root=Yearlies_new_environment_energy/H/H2/H24/ebc22288

Table 5.13: Total electricity consumption for the year 2007

Base-case	**EU 27 stock electricity consumption in 2007 (TWh)**	**Share of the total electricity consumption of the 6 lamp types**
Base-case GLS-C	10.96	13.2%
Base-case GLS-F	35.78	43.0%
Base-case HL-MV-LW	2.26	2.7%
Base-case HL-MV-HW	15.09	18.2%
Base-case HL-LV	7.83	9.4%
Base-case CFLi	11.23	13.5%
TOTAL	**83.16**	**100.0%**

■ **Total consumer expenditure in 2006**

Regarding the total consumer expenditure in 2007 related to the 6 base-cases, about 81 % of the 15.6 billion euros is due to the electricity costs. The distribution per base-case is given in Figure 5.17, and details on consumer expenditure are presented in Table 5.14.

Table 5.14: Comparison of total consumer expenditure (EU 27) in 2007

	GLS-C	***GLS-F***	***HL-MV-LW***	***HL-MV-HW***	***HL-LV***	***CFLi***	***TOTAL***
Lumen output per lamp (lm)	594.0	572.4	480.0	5177.3	435.0	559.0	
EU 27 sales (mln unit)	179	585	76	54	90	353	1337
Share of the EU 27 sales	13.4%	43.7%	5.7%	4.1%	6.7%	26.4%	100.0%
Product price (mln €)	107	351	420	163	269	1633	2943
Electricity (mln €)	1674	5466	346	2306	1196	1685	12673
Total (mln €)	**1782**	**5817**	**766**	**2469**	**1465**	**3318**	**15616**

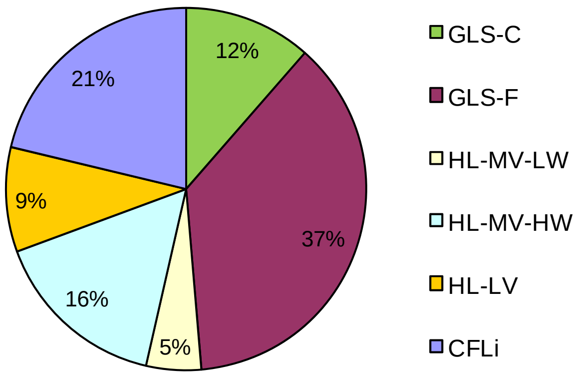

Figure 5.17: Base-cases' share of the total consumer expenditure in 2007

Total consumer expenditure in 2006 related to incandescent lamps (both clear and frosted) represent 49 %, whereas these lamp types represent about 57 % of the sales. However, it is not surprising that these values differ, as the power outputs and the annual operational times are different for the 6 base-cases.

5.5 EU Totals for all sectors

Lamp types identified as base-cases in this study (part 1) are also used in other sectors than the domestic one. Therefore, this section presents environmental and economic results for the "other sectors" keeping the lamp lifetime, the average wattage and the lamp price constant.

- **Market data for all sectors**

In order to carry out the environmental and economic assessment with the EcoReport tool of the base-cases at the EU-27 level for all sectors, it is required to have sales data, stock data as well as annual burning hours. They are presented in Table 5.15.

Sales in the "other sectors" were calculated by making the difference between the total sales and sales in the domestic sectors, which were presented in chapter 2 (see section 2.2.5). Total sales were not provided for the base-cases HL-MV-LW and HL-MV-HW, but only for the sum. Thus, the same ratio between HL-MV-LW sales and HL-MV-HW sales as for the domestic sector was used. Regarding CFLi, it was assumed that sales in the non-domestic sector (offices, shops, restaurants, hotels…) were negligible compared to the sales in the domestic sector, and CFLni (analysed in Lot 8) are mostly used in this sector.

We assumed the same shares of NDLS and DLS in the other sectors as in the domestic sector, i.e. for NDLS: 99 % for GLS-F, 66 % for GLS-C, 55 % for HL-MV, and 41 % for HL-LV.

For the calculation of the stock in 2007 for each base-case, following formulas were used:

1) Replacement sales = Share of Replacement Sales x Total Sales

2) Replacement sales = Stock x Annual Burning hours / Lifetime

The shares of replacement sales for the non-domestic sector were assumed to be the same as in the domestic sector: 131 % for GLS-F, 125 % for GLS-C, 28 % for HL-MV-LW, 45 % for HL-MV-HW, and 85 % for HL-LV.

Further, we assumed that all base-cases in the non-domestic sector operated 1800 hours per year, based on an average of 250 days per years and around 7 operating hours per day.

Thus, based on formula 1) and 2) the formula allowing obtaining the stock of lamps for "other sectors" is:

Total Stock = (Lifetime/Annual Burning hours) x Share of Replacement Sales x Total Sales

By combining market data for both the domestic and the non-domestic sectors, it was possible to obtain data for the 6 base-cases used in all sectors (see Table 5.16). Annual burning hours were calculated based on a weighted average as detailed in the following formula:

$$\text{Burning Hours}_{All} = (\text{Burning Hours}_{Dom} \times \text{Sales}_{Dom} + \text{Burning Hours}_{Other} \times \text{Sales}_{Other}) / \text{Sales}_{All}$$

Table 5.15: Market and technical data for the non-domestic sectors in 2007

	Other sectors					
	GLS-F	GLS-C	HL-MV LW	HL-MV HW	HL-LV	CFLi
Stock NDLS (mln)	144.1	61.2	8.8	7.6	88.2	0
Sales NDLS (mln)	182.4	118.2	21.0	29.7	57.3	0
Average wattage (W)	54	54	40	300	30	13
Lifetime (h)	1000	1000	1500	1500	3000	6000
Annual burning hours (h)	1800	1800	1800	1800	1800	1800

Table 5.16: Market and technical data for all sectors in 2007

	All sectors (domestic + other)					
	GLS-F	GLS-C	HL-MV LW	HL-MV HW	HL-LV	CFLi
Stock NDLS (mln)	**1800.1**	**568.5**	**134.4**	**119.4**	**558.3**	**1010.1**
Sales NDLS (mln)	**767.4**	**297.0**	**97.4**	**84.1**	**147.0**	**353.0**
Average wattage (W)	**54**	**54**	**40**	**300**	**30**	**13**
Lifetime (h)	**1000**	**1000**	**1500**	**1500**	**3000**	**6000**
Annual burning hours (h)	**505**	**551**	**538**	**536**	**705**	**800**

- **Environmental impacts of the stock in 2007 for all sectors**

Table 5.17 shows the total environmental impact of all products in operation in EU-27 in 2007, assuming that all the products have the same impacts as the base-case of their category. These figures come from the EcoReport tool by multiplying the individual environmental impacts of a base-case with the stock of this base-case in 2007 for all sectors.

Table 5.17: Environmental impacts of the EU stock in 2007 for all sectors

		GLS-C	GLS-F	HL-MV-LW	HL-MV-HW	HL-LV	CFLi	TOTAL
main environmental indicators	**unit**	**Value**	**value**	**value**	**value**	**value**	**value**	**value**
Total Energy (GER)	PJ	**193.539**	**556.582**	**35.407**	**206.204**	**145.320**	**138.775**	**1275.826**
of which, electricity	TWh	**16.917**	**49.092**	**2.892**	**19.219**	**13.114**	**11.234**	**112.468**
Water (process)	mln.m3	**11.887**	**34.481**	**2.026**	**13.459**	**9.182**	**10.331**	**81.367**
Waste, non-haz./ landfill*	kton	**230.383**	**660.795**	**40.456**	**239.232**	**167.577**	**171.431**	**1509.875**
Waste, hazardous/ incinerated*	kton	**4.397**	**12.663**	**0.799**	**4.736**	**3.323**	**31.988**	**57.906**
Emissions (Air)								
Greenhouse Gases in GWP100	mt CO2eq.	**9.139**	**26.078**	**1.767**	**9.192**	**6.678**	**6.893**	**59.747**
Acidifying agents (AP)	kt SO2eq.	**49.407**	**142.210**	**8.992**	**52.984**	**37.230**	**35.907**	**326.729**
Volatile Org. Compounds (VOC)	kt	**0.085**	**0.242**	**0.017**	**0.081**	**0.060**	**0.089**	**0.573**
Persistent Org. Pollutants (POP)	g i-Teq.	**1.306**	**3.745**	**0.229**	**1.354**	**0.948**	**0.896**	**8.477**
Heavy Metals (HM)	ton Ni eq.	**3.955**	**11.188**	**0.780**	**3.698**	**2.754**	**3.203**	**25.579**
PAHs	ton Ni eq.	**1.167**	**3.126**	**0.315**	**0.618**	**0.657**	**1.223**	**7.106**
Particulate Matter (PM, dust)	kt	**1.858**	**5.112**	**0.226**	**1.242**	**0.897**	**1.320**	**10.655**
Emissions (Water)								
Heavy Metals (HM)	ton Hg/20	**1.217**	**3.510**	**0.205**	**1.312**	**0.901**	**2.814**	**9.960**
Eutrophication (EP)	kt PO4	**0.008**	**0.022**	**0.001**	**0.007**	**0.005**	**0.026**	**0.069**

Summary of environmental impacts of base-cases as a % of total impact for these lamp types, as well as the lot 19 (part 1) totals are presented in Figure 5.18.

For most of the environmental indicators presented in this figure, the share of the incandescent lamps (both clear and frosted) is about 59 %, in the same order of magnitude as for the domestic sector.

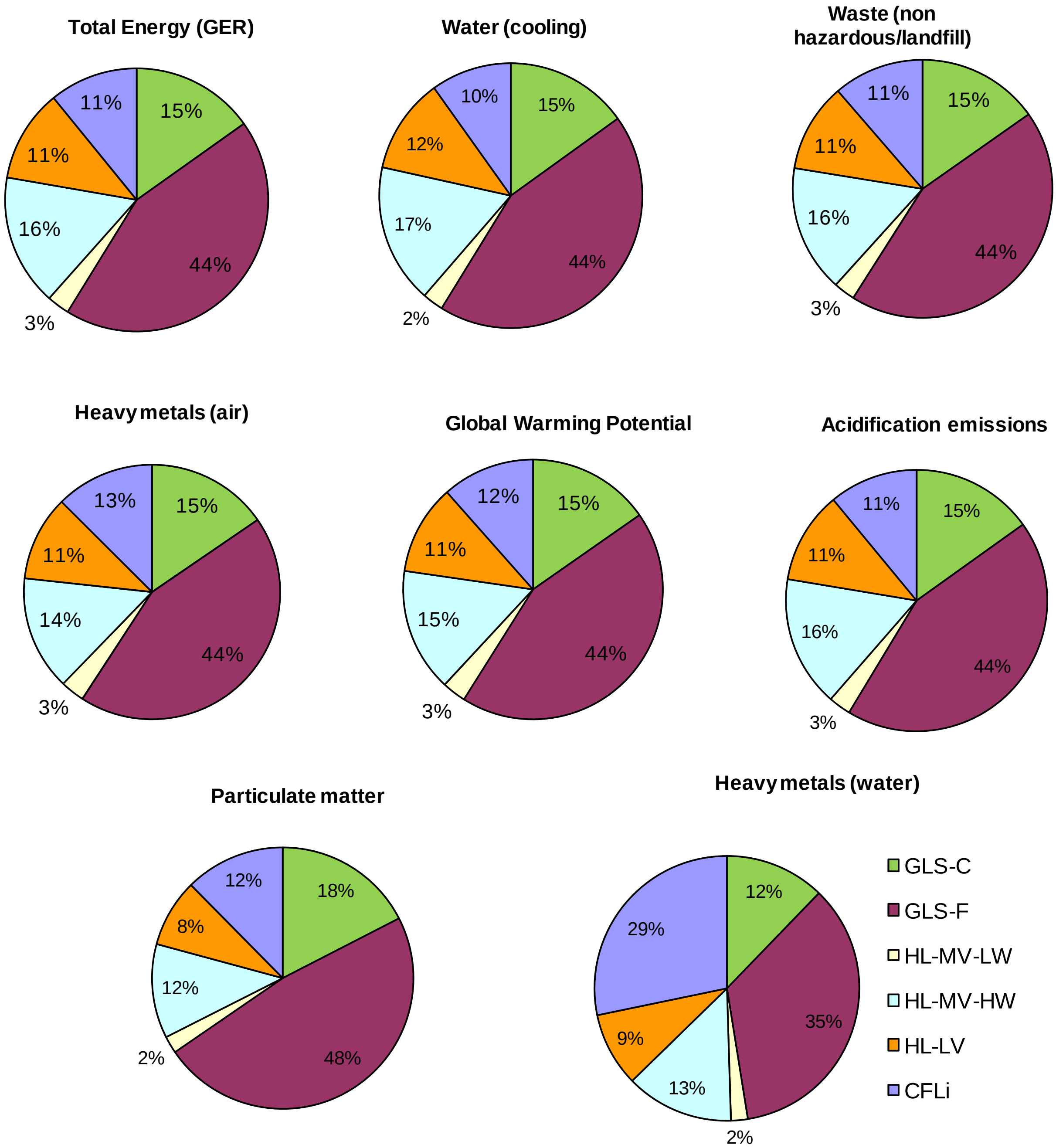

Figure 5.18: Base-cases' share of the environmental impacts of the 2007 stock for all sectors

Table 5.18 summarises the total electricity consumption (during the use phase) of each base-case, assuming that the whole stock is composed of base-cases. Therefore, the total electricity consumption in 2007 of non-directional lighting sources which are in the scope of this study (part 1) and used in all sectors (not only the domestic sector) is about 112.5 TWh. This represents about 4.00 % of the EU-27 total electricity consumption[6]. Therefore, it can be deducted that the electricity consumption in the non-domestic sector for these 5 lamp types represents about 1.05 % (= 4.0 % - 2.95 %) of the EU-27 total electricity consumption.

[6]Source Eurostat: EU-27 electricity consumption in 2006 = 242 million toe = 2,815 TWh

Table 5.18: Total electricity consumption for the year 2007 for all sectors

Base-case	EU 27 stock electricity consumption in 2007 for all sectors (TWh)	Share of the total electricity consumption of the 6 lamp types
Base-case GLS-C	16.92	15.0%
Base-case GLS-F	49.09	43.6%
Base-case HL-MV-LW	2.89	2.6%
Base-case HL-MV-HW	19.22	17.1%
Base-case HL-LV	13.11	11.7%
Base-case CFLi	11.23	10.0%
TOTAL	**112.47**	**100.0%**

- **Total consumer expenditure in 2007**

Regarding the total consumer expenditure in 2007 related to the 6 base-cases, about 83 % of the 20.7 billion euros (i.e. 5.1 billion euros concern the non-domestic sectors) is due to the electricity costs. This share is almost similar to the one for the domestic sector. The distribution per base-case is given in Figure 5.19, and details on consumer expenditure are presented in Table 5.19.

Table 5.19: Comparison of total consumer expenditure (EU 27) in 2007 for all sectors

	GLS-C	***GLS-F***	***HL-MV-LW***	***HL-MV-HW***	***HL-LV***	***CFLi***	***TOTAL***
Lumen output per lamp (lm)	594.0	572.4	480.0	5177.3	435.0	559.0	
EU 27 sales (mln unit)	297	767	97	84	147	353	1746
Share of the EU 27 sales	17.0%	44.0%	5.6%	4.8%	8.4%	20.2%	100.0%
Product price (mln €)	178	460	536	252	441	1633	3500
Electricity[7] (mln €)	2584	7498	442	2937	2004	1685	17150
Total (mln €)	**2762**	**7959**	**978**	**3189**	**2445**	**3318**	**20650**

[7] The electricity tariff used for the calculation is the same as for domestic purpose, i.e. 0.1528 €/kWh.

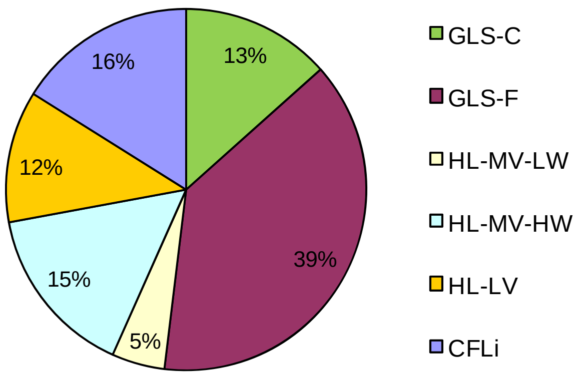

Figure 5.19: Base-cases' share of the total consumer expenditure in 2007 for all sectors

Total consumer expenditure in 2007 related to incandescent lamps (both clear and frosted) in all sectors represent 52 %, whereas these lamp types represent about 61 % of the total sales.

5.6 "Comparison" of the base-cases

As the luminous efficacy of the 6 base-cases defined in this chapter differs, it is interesting and relevant to compare their environmental impacts as well as their life cycle cost taking account this difference. Therefore, Table 5.20, Table 5.21 and Table 5.22 present data per lumen and per hour**.** In Table 5.20, for each environmental indicator, variations with reference to the base-case GLS-F are also given.

Table 5.20: Environmental impacts per lumen and per hour

		GLS-C	**GLS-F**	**HL-MV-LW**	**HL-MV-HW**	**HL-LV**	**CFLi**
main environmental indicators	**unit**	**value per lumen per hour**	**value per lumen per hour**	**value per lumen per hour**	**value per lumen per hour**	**value per lumen per hour**	**value per lumen per hour**
Total Energy (GER)	J	**1045.2**	**1084.6**	**946.9**	**615.2**	**843.5**	**275.8**
	variation with GLS-F	*-3.6%*	*0.0%*	*-12.7%*	*-43.3%*	*-22.2%*	*-74.6%*
of which, electricity	J	**955.0**	**991.0**	**875.0**	**608.4**	**803.8**	**258.2**
	variation with GLS-F	*-3.6%*	*0.0%*	*-11.7%*	*-38.6%*	*-18.9%*	*-73.9%*
Water (process)	µltr	**63.9**	**66.3**	**58.4**	**40.6**	**53.6**	**19.3**
	variation with GLS-F	*-3.6%*	*0.0%*	*-12.0%*	*-38.8%*	*-19.2%*	*-70.9%*
Waste, non-haz./ landfill*	µg	**2545.5**	**2641.5**	**2333.3**	**1622.5**	**2143.4**	**684.5**
	variation with GLS-F	*-3.6%*	*0.0%*	*-11.7%*	*-38.6%*	*-18.9%*	*-74.1%*
Waste, hazardous/ incinerated*	µg	**1245.8**	**1292.8**	**1089.3**	**713.5**	**973.3**	**328.7**
	variation with GLS-F	*-3.6%*	*0.0%*	*-15.7%*	*-44.8%*	*-24.7%*	*-74.6%*
Emissions (Air)							
Greenhouse Gases in GWP100	mg CO2 eq.	**49.5**	**51.4**	**44.5**	**27.1**	**38.6**	**12.7**
	variation with GLS-F	*-3.6%*	*0.0%*	*-13.5%*	*-47.2%*	*-25.0%*	*-75.2%*
Acidifying agents (AP)	µg SO2 eq.	**266.7**	**276.8**	**242.0**	**158.2**	**216.2**	**71.2**
	variation with GLS-F	*-3.6%*	*0.0%*	*-12.6%*	*-42.8%*	*-21.9%*	*-74.3%*
Volatile Org. Compounds (VOC)	ng	**463.7**	**481.2**	**402.4**	**236.4**	**344.5**	**134.7**
	variation with GLS-F	*-3.6%*	*0.0%*	*-16.4%*	*-50.9%*	*-28.4%*	*-72.0%*
Persistent Org. Pollutants (POP)	10^{-3} pg i-Teq	**7.06**	**7.33**	**6.16**	**4.04**	**5.50**	**1.80**
	variation with GLS-F	*-3.6%*	*0.0%*	*-15.9%*	*-44.9%*	*-24.9%*	*-75.5%*
Heavy Metals (HM)	ng Ni eq.	**21.53**	**22.34**	**18.71**	**10.80**	**15.83**	**5.43**
	variation with GLS-F	*-3.6%*	*0.0%*	*-16.3%*	*-51.7%*	*-29.1%*	*-75.7%*
PAHs	ng Ni eq.	**6.51**	**6.76**	**5.36**	**1.54**	**3.59**	**1.35**
	variation with GLS-F	*-3.6%*	*0.0%*	*-20.6%*	*-77.3%*	*-46.8%*	*-80.1%*
Particulate Matter (PM, dust)	µg	**10.25**	**10.63**	**5.65**	**3.55**	**5.15**	**1.99**
	variation with GLS-F	*-3.6%*	*0.0%*	*-46.8%*	*-66.6%*	*-51.6%*	*-81.3%*
Emissions (Water)							
Heavy Metals (HM)	ng Hg/20	**6.57**	**6.81**	**5.77**	**3.94**	**5.25**	**3.41**
	variation with GLS-F	*-3.6%*	*0.0%*	*-15.3%*	*-42.2%*	*-22.9%*	*-50.0%*
Eutrophication (EP)	ng PO4	**43.2**	**44.8**	**29.7**	**19.3**	**26.3**	**27.3**
	variation with GLS-F	*-3.6%*	*0.0%*	*-33.7%*	*-57.0%*	*-41.4%*	*-38.9%*

Table 5.20 highlights that a typical frosted incandescent lamp represents highest environmental impacts over its life cycle compared to the others lamp types. This can be explained by two factors:

- the use phase is the most significant stage of the life cycle for any type of lamp, and
- the base-case GLS-F has the lowest lumen efficacy (10.6 lm/W).

For all environmental indicators, the base-case GLS-C presents a decrease of 3.6 % compared to the base-case GLS-F. This observation is logical as these two types of lamps have the same bill of materials, power output (54 W), and lifespan (2.5 years). The only difference is in their luminous efficacy (11.0 lm/W for the GLS-C and 10.6 lm/W for the GLS-F, i.e. a difference of about 3.6 %).

For two main environmental impact indicators (GER and GWP), Figure 5.20 and Figure 5.21 show the results per lumen and per year for the 6 base-cases with reference to the base-case GLS-F. As expected, incandescent lamps, being the least energy efficient, have the highest magnitude of impacts.

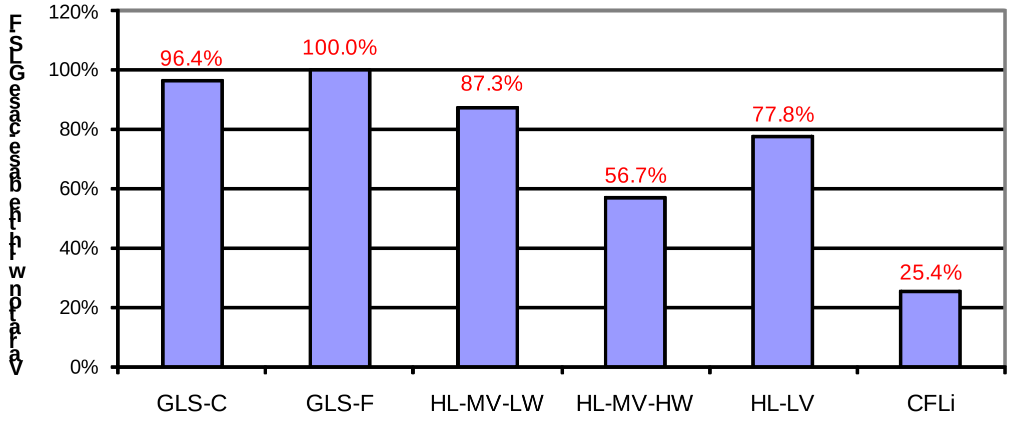

Figure 5.20: Comparison of the base-cases for the GER indicator

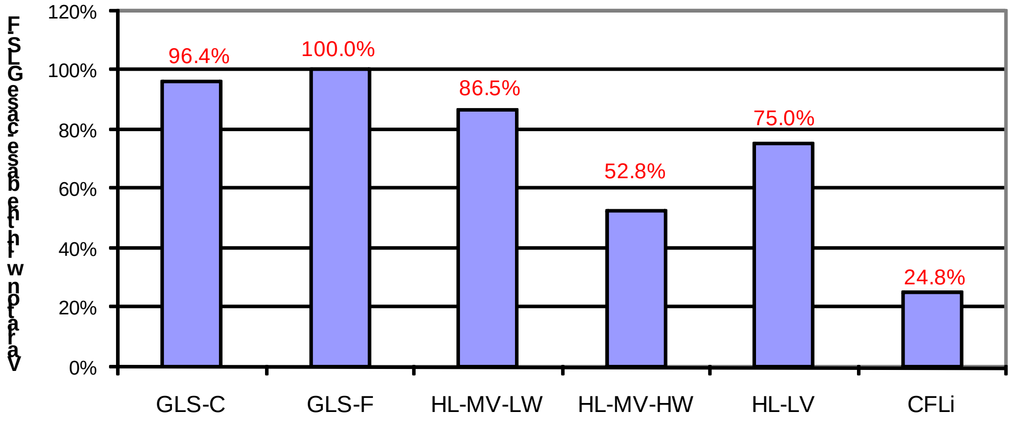

Figure 5.21: Comparison of the base-cases for the GWP indicator

Based on Figure 5.20 and Figure 5.21, one can be surprised that the base-case HL-MV-HW is "more efficient" than the base-case HL-LV. The explanations can be that GER and GWP of the distribution phase are almost equal for both base-cases (52 MJ and 4.5 kg CO_2 eq.) whereas they do not have the same lumen output (435 lm for the base-case HL-LV and 5177 lm for the base-case HL-MV-HW). Thus, to obtain GER and GWP per lumen and per hour for the distribution phase, total values have to be divided by 0.65×10^6 for the base-case HL-LV and 7.77×10^6 for the base-case HL-MV-HW. Therefore, when comparing the two base-cases for these environmental indicators over their entire life cycle, the base-case HL-MV-HW seems “more efficient” than the base-case HL-LV.

Moreover, the power output of the two base-cases is very different (300 W for HL-MV-HW and 30 W for HL-LV). As the lamp efficacy increases with the power output, the comparison between these two base-cases should be made carefully.

Regarding mercury emissions, Table 5.21 compares values per lumen and per hour for the 6 base-cases. As already discussed in section 5.2, only the base-case CFL with integrated ballast emits mercury to air during end-of-life.

Table 5.21: Mercury emissions to air for each base-case per lumen and per hour

	GLS-C	***GLS-F***	***HL-MV-LW***	***HL-MV-HW***	***HL-LV***	***CFLi***
Product life time (hours)	1000	1000	1500	1500	3000	6000
Lumen output per lamp (lm)	594.0	572.4	480.0	5177.3	435.0	559.0
Mercury emitted to air for the production of 1 kWh (mg)	0.016					
Mercury emitted during the use phase (mg)	0.86	0.86	0.96	7.20	1.60	1.31
Mercury emitted during the end-of-life (mg)	0	0	0	0	0	3.2
Mercury emitted over lifetime per lumen per hour (ng)	**1.45**	**1.51**	**1.33**	**0.93**	**1.22**	**1.34**
Difference with the base-case GLS-F	*-3.6%*	*0.0%*	*-11.7%*	*-38.6%*	*-18.9%*	*-10.9%*

Due to emissions occurring at its end-of-life (3.2 mg) the base-case does not have the lowest amount of mercury emissions (per lumen and per hour) during its entire life cycle even if it is the most efficient lamp type. The reduction is ‘only’ of 10.9 % compared to the base-case frosted incandescent lamp.

As shown in Figure 5.22, the base-case HL-MV-HW is the ‘best’ lamp when focusing on mercury emissions. However, improvements can be expected for recycling CFLi in order to increase the share of CFLi recycled (20 % nowadays). Therefore, if all CFLi were recycled, this lamp type would be the best choice in terms of mercury emissions due to low electricity consumption per lumen and per hour.

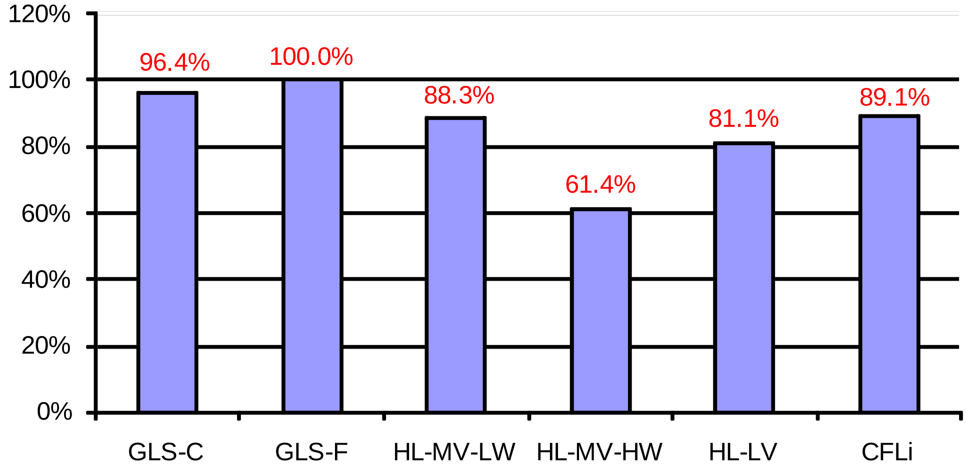

Figure 5.22: Comparison of the base-cases for mercury emissions over lifetime

Table 5.22: Economic data per lumen and per hour

	GLS-C	***GLS-F***	***HL-MV-LW***	***HL-MV-HW***	***HL-LV***	***CFLi***
Product life time (hours)	1000	1000	1500	1500	3000	6000
Lumen output per lamp (lm)	594.0	572.4	480.0	5177.3	435.0	559.0
Product price per lumen per hour (10^{-6} €)	1.01	1.05	7.64	0.39	2.30	1.38
Electricity per lumen per hour (10^{-6} €)	13.46	13.97	12.25	8.52	10.99	3.46
LCC per lumen per hour (10^{-6} €)	**14.47**	**15.02**	**19.89**	**8.91**	**13.29**	**4.84**
Difference with the LCC of the base-case GLS-F	*-3.64%*	*0.0%*	*32.4%*	*-40.7%*	*-11.5%*	*-67.8%*

The life cycle cost per lumen and per hour for each base-case is highlighted in Figure 5.23. It is clearly visible that the use of the base-case HL-MV-LW implies the highest cost over lifetime (product price + electricity cost): 19.89×10^{-6} €. Due to its relatively high purchase price, its life cycle cost is even higher than the LCC of the base-case GLS-F ($15.02\text{x}10^{-6}$ €). On the contrary, the base-case HL-MV-HW presents a significant reduction compared to the base-case HL-MV-LW (- 55.2 %) due to its low product price even with a high wattage (300 W).

As expected and demonstrated already, incandescent and halogen lamps are less efficient and less cost-effective than compact fluorescent lamps with integrated ballast as shown in Figure 5.23. The use of a typical compact fluorescent lamp (CFLi) instead of a typical frosted incandescent lamp allows decreasing the life cycle cost by about 67.8 %.

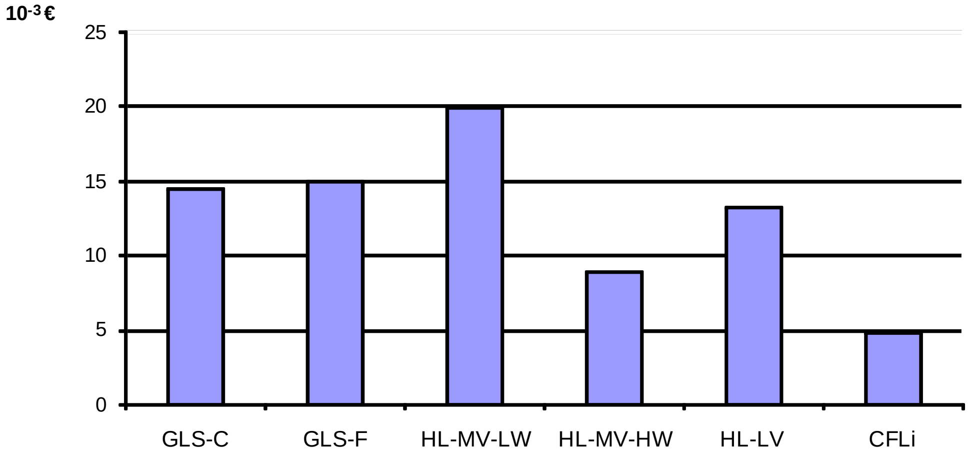

Figure 5.23: Life Cycle Cost per lumen and per hour

The environmental and economical analysis of the 6 base-cases shows that the compact fluorescent lamp with integrated ballast is the “best choice” in terms of LCC and environmental impacts, except for the mercury emissions for which the base-case HL-MV-HW is the least impacting.

5.7 EU-27 Total System Impact

This analysis will be elaborated in part 2 of the study.

5.8 Conclusions

The environmental impact assessment carried out with the EcoReport tool for each base-case shows that the use phase is, not surprisingly, the most significant stage of the life cycle in terms of energy and resource consumption as well as for environmental impacts. Therefore, the analysis of the improvement potential in chapter 7 will primarily focus on technologies that reduce the electricity consumption, for instance by increasing the lamp efficacy. Regarding environmental impacts, the CFLi is, not surprisingly, the best lamp choice and incandescent lamps the worst choice.

Furthermore, mercury is a hazardous substance and the environmental impacts arising from its use in certain lamps should be limited. Therefore, the improvement options that will be identified in chapter 7 should also allow the reduction of mercury emissions over the entire life cycle. The base-case HL-MV-HW allows the lowest amount of mercury emissions even if its lamp efficacy and lamp lifetime is lower compared to the base-case CFLi, as a CFLi emits mercury at end-of-life.

Regarding the Life Cycle Cost of the 6 base-cases, compared per lumen and per hour, the base-case CFLi appears as the “best lamp” due to its low electricity consumption, i.e. its high lamp efficacy. Moreover, as incandescent lamps (both GLS-C and GLS-F) have the lowest lamp efficacy these lamps present the highest LCC.

6 IMPROVEMENT POTENTIAL

For more info see website www.eup4light.net.

7 SCENARIO- POLICY- IMPACT- AND SENSITIVITY ANALYSIS

For more info see website www.eup4light.net.

8 REFERENCES

9 ABBREVIATIONS AND ACRONYMS

10 ANNEXES