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Final report, Task 5

Environment & Economics
(base case LCA & LCC)

Energy

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Contents

Executive Summary

This document covers MEErP Task 5 and deals with the environmental impacts and the life cycle costs (LCC) of all base case types of light sources [1] considered in Task 2, 3 and 4 reports of this study. The assessments are based on the EcoReport [2], that has been specifically developed for this purpose in the context of the MEErP.

The EcoReport quantifies the environmental impacts for production, distribution, use and end-of-life stage of the 19 base cases for the reference year 2013. It distinguishes materials use (10 categories), energy & water resources as well as waste (6 parameters), emissions to air (7 parameters) and emissions to water (2 parameters). Furthermore, based on a manual calculation, this report looks into the consumption of critical raw materials as well as the mercury balance of light sources.

The major part of the input required for the EcoReports has been presented in the Task 4 report. This included 2013 sales and stock, useful lifetimes, power, operating hours, product price, installation costs, repair and maintenance costs, electricity rates and the bill-of-materials (BoM). Additional input parameters are specified in this report. For 1.5% of the total weight of lamps sold in 2013 no impact data are available.

Furthermore, also based on MEErP methodology and mainly inputs from previous task reports, the Life Cycle Costs (LCC) and consumer expenditure for lamps are calculated.

The main results for the environmental impacts are:

- Lamps consume 9.5% (265 TWh) of EU-electricity, which takes up 3.2% (2398 PJ) of EU primary energy consumption to generate and distribute.
- The lamp-related greenhouse gas emissions (103 Mt CO2 eq.) and the emissions of acidifying agents (455 kt SO2 eq.) are 2% of EU total. Other aggregated emissions to air take up less than 0.6% of EU totals.
- Lamp-related emissions to water and consumption of non-energy resources constitute less than 0.1% of EU-totals.
- Mercury emissions, two-thirds at use phase and one-third at end-of-life, are 8% (6.3 t) of EU-total with a declining trend.
- Lamps produced for the EU market, in- and outside the EU, consume 158 tonnes Sb equivalent of critical raw materials, which equals 1.4% of EU consumption.
- The lamp-waste is 174 kt (EU 2013), of which almost half (45 weight %) is packaging. The end-of-life lamps, without packaging, are around 1% of electric and electronic waste (WEEE). The lamp-waste is 15% of the solid waste from the annual electricity production needed to operate the lamps (1.2 Mt). In total, the 1.4 Mt of waste related to lamps and their energy use are 0.04% of the EU-total non-hazardous and hazardous waste.

[1] The distinction between directional and non-directional LEDs has been dropped. The main reason for this is that this distinction is not expected to be useful in the scenario analyses.

[2] MEErP 2011, 'Methodology for Ecodesign of Energy-related Products', part 1: 'Methods' and part 2: 'Environmental policies and data', René Kemna (VHK) 28 November 2011, and EcoReport 2014 are available from: http://ec.europa.eu/enterprise/policies/sustainable-business/ecodesign/methodology/index_en.htm

- The EcoReport tool provides no data for process water in electricity generation and thus the use phase for this parameter is void, i.e. all process water is partitioned between the other phases. This is a data problem and should not be perceived as significant in the overall environmental profile of lamps.
- Typically the use phase makes up 90-99% of the total impact of all parameters, with some exceptions:
  - For simple (filament) lamps with a relatively short product life such as GLS and HL, parameters relating to distribution (PAHs, Particulate Matter) are significant and may constitute up to half of the total PAHs and Particulate Matter emissions.
  - For energy-efficient lamps with a long product life, i.e. LEDs, the absolute impact per unit of light output (in klm) is lowest of all but --because the energy consumption during the use-phase is low-- some production parameters become relatively more significant, such as the share of hazardous waste linked to production (62% of total), the share of POP-emissions (36%), heavy metals emissions (12% to air, 24% to water), etc..

Regarding monetary life cycle costs and total EU-28 expenditure the report concludes:

- With a functional unit of million lumen output per hour (Mlmh)[3], the Life Cycle Cost (LCC) was calculated for lamps sold in 2013, assuming an escalation rate for electricity of 4%.
- As shown in Figure 1, the most uneconomical in 2013 were the halogen and incandescent lamps with a specific LCC of 16-23 euros/Mlmh for most types. The CFLs have a specific LCC of 5.6-6.2 euros/Mlmh and LEDs had a specific LCC of 3.4 euros/Mlmh. The most economical were still linear fluorescent and high intensity discharge (HID) lamps in the range of 1.6 to 3 euros per Mlmh, but especially for HID lamps the low colour rendering (CRI in Ra) makes them unsuitable for most indoor applications.
- Note that the LCC values represent a 2013 snapshot, assuming an average efficacy of 80 lm/W, a price of €23.3/klm and 20 000 h useful life for LED lamps. Over the last two years LED lamps have advanced significantly in terms of higher efficiency and lower purchase prices. Following the proposal for LED projections in Task 4, the LCC of LED-lamps in 2015 is 2.8 euros/Mlmh (100 lm/W, €19/klm) and will be 1.3 euros/Mlmh in 2020 (175 lm/W, €7.5/klm).
- The total consumer expenditure for lighting in 2013 was 54.8 billion euros, of which 67% are electricity costs. LFLs account for 38% of the total expenditure.

[3] 1 Mlmh is e.g. a 1000 lumen lamp with a useful life of 1000 operating hours or a 500 lumen lamp with 2000 operating hours, etc.

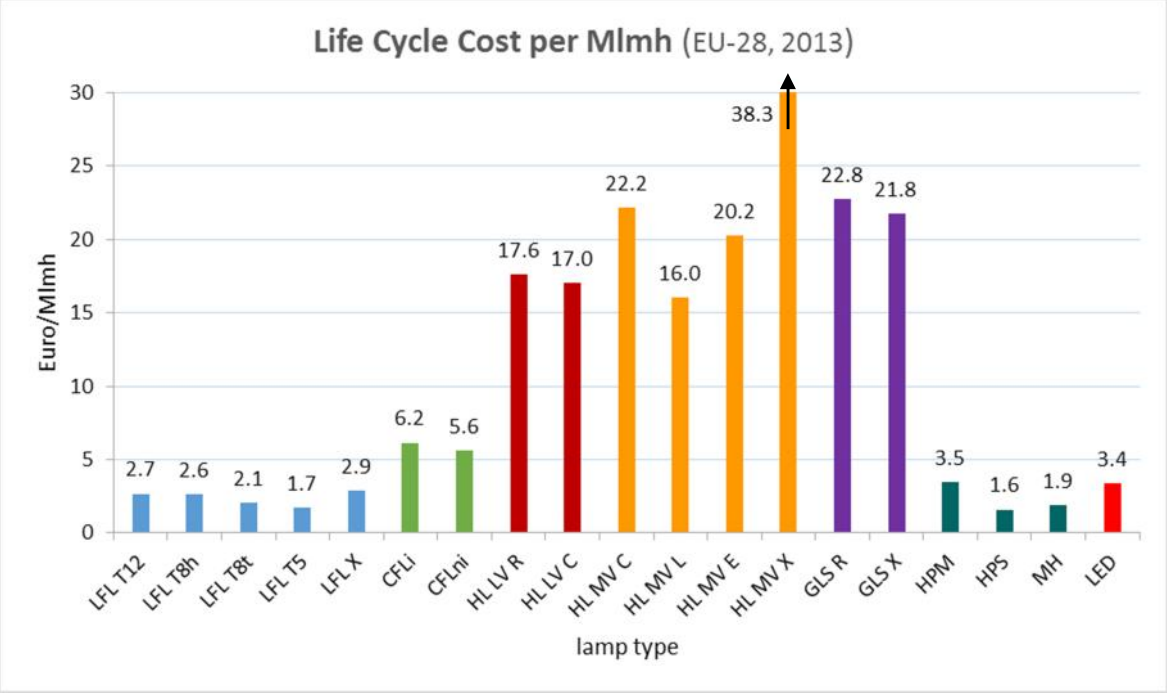


Figure 1 Life Cycle Cost in Euro per million lumen hours (Mlmh).

Legend:
LFL : linear fluorescent lamp type T12, T8 halo-phosphor, T8 tri-phosphor, new T5 or other (X);
CFL : compact fluorescent with (i) or without (ni) integrated gear;
HL LV: low voltage halogen lamp, reflector (R) or capsules (C);
HL MV: mains voltage halogen lamp with G9 cap (C), R7 linear cap (L), E14/E17 cap (E) or other (X);
GLS: incandescent lamps with (R) or without (X) reflector;
HPM, HPS and MH: High Intensity Discharge lamps with respectively mercury, sodium or metal halides;
LED: light emitting diode lamp.

1. Introduction

This document covers MEErP Task 5 and deals with environmental and economic aspects of light sources.

The report assesses the environmental impacts and the life cycle costs (LCC) of all types of light sources considered in this study. These assessments are based on the EcoReport [4], that has been specifically developed for this purpose in the context of the MEErP. The EcoReport does not perform a full detailed life cycle assessment (LCA) but is an approximation that permits the use of the same methodology, with the same underlying data, in all eco-design studies.

For the general function of Task 5 according to the MEErP, see Annex B.

[4] MEErP 2011, 'Methodology for Ecodesign of Energy-related Products', part 1: 'Methods' and part 2: 'Environmental policies and data', René Kemna (VHK) 28 November 2011, and EcoReport 2014 are available from: http://ec.europa.eu/enterprise/policies/sustainable-business/ecodesign/methodology/index_en.htm

2. Product-specific inputs

2.1. Survey of base cases

The base cases for light sources considered in this report are the same as those used in the Task 2, 3 and 4 reports. For convenience the list is presented again in Table 1. The only difference with the preceding Task reports is that all LED light sources, lamps and luminaires are presented by a single base case.

The distinction between directional and non-directional LEDs has been dropped. The main reason for this is that the distinction is not expected to be useful in the scenario analyses. In addition, for some types of LED lamps it is not immediately clear if they are to be considered as directional or non-directional, e.g. LED retrofit tubes with beam angles of 120-150˚ or LED wide beam spots with beam angle 120˚. It is also expected that non-directional classic lamps may be substituted in future by LED lamps that would be directional according to the current definition of regulation 1194/2012 [5]. The DLS/NDLS distinction for LED lamps would therefore be expected to lead to additional complexity and confusion rather than to additional insights.

The LED base case is intended to represent all LED lighting products, including LED retrofit lamps and dedicated LED luminaires, but the treatment of the latter is limited. As regards sales and stock, the base case covers the total of all LED lighting products, but the bill-of-materials and the product costs are for LED retrofit lamps with integrated control gear. This means that part of the material of the LED luminaires, and part of their cost are not included.

For the year 2013, that is taken as a reference in this report, this is not a severe drawback, because the impact of LED lighting on the total of lighting products is still small. In the scenario analyses of Task 7, the lack of parts of the luminaire impacts will be resolved by means of a sensitivity analysis.

As explained in the Task 4 report par. 6.3.19, the BoM for LEDs is for a 1000 lm retrofit lamp. All other input data for the LED EcoReport have been adapted to be compatible with this light output level, see details in par. 2.2.9 and 2.2.10.

Table 1: Base cases considered in this report

Main type	Acronym	Base case description
Linear fluorescent lamps	LFL T12	T12
	LFL T8h	T8 halo-phosphor
	LFL T8t	T8 tri-phosphor
	LFL T5	T5 new (14 - 80w) including circular
	LFL X	All other LFL (including T5 old types 4 - 13w and special FL)
Compact fluorescent lamps	CFL i	with integrated ballast (retrofit for GLS)
	CFL ni	without integrated ballast (non-retrofit)
Halogen lamps	HL LV R	Low voltage, mirrored [M16, M25 etc.]
	HL LV C	Low voltage, halogen capsule [G4, GY6.35]
	HL MV C	Mains voltage, halogen capsule [G9]
	HL MV L	Mains voltage, linear, double-ended [R7s]
	HL MV E	Mains voltage, substitute for GLS and reflector [E14, E27]
	HL MV X	Mains voltage, other, PAR 16/20/25/30 Hard glass reflectors, GU10 etc.
Incandescent lamps	GLS R	Non-halogen incandescent lamp, Reflector
	GLS X	Non-halogen incandescent lamp, Other, including clear/pearl, candles, coloured & decorative)

[5] "directional lamp means a lamp having at least 80% light output within a solid angle of π sr (corresponding to a cone with angle of 120°)"

Table 1: Base cases considered in this report

Main type	Acronym	Base case description
High intensity discharge lamps	HPM	All mercury lamps (including mixed)
	HPS	All sodium lamps
	MH	Metal halide lamps
Light emitting diode lamps	LED	LED retrofit lamps (and luminaires)

2.2. Inputs for the EcoReports

2.2.1. Reference year for EcoReport input

The input data for the EcoReports refer to the year 2013, which is the most recent year for which most data are available. In particular this applies to sales volumes, installed stock, average power of sold lamps, and average price of sold lamps.

2.2.2. Averaging of residential and non-residential data

The EcoReports have NOT been subdivided in residential use and non-residential use, but are presented for one generic product of each base case.

However, for some base cases, some of the input parameters for the EcoReport would be different for the residential and non-residential sector, e.g. operating hours (and thus lifetime in years), electricity rate, product price (with or without VAT), installation costs and maintenance costs.

Consequently, weighted averages over the residential and non-residential sectors have been used as input for the EcoReports. Operating hours, electricity rates and maintenance costs are stock- or energy-consumption-weighted averages, while product price and installation costs are sales-weighted averages. The average lifetime in years is computed as the lifetime in hours divided by the average operating hours.

2.2.3. Basic economic parameters

Table 2 reports the values used for the basic economic parameters. These values are according to the MEErP, part 1, chapter 2. Variation of these values will be considered during the sensitivity analyses in Task 7.

2.2.4. Energy costs

Electricity prices for consumers have been presented in the Task 3 report, par. 2.8, table 28 [6]. For the year 2013 the unitary prices are (in fixed 2010 euros):

- For residential use: 0.191 euros/kWh (incl. VAT)
- For non-residential use: 0.119 euros/kWh (excl. VAT)

For years preceding 2013 see the Task 3 report. For years following 2013 the escalation rate of Table 2 will be applied.

[6] For residential these prices are based on Eurostat tariff group Dc: "annual consumption of 3500 kWh among which 1300 kWh overnight (standard dwelling of 90m²)". For non-residential the reference was tariff group Ie: "annual consumption of 2 000 MWh, maximum demand of 500kW and annual load of 4 000 hours". These tariff group definitions are according to the old (2007) methodology.

Table 2: Basic economic parameters applied in the analyses.

Parameter	Value	Remarks
Interest rate	6.5 %/a	Both for consumers and for enterprises.
Inflation rate	2.5 %/a	
Discount rate	4 %/a	This is the value recommended in MEErP part 1, chapter 2, and derives from the value used in the Commission's impact assessments [7].
Escalation rate for electricity prices	4 %/a	This is the real (inflation-corrected) increase.
VAT	20 %	(applied only for residential sector)
Efficiency of electricity generation and distribution	40 %	This implies that 1 MWh electric = 9000 MJ primary energy

2.2.5. Inputs for the material section: bill-of-materials

For all base cases, the bill-of-materials (BoM) has been presented (and motivated) in the Task 4 report, par. 6.3. The BoM also includes packaging materials.

The presentation of material data in the Task 4 report also shows the choice of the Ecoreport 'categories' and the Ecoreport 'materials or processes'. For some lamp materials, representing 1.7% of total lamp weight, no corresponding EcoReport category was found (see details in par. 2.3.1).

For most lamp types, the major part of the weight falls into the category 'Misc', that includes both 'glass for lamps' and 'cardboard' for the packaging.

2.2.6. Inputs for the manufacturing section

The only input required here is the percentage of sheet metal scrap. The value has been changed to 20% (default is 25%), conforming to the approach in the 2007-2009 preparatory studies on lighting. The amount of sheet metal used for the lamps is minimal, so the impact of this value is negligible.

2.2.7. Inputs for the distribution section

The volume of the final packaged product has been reported for all non-LED base cases in the Task 4 report, par. 6.3. For LEDs a gross volume of 0.75 dm^3 has been used. The impact of changes in these volumes, within reasonable bounds, is negligible.

The impact of the distribution phase remains very small in all cases (see additional remarks in par. 2.3.2).

[7] As explained in the MEErP: The discount rate is expressed in real terms, taking account of inflation. This rate of 4%, used in the Commission's impact assessments (http://ec.europa.eu/governance/impact/commission_guidelines/docs/ia_guidelines_annexes_en.pdf), broadly corresponds to the average real yield on longer-term government debt in the EU over a period since the early 1980s. For impacts occurring more than 30 years in the future, the use of a declining discount rate could be used for sensitivity analysis, if this can be justified in the particular context.

2.2.8. Inputs for the use phase section, indirect ErP impacts

Lamps produce heat and consequently can have an influence on the heating and cooling of the spaces in which they are being used (see Task 3 report, chapter 4). In the basic approach, for which the results are presented in this report, this effect is ignored.

2.2.9. Inputs for the use phase section, direct ErP impacts

For all base cases except LEDs, the product service life in years, the energy consumption per hour (power), and the operating hours per year, have been presented in the Task 4 report chapter 5 (see the paragraphs on BC description). These data are weighted averages over the residential and non-residential sector (see par. 2.2.2).

Standby-mode and off-mode energy consumption have not been considered.

The number of kilometres travelled for repair-, maintenance- and service- purposes has been left zero for all lamp types.

As regards the LED base case, the following input has been used (year 2013):

- Operating hours per year : 585 h/a [8]
- Consumption per hour (lamp power) : 12.5 Wh/h [9]
- Product service life : 34 years [10]

2.2.10. Inputs for the EU-totals and product LCC section

This input regards: annual sales, EU-stock, product cost, installation costs [11], repair and maintenance costs (over product life) and electricity rate (see par. 2.2.4).

For all base cases except LEDs, these data have been presented in the Task 4 report chapter 5. The data are sums or weighted averages over the residential and non-residential sector (see par. 2.2.2).

The default discount rate and escalation rate (both 4%) have not been changed (see par. 2.2.3).

For all base cases except LEDs, the efficiency ratio between stock and new sales is 1.0.

As regards the LED base case, the following input has been used (year 2013):

Sales : 57.0 million units [12]

Stock : 95.4 million units [13]

[8] This is the stock weighted average for year 2013 from MELISA, assumed to be independent from the light output level:
1500 h/a for Non-Residential, NDLS, stock: 8 mln ; 984 h/a for Non-Residential, DLS, stock: 9 mln
500 h/a for Residential, NDLS, stock: 57 mln ; 500 h/a for Residential, DLS, stock: 70 mln

[9] In MELISA the average LED efficacy for year 2013 is 80 lm/W. The EcoReport is for a lamp of 1000 lm, so this corresponds to 1000/80 = 12.5 W.

[10] MELISA assumes a life of 20,000 hours. Divided by 585 operating hours per year, this leads to lifetime 34.19 years.

[11] MEErP, part 1, par. 2.8: Acquisition costs are the sum of purchase price and, where applicable, installation costs. For the residential sector (B2C sales) the VAT is included; for the non-residential sector (B2B sales) the VAT is excluded.

[12] According to MELISA, for year 2013, the combined EU-28 sales of all LEDs (DLS, NDLS, residential and non-residential) are 81.67 mln units, but in the EcoReport we need the equivalent sales for 1000 lm lamps.
According to MELISA, for sales in year 2013: Residential, DLS, 600 lm, 33.3 mln units ; Residential, NDLS, 600 lm, 34.4 mln units ; Non-Residential, DLS, 600 lm, 7.5 mln units ; Non-Residential, NDLS, 1800 lm, 6.6 mln units. Total LED lumens sold in 2013: 57,000 mln lm (average 697 lm). Divided by 1000 lm / lamp -> 57 mln sales equivalent.

[13] According to MELISA, for year 2013, the total EU-28 stock of all LEDs (DLS, NDLS, residential and non-residential) is 144 mln units, but in the EcoReport we need the equivalent stock of 1000 lm lamps.
According to MELISA, the EU-28 total LED lumens installed in 2013 are 0.0954E12 lm.
With 1000 lumens per lamp, this means 0.0954E9 lamps, or 95.4 mln units

Product price :	23.30 euros/unit [14]
Installation costs:	1.06 euros/unit [15]
Repair and maintenance costs:	1.85 euros/unit (over lifetime) [16]
Electricity rate:	0.165 euros/kWh [17]
Efficiency ratio stock/new:	0.75 [18]

2.2.11. Inputs for the end-of-life section

For all lamp types, the re-use percentages have been put to zero, and the recyclability has been defined as 'average' for all categories (default value). For metals (ferrous, non-ferrous and coating) the default EoL-fractions in the EcoReport cannot be changed.

Incandescent lamps (GLS) and halogen lamps are normally not separately collected and recycled. These lamps will end up in an incinerator or a landfill as mixed domestic waste, which does not exclude that a fraction can be recycled. It has been assumed that this is expressed by the default values in the EcoReport, see Table 3 [19].

As regards discharge lamps (CFL, LFL, HID-lamps), the information from the Task 3 report is used as a basis, i.e. 30% is collected of which 80% is recycled. Consequently, it is assumed in the EcoReports that 80%*30%=24% is completely recycled and 76% ends up in an incinerator or a landfill as mixed waste, of which a part can anyway also be recycled, according to the default distribution of the EcoReport [20]. However, for mercury it has been assumed that no additional recycling results from the 76% mixed waste. The resulting end-of-life weight fraction distribution is shown in Table 4 [19].

LED lighting products have only recently been introduced on the market and they have a long lifetime, so there are no significant waste volumes yet. In principle they have to

[14] According to MELISA v0, for year 2013, the average LED product price is 0.020 euros/lumen or 20 euros per 1000 lm, exclusive VAT. The percentage VAT to be added depends on the distribution of sales over the residential sector (20% VAT) and the non-residential sector (no VAT). According to MELISA v0, for year 2013, 67.6 million LEDs on a total of 81.7 million LEDs are sold in the residential sector, so the average VAT percentage is 67.6/81.7*20% = 16.5%. This leads to a product price of 20*(1+16.5%)= 23.3 euros incl. VAT per 1000 lm LED lamp.

[15] Installation costs are based on a time of 10 minutes per light source and an hourly rate of 37 euros/hour. The 10 minutes is an estimated weighted average between 3 min/lamp for group replacements and 20 min/lamp for individual (spot) replacements, see Task 3 report par. 7.5. These costs regard only the light sources, not the installation of new luminaires, nor the changing of control gears. This gives (10/60)*37 = 6.17 euros/lamp. These installation costs are considered only for the non-residential sector, that accounts for 14.1/81.7 of the sales in 2013. Consequently the average sales weighted installation costs are 14.1/81.7*6.17 = 1.06 euros/lamp.

[16] Maintenance costs are per light source, for the lifetime of the light source (not per year). The estimate is based on a time of 1.5 minute per luminaire cleaning operation, an average of 2 light sources per luminaire, one cleaning operation per year, and an hourly rate of 37 euros/hour. See also Task 3 report par. 7.5. This leads to (1.5/60)/2*37*34.19 = 15.81 euros/lamp over the lamp lifetime.
These repair and maintenance costs are considered only for the non-residential sector, that accounts for 16.91/144 of the stock in 2013. Consequently the average stock weighted installation costs are 16.91/144*15.81 = 1.85 euros/lamp.

[17] According to MELISA v0, in year 2013, the applicable rates are: 0.119 for Non-Residential exclusive VAT ; 0.191 for Residential inclusive VAT. The weighted average has been based on the energy consumption (TWh/a) of the LED lamps in the two sectors according to MELISA v0 for year 2013: residential energy: 0.645/1.02 = 63.2% ; non-residential energy: 0.375/1.02 = 36.8%. 0.191*63.2%+0.119*36.8% = 0.165 euros/kWh

[18] This value has been chosen to get the same use-phase energy in the EcoReport as in MELISA v0 for year 2013.

[19] Categories for which there is zero associated lamp material weight are intentionally not shown in the tables. This includes 'refrigerant', 'extra' and 'auxiliaries'. For filament lamps it also includes 'mercury'.

[20] E.g. the 46% for plastics recycling derives from 24% + 29%*76%, where 29% is the EcoReport default recycling percentage for plastics from the mixed waste stream.

be separately collected, just as all other products under the WEEE directive (Task 3 report), but no specific data on collection and recycling percentages are available. For the moment, for the modelling in the EcoReport, the same percentages are assumed as for the discharge lamps, see Table 4.

Packaging materials are recycled for 64.6% (Task 4 report par. 6.4). In the EcoReport they are mixed with e.g. 'glass-for-lamps' in the 'Misc' category. According to the two tables this category has 64% or 73% recycling, which is considered adequate also for packaging.

Table 3 End-of-life mass fractions used for filament lamps (GLS and halogen lamps). The EcoReport default values have been maintained, except that re-use has been put to zero and added to landfill.

EoL mass fraction (in %) to:	Bulk Plastics	TecPlastics	Ferro	Non-ferro	Coating	Electronics	Misc. , excluding refrigant & Hg
re-use						0%	
(materials) recycling	29%	29%	95%			50%	64%
(heat) recovery	15%	15%	0%			0%	1%
non-recovery incineration	22%	22%	0%			30%	5%
landfill/missing/fugitive	34%	34%	5%			20%	30%

Table 4 End-of-life mass fractions used for discharge lamps (LFL, CFL, HID-lamps) and LED lamps. The distribution is based on Eurostat information that 30% is collected, of which 80% recycled, see text for details.

EoL mass fraction (in %) to:	Bulk Plastics	TecPlastics	Ferro	Non-ferro	Coating	Electronics	Misc. , excluding refrigant & Hg	Hg (mercury), **in mg/unit**
re-use						0%		0%
(materials) recycling	46%	46%	95%			62%	73%	24%
(heat) recovery	11%	11%	0%			0%	1%	0%
non-recovery incineration	17%	17%	0%			23%	4%	6%
landfill/missing/fugitive	26%	26%	5%			15%	23%	70%

2.3. Other remarks on inputs for the EcoReports

2.3.1. Materials without impact

For some of the declared materials no corresponding 'category' and 'material or process' is available in the EcoReport. In this case the 'category' has been left blank, which implies that the material is ignored for the purposes of environmental impact calculations. As shown in Table 6 this regards 1.7% of the total EU-28 lamp stock weight in 2013, or 1.5% of the total weight of lamps sold in 2013. The materials involved are for example: phosphors, gas fillings, tungsten (for filaments and electrodes), electrode coatings, support or lead wires (Mo, dumet), some potting / cement materials, mercury, and getters. It was not feasible, in the context of this study, to determine life cycle

impact indicators for these materials and define them as 'extra' materials in the Ecoreport.

Note that LED dies/packages have been represented using category 6 (electronics) and material/process 49 (SMD/ LED's avg.). Materials inside these dies/packages, e.g. semiconductors and phosphors, have not been declared individually, and consequently do NOT result as materials without impact.

Although the share of weight without impact in the EcoReports is small, some of the materials involved might anyway have a significant environmental impact.

2.3.2. Share of packaging weight in gross lamp weight

For packaging weights see also the Task 4 report, par. 6.2. These weights do not only include the primary packaging, but also the corresponding share of secondary and shipment packaging.

As shown in Table 7, considering the entire EU-28 lamp stock of 2013, the declared package weights account for 44% of the total gross lamp weight (= net lamp weight + packaging), with peak values over 80% for the halogen capsules. Considering 2013 sales, the declared package weight accounts for 45% of total gross lamp weight.

Note that different from the lamp materials, that become waste at the end of the useful life, the packaging materials become waste at the start of the useful life. This implies that the end-of-life stock-effect calculated in the EcoReports [21] is not correct in the case of lamps with strongly increasing or decreasing sales.

Table 7 also clarifies that LFLs represent 41% and CFLs 42% of the total net lamp weight for the EU-28 stock in 2013. For the 2013 sales, this is respectively 41% and 21%.

2.3.3. Input regarding mercury

Table 8 reports the mercury content that has been declared in the EcoReports. For a motivation of these values, see the Task 4 report paragraph 6.3. For some lamp types (LFL T8t, LFL T5, LFL X, CFL and HPS) it has been specified that new lamps contain less mercury than the lamps of 'lifetime' ago.

The total mercury content of the 2013 EU-28 stock is estimated between 17.1 and 25.9 ton [22], average 21.5 ton = 21 500 kg. Considering that the density of mercury is 13.6 kg/dm^3, this corresponds to a volume of approximately 1580 dm^3 = 1.58 m^3.

The total mercury content of the lamps sold in 2013 is estimated at 2.1 ton = 2,100 kg.

The mercury content of lamps at end-of-life is around 3000 kg, of which approximately 70% is released as emissions to air or landfill according to Eurostat. For comparison: the mercury emissions to air from electricity production for the use of light sources

[21] The EoL stock-effect shows that the mass discarded seldom equals the mass of new products sold. For example, LFL T12 lamps that show strongly decreasing sales over the years, have a declared weight of 254 g/unit, but the amount of waste corresponds to 1363 g/unit, with a stock-effect of 254-1363= -1109 g/unit.

[22] The lower value would be valid if all lamps of the stock had the same mercury content as current (2013) lamps. The higher value would be valid if the entire stock had the same mercury content as the lamps from 'lifetime' ago.

amounts to 4240 kg.[23] The total mercury emissions of the EU amounts to approximately 80 t [24], of which the production and use of lamps (total ca. 6300 kg) make up 8.1%.

According to UNEP, the EU makes up 4.5% of global anthropogenic emissions of mercury to air. The figure below gives the split-up of EU emissions 2010.

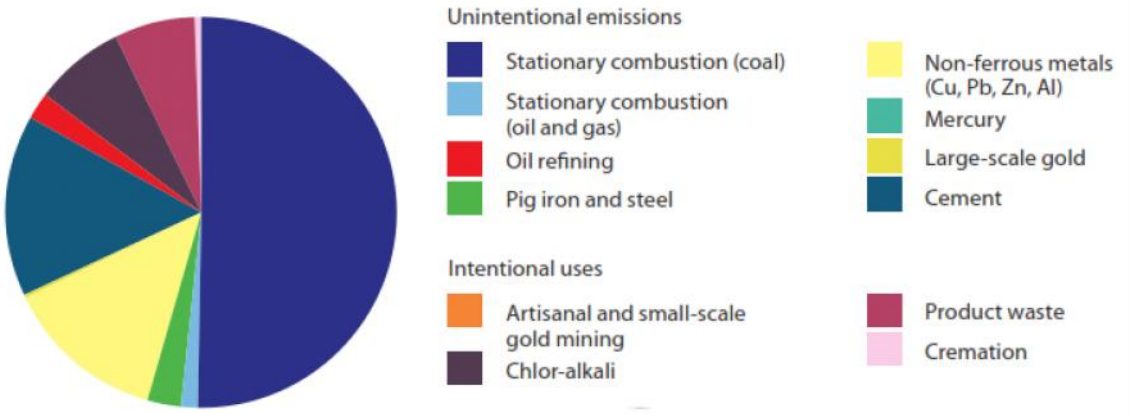


Figure 2. EU27 anthropogenic mercury emissions 2010 (source: UNEP, Global Mercury Assessment 2013). Around 9.5% of the Hg emissions for 'stationary combustion' (coal, oil and gas) can be partitioned to the use of lamps. Up to 40% of the 'product waste' category comes from discarded/broken lamps. In total an estimated 8.1% of all mercury emissions comes from lamps.

2.3.4. Input regarding critical raw materials

The EcoReport has a sheet CRM in which weights of critical raw materials contained in the lamps can be declared. These weights are multiplied in the sheet by a characterization factor expressed in kg Sb equivalent / kg CRM and then summed to produce a CRM indicator value. Table 5 provides the list of materials and their associated factors.

The study team made an attempt to specify the CRM weights, as far as available information allowed. A more detailed elaboration of EU-28 stock totals per base case is provided in Table 9. These data might not be very accurate and should be used with caution. The following remarks can be made regarding this table:

- Antimony (Sb) values derive from solder material containing 0.3% Sb.
- Tungsten (W) is not only used for the filaments of GLS and halogen lamps, but also for the electrodes of discharge lamps (LFL, CFL, HID-lamps).
- Niobium (Nb) is used in the burner tubes of high-pressure sodium lamps and metal-halide lamps.

[23] Based on 0.016 mg Hg/kWh electricity and 265 TWh/year for electricity use. Source: http://ec.europa.eu/health/scientific_committees/opinions_layman/mercury-in-cfl/en/mercury-cfl/l-2/3-emissions-risk-environment.htm

[24] EEA Technical report No 8/2012. European Union emission inventory report 1990-2010, 2012. Estimation from 2010: 87 t Hg and decrease ca. 2 t/yr.

- Rare earth elements (Sc, Y, Nd) are used primarily in the light down-converting phosphors of tri-phosphor fluorescent lamps, in the phosphors of LED lamps, and in the coatings on the electrodes of discharge lamps.

- Germanium (Ge) is used as a substrate/carrier material for some LED dies. The value found for one type of LED die is 10.8 mg/klm, but it is believed that many other manufacturers do not use this material, so the value in the EcoReport has been halved, and this may still be far too much as an average. Note that the CRM indicator for LEDs depends heavily on this Ge-value.

- Gallium (Ga) is used as a semiconductor material for LED dies. The quantity per LED lamp is anyway small and estimated as 0.34 mg/klm (see Task 4 report, par. 6.3.19).

- Indium (In) is used as a semiconductor material for LED dies. The value found for one type of LED is 0.0002 mg/klm, but it is expected that this can be far higher in other types of LEDs. Anyway, even if it would be a thousand times higher, its influence on the CRM indicator for LEDs would remain small.

- Overall, the CRM indicator derives almost entirely from rare earth elements contained in the down-converting phosphors of fluorescent lamps.

Table 5 Critical raw materials listed on the CRM sheet of the EcoReport, together with their antimony equivalent in kg Sb / kg CRM

		TOTAL		of which lamps	
Critical raw material (CRM)	kg Sb eq. / kg	EU consumption (t/a)*	EU consumption (t Sb eq./a)	EU consumption (t/a)	EU consumption (t Sb eq./a)
Germanium (Ge)	18	31	558	0.52	10
Beryllium (Be)	12	42	504		
Tantalum (Ta)	9	131	1179		
Indium (In)	9	58	522	0	0
Platinum Group metals (PGM)	8	110	880		
Gallium (Ga)	8	78	624	0	0
Antimony (Sb)	1	792	792	2	2
Tungsten	0.2	7300	1460	181	36
Niobium (Nb)	0.04	19700	788	77	3
Rare earth elements (Sc,Y,Nd)	0.03	17600	528	3561	107
Cobalt (Co)	0.02	26500	530		
Graphite (C)	0.01	128421	1284		
Fluorspar (CaF2)	0.001	715000	715		
Magnesium (Mg)	0.0005	1418000	709		
TOTAL		2333763	11073	3822	158 (1.4%)

*=EU consumption 2006/'07 (source: VHK, MEErP 2011)

2.3.5. Changes made to the EcoReport for the distribution phase

The first versions of the EcoReports for this study showed a surprisingly high influence of the distribution phase for various impact parameters. Investigating this, it was observed that the EcoReport uses some fixed values per product for the impacts of final assembly, distribution and retail, in addition to other values that depend on the gross product shipping volume (which is very small for lamps, typically 0.001 m^3 or less).

The fixed per-product-values in the EcoReport have been developed with products in mind that have an average space requirement of 20 units/m^2.[25] For lamps, the study team estimates that this is closer to 500 units/m^2, i.e. with a 25 times smaller impact per product.[26] For this reason all fixed per-product distribution-phase values [27] have been divided by 25.

[25] Average based on stacked storage of medium-sized domestic appliances and consumer electronics.

[26] Based on floor-productivity of €1647/m2 for DIY-market (source: NL permit-studies for DIY markets) and price of €2-3/lamp as well as own observations of DIY shop vertical racks (ca. 2 x 1 m, depth 0.5 m + 0.5 m pathway) with 50 hooks for lamp blister-packs and 10 lamps per hook.

[27] See EcoReport, sheet 'Data2', unit indicators 62 (final assembly) and 65 (distribution and retail), all values on these rows.

Table 6 Total gross lamp weight, and shares of materials with and without environmental impacts in the Ecoreports. Upper (green) part of the table: unit data (per lamp in g). Central (blue) part of the table: EU-28 stock 2013 totals in kilotonnes. Lower (yellow) part of the table: EU-28 sales 2013 totals in kilotonnes. The EU-28 sales and stock for 2013 are indicated on the first two lines.

Parameter	Unit	LFL T12	LFL T8h	LFL T8t	LFL T5	LFL X	Sum LFL	CFLi	CFLni	Sum CFL	HL LV R	HL LV C	HL MV C	HL MV L	HL MV E	HL MV X	Sum HL	GLS R	GLS X	Sum GLS	HPM	HPS	MH	Sum HID	LED	Sum ALL
EU-28 sales (2013)	mln	1.2	2.2	245	76	19	344	271	72	342	164	42	67	38	303	158	772	36	123	159	2.2	14	16	33	57	1706
EU-28 stock (2013)	mln	20	152	1376	501	160	2209	3827	633	4460	683	211	230	87	800	558	2569	104	457	561	6	42	37	84	95	9980
Per unit data																										
total weight	g	258	171	171	110	67		120	100		60	17	19	30	84	80		120	85		250	218	160		190	
o/w weight with impact	g	252	167	167	108	66		118	98		60	17	19	29	83	79		120	85		250	213	158		190	
o/w weight without impact	g	6.07	3.80	3.80	2.22	1.36		1.90	2.50		0.34	0.06	0.06	0.60	1.54	1.09		0.19	0.16		0.04	4.44	1.82		0.00	
Stock totals 2013																										
total weight	kt	5	26	235	55	11	332	459	63	523	41	4	4	3	67	45	164	12	39	51	1	9	6	16	18	1104
o/w weight with impact	kt	5	25	230	54	10	325	452	62	514	41	4	4	3	66	44	161	12	39	51	1	9	6	16	18	1086
o/w weight without impact	kt	0	1	5	1	0	7	7	2	9	0	0	0	0	1	1	2	0	0	0	0	0	0	0	0	19
% weight without impact	%	2.4%	2.2%	2.2%	2.0%	2.0%	2.2%	1.6%	2.5%	1.7%	0.6%	0.3%	0.3%	2.0%	1.8%	1.4%	1.3%	0.2%	0.2%	0.2%	0.0%	2.0%	1.1%	1.5%	0.0%	1.7%
share of total weight	%	0.5%	2.4%	21.3%	5.0%	1.0%	30%	41.6%	5.7%	47%	3.7%	0.3%	0.4%	0.2%	6.1%	4.0%	15%	1.1%	3.5%	5%	0.1%	0.8%	0.5%	1%	1.6%	100%
Sales totals 2013																										
total weight	kt	0	0	42	8	1	52	32	7	40	10	1	1	1	25	13	51	4	10	15	1	3	3	6	11	175
o/w weight with impact	kt	0	0	41	8	1	51	32	7	39	10	1	1	1	25	12	50	4	10	15	1	3	3	6	11	172
o/w weight without impact	kt	0	0	1	0	0	1	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	3
% weight without impact	%	2.4%	2.2%	2.2%	2.0%	2.0%	2.2%	1.6%	2.5%	1.8%	0.6%	0.3%	0.3%	2.0%	1.8%	1.4%	1.4%	0.2%	0.2%	0.2%	0.0%	2.0%	1.1%	1.5%	0.0%	1.5%
share of total weight	%	0.2%	0.2%	24.0%	4.8%	0.7%	30%	18.6%	4.1%	23%	5.6%	0.4%	0.7%	0.7%	14.6%	7.2%	29%	2.5%	6.0%	8%	0.3%	1.7%	1.5%	4%	6.2%	100%

Table 7 Lamp packaging weight, with cardboard and PET shares, and net lamp weight. Upper (green) part of the table: unit data (per lamp in g). Central (blue) part of the table: EU-28 stock 2013 totals in kiltonnes. Lower (yellow) part of the table: EU-28 sales 2013 totals in kilotonnes. The EU-28 sales and stock for 2013 are indicated on the first two lines.

Parameter	Unit	LFL T12	LFL T8h	LFL T8t	LFL T5	LFL X	Sum LFL	CFLi	CFLni	Sum CFL	HL LV R	HL LV C	HL MV C	HL MV L	HL MV E	HL MV X	Sum HL	GLS R	GLS X	Sum GLS	HPM	HPS	MH	Sum HID	LED	Sum ALL
EU-28 sales (2013)	mln	1.2	2.2	245	76	19	344	271	72	342	164	42	67	38	303	158	772	36	123	159	2.2	14	16	33	57	1706
EU-28 stock (2013)	mln	20	152	1376	501	160	2209	3827	633	4460	683	211	230	87	800	558	2569	104	457	561	6	42	37	84	95	9980
Per unit data																										
package weight	g	60	40	40	30	20		60	50		30	15	15	20	60	40		90	60		90	60	50		40	
o/w cardboard / paper-based	g	60	40	40	30	20		54	45		27	14	14	18	54	36		81	54		90	60	50		36	
o/w PET (plastic)	g	0	0	0	0	0		6	5		3	2	2	2	6	4		9	6		0	0	0		4	
net lamp weight	g	198	131	131	80	47		60	50		30	2	4	10	24	40		30	25		160	158	110		150	
Stock totals																										
package weight	kt	1	6	55	15	3	81	230	32	261	20	3	3	2	48	22	99	9	27	37	1	3	2	5	4	486
o/w cardboard / paper-based	kt	1	6	55	15	3	81	207	28	235	18	3	3	2	43	20	89	8	25	33	1	3	2	5	3	446
o/w PET (plastic)	kt	0	0	0	0	0	0	23	3	26	2	0	0	0	5	2	10	1	3	4	0	0	0	0	0	40
net lamp weight	kt	4	20	180	40	8	252	230	32	261	20	1	1	1	19	22	64	3	11	15	1	7	4	12	14	618
% package / total	%	23%	23%	23%	27%	30%	24%	50%	50%	50%	50%	86%	81%	67%	71%	50%	61%	75%	71%	72%	36%	28%	31%	30%	21%	44%
share of net lamp weight	%	0.6%	3.2%	29.2%	6.5%	1.2%	41%	37.2%	5.1%	42%	3.3%	0.1%	0.1%	0.1%	3.1%	3.6%	10%	0.5%	1.9%	2%	0.1%	1.1%	0.6%	2%	2.3%	100%
share of package weight	%	0.2%	1.3%	11.3%	3.1%	0.7%	17%	47.2%	6.5%	54%	4.2%	0.7%	0.7%	0.4%	9.9%	4.6%	20%	1.9%	5.6%	8%	0.1%	0.5%	0.4%	1%	0.8%	100%
Sales totals																										
package weight	kt	0	0	10	2	0	13	16	4	20	5	1	1	1	18	6	32	3	7	11	0	1	1	2	2	79
o/w cardboard / paper-based	kt	0	0	10	2	0	13	15	3	18	4	1	1	1	16	6	29	3	7	10	0	1	1	2	2	73
o/w PET (plastic)	kt	0	0	0	0	0	0	2	0	2	0	0	0	0	2	1	3	0	1	1	0	0	0	0	0	6
net lamp weight	kt	0	0	32	6	1	40	16	4	20	5	0	0	0	7	6	19	1	3	4	0	2	2	4	9	96
% package / total	%	23%	23%	23%	27%	30%	24%	50%	50%	50%	50%	86%	81%	67%	71%	50%	62%	75%	71%	72%	36%	28%	31%	30%	21%	45%
share of net lamp weight	%	0.2%	0.3%	33.5%	6.3%	0.9%	41%	17.0%	3.7%	21%	5.1%	0.1%	0.2%	0.4%	7.7%	6.6%	20%	1.1%	3.2%	4%	0.4%	2.3%	1.9%	5%	8.9%	100%
share of package weight	%	0.1%	0.1%	12.4%	2.9%	0.5%	16%	20.6%	4.5%	25%	6.2%	0.8%	1.3%	1.0%	23.0%	8.0%	40%	4.1%	9.4%	13%	0.3%	1.1%	1.0%	2%	2.9%	100%

Table 8 Lamp mercury contents. Upper (green) part of the table: unit data (per lamp in mg). Central (blue) part of the table: EU-28 stock 2013 totals in tonnes. Lower (yellow) part of the table: EU-28 sales 2013 totals in tonnes. The EU-28 sales and stock for 2013 are indicated on the first two lines.

Parameter	Unit	LFL T12	LFL T8h	LFL T8t	LFL T5	LFL X	Sum LFL	CFLi	CFLni	Sum CFL	HL LV R	HL LV C	HL MV C	HL MV L	HL MV E	HL MV X	Sum HL	GLS R	GLS X	Sum GLS	HPM	HPS	MH	Sum HID	LED	Sum ALL
EU-28 sales (2013)	mln	1.2	2.2	245	76	19	344	271	72	342	164	42	67	38	303	158	772	36	123	159	2.2	14	16	33	57	1706
EU-28 stock (2013)	mln	20	152	1376	501	160	2209	3827	633	4460	683	211	230	87	800	558	2569	104	457	561	6	42	37	84	95	9980
Per unit data																										
mercury content (now)	mg	8	8	3	2	2		2	2		0	0	0	0	0	0		0	0		38	18	10		0	
mercury content (lifetime yrs ago)	mg	8	8	4	3	3		4	4		0	0	0	0	0	0		0	0		38	20	10		0	
Stock totals (2013)																										
mercury content (now)	ton	0.161	1.217	4.129	1.001	0.320	6.8	7.654	1.267	8.9	0	0	0	0	0	0	0	0	0	0	0.211	0.760	0.365	1.3	0	17.1
mercury content (lifetime yrs ago)	ton	0.161	1.217	5.505	1.502	0.480	8.9	13.395	2.217	15.6	0	0	0	0	0	0	0	0	0	0	0.211	0.844	0.365	1.4	0	25.9
Sales totals (2013)																										
mercury content (now)	ton	0.009	0.017	0.736	0.151	0.039	1.0	0.541	0.143	0.7	0	0	0	0	0	0	0	0	0	0	0.085	0.251	0.164	0.5	0	2.1
mercury content (lifetime yrs ago)	ton	0.009	0.017	0.981	0.227	0.058	1.3	0.947	0.251	1.2	0	0	0	0	0	0	0	0	0	0	0.085	0.278	0.164	0.5	0	3.0

Table 9 Weights of Critical Raw Materials declared on the Ecoreports and corresponding CRM indicator (in Sb equivalent). The EU-28 stock for 2013 is indicated on the first line. Upper (green) part of the table: unit data (per lamp, in mg). Lower (blue) part of the table: EU-28 stock totals (in ton). CRM that do not appear in any of the lamp types have been removed from the table for clarity.

Parameter	Unit	LFL T12	LFL T8h	LFL T8t	LFL T5	LFL X	Sum LFL	CFLi	CFLni	Sum CFL	HL LV R	HL LV C	HL MV C	HL MV L	HL MV E	HL MV X	Sum HL	GLS R	GLS X	Sum GLS	HPM	HPS	MH	Sum HID	LED	Sum ALL
EU-28 stock (2013)	mln	20	152	1,376	501	160	2,209	3,827	633	4,460	683	211	230	87	800	558	2,569	104	457	561	6	42	37	84	95	9,980
Per unit data																										
Germanium (Ge)	mg	0	0	0	0	0		0	0		0	0	0	0	0	0		0	0		0	0	0		5.4	
Indium (In)	mg	0	0	0	0	0		0	0		0	0	0	0	0	0		0	0		0	0	0		0.0002	
Gallium (Ga)	mg	0	0	0	0	0		0	0		0	0	0	0	0	0		0	0		0	0	0		0.340	
Antimony (Sb)	mg	11	7	0	0	0		0	0		0	0	0	0	0	0		0	0		26	16	8		0	
Tungsten	mg	20	20	20	20	20		20	20		3	3	3	20	3	3		10	10		431	711	0		0	
Niobium (Nb)	mg	0	0	0	0	0		0	0		0	0	0	0	0	0		0	0		0	1450	440		0	
Rare earth elements (Sc, Y, Nd)	mg	0	0	917	560	341		420	560		0	0	0	0	0	0		0	0		140	32	0.5		0.8	
Total CRM mass	mg	31	27	937	580	361		440	580		3	3	3	20	3	3		10	10		597	2209	449		7	
CRM indicator	mg Sb eq.	15	11	32	21	14		17	21		1	1	1	4	1	1		2	2		116	218	26		100	
Total EU-28 stock																										
Germanium (Ge)	ton	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	1
Indium (In)	ton	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0000	0
Gallium (Ga)	ton	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.032	0
Antimony (Sb)	ton	0.2	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	2
Tungsten	ton	0.4	3	28	10	3	44	77	13	89	2	1	1	2	2	2	9	1	5	6	2	30	0	32	0	181
Niobium (Nb)	ton	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	61	16	77	0	77
Rare earth elements (Sc, Y, Nd)	ton	0	0	1262	280	54	1597	1607	355	1962	0	0	0	0	0	0	0	0	0	0	1	1	0.0	2	0.1	3561
Total CRM mass	ton	0.6	4	1290	290	58	1642	1684	367	2051	2	1	1	2	2	2	9	1	5	6	3	93	16	113	1	3822
CRM indicator	ton Sb eq.	0.3	2	43	10	2	58	64	13	77	0	0	0	0	0	0	2	0	1	1	1	9	1	11	10	158

3. Base case environmental impact assessment

3.1. Environmental life cycle impacts per phase

Annex C provides extracts from the EcoReports regarding the life cycle impacts per unit for all base cases. In addition, a table and a graph for each base case show the distribution of the impacts over the various phases, i.e. production, distribution, use, and end-of-life (EoL).

Table 10 through Table 13 have been elaborated based on the information in Annex C and summarize the life cycle impact shares for each phase. Values 'out-of-the-ordinary' have been highlighted. The following remarks can be made regarding these tables:

- In general, by far the major impacts derive from the use-phase and are related to the electricity consumption. The share of the use-phase in primary energy consumption is between 97 and 100% for all lamp types.

  The other comments focus on the exceptions on the above general rule.

- Water (process) is consumed in particular in the production phase. In the end-of-life phase there is a recycling credit (negative consumption) that can be higher than the consumption in production. This happens in particular for lamp types with strongly decreasing sales in the years: in these cases, the number of lamps reaching their end-of-life in 2013 is much larger than the new lamps being produced. As shown in the tables, this sometimes leads to percentages that seem strange at first sight, i.e. shares above 100% and negative shares.

- Particulate matter ('dust' in the air) does not only derive from the generation of electricity (use-phase) but also for a significant share from the distribution phase (exhaust gases from transport means). The use-phase share varies from 31% to 93%; the distribution-phase share from 7% to 67%.

- As regards the release of Heavy metals to the air, the major impact is from the use-phase, deriving from the electricity generation, but the effect of the end-of-life recycling credit is also visible in the tables.

- PAH's (Polycyclic Aromatic Hydrocarbons) are released to the air mainly during electricity generation (use-phase), but there are significant contributions also from the distribution phase (up to 12%) and the production phase (up to 16%), depending on the lamp type. Also for this parameter there are end-of-life credit effects.

- For several parameters, Compact fluorescent lamps with integrated ballast (CFLi's) have a higher influence of the production-phase than other lamp types. This is partly due to the integrated electronic ballast (higher production impact) and partly to the relatively low energy consumption throughout the product life (lower use-phase impact).

- For several parameters, LED lamps have a higher influence of the production-phase than other lamp types. This is mainly due to the integrated control gear and the heat sink (higher production impact).

Table 10 Share (% of life cycle impacts per unit) of the indicated impacts caused by the USE PHASE. Values of 90% or less are on a gold colour background; values of 110% or more on a light brown background. See text for comments.

Parameter	Unit	LFL T12	LFL T8h	LFL T8t	LFL T5	LFL X	CFLi	CFLni	HL LV R	HL LV C	HL MV C	HL MV L	HL MV E	HL MV X	GLS R	GLS X	HPM	HPS	MH	LED
Useful life (for reference)	yr	4.9	5.7	6.4	9.5	5.7	12.0	8.4	4.4	4.4	3.3	2.2	3.3	3.3	2.2	2.2	2.0	3.0	2.0	34.2
Operating Hours (for reference)	h/yr	1623	1398	2017	2099	1879	500	1197	450	450	450	450	450	450	450	450	4000	4000	4000	585
Capacity (for reference)	lm	2450	2400	2400	2275	1032	523	633	490	490	420	3000	432	420	513	513	10000	13300	13120	1000
Power (for reference)	W	35	32	30	25	12	9.5	11.5	35	35	35	250	36	35	54	54	250	140	160	12.5
Other Resources & Waste																				
Total Energy (GER)	MJ	100%	103%	100%	100%	100%	97%	99%	99%	99%	99%	100%	98%	99%	98%	99%	100%	100%	100%	99%
o/w electricity (in primary MJ)	MJ	100%	101%	100%	100%	100%	99%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	99%
Water (process)	ltr	1%	0%	1%	1%	2%	1%	1%	1%	1%	1%	1%	1%	1%	1%	4%	2%	1%	2%	1%
Water (cooling)	ltr	100%	103%	100%	100%	100%	87%	98%	99%	100%	100%	100%	98%	99%	96%	98%	100%	99%	100%	92%
Waste, non-haz./ landfill	g	100%	107%	99%	100%	99%	83%	98%	98%	98%	98%	99%	96%	97%	95%	97%	100%	99%	99%	93%
Waste, hazardous/ incinerated	g	100%	103%	100%	100%	99%	27%	99%	99%	99%	99%	100%	98%	98%	98%	99%	100%	100%	100%	54%
Emissions (Air)																				
Greenhouse Gases in GWP100	kg CO2 eq.	100%	103%	100%	100%	99%	96%	99%	98%	99%	98%	100%	98%	98%	97%	98%	100%	100%	100%	98%
Acidification, emissions	g SO2 eq.	100%	104%	100%	100%	99%	94%	99%	99%	99%	99%	100%	98%	98%	98%	98%	100%	100%	100%	97%
Volatile Organic Compounds (VOC)	g	100%	100%	100%	100%	100%	99%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Persistent Organic Pollutants (POP)	ng i-Teq	101%	112%	99%	100%	99%	83%	99%	98%	98%	98%	99%	94%	97%	96%	98%	100%	97%	98%	77%
Heavy Metals	mg Ni eq.	9716%	609%	110%	103%	113%	102%	114%	96%	96%	95%	99%	91%	94%	94%	96%	45%	562%	148%	90%
PAHs	mg Ni eq.	117%	288%	96%	97%	94%	82%	94%	92%	92%	90%	97%	83%	89%	84%	90%	99%	98%	98%	82%
Particulate Matter (PM, dust)	g	67%	83%	80%	92%	84%	40%	69%	70%	78%	72%	90%	42%	57%	31%	42%	89%	89%	93%	70%
Emissions (Water)																				
Heavy Metals	mg Hg/20	105%	170%	99%	99%	99%	65%	98%	99%	100%	99%	100%	96%	96%	98%	100%	100%	99%	99%	83%
Eutrophication	g PO4	100%	119%	99%	99%	98%	45%	91%	97%	99%	98%	99%	85%	95%	77%	83%	100%	94%	95%	65%

Table 11 Share (% of life cycle impacts per unit) of the indicated impacts caused by the DISTRIBUTION PHASE. Values of 10% or more are on a gold colour background. See text for comments.

Parameter	Unit	LFL T12	LFL T8h	LFL T8t	LFL T5	LFL X	CFLi	CFLni	HL LV R	HL LV C	HL MV C	HL MV L	HL MV E	HL MV X	GLS R	GLS X	HPM	HPS	MH	LED
Useful life (for reference)	yr	4.9	5.7	6.4	9.5	5.7	12.0	8.4	4.4	4.4	3.3	2.2	3.3	3.3	2.2	2.2	2.0	3.0	2.0	34.2
Operating Hours (for reference)	h/yr	1623	1398	2017	2099	1879	500	1197	450	450	450	450	450	450	450	450	4000	4000	4000	585
Capacity (for reference)	lm	2450	2400	2400	2275	1032	523	633	490	490	420	3000	432	420	513	513	10000	13300	13120	1000
Power (for reference)	W	35	32	30	25	12	9.5	11.5	35	35	35	250	36	35	54	54	250	140	160	12.5
Other Resources & Waste																				
Total Energy (GER)	MJ	0%	0%	0%	0%	0%	1%	0%	1%	1%	1%	0%	1%	1%	1%	1%	0%	0%	0%	0%
o/w electricity (in primary MJ)	MJ	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Water (process)	ltr	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Water (cooling)	ltr	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Waste, non-haz./ landfill	g	0%	0%	0%	0%	1%	1%	1%	1%	1%	2%	0%	2%	2%	2%	2%	0%	0%	0%	0%
Waste, hazardous/ incinerated	g	0%	0%	0%	0%	0%	0%	1%	1%	1%	1%	0%	1%	1%	1%	1%	0%	0%	0%	0%
Emissions (Air)																				
Greenhouse Gases in GWP100	kg CO2 eq.	0%	0%	0%	0%	1%	2%	1%	1%	1%	2%	0%	2%	2%	2%	2%	0%	0%	0%	0%
Acidification, emissions	g SO2 eq.	0%	0%	0%	0%	0%	1%	1%	1%	1%	1%	0%	1%	1%	1%	1%	0%	0%	0%	0%
Volatile Organic Compounds (VOC)	g	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Persistent Organic Pollutants (POP)	ng i-Teq	0%	1%	0%	0%	1%	2%	1%	2%	2%	2%	0%	2%	2%	2%	2%	0%	0%	0%	0%
Heavy Metals	mg Ni eq.	100%	6%	1%	1%	2%	5%	3%	3%	3%	4%	1%	4%	5%	5%	5%	0%	1%	0%	1%
PAHs	mg Ni eq.	3%	8%	2%	1%	4%	10%	5%	8%	7%	10%	2%	10%	10%	12%	11%	1%	1%	1%	2%
Particulate Matter (PM, dust)	g	34%	31%	20%	8%	16%	51%	29%	29%	22%	27%	10%	56%	42%	67%	57%	11%	11%	7%	20%
Emissions (Water)																				
Heavy Metals	mg Hg/20	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Eutrophication	g PO4	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Table 12 Share (% of life cycle impacts per unit) of the indicated impacts caused by the PRODUCTION PHASE. Values of 10% or more are on a gold colour background; values over 100% on a light brown background. See text for comments.

Parameter	Unit	LFL T12	LFL T8h	LFL T8t	LFL T5	LFL X	CFLi	CFLni	HL LV R	HL LV C	HL MV C	HL MV L	HL MV E	HL MV X	GLS R	GLS X	HPM	HPS	MH	LED
Useful life (for reference)	yr	4.9	5.7	6.4	9.5	5.7	12.0	8.4	4.4	4.4	3.3	2.2	3.3	3.3	2.2	2.2	2.0	3.0	2.0	34.2
Operating Hours (for reference)	h/yr	1623	1398	2017	2099	1879	500	1197	450	450	450	450	450	450	450	450	4000	4000	4000	585
Capacity (for reference)	lm	2450	2400	2400	2275	1032	523	633	490	490	420	3000	432	420	513	513	10000	13300	13120	1000
Power (for reference)	W	35	32	30	25	12	9.5	11.5	35	35	35	250	36	35	54	54	250	140	160	12.5
Other Resources & Waste																				
Total Energy (GER)	MJ	0%	0%	0%	0%	0%	2%	0%	0%	0%	0%	0%	1%	0%	1%	1%	0%	0%	0%	1%
o/w electricity (in primary MJ)	MJ	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%
Water (process)	ltr	83%	5%	118%	104%	229%	110%	124%	126%	130%	127%	133%	117%	133%	146%	375%	195%	152%	179%	129%
Water (cooling)	ltr	0%	0%	0%	0%	0%	15%	3%	1%	0%	0%	0%	2%	1%	5%	4%	0%	1%	1%	10%
Waste, non-haz./ landfill	g	1%	0%	0%	0%	0%	18%	1%	1%	0%	0%	0%	3%	1%	4%	3%	0%	1%	1%	8%
Waste, hazardous/ incinerated	g	0%	0%	0%	0%	0%	82%	0%	0%	0%	0%	0%	1%	0%	1%	1%	0%	0%	0%	62%
Emissions (Air)																				
Greenhouse Gases in GWP100	kg CO2 eq.	0%	0%	0%	0%	0%	2%	0%	0%	0%	0%	0%	1%	0%	1%	1%	0%	0%	0%	2%
Acidification, emissions	g SO2 eq.	0%	0%	0%	0%	0%	5%	1%	0%	0%	0%	0%	1%	1%	1%	1%	0%	0%	0%	4%
Volatile Organic Compounds (VOC)	g	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Persistent Organic Pollutants (POP)	ng i-Teq	1%	1%	0%	0%	1%	18%	0%	0%	0%	0%	0%	5%	1%	3%	3%	1%	6%	5%	36%
Heavy Metals	mg Ni eq.	44%	2%	0%	0%	1%	29%	1%	1%	0%	0%	0%	6%	2%	3%	3%	0%	32%	7%	12%
PAHs	mg Ni eq.	11%	16%	3%	2%	6%	9%	1%	0%	0%	0%	1%	9%	1%	9%	8%	0%	2%	3%	25%
Particulate Matter (PM, dust)	g	1%	1%	0%	0%	1%	9%	2%	1%	0%	0%	0%	2%	1%	2%	2%	0%	1%	1%	11%
Emissions (Water)																				
Heavy Metals	mg Hg/20	2%	3%	1%	1%	2%	39%	2%	2%	0%	0%	0%	4%	7%	3%	3%	1%	2%	2%	24%
Eutrophication	g PO4	3%	2%	1%	1%	2%	60%	10%	3%	2%	2%	2%	18%	6%	26%	22%	1%	11%	10%	39%

Table 13 Share (% of life cycle impacts per unit) of the indicated impacts caused by the END-OF-LIFE PHASE. Values of -10% or lower are on a gold colour background; values below -100% on a light brown background. See text for comments.

Parameter	Unit	LFL T12	LFL T8h	LFL T8t	LFL T5	LFL X	CFLi	CFLni	HL LV R	HL LV C	HL MV C	HL MV L	HL MV E	HL MV X	GLS R	GLS X	HPM	HPS	MH	LED
Useful life (for reference)	yr	4.9	5.7	6.4	9.5	5.7	12.0	8.4	4.4	4.4	3.3	2.2	3.3	3.3	2.2	2.2	2.0	3.0	2.0	34.2
Operating Hours (for reference)	h/yr	1623	1398	2017	2099	1879	500	1197	450	450	450	450	450	450	450	450	4000	4000	4000	585
Capacity (for reference)	lm	2450	2400	2400	2275	1032	523	633	490	490	420	3000	432	420	513	513	10000	13300	13120	1000
Power (for reference)	W	35	32	30	25	12	9.5	11.5	35	35	35	250	36	35	54	54	250	140	160	12.5
Other Resources & Waste																				
Total Energy (GER)	MJ	-1%	-3%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
o/w electricity (in primary MJ)	MJ	0%	-1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Water (process)	ltr	-184%	-105%	-19%	-5%	-131%	-11%	-25%	-28%	-31%	-28%	-34%	-18%	-34%	-47%	-278%	-97%	-54%	-80%	-31%
Water (cooling)	ltr	0%	-3%	0%	0%	0%	-1%	0%	0%	0%	0%	0%	0%	0%	-1%	-2%	0%	0%	0%	-2%
Waste, non-haz./ landfill	g	-1%	-8%	0%	0%	0%	-2%	0%	0%	0%	0%	0%	0%	0%	-1%	-2%	0%	0%	0%	-2%
Waste, hazardous/ incinerated	g	0%	-3%	0%	0%	0%	-9%	0%	0%	0%	0%	0%	0%	0%	0%	-1%	0%	0%	0%	-15%
Emissions (Air)																				
Greenhouse Gases in GWP100	kg CO2 eq.	-1%	-4%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Acidification, emissions	g SO2 eq.	-1%	-4%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	-1%
Volatile Organic Compounds (VOC)	g	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Persistent Organic Pollutants (POP)	ng i-Teq	-2%	-14%	0%	0%	0%	-3%	0%	0%	0%	0%	0%	-1%	0%	-2%	-3%	-1%	-2%	-2%	-13%
Heavy Metals	mg Ni eq.	-9959%	-717%	-11%	-4%	-16%	-36%	-18%	0%	0%	0%	0%	-1%	-1%	-2%	-3%	-146%	-495%	-55%	-3%
PAHs	mg Ni eq.	-31%	-411%	-1%	0%	-4%	-1%	0%	0%	0%	0%	0%	-2%	0%	-5%	-10%	0%	-1%	-2%	-9%
Particulate Matter (PM, dust)	g	-2%	-14%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	-1%	0%	0%	0%	-2%
Emissions (Water)																				
Heavy Metals	mg Hg/20	-7%	-73%	0%	0%	-2%	-4%	-1%	-1%	0%	0%	0%	-1%	-3%	-2%	-3%	0%	-1%	-1%	-7%
Eutrophication	g PO4	-3%	-22%	0%	0%	-1%	-4%	-1%	0%	0%	0%	0%	-3%	0%	-3%	-6%	0%	-4%	-5%	-4%

3.2. Environmental life cycle impacts per lamp

Three tables are presented at the end of this paragraph:

- Table 14 presents for each base case the life cycle impact per product, over its lifetime. This table has been compiled from the total values (sum of all phases) in the corresponding table of the EcoReports for the single base cases (as reported in Annex C).
- Table 15 is similar to Table 14, but per year, i.e. values have been divided by the product lifetime (see the first line of Table 13 for the useful life).
- Table 16 shows the environmental impacts per Mega-lumen-hour (Mlmh). This is not a standard EcoReport table, but for light sources, with large differences in lifetimes and capacities between the base cases, it is a better basis for comparison. The values in this table derive from those in Table 14 dividing them by (lifetime(yr)*operating hours (h/yr)*capacity(lm) / 1,000,000). For the latter data, see e.g. the first lines of Table 13.

The following remarks can be made regarding these tables:

- The weights in the tables are gross lamp weights, inclusive packaging materials. By far the largest share of weight is in the EcoReport 'Misc' category, consisting mainly of 'glass-for-lamps' and of 'cardboard' for the packaging.

- As regards the end-of-life weight distribution, that is reported in Table 14 below the total weight line, the stock-effect is clearly visible for many lamp types that have decreasing sales in recent years, e.g. LFL T12 and T8 halo-phosphor, GLS and HPM-lamps. For some lamp types this stock-effect leads to negative values for the emission of heavy metals to air.

- The total energy (GER in MJ) consists almost entirely of electricity. The highest values in Table 14 (over lifetime) are found for HID-lamps, that have high power and long operating times. At first sight the energy value for LEDs in Table 14 may seem surprisingly high, but this is due to the very long useful life. The per-year value in Table 15 is among the lowest for all lamp types, as expected.

- The consumption of process water is negligible as compared to that of cooling water.

- The amount of non-hazardous waste is far higher than the amount of (incinerated) hazardous waste.

- Most emissions to air and water are closely related to the amount of energy consumed, and consequently the highest values in Table 14 and Table 15 are found for HID-lamps.

- Table 15 clearly identifies LEDs and CFLs with integrated control gear as the lamp types with the lowest per-year energy consumption. Please note that LEDs are 1000 lm (12.5W) lamps that burn 585 h/a, while CFLi's are 523 lm (9.5W) lamps that burn 500 h/a. This explains why CFLi's appear better than LEDs in this table.

- Table 16 shows a high material resource consumption (g/Mlmh) for GLS-lamps and for halogen lamps that aim to substitute these lamps, see also Figure 3. The weight of these lamps (including packaging) is high when considering their low lifetime and operating hours, and moderate capacity.

- As regards total energy, Table 16 identifies LFL T5 and HPS lamps as the ones with the lowest specific consumption (in terms of MJ/Mlmh), see also Figure 4. The highest values are found for GLS, HL-MV and HL-LV lamps, which reflects their low efficacy.
  Note that the specific energy for LEDs (114 MJ/Mlmh) reflects the state of 2013, with an average efficacy of 80 lm/W. At 120 lm/W (expected to be reached around 2016) this would reduce to 76 MJ/Mlmh, which would be lower than for all other lamp types.

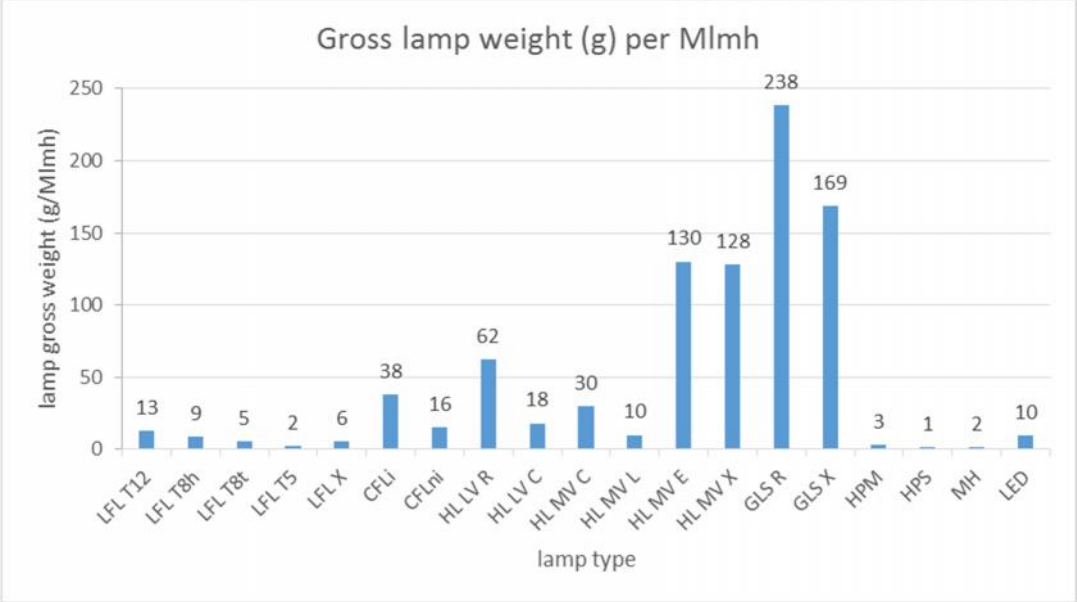


Figure 3 Gross lamp weight (including packaging materials) in g/Mlmh, for all base cases, see Table 16 for the underlying data.

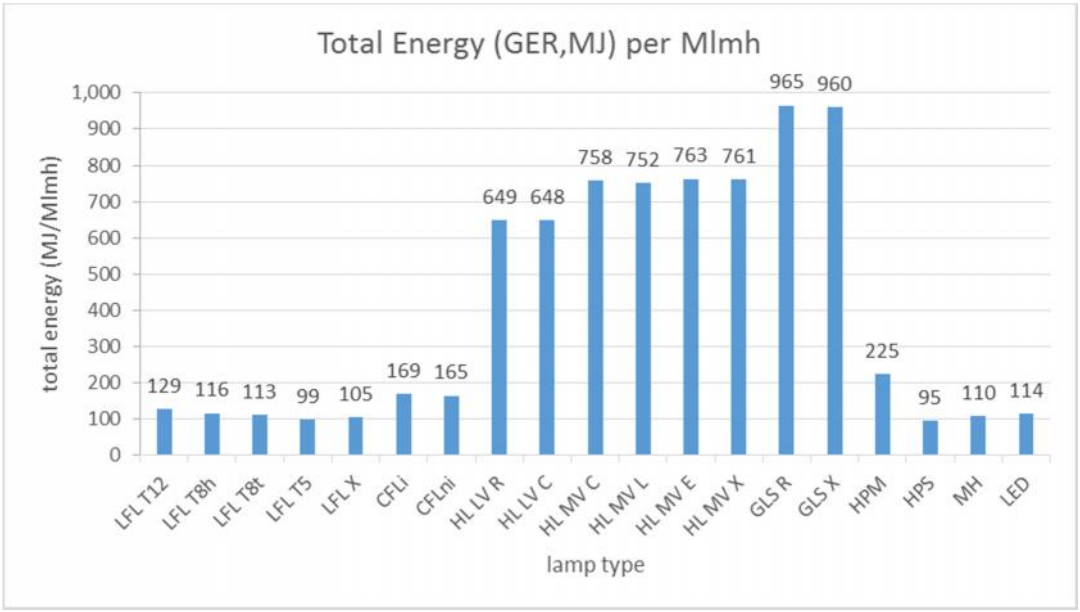


Figure 4 Total primary energy consumption in MJ/Mlmh, for all base cases, see Table 16 for the underlying data. Many other impact parameters, e.g. greenhouse gas and acidification emissions, are strongly related to energy consumption and show similar distributions when graphed.

Table 14 Life cycle impact per product, total over all phases and over lifetime. See tables in Annex C for details per phase.

Parameter	Unit	LFL T12	LFL T8h	LFL T8t	LFL T5	LFL X	CFLi	CFLni	HL LV R	HL LV C	HL MV C	HL MV L	HL MV E	HL MV X	GLS R	GLS X	HPM	HPS	MH	LED
Materials																				
Bulk Plastics	g	0	0	0	0	0	18	16	3	2	2	2	6	4	9	6	0	0	0	4
TecPlastics	g	1	1	1	0	0	2	1	0	0	0	0	0	0	2	1	0	0	0	30
Ferro	g	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	4	1
Non-ferro	g	6	4	4	2	2	2	1	1	0	0	0	1	2	1	1	17	34	24	78
Coating	g	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2	0
Electronics	g	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0	9	4	2	27
Misc.	g	247	165	165	106	64	82	80	57	16	17	27	76	74	109	77	226	169	128	53
Total weight	g	254	169	169	109	66	119	98	60	18	19	30	83	80	121	86	252	215	160	192
o/w EoL disposal	g	504	3 058	25	5	34	15	24	20	8	7	11	19	30	68	106	122	54	51	43
o/w EoL recycling	g	1 426	8 620	70	14	97	36	57	35	14	12	20	34	55	117	186	358	185	172	149
o/w EoL stock	g	-1 676	-11 510	75	90	-64	68	17	5	-4	-1	-2	31	-6	-64	-206	-228	-23	-63	0
Other Resources & Waste																				
Total Energy (GER)	MJ	2 519	2 237	3 519	4 507	1 193	529	1 044	630	629	473	2 233	489	475	490	488	18 012	15 138	11 532	2 282
o/w electricity (in primary MJ)	MJ	2 517	2 272	3 511	4 501	1 188	517	1 036	624	624	468	2 228	482	468	482	481	18 002	15 127	11 524	2 263
Water (process)	ltr	-2	-20	1	1	0	3	0	0	0	0	0	0	0	0	0	1	1	1	6
Water (cooling)	ltr	112	100	156	200	53	26	47	28	28	21	99	22	21	22	22	800	676	514	108
Waste, non-haz./ landfill	g	1 296	1 105	1 818	2 327	618	320	544	328	327	246	1 154	259	248	260	255	9 288	7 847	5 971	1 246
Waste, hazardous/ incinerated	g	40	35	56	71	19	31	16	10	10	7	35	8	7	8	8	284	239	182	67
Emissions (Air)																				
Greenhouse Gases in GWP100	kg CO2 eq.	108	95	150	193	51	23	45	27	27	20	95	21	20	21	21	769	646	492	98
Acidification, emissions	g SO2 eq.	476	419	665	852	226	103	198	119	119	89	422	93	90	93	92	3 403	2 863	2 180	438
Volatile Organic Compounds (VOC)	g	56	51	78	101	27	12	23	14	14	10	50	11	10	11	11	402	338	257	50
Persistent Organic Pollutants (POP)	ng i-Teq	6	5	8	11	3	1	2	1	1	1	5	1	1	1	1	42	37	28	7
Heavy Metals	mg Ni eq.	0	-4	32	44	11	5	9	7	7	5	23	5	5	5	5	-402	27	79	25
PAHs	mg Ni eq.	5	-2	9	11	3	1	3	2	2	1	5	1	1	1	1	42	36	27	6
Particulate Matter (PM, dust)	g	15	11	18	20	6	5	6	4	3	3	10	5	3	6	5	81	68	50	13
Emissions (Water)																				
Heavy Metals	mg Hg/20	10	6	15	19	5	3	5	3	3	2	10	2	2	2	2	78	66	50	12
Eutrophication	g PO4	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	3	3	2	1

Table 15 Life cycle impact per product, total over all phases, per year.

Parameter	Unit	LFL T12	LFL T8h	LFL T8t	LFL T5	LFL X	CFLi	CFLni	HL LV R	HL LV C	HL MV C	HL MV L	HL MV E	HL MV X	GLS R	GLS X	HPM	HPS	MH	LED
Materials																				
Bulk Plastics	g	0	0	0	0	0	2	2	1	0	0	1	2	1	4	3	0	0	0	0
TecPlastics	g	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1
Ferro	g	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0
Non-ferro	g	1	1	1	0	0	0	0	0	0	0	0	0	0	1	0	9	11	12	2
Coating	g	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
Electronics	g	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	4	1	1	1
Misc.	g	50	29	26	11	11	7	10	13	4	5	12	23	22	49	35	113	56	64	2
Total weight	g	52	30	26	11	11	10	12	14	4	6	13	25	24	55	39	126	72	80	6
o/w EoL disposal	g	102	534	4	1	6	1	3	4	2	2	5	6	9	31	48	61	18	25	1
o/w EoL recycling	g	289	1 506	11	1	17	3	7	8	3	4	9	10	17	53	84	179	62	86	4
o/w EoL stock	g	-340	-2 011	12	9	-11	6	2	1	-1	0	-1	9	-2	-29	-94	-114	-8	-31	0
Other Resources & Waste																				
Total Energy (GER)	MJ	511	391	546	473	204	44	125	143	143	143	1 015	148	144	223	222	9 006	5 046	5 766	67
o/w electricity (in primary MJ)	MJ	511	397	545	472	203	43	124	142	142	142	1 013	146	142	219	219	9 001	5 042	5 762	66
Water (process)	ltr	0	-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Water (cooling)	ltr	23	17	24	21	9	2	6	6	6	6	45	7	6	10	10	400	225	257	3
Waste, non-haz./ landfill	g	263	193	282	244	106	27	65	75	74	75	525	79	75	118	116	4 644	2 616	2 985	36
Waste, hazardous/ incinerated	g	8	6	9	7	3	3	2	2	2	2	16	2	2	4	4	142	80	91	2
Emissions (Air)																				
Greenhouse Gases in GWP100	kg CO2 eq.	22	17	23	20	9	2	5	6	6	6	43	6	6	10	10	385	215	246	3
Acidification, emissions	g SO2 eq.	96	73	103	89	39	9	24	27	27	27	192	28	27	42	42	1 702	954	1 090	13
Volatile Organic Compounds (VOC)	g	11	9	12	11	5	1	3	3	3	3	23	3	3	5	5	201	113	129	1
Persistent Organic Pollutants (POP)	ng i-Teq	1	1	1	1	0	0	0	0	0	0	2	0	0	1	1	21	12	14	0
Heavy Metals	mg Ni eq.	0	-1	5	5	2	0	1	1	1	2	10	2	2	2	2	-201	9	40	1
PAHs	mg Ni eq.	1	0	1	1	1	0	0	0	0	0	2	0	0	1	1	21	12	14	0
Particulate Matter (PM, dust)	g	3	2	3	2	1	0	1	1	1	1	4	1	1	3	2	40	23	25	0
Emissions (Water)																				
Heavy Metals	mg Hg/20	2	1	2	2	1	0	1	1	1	1	4	1	1	1	1	39	22	25	0
Eutrophication	g PO4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	1	0

Table 16 Life cycle impact per product, total over all phases, per Mega-lumen-hours (Mlmh).

Parameter	Unit	LFL T12	LFL T8h	LFL T8t	LFL T5	LFL X	CFLi	CFLni	HL LV R	HL LV C	HL MV C	HL MV L	HL MV E	HL MV X	GLS R	GLS X	HPM	HPS	MH	LED
Materials																				
Bulk Plastics	g	0	0	0	0	0	6	3	3	2	2	1	9	6	18	12	0	0	0	0
TecPlastics	g	0	0	0	0	0	1	0	0	0	0	0	0	0	3	3	0	0	0	1
Ferro	g	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Non-ferro	g	0	0	0	0	0	1	0	1	0	0	0	2	2	3	2	0	0	0	4
Coating	g	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Electronics	g	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	1
Misc.	g	13	9	5	2	6	26	13	58	16	27	9	118	118	214	152	3	1	1	3
Total weight	g	13	9	5	2	6	38	16	62	18	30	10	130	128	238	169	3	1	2	10
o/w EoL disposal	g	26	159	1	0	3	5	4	20	8	12	4	29	49	133	210	2	0	0	2
o/w EoL recycling	g	73	449	2	0	9	11	9	36	14	20	7	52	88	231	365	4	1	2	7
o/w EoL stock	g	-86	-599	2	2	-6	22	3	6	-4	-1	-1	48	-9	-126	-406	-3	0	-1	0
Other Resources & Waste																				
Total Energy (GER)	MJ	129	116	113	99	105	169	165	649	648	758	752	763	761	965	960	225	95	110	114
o/w electricity (in primary MJ)	MJ	128	118	113	99	105	165	164	643	643	750	750	751	751	949	948	225	95	110	113
Water (process)	ltr	0	-1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Water (cooling)	ltr	6	5	5	4	5	8	7	29	29	33	33	34	34	44	43	10	4	5	5
Waste, non-haz./ landfill	g	66	58	58	51	54	102	86	338	337	395	389	404	398	512	503	116	49	57	62
Waste, hazardous/ incinerated	g	2	2	2	2	2	10	3	10	10	12	12	12	12	15	15	4	1	2	3
Emissions (Air)																				
Greenhouse Gases in GWP100	kg CO2 eq.	5	5	5	4	5	7	7	28	28	33	32	33	33	42	41	10	4	5	5
Acidification, emissions	g SO2 eq.	24	22	21	19	20	33	31	123	123	143	142	144	144	183	182	43	18	21	22
Volatile Organic Compounds (VOC)	g	3	3	3	2	2	4	4	14	14	17	17	17	17	21	21	5	2	2	3
Persistent Organic Pollutants (POP)	ng i-Teq	0	0	0	0	0	0	0	2	2	2	2	2	2	2	2	1	0	0	0
Heavy Metals	mg Ni eq.	0	0	1	1	1	2	1	7	7	8	8	8	8	10	10	-5	0	1	1
PAHs	mg Ni eq.	0	0	0	0	0	0	0	2	2	2	2	2	2	3	2	1	0	0	0
Particulate Matter (PM, dust)	g	1	1	1	0	1	2	1	4	3	4	3	7	5	12	9	1	0	0	1
Emissions (Water)																				
Heavy Metals	mg Hg/20	1	0	0	0	0	1	1	3	3	3	3	3	3	4	4	1	0	0	1
Eutrophication	g PO4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

3.3. EU-28 total environmental impacts of new sold lamps and of the stock

Three tables are included at the end of this paragraph:

- Table 17 presents for each base case the EU-28 total environmental impact of new sold lamps in 2013, over their lifetime. This table has been compiled from the total values (sum of all phases) in the corresponding tables of the EcoReports [28].
- Table 18 presents for each base case the EU-28 total environmental impact of the installed lamp stock in 2013. This table has been compiled from the total values (sum of all phases) in the corresponding tables of the EcoReports. The material resource data in this table are identical to those in the preceding table as they still regard the production of the lamps sold in 2013.
- Table 19 is a summary of Table 18 for the main lamp technology types, and additionally compares the EU-28 total environmental impact of lamps with the EU-28 total environmental impact from all activities and products.

The following remarks can be made regarding these tables:

- The total weight of lamps sold in the EU-28 in 2013, including their packaging, is 174 kt [29]. The major part (146 kt) is from the EcoReport category 'Misc' (glass-for-lamps and cardboard for the packaging). Of the total amount, 123 kt is recycled [30] and 55 kt is disposed of (landfill).

- The subdivision of the 174 kt over the main lamp technology types is: 52 kt LFLs (mainly for LFL T8 tri-phosphor), 51 kt halogen lamps, 39 kt CFLs (mainly for CFLi), 15 kt GLS, 11 kt LEDs and 6 kt HID-lamps (Figure 5).

- Lamps sold in the EU-28 in 2013 consume 2570 PJ of primary energy over their lifetime. Slightly less than half of this energy is used for LFLs.

- The EU-28 2013 installed lamp stock consumed 2398 PJ of primary energy in that year (corresponding to 265 TWh of electricity [31] [32]). The subdivision of this energy over the main technology types is: 1093 PJ/a for LFLs, 474 PJ/a for HID lamps, 449 PJ/a for halogen lamps, 247 PJ/a for CFLs, 124 PJ/a for GLS and 11 PJ/a for LED (Figure 6).

- The EU-28 2013 installed lamp stock accounts for 9.46% of the total EU-28 annual electricity consumption (considering the reference values of the EcoReport), for 3.17% of the total primary energy, and for 2.03% of the greenhouse gas emissions and acidification emissions.

- The contribution of the EU-28 2013 installed lamp stock to the EU-28 annual total is between 0.3% and 0.6% for Volatile Organic Compounds (VOC), Persistent Organic Pollutants (POP), Heavy metals emission to air, Polycyclic Aromatic Hydrocarbons (PAH), and Particulate Matter (PM, dust).

[28] These tables are not included in this report but will be made separately available on the project website http://ecodesign-lightsources.eu/documents

[29] Mt= megatonnes (metric)= 10^9 kg; kt= kilotonnes (metric)= 10^9g; ton(metric)= 10^9g; g=gram= 10^9 ng ; mln. M3 = million cubic metres= 10^9 litres; PJ= petaJoules= 10^9 MJ (megajoules) = 10^{15} Joules.

[30] Including incineration, with or without heat recovery

[31] It has been verified that the electricity consumption for the use-phase corresponds to the one from MELISA presented in the Task 3 report.

[32] This is exclusive energy for external control gears, energy consumption in stand-by, energy consumption by special purpose lamps, and energy consumption of the so called GLS- and Tungsten stock (see MELISA description in the Task 2 report).

- The contribution of the EU-28 2013 installed lamp stock to the EU-28 annual total is less than 0.1% for consumption of plastics, metals and water, for the production of waste, and for emissions to water.

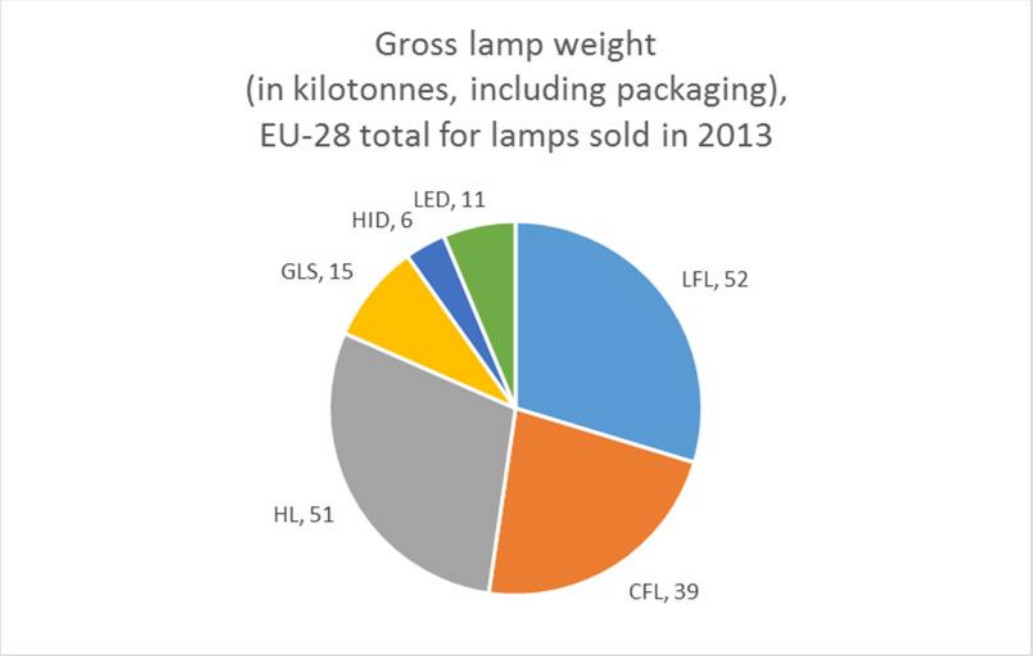


Figure 5 EU-28 total gross lamp weight (including packaging) for lamps sold in 2013, in kilotonnes (metric), see Table 17 for the underlying data. Total is 174 kt.

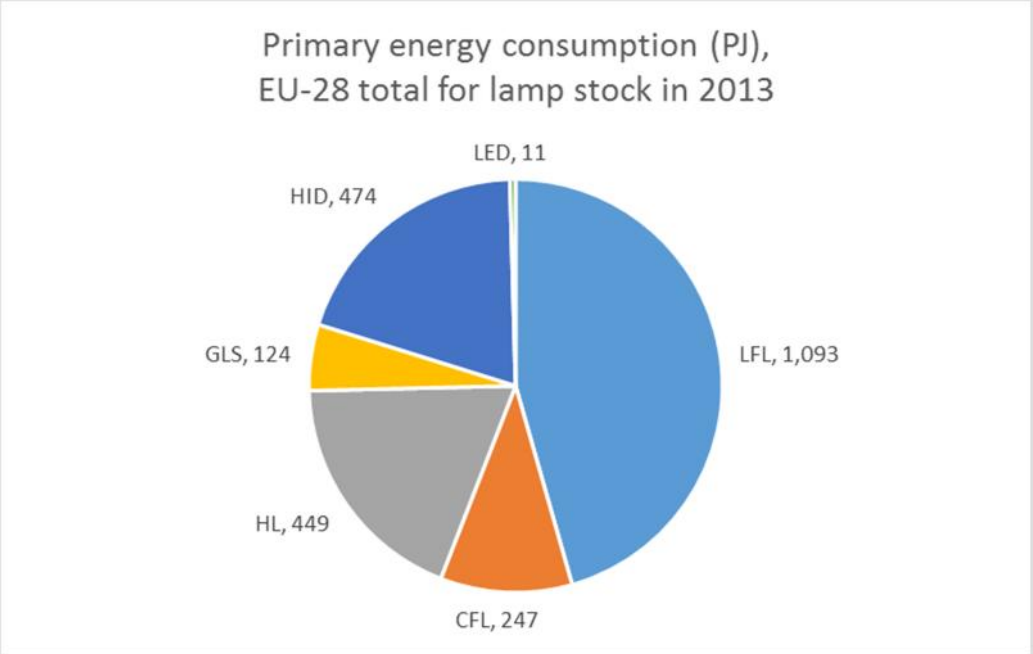


Figure 6 EU-28 total primary energy consumption for the 2013 lamp stock, in PJ/year, see Table 18 for the underlying data. Total is 2398 PJ (corresponding to 265 TWh of electricity). This is 3.17% of the overall EU-28 energy consumption, or 9.48% of the overall EU-28 electricity consumption.

Table 17 EU-28 total impact of new lamps sold in 2013, over their lifetime.

Parameter	Unit	LFL T12	LFL T8h	LFL T8t	LFL T5	LFL X	Sum LFL	CFLi	CFLni	Sum CFL	HL LV R	HL LV C	HL MV C	HL MV L	HL MV E	HL MV X	Sum HL	GLS R	GLS X	Sum GLS	HPM	HPS	MH	Sum HID	LED	Total
Materials																										
Bulk Plastics	kt	0	0	0	0	0	0	5	1	6	0	0	0	0	2	1	3	0	1	1	0	0	0	0	0	11
TecPlastics	kt	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3
Ferro	kt	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Non-ferro	kt	0	0	1	0	0	1	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	4	8
Coating	kt	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Electronics	kt	0	0	0	0	0	0	4	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	6
Misc.	kt	0	0	40	8	1	50	22	6	28	9	1	1	1	23	12	47	4	10	13	1	2	2	5	3	146
Total weight	kt	0	0	41	8	1	52	32	7	39	10	1	1	1	25	13	51	4	11	15	1	3	3	6	11	174
o/w EoL disposal	kt	1	7	6	0	1	14	4	2	6	3	0	0	0	6	5	15	2	13	16	0	1	1	2	2	55
o/w EoL recycling	kt	2	19	17	1	2	40	10	4	14	6	1	1	1	10	9	27	4	23	27	1	3	3	6	9	123
o/w EoL stock	kt	-2	-25	18	7	-1	-3	18	1	20	1	0	0	0	9	-1	9	-2	-25	-28	-1	0	-1	-2	0	-4
Resources & Waste																										
Total Energy (GER)	PJ	3	5	863	341	23	1235	143	75	218	103	26	32	85	148	75	469	18	60	78	40	211	189	440	130	2570
o/w electricity (prim. PJ)	PJ	3	5	861	340	23	1233	140	74	214	102	26	31	85	146	74	464	17	59	77	40	211	189	439	129	2556
Water (process)	mln. m3	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Water (cooling)	mln. m3	0	0	38	15	1	55	7	3	11	5	1	1	4	7	3	21	1	3	3	2	9	8	20	6	115
Waste, non-haz./ landfill	kt	2	2	446	176	12	638	87	39	126	54	14	16	44	79	39	246	9	31	41	21	109	98	228	71	1349
Waste, haz./ incinerated	kt	0	0	14	5	0	19	8	1	10	2	0	0	1	2	1	7	0	1	1	1	3	3	7	4	49
Emissions (Air)																										
GHG in GWP100	mt CO2eq.	0	0	37	15	1	53	6	3	9	4	1	1	4	6	3	20	1	3	3	2	9	8	19	6	110
Acidification, emissions	kt SO2 eq.	1	1	163	64	4	233	28	14	42	20	5	6	16	28	14	89	3	11	15	8	40	36	83	25	487
VOC	kt	0	0	19	8	1	28	3	2	5	2	1	1	2	3	2	10	0	1	2	1	5	4	10	3	57
POP	g i-Teq	0	0	2	1	0	3	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	1	0	6
Heavy Metals	ton Ni eq.	0	0	8	3	0	11	1	1	2	1	0	0	1	2	1	5	0	1	1	-1	0	1	1	1	21
PAHs	ton Ni eq.	0	0	2	1	0	3	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	1	0	6
Particulate (PM, dust)	kt	0	0	4	1	0	6	1	0	2	1	0	0	0	1	1	3	0	1	1	0	1	1	2	1	14
Emissions (Water)																										
Heavy Metals	ton Hg/20	0	0	4	1	0	5	1	0	1	0	0	0	0	1	0	2	0	0	0	0	1	1	2	1	12
Eutrophication	kt PO4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Table 18 EU-28 total impact of lamp stock in 2013

Parameter	Unit	LFL T12	LFL T8h	LFL T8t	LFL T5	LFL X	Sum LFL	CFLi	CFLni	Sum CFL	HL LV R	HL LV C	HL MV C	HL MV L	HL MV E	HL MV X	Sum HL	GLS R	GLS X	Sum GLS	HPM	HPS	MH	Sum HID	LED	Total
Materials																										
Bulk Plastics	kt	0	0	0	0	0	0	5	1	6	0	0	0	0	2	1	3	0	1	1	0	0	0	0	0	11
TecPlastics	kt	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3
Ferro	kt	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Non-ferro	kt	0	0	1	0	0	1	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	4	8
Coating	kt	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Electronics	kt	0	0	0	0	0	0	4	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	6
Misc.	kt	0	0	40	8	1	50	22	6	28	9	1	1	1	23	12	47	4	10	13	1	2	2	5	3	146
Total weight	kt	0	0	41	8	1	52	32	7	39	10	1	1	1	25	13	51	4	11	15	1	3	3	6	11	174
o/w EoL disposal	kt	1	7	6	0	1	14	4	2	6	3	0	0	0	6	5	15	2	13	16	0	1	1	2	2	55
o/w EoL recycling	kt	2	19	17	1	2	40	10	4	14	6	1	1	1	10	9	27	4	23	27	1	3	3	6	9	123
o/w EoL stock	kt	-2	-25	18	7	-1	-3	18	1	20	1	0	0	0	9	-1	9	-2	-25	-28	-1	0	-1	-2	0	-4
Resources & Waste																										
Total Energy (GER)	PJ	10	61	752	237	33	1093	168	79	247	98	30	33	88	119	80	449	23	101	124	50	213	211	474	11	2398
o/w electricity (prim. PJ)	PJ	10	61	750	237	32	1091	165	79	243	97	30	33	88	117	79	444	23	100	123	50	213	210	473	9	2383
Water (process)	mln. m3	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Water (cooling)	mln. m3	0	3	33	11	1	49	8	4	12	4	1	1	4	5	4	20	1	5	6	2	10	9	21	1	108
Waste, non-haz./ landfill	kt	5	32	389	122	17	565	101	41	142	51	16	17	46	64	42	235	12	53	65	26	111	109	246	10	1264
Waste, haz./ incinerated	kt	0	1	12	4	1	17	10	1	11	2	0	1	1	2	1	7	0	2	2	1	3	3	7	2	47
Emissions (Air)																										
GHG in GWP100	mt CO2eq.	0	3	32	10	1	47	7	3	11	4	1	1	4	5	3	19	1	4	5	2	9	9	20	0	103
Acidification, emissions	kt SO2 eq.	2	12	142	45	6	207	33	15	48	19	6	6	17	23	15	85	4	19	23	9	40	40	90	3	455
VOC	kt	0	1	17	5	1	24	4	2	5	2	1	1	2	3	2	10	1	2	3	1	5	5	11	0	53
POP	g i-Teq	0	0	2	1	0	3	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	1	1	0	6
Heavy Metals	ton Ni eq.	0	1	8	2	0	11	2	1	3	1	0	0	1	1	1	5	0	1	1	1	2	2	5	0	25
PAHs	ton Ni eq.	0	0	2	1	0	3	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	1	1	0	6
Particulate (PM, dust)	kt	0	0	4	1	0	5	1	0	2	1	0	0	0	1	1	3	0	1	1	0	1	1	2	0	14
Emissions (Water)																										
Heavy Metals	ton Hg/20	0	0	3	1	0	5	1	0	1	0	0	0	0	1	0	2	0	0	1	0	1	1	2	0	11
Eutrophication	kt PO4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Table 19 EU-28 total impact of stock in 2013, summary and comparison with EU-28 overall totals. The last column provides the share of total EU-28 impact that derives from lamps.

Parameter	Unit	Sum LFL	Sum CFL	Sum HL	Sum GLS	Sum HID	LED	Total EU28 lamps	Total EU28 overall	% impact of lamps
Materials										
Plastics	kt	0.2	6.6	3.2	1.3	0.0	1.9	13.2	48 000	0.03%
Ferrous metals	kt	0.0	0.0	0.1	0.0	0.1	0.0	0.3	206 000	0.00%
Non-ferrous metals	kt	1.1	0.7	0.7	0.2	0.9	4.4	8.0	20 000	0.04%
Other Resources & Waste										
Total Energy (GER)	PJ	1 093	247	449	124	474	11	2 398	75 697	3.17%
o/w electricity	TWh	121	27	49	14	53	1.03	265	2 800	9.46%
Water	mln.m3	0	1	0	0	0	0	2	247 000	0.00%
Waste, non-haz./ landfill	Mt	1	0	0	0	0	0	1	2 947	0.04%
Waste, hazardous/ incinerated	kt	0	0	0	0	0	0	0	89	0.05%
Emissions (Air)										
Greenhouse Gases in GWP100	mt CO2 eq.	47	11	19	5	20	0.5	103	5 054	2.03%
Acidification, emissions	kt SO2eq.	207	48	85	23	90	3	455	22 432	2.03%
Volatile Organic Compounds (VOC)	kt	24	5	10	3	11	0	53	8 951	0.59%
Persistent Organic Pollutants (POP)	g i-Teq.	3	1	1	0	1	0	6	2 212	0.27%
Heavy Metals	ton Ni eq.	11	3	5	1	5	0	25	5 903	0.43%
PAHs	ton Ni eq.	3	1	1	0	1	0	6	1 369	0.45%
Particulate Matter (PM, dust)	kt	5	2	3	1	2	0	14	3 522	0.39%
Emissions (Water)										
Heavy Metals	ton Hg/20	5	1	2	1	2	0	11	12 853	0.09%
Eutrophication	kt PO4	0	0	0	0	0	0	1	900	0.06%

4. Base case life cycle costs and EU-28 total expenditure

Table 20 provides the Life Cycle Costs (LCC) per product, and the total annual (2013) expenditure for lighting in the EU-28. The data include 20% VAT for the residential sector and exclude VAT for the non-residential sector. The expenditure excludes external control gears and luminaires. Electricity costs are for the electricity consumption considered in the EcoReports [32].

The lowest life cycle costs per lamp are for non-halogen filament lamps (GLS), around 11 euros (Table 20 central part). HID-lamps have by far the highest LCC: above 200 euros. This is mainly due to their high powers and long operating hours (high electricity cost).

For light sources, the LCC does not provide a good basis for comparison of the base cases, because there are large differences in lifetime operating hours and in capacities between the various lamp types. Therefore the study team also elaborated LCC values normalized to a million Mega-lumen-hour (Mlmh) [33], dividing the LCC by (lifetime(yr)*operating hours (h/yr)*capacity(lm) / 1,000,000).

As shown in Figure 7, the most uneconomical in 2013 were the halogen and incandescent lamps with a specific LCC of 16-23 euros/Mlmh for most types. The CFLs have a specific LCC of 5.6-6.2 euros/Mlmh and LEDs had a specific LCC of 3.4 euros/Mlmh. The most economical were still linear fluorescent and high intensity discharge (HID) lamps in the range of 1.6 to 3 euros per Mlmh, but especially for HID lamps the low colour rendering (CRI in Ra) makes them unsuitable for most indoor applications.

Note that the LCC values represent a 2013 snapshot, assuming an average efficacy of 80 lm/W, a price of €23.3/klm and 20 000 h useful life for LED lamps. Over the last two years LED lamps have advanced significantly in terms of higher efficiency and lower purchase prices. Following the proposal for LED projections in Task 4, the LCC of LED-lamps in 2015 is 2.8 euros/Mlmh (100 lm/W, €19/klm) and will be 1.3 euros/Mlmh in 2020 (175 lm/W, €7.5/klm).

The total consumer expenditure for lighting in 2013 is 54.8 billion euro (Table 20 bottom part), of which 67% are electricity costs. LFLs account for 38% of the total expenditure. The upper part of Figure 8 shows the subdivision of the EU-28 total expenditure over purchase costs (product price), installation costs, electricity costs, and repair and maintenance costs. The lower part of the same figure provides the subdivision over the main lamp technologies.

[33] 1 Mlmh is e.g. a 1000 lumen lamp with a useful life of 1000 operating hours or a 500 lumen lamp with 2000 operating hours, etc.

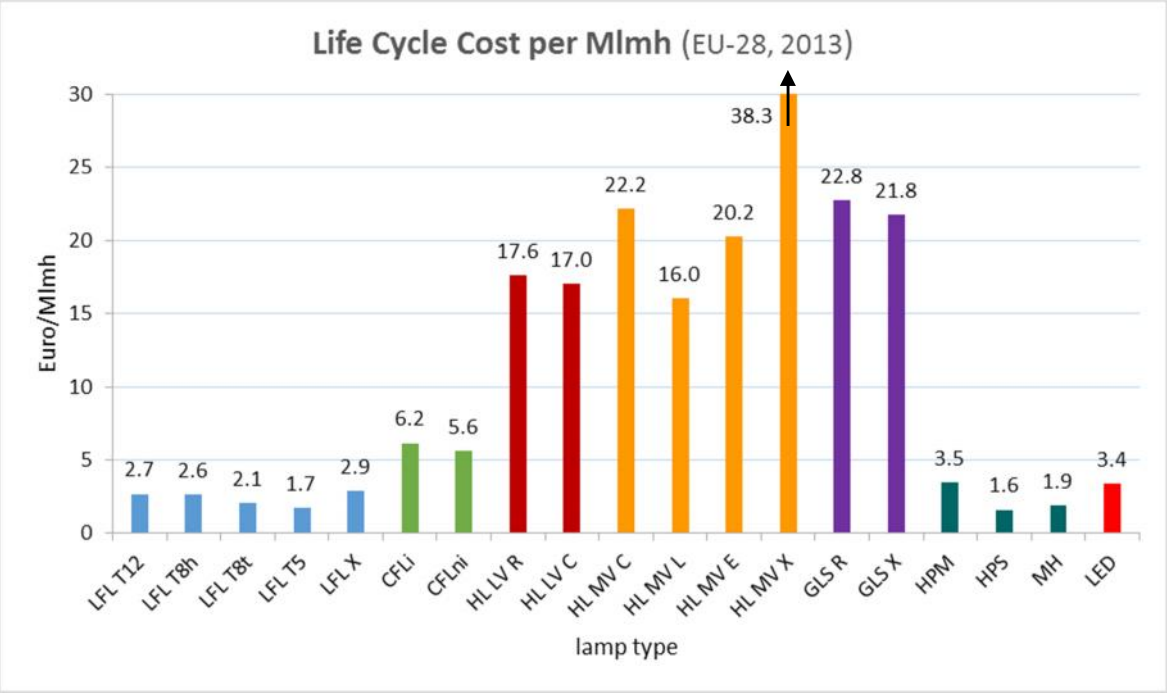
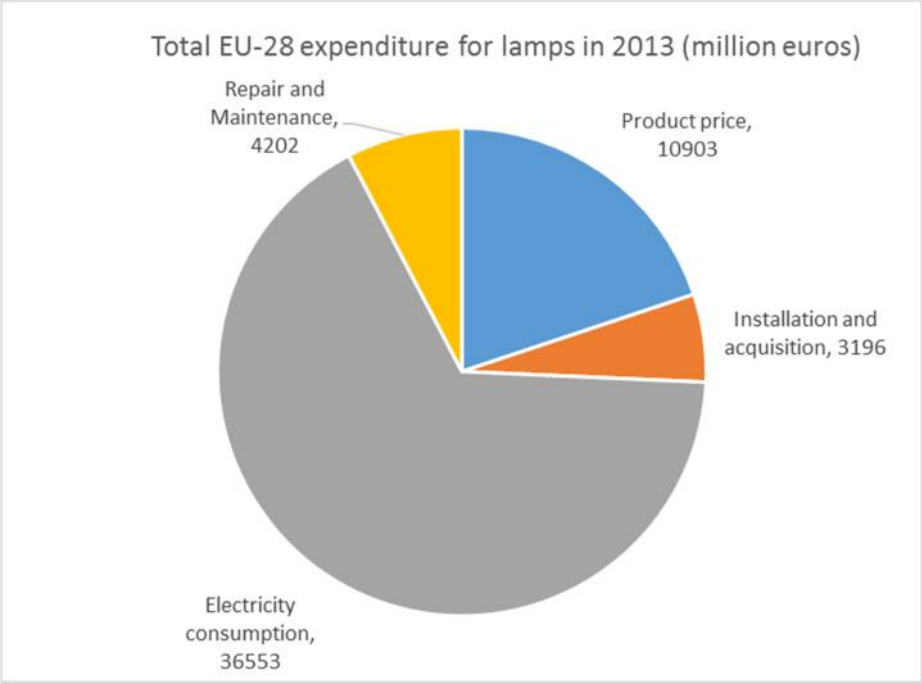


Figure 7 Life Cycle Cost per lamp per Mlmh, see Table 20 for underlying data.

Legend:
LFL : linear fluorescent lamp type T12, T8 halo-phosphor, T8 tri-phosphor, new T5 or other (X);
CFL : compact fluorescent with (i) or without (ni) integrated gear;
HL LV: low voltage halogen lamp, reflector (R) or capsules (C);
HL MV: mains voltage halogen lamp with G9 cap (C), R7 linear cap (L), E14/E17 cap (E) or other (X);
GLS: incandescent lamps with (R) or without (X) reflector;
HPM, HPS and MH: High Intensity Discharge lamps with respectively mercury, sodium or metal halides;
LED: light emitting diode lamp.



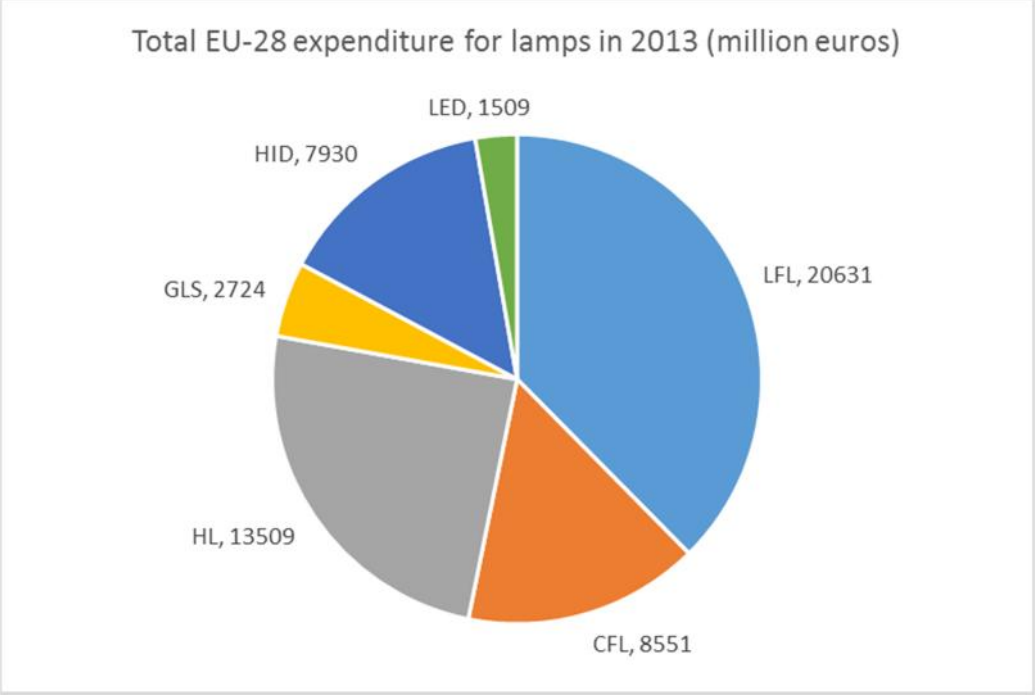


Figure 8 Subdivision of the total EU-28 expenditure for lamps in 2013. Top: shares of product purchase price, installation costs, electricity costs and repair and maintenance costs. Bottom: shares of major lamp technologies in total expenditure. Prices inclusive 20% VAT for residential sector; exclusive VAT for non-residential sector.

Table 20 Life Cycle Costs per product (over their lifetime and per Mlmh) and Total annual expenditure (2013) in the EU-28. Inclusive 20% VAT for residential sector; exclusive VAT for non-residential sector.

Parameter	Unit	LFL T12	LFL T8h	LFL T8t	LFL T5	LFL X	Sum LFL	CFLi	CFLni	Sum CFL	HL LV R	HL LV C	HL MV C	HL MV L	HL MV E	HL MV X	Sum HL	GLS R	GLS X	Sum GLS	HPM	HPS	MH	Sum HID	LED	Total
for reference																										
Useful life	yr	4.9	5.7	6.4	9.5	5.9		12	8.4		4.4	4.4	3.3	2.2	3.3	3.3		2.2	2.2		2	3	2		34.19	
Operating Hours	h/yr	1623	1398	2017	2099	1879		500	1197		450	450	450	450	450	450		450	450		4000	4000	4000		585	
Capacity	lm	2450	2400	2400	2275	1032		523	633		490	490	420	3000	432	420		513	513		10000	13300	13120		1000	
Power	W	35	32	30	25	12		9.5	11.5		35	35	35	250	36	35		54	54		250	140	160		12.5	
per product (LCC)																										
Product price	euros	8.5	8.5	8.5	8.0	8.0		4.9	4.7		3.7	3.1	3.7	3.1	2.5	13.7		1.3	0.8		17.0	27.0	27.0		23.3	
Installation and acquisition	euros	5.8	5.8	5.8	5.8	5.8		0.7	4.3		0.4	0.4	0.4	0.4	0.4	0.4		0.4	0.4		9.3	9.3	9.3		1.1	
Electricity consumption	euros	36.7	35.3	47.6	61.0	16.5		9.2	15.9		12.3	12.3	9.2	43.8	9.5	9.2		9.5	9.5		238.0	199.9	152.3		41.3	
Repair and Maintenance	euros	1.4	1.2	2.6	4.1	2.1		4.4	10.7		0.8	0.8	0.6	0.4	0.6	0.6		0.4	0.4		12.3	18.5	12.3		1.9	
Total product LCC	euros	52.4	50.8	64.5	78.9	32.4		19.3	35.6		17.1	16.5	13.8	47.6	13.0	23.9		11.6	11.1		276.6	254.7	200.9		67.5	
LCC/Mlmh	euros	2.7	2.6	2.1	1.7	2.9		6.2	5.6		17.6	17.0	22.2	16.0	20.2	38.3		22.8	21.8		3.5	1.6	1.9		3.4	
EU-28 annual expenditure (2013)																										
Purchase (Product price)	mln euros	10	18	2 090	607	155	2 880	1 329	333	1 662	600	128	244	116	769	2 173	4 030	47	100	147	38	376	442	855	1 328	10 903
Installation and acquisition	mln euros	7	13	1 413	436	111	1 980	200	310	510	61	16	25	14	112	59	285	13	46	59	21	129	151	301	60	3 196
Electricity consumption	mln euros	150	939	10 160	3 205	451	14 905	2 945	1 203	4 148	1 904	589	641	1 733	2 294	1 555	8 717	447	1 966	2 413	662	2 813	2 780	6 254	115	36 553
Repair and Maintenance	mln euros	6	33	555	215	58	866	1 416	814	2 230	127	39	43	16	148	103	476	19	85	105	34	260	225	520	5	4 202
Total expenditure	mln euros	172	1 003	14 218	4 463	775	20 631	5 890	2 660	8 551	2 692	773	952	1 879	3 323	3 890	13 509	527	2 197	2 724	754	3 578	3 598	7 930	1 509	54 854

References

See footnotes in text

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Acronyms

a	Annum, year
B2B	Business-to-Business (non-residential trading)
B2C	Business-to-Consumer (residential trading)
BC	Base Case (as used in MEErP)
bn / bln	Billion (10^9)
BoM	Bill Of Materials
CCT	Correlated Colour Temperature
CDR	Commission Delegated Regulation
CFL	Compact fluorescent lamps
CFLi	CFL with integrated ballast
CFLni	CFL without integrated ballast
CRI	Colour Rendering Index
DLS	Directional light sources
E14, E27	Screw-type lamp caps for general purpose lamp
EC	European Commission
EoL	End-of-Life
ErP	Energy related Product
EU	European Union
G4, GY6.35	Low-voltage halogen lamp types, 2 pin cap, single ended
G9	Mains-voltage halogen lamp, 2-pin cap, single ended

GaN	Gallium Nitride
GLS	General Lighting Service (a.k.a. incandescent lamp)
h	Hour
Hg	Mercury
HID	High-Intensity Discharge
HL	Halogen
HPM	High-Pressure Mercury
HPS	High-Pressure Sodium
klm	Kilo lumen (see lm)
kt	Kilotonnes (1000 metric tons = million kg)
LCA	Life Cycle Analysis
LCC	Life Cycle Cost
LED	Light Emitting Diode
LFL	Linear Fluorescent Lamp
lm	lumen
LV	Low Voltage (typical 12V)
max	maximum
MELISA	Model for European Light Sources Analysis
MEErP	Methodology for Ecodesign of Energy-related Products
MH	Metal Halide
min	minimum
mn / mln	Million (10^6)
Mt	Mega tonnes (10^9 kg)
MV	Mains Voltage (typical 230V)
NDLS	Non-directional light sources
OJ	Official Journal of the European Union
PJ	Pico-Joules (=10^9 MJ =10^{15} J)
par	paragraph
-R	Reflector
R7s	Mains voltage linear halogen lamp, double ended
Ra	Colour rendering index, unit
ref	reference
TWh	Tera Watt hour (10^12)
V	Volt
VHK	Van Holsteijn en Kemna
VITO	Vlaamse Instelling voor Technologisch Onderzoek
W	Watt
yr	year

Annex A. Statement of contractor on right to delivered result

I, Dirk Fransaer, representing the “Consortium of VITO NV, VHK BV, Viegand & MaagØe ApS, Wuppertal Institute for Climate, Environment and Energy GmbH, and ARMINES”, party to the contract ‘Preparatory Study on Lighting Systems for Ecodesign and/or Energy Labelling Requirements (‘Lot 8/9/19’), specific contract No. ENER/C3/2012-418 LOT1/07/SI2.668526 implementing framework contract No. ENER/C3/2012-418-Lot 1’, warrant that the Contractor holds full right to the delivered Task 5 report of the ‘Preparatory Study on Lighting Systems for Ecodesign and/or Energy Labelling Requirements (‘Lot 8/9/19’)’, which is free of any claims, including claim of the creators who transferred all their rights and will be paid as agreed within 30 days from the receipt of confirmation of acceptance of work.

Mol, Belgium,
Date:
Signature:

Dirk Fransaer
Managing Director VITO NV

Annex B. Description of MEErP Task 5

The MEErP [34] prescribes the following topics to be addressed in Task 5, Environment & Economics:

From MEErP part 1 (general):

Task 5 requires that one or more average EU product (s) have to be defined or a representative product category as the "Base-case" for the whole of the EU-27 has to be chosen. On this Base-Case most of the environmental and Life Cycle Cost analyses will be built throughout the rest of the study.

The Base-Case is a conscious abstraction of reality, necessary one for practical reasons. Having said that, the question if this abstraction leads to inadmissible conclusions for certain market segments will be addressed in the impact- and sensitivity analysis.

The description of the Base-Case is the synthesis of the results of Tasks 1 to 4 and the point-of-reference for tasks 6 (improvement potential) and 7 (policy, scenario, impact and sensitivity analysis).

From MEErP part 1 (specific):

5 ENVIRONMENT & ECONOMICS

5.1 Product-specific inputs

Choose from the previous tasks the most appropriate information

From all tasks 1 to 4:

Definition of the base case(s) (from all previous Tasks 1 to 4)
with per Base Case:

Task 1: The most appropriate test standard for performance and consumption data

Task 2: EU-27 annual unit sales 2010
EU-27 unit stock 2010
Purchase price. the installation costs (specify end-of-life disposal costs comprised in product price)
Repair and maintenance costs
Unitary rates for energy, water and/or other consumables
Discount, inflation, interest rates to be applied
Product service life

Task 3: Annual resources consumption (energy, water, consumables, from Task 3.1) and emissions caused during product life (from Task 3.2);
Product use & stock life, if appropriate (i.e. if deviates from product service life)
As appropriate, multiplier(s) to transform standard test data to real-life data
Average user demand/ load
Collection rate at end-of-life (per fraction if applicable)

Task4: Product weight and Bill-of-Materials (BOM), preferably in EcoReport format (from Task 4)
Primary scrap production during sheet metal manufacturing (avg. EU);[12]
Volume and weight of the packaged product avg. EU;
Selected EU scenario at end-of-life of materials flow for:

- o Disposal (landfill, pyrolytic incineration);
- o Thermal Recycling (non-hazardous incineration optimised for energy recovery);
- o Re-use or materials recycling scenario.

[34] MEErP 2011, Methodology for Ecodesign of Energy-related Products, part 1: Methods and part 2: Environmental policies and data, René Kemna (VHK) November 28th 2011

5.2 Base-Case Environmental Impact Assessment.

Using the EcoReport and the above inputs calculate emission/resources categories in MEErP format for:

- Raw Materials Use and Manufacturing;
- Distribution;
- Use phase;
- End-of-Life Phase.

Furthermore, if more than one type of resource is used in the use phase, make a split-up between resources and their individual impacts.

5.3 Base-Case Life Cycle Costs for consumer

Combining the results from tasks 2 and 3 for the Real-Life Base-Case determine the Life Cycle Costs

LCC = PP + PWF * OE + EoL, where LCC is Life Cycle Costs, PP is the purchase price, OE is the operating expense, PWF (Present Worth Factor) is PWF= {1 – 1/(1+ r) N }/r , in which N is the product life and r is the discount rate minus the growth rate of running cost components (e.g. energy, water rates) and EoL the End-of-Life costs

5.4 EU Totals

Aggregate the Real-Life Base-Case environmental impact data and the Life Cycle Cost data (subtask 5.3 and 5.4) to EU-27 level, using stock and market data from task 2, indicating

5.4.1. The life cycle environmental impact and total LCC of the new products designed in 2010 or most recent year for which there are reliable date (this relates to a period of 2010 up to 2010+product life);

5.4.2 The annual (2010) impact of production, use and (estimated) disposal of the product group, both in terms of the annual environmental impacts and the annual monetary costs for consumers.

Annex C. Life cycle impacts per lamp

This annex provides for each base case:

- Table taken from the Ecoreport showing the Life Cycle Impact per unit
- Table derived from the Ecoreport showing the percentage of impact per phase
- Figure visualizing the percentage of impact per phase

Note that the comma (,) is used as 1000-separator in the tables. The dot (.) is the decimal separator.

Table 21 Life Cycle Impact (per unit) of LFL T12

Nr	Life cycle Impact per product:	Reference year	Author
0	LFL T12	2013	vhk, izm

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Stock	
	Materials	unit									
1	Bulk Plastics	g			0		0	0	0	0	0
2	TecPlastics	g			1		0	2	3	-5	0
3	Ferro	g			0		0	0	0	0	0
4	Non-ferro	g			6		0	2	45	-41	0
5	Coating	g			0		0	0	0	0	0
6	Electronics	g			0		0	0	0	0	0
7	Misc.	g			245		2	499	1,378	-1,630	0
8	Extra	g			0		0	0	0	0	0
9	Auxiliaries	g			0		0	0	0	0	0
10	Refrigerant	g			0		0	0	0	0	0
	Total weight	g			252		3	504	1,426	-1,676	0
	Other Resources & Waste							debet	credit		
11	Total Energy (GER)	MJ	6	0	6	6	2,520	1	-14		2,519
12	of which, electricity (in primary MJ)	MJ	3	0	3	0	2,520	0	-6		2,517
13	Water (process)	ltr	2	0	2	0	0	0	-3		-2
14	Water (cooling)	ltr	0	0	0	0	112	0	0		112
15	Waste, non-haz./ landfill	g	8	1	9	5	1,299	3	-19		1,296
16	Waste, hazardous/ incinerated	g	0	0	0	0	40	0	0		40
	Emissions (Air)										
17	Greenhouse Gases in GWP100	kg CO2 eq.	0	0	0	0	108	0	-1		108
18	Acidification, emissions	g SO2 eq.	1	0	1	1	476	0	-3		476
19	Volatile Organic Compounds (VOC)	g	0	0	0	0	56	0	0		56
20	Persistent Organic Pollutants (POP)	ng i-Teq	0	0	0	0	6	0	0		6
21	Heavy Metals	mg Ni eq.	0	0	0	0	25	5	-31		0
22	PAHs	mg Ni eq.	1	0	1	0	6	0	-2		5
23	Particulate Matter (PM, dust)	g	0	0	0	5	10	0	0		15
	Emissions (Water)										
24	Heavy Metals	mg Hg/20	0	0	0	0	11	0	-1		10
25	Eutrophication	g PO4	0	0	0	0	0	0	0		0

Table 22 Life Cycle Impact (per unit) of LFL T12, percentages per phase

	Production	Distribution	Use	EoL
Total Energy (GER)	0%	0%	100%	-1%
of which, electricity (in primary MJ)	0%	0%	100%	0%
Water (process)	83%	0%	1%	-184%
Water (cooling)	0%	0%	100%	0%
Waste, non-haz./ landfill	1%	0%	100%	-1%
Waste, hazardous/ incinerated	0%	0%	100%	0%
Greenhouse Gases in GWP100	0%	0%	100%	-1%
Acidification, emissions	0%	0%	100%	-1%
Volatile Organic Compounds (VOC)	0%	0%	100%	0%
Persistent Organic Pollutants (POP)	1%	0%	101%	-2%
Heavy Metals (air)	44%	100%	9716%	-9959%
PAHs	11%	3%	117%	-31%
Particulate Matter (PM, dust)	1%	34%	67%	-2%
Heavy Metals (water)	2%	0%	105%	-7%
Eutrophication	3%	0%	100%	-3%

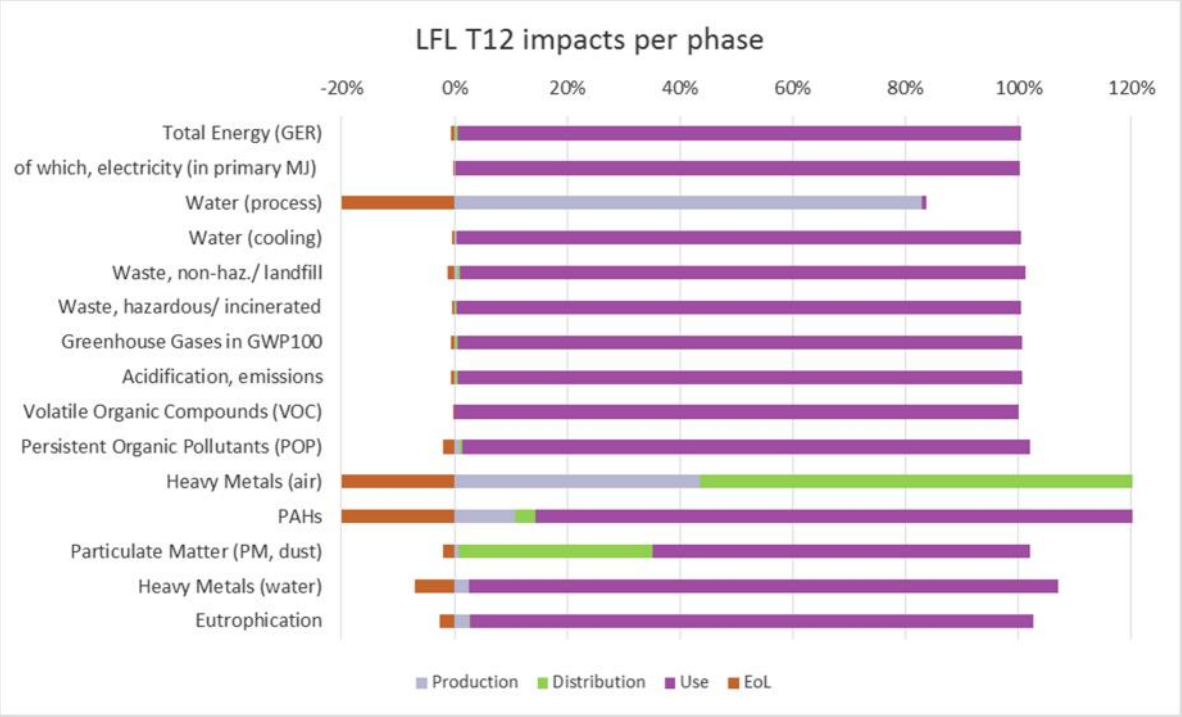

Table 23 Life Cycle Impact (per unit) of LFL T8h

Nr	Life cycle Impact per product:	Reference year	Author
0	LFL T8 halo-phosphor	2013	vhk, izm

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Stock	
	Materials	unit									
1	Bulk Plastics	g			0		0	0	0	0	0
2	TecPlastics	g			1		0	15	20	-34	0
3	Ferro	g			0		0	0	0	0	0
4	Non-ferro	g			4		0	12	236	-245	0
5	Coating	g			0		0	0	0	0	0
6	Electronics	g			0		0	0	0	0	0
7	Misc.	g			163		2	3,031	8,364	-11,230	0
8	Extra	g			0		0	0	0	0	0
9	Auxiliaries	g			0		0	0	0	0	0
10	Refrigerant	g			0		0	0	0	0	0
	Total weight	g			167		2	3,058	8,620	-11,510	0
	Other Resources & Waste							debet	credit		
11	Total Energy (GER)	MJ	4	0	4	6	2,304	4	-81		2,237
12	of which, electricity (in primary MJ)	MJ	2	0	2	0	2,304	0	-34		2,272
13	Water (process)	ltr	1	0	1	0	0	0	-21		-20
14	Water (cooling)	ltr	0	0	0	0	102	0	-3		100
15	Waste, non-haz./ landfill	g	5	0	5	5	1,187	15	-108		1,105
16	Waste, hazardous/ incinerated	g	0	0	0	0	36	0	-1		35
	Emissions (Air)										
17	Greenhouse Gases in GWP100	kg CO2 eq.	0	0	0	0	98	0	-4		95
18	Acidification, emissions	g SO2 eq.	1	0	1	1	435	0	-18		419
19	Volatile Organic Compounds (VOC)	g	0	0	0	0	51	0	0		51
20	Persistent Organic Pollutants (POP)	ng i-Teq	0	0	0	0	5	0	-1		5
21	Heavy Metals	mg Ni eq.	0	0	0	0	23	5	-32		-4
22	PAHs	mg Ni eq.	0	0	0	0	5	0	-8		-2
23	Particulate Matter (PM, dust)	g	0	0	0	3	9	0	-2		11
	Emissions (Water)										
24	Heavy Metals	mg Hg/20	0	0	0	0	10	0	-4		6
25	Eutrophication	g PO4	0	0	0	0	0	0	0		0

Table 24 Life Cycle Impact (per unit) of LFL T8h, percentages per phase

	Production	Distribution	Use	EoL
Total Energy (GER)	0%	0%	103%	-3%
of which, electricity (in primary MJ)	0%	0%	101%	-1%
Water (process)	5%	0%	0%	-105%
Water (cooling)	0%	0%	103%	-3%
Waste, non-haz./ landfill	0%	0%	107%	-8%
Waste, hazardous/ incinerated	0%	0%	103%	-3%
Greenhouse Gases in GWP100	0%	0%	103%	-4%
Acidification, emissions	0%	0%	104%	-4%
Volatile Organic Compounds (VOC)	0%	0%	100%	0%
Persistent Organic Pollutants (POP)	1%	1%	112%	-14%
Heavy Metals (air)	2%	6%	609%	-717%
PAHs	16%	8%	288%	-411%
Particulate Matter (PM, dust)	1%	31%	83%	-14%
Heavy Metals (water)	3%	0%	170%	-73%
Eutrophication	2%	0%	119%	-22%

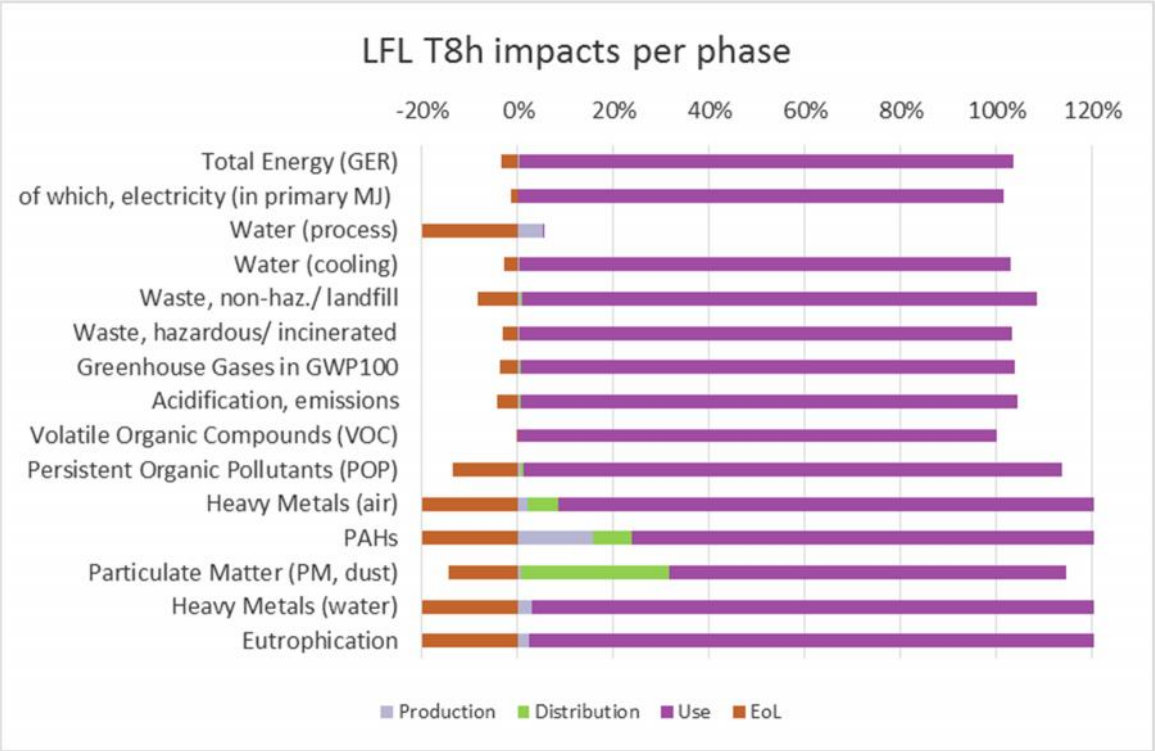

Table 25 Life Cycle Impact (per unit) of LFL T8t

Nr	Life cycle Impact per product:	Reference year	Author
0	LFL T8 tri-phosphor	2013	vhk, izm

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Stock	
	Materials	unit									
1	Bulk Plastics	g			0		0	0	0	0	0
2	TecPlastics	g			1		0	0	0	0	0
3	Ferro	g			0		0	0	0	0	0
4	Non-ferro	g			4		0	0	2	2	0
5	Coating	g			0		0	0	0	0	0
6	Electronics	g			0		0	0	0	0	0
7	Misc.	g			163		2	24	68	73	0
8	Extra	g			0		0	0	0	0	0
9	Auxiliaries	g			0		0	0	0	0	0
10	Refrigerant	g			0		0	0	0	0	0
	Total weight	g			167		2	25	70	75	0
	Other Resources & Waste							debet	credit		
11	Total Energy (GER)	MJ	4	0	4	6	3,510	0	-1		3,519
12	of which, electricity (in primary MJ)	MJ	2	0	2	0	3,510	0	0		3,511
13	Water (process)	ltr	1	0	1	0	0	0	0		1
14	Water (cooling)	ltr	0	0	0	0	156	0	0		156
15	Waste, non-haz./ landfill	g	5	0	5	5	1,809	0	-1		1,818
16	Waste, hazardous/ incinerated	g	0	0	0	0	55	0	0		56
	Emissions (Air)										
17	Greenhouse Gases in GWP100	kg CO2 eq.	0	0	0	0	150	0	0		150
18	Acidification, emissions	g SO2 eq.	1	0	1	1	663	0	0		665
19	Volatile Organic Compounds (VOC)	g	0	0	0	0	78	0	0		78
20	Persistent Organic Pollutants (POP)	ng i-Teq	0	0	0	0	8	0	0		8
21	Heavy Metals	mg Ni eq.	0	0	0	0	35	1	-4		32
22	PAHs	mg Ni eq.	0	0	0	0	8	0	0		9
23	Particulate Matter (PM, dust)	g	0	0	0	3	14	0	0		18
	Emissions (Water)										
24	Heavy Metals	mg Hg/20	0	0	0	0	15	0	0		15
25	Eutrophication	g PO4	0	0	0	0	1	0	0		1

Table 26 Life Cycle Impact (per unit) of LFL T8t, percentages per phase

	Production	Distribution	Use	EoL
Total Energy (GER)	0%	0%	100%	0%
of which, electricity (in primary MJ)	0%	0%	100%	0%
Water (process)	118%	0%	1%	-19%
Water (cooling)	0%	0%	100%	0%
Waste, non-haz./ landfill	0%	0%	99%	0%
Waste, hazardous/ incinerated	0%	0%	100%	0%
Greenhouse Gases in GWP100	0%	0%	100%	0%
Acidification, emissions	0%	0%	100%	0%
Volatile Organic Compounds (VOC)	0%	0%	100%	0%
Persistent Organic Pollutants (POP)	0%	0%	99%	0%
Heavy Metals (air)	0%	1%	110%	-11%
PAHs	3%	2%	96%	-1%
Particulate Matter (PM, dust)	0%	20%	80%	0%
Heavy Metals (water)	1%	0%	99%	0%
Eutrophication	1%	0%	99%	0%

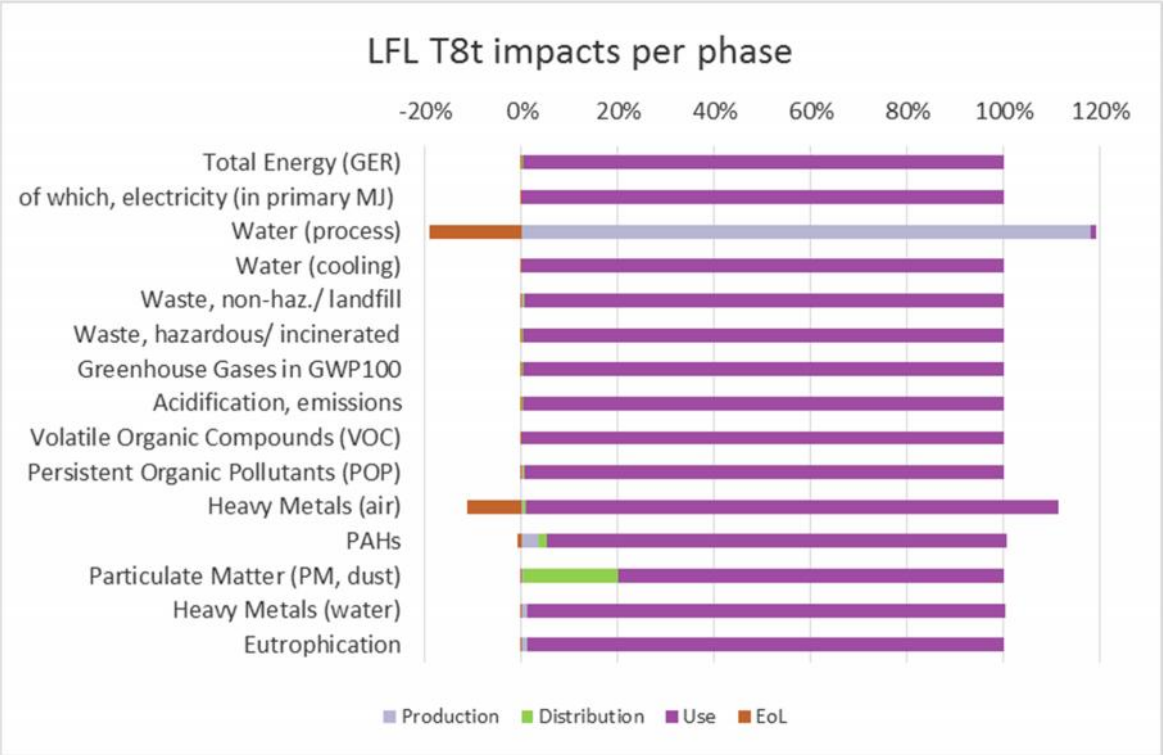

Table 27 Life Cycle Impact (per unit) of LFL T5

Nr	Life cycle Impact per product:	Reference year	Author
0	LFL T5	2013	vhk, izm

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Stock	
	Materials	unit									
1	Bulk Plastics	g			0		0	0	0	0	0
2	TecPlastics	g			0		0	0	0	0	0
3	Ferro	g			0		0	0	0	0	0
4	Non-ferro	g			2		0	0	0	2	0
5	Coating	g			0		0	0	0	0	0
6	Electronics	g			0		0	0	0	0	0
7	Misc.	g			105		1	5	13	88	0
8	Extra	g			0		0	0	0	0	0
9	Auxiliaries	g			0		0	0	0	0	0
10	Refrigerant	g			0		0	0	0	0	0
	Total weight	g			108		1	5	14	90	0
	Other Resources & Waste							debet	credit		
11	Total Energy (GER)	MJ	2	0	3	5	4,500	0	0		4,507
12	of which, electricity (in primary MJ)	MJ	1	0	1	0	4,500	0	0		4,501
13	Water (process)	ltr	1	0	1	0	0	0	0		1
14	Water (cooling)	ltr	0	0	0	0	200	0	0		200
15	Waste, non-haz./ landfill	g	3	0	4	5	2,319	0	0		2,327
16	Waste, hazardous/ incinerated	g	0	0	0	0	71	0	0		71
	Emissions (Air)										
17	Greenhouse Gases in GWP100	kg CO2 eq.	0	0	0	0	192	0	0		193
18	Acidification, emissions	g SO2 eq.	1	0	1	1	850	0	0		852
19	Volatile Organic Compounds (VOC)	g	0	0	0	0	101	0	0		101
20	Persistent Organic Pollutants (POP)	ng i-Teq	0	0	0	0	11	0	0		11
21	Heavy Metals	mg Ni eq.	0	0	0	0	46	0	-2		44
22	PAHs	mg Ni eq.	0	0	0	0	11	0	0		11
23	Particulate Matter (PM, dust)	g	0	0	0	2	18	0	0		20
	Emissions (Water)										
24	Heavy Metals	mg Hg/20	0	0	0	0	19	0	0		19
25	Eutrophication	g PO4	0	0	0	0	1	0	0		1

Table 28 Life Cycle Impact (per unit) of LFL T5, percentages per phase

	Production	Distribution	Use	EoL
Total Energy (GER)	0%	0%	100%	0%
of which, electricity (in primary MJ)	0%	0%	100%	0%
Water (process)	104%	0%	1%	-5%
Water (cooling)	0%	0%	100%	0%
Waste, non-haz./ landfill	0%	0%	100%	0%
Waste, hazardous/ incinerated	0%	0%	100%	0%
Greenhouse Gases in GWP100	0%	0%	100%	0%
Acidification, emissions	0%	0%	100%	0%
Volatile Organic Compounds (VOC)	0%	0%	100%	0%
Persistent Organic Pollutants (POP)	0%	0%	100%	0%
Heavy Metals (air)	0%	1%	103%	-4%
PAHs	2%	1%	97%	0%
Particulate Matter (PM, dust)	0%	8%	92%	0%
Heavy Metals (water)	1%	0%	99%	0%
Eutrophication	1%	0%	99%	0%

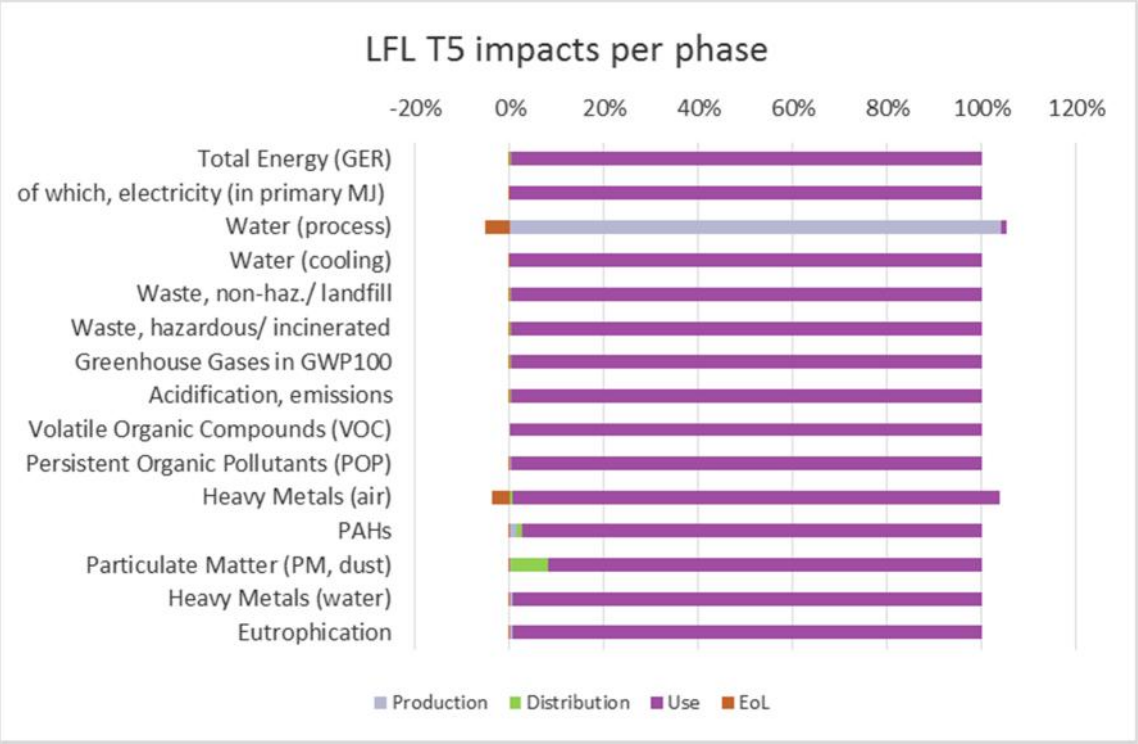

Table 29 Life Cycle Impact (per unit) of LFL X

Nr	Life cycle Impact per product:	Reference year	Author
0	LFL X (Other, incl. T5 old types 4-13W, special FL)	2013	vhk, izm

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Stock	
	Materials	unit									
1	Bulk Plastics	g			0		0	0	0	0	0
2	TecPlastics	g			0		0	0	0	0	0
3	Ferro	g			0		0	0	0	0	0
4	Non-ferro	g			2		0	0	4	-2	0
5	Coating	g			0		0	0	0	0	0
6	Electronics	g			0		0	0	0	0	0
7	Misc.	g			63		1	33	92	-62	0
8	Extra	g			0		0	0	0	0	0
9	Auxiliaries	g			0		0	0	0	0	0
10	Refrigerant	g			0		0	0	0	0	0
	Total weight	g			66		1	34	97	-64	0
	Other Resources & Waste							debet	credit		
11	Total Energy (GER)	MJ	2	0	2	5	1,188	0	-1		1,193
12	of which, electricity (in primary MJ)	MJ	1	0	1	0	1,188	0	0		1,188
13	Water (process)	ltr	0	0	0	0	0	0	0		0
14	Water (cooling)	ltr	0	0	0	0	53	0	0		53
15	Waste, non-haz./ landfill	g	2	0	3	4	612	0	-1		618
16	Waste, hazardous/ incinerated	g	0	0	0	0	19	0	0		19
	Emissions (Air)										
17	Greenhouse Gases in GWP100	kg CO2 eq.	0	0	0	0	51	0	0		51
18	Acidification, emissions	g SO2 eq.	0	0	0	1	224	0	0		226
19	Volatile Organic Compounds (VOC)	g	0	0	0	0	27	0	0		27
20	Persistent Organic Pollutants (POP)	ng i-Teq	0	0	0	0	3	0	0		3
21	Heavy Metals	mg Ni eq.	0	0	0	0	12	0	-2		11
22	PAHs	mg Ni eq.	0	0	0	0	3	0	0		3
23	Particulate Matter (PM, dust)	g	0	0	0	1	5	0	0		6
	Emissions (Water)										
24	Heavy Metals	mg Hg/20	0	0	0	0	5	0	0		5
25	Eutrophication	g PO4	0	0	0	0	0	0	0		0

Table 30 Life Cycle Impact (per unit) of LFL X, percentages per phase

	Production	Distribution	Use	EoL
Total Energy (GER)	0%	0%	100%	0%
of which, electricity (in primary MJ)	0%	0%	100%	0%
Water (process)	229%	0%	2%	-131%
Water (cooling)	0%	0%	100%	0%
Waste, non-haz./ landfill	0%	1%	99%	0%
Waste, hazardous/ incinerated	0%	0%	99%	0%
Greenhouse Gases in GWP100	0%	1%	99%	0%
Acidification, emissions	0%	0%	99%	0%
Volatile Organic Compounds (VOC)	0%	0%	100%	0%
Persistent Organic Pollutants (POP)	1%	1%	99%	0%
Heavy Metals (air)	1%	2%	113%	-16%
PAHs	6%	4%	94%	-4%
Particulate Matter (PM, dust)	1%	16%	84%	0%
Heavy Metals (water)	2%	0%	99%	-2%
Eutrophication	2%	0%	98%	-1%

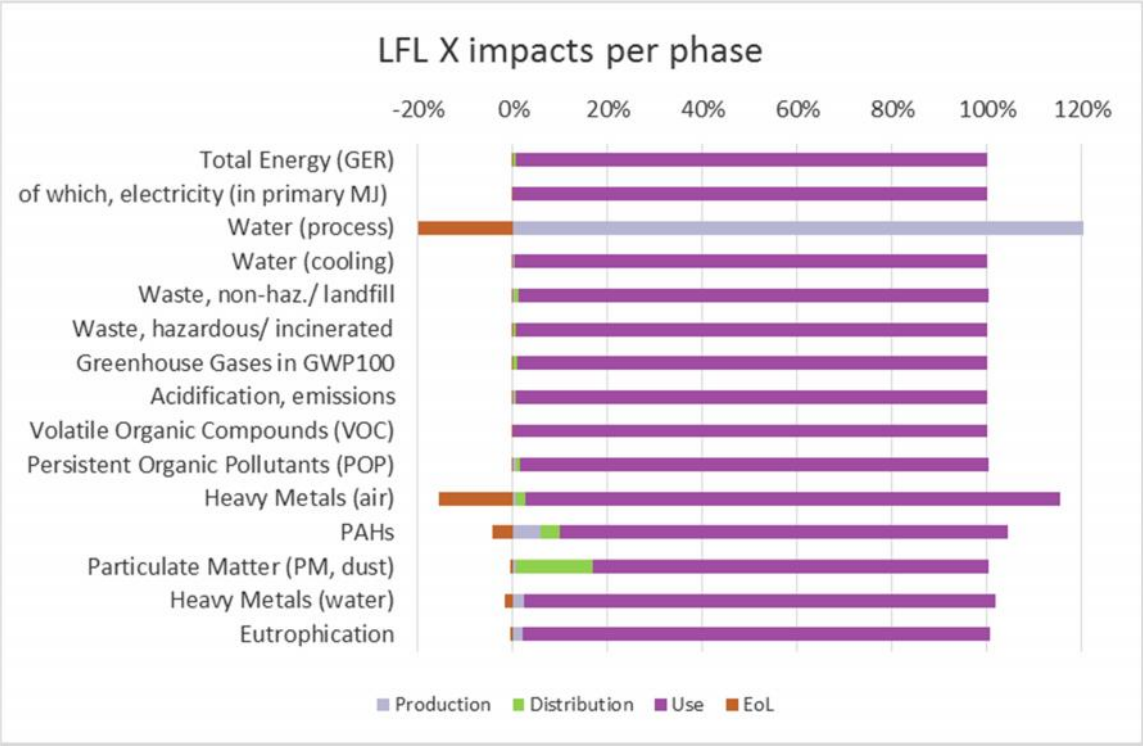

Table 31 Life Cycle Impact (per unit) of CFLi

Nr	Life cycle Impact per product:	Reference year	Author
0	CFLi (with integrated gear)	2013	vhk, izm

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Stock	
	Materials	unit									
1	Bulk Plastics	g			18		0	3	4	10	0
2	TecPlastics	g			2		0	0	0	1	0
3	Ferro	g			0		0	0	0	0	0
4	Non-ferro	g			2		0	0	1	1	0
5	Coating	g			0		0	0	0	0	0
6	Electronics	g			15		0	2	4	9	0
7	Misc.	g			81		1	9	26	47	0
8	Extra	g			0		0	0	0	0	0
9	Auxiliaries	g			0		0	0	0	0	0
10	Refrigerant	g			0		0	0	0	0	0
	Total weight	g			118		1	15	36	68	0
	Other Resources & Waste							debet	credit		
11	Total Energy (GER)	MJ	10	3	12	5	513	0	-1		530
12	of which, electricity (in primary MJ)	MJ	3	1	3	0	513	0	0		516
13	Water (process)	ltr	2	0	2	0	0	0	0		2
14	Water (cooling)	ltr	3	1	4	0	23	0	0		26
15	Waste, non-haz./ landfill	g	37	4	41	5	265	1	-4		307
16	Waste, hazardous/ incinerated	g	13	0	13	0	8	0	-1		20
	Emissions (Air)										
17	Greenhouse Gases in GWP100	kg CO2 eq.	0	0	1	0	22	0	0		23
18	Acidification, emissions	g SO2 eq.	4	1	5	1	97	0	0		103
19	Volatile Organic Compounds (VOC)	g	0	0	0	0	11	0	0		12
20	Persistent Organic Pollutants (POP)	ng i-Teq	0	0	0	0	1	0	0		1
21	Heavy Metals	mg Ni eq.	1	0	1	0	5	0	-2		5
22	PAHs	mg Ni eq.	2	0	2	0	1	0	0		3
23	Particulate Matter (PM, dust)	g	0	0	1	3	2	0	0		5
	Emissions (Water)										
24	Heavy Metals	mg Hg/20	1	0	1	0	2	0	0		3
25	Eutrophication	g PO4	0	0	0	0	0	0	0		0

Table 32 Life Cycle Impact (per unit) of CFLi, percentages per phase

	Production	Distribution	Use	EoL
Total Energy (GER)	2%	1%	97%	0%
of which, electricity (in primary MJ)	1%	0%	99%	0%
Water (process)	110%	0%	1%	-11%
Water (cooling)	14%	0%	87%	-1%
Waste, non-haz./ landfill	13%	2%	86%	-1%
Waste, hazardous/ incinerated	65%	0%	41%	-7%
Greenhouse Gases in GWP100	3%	2%	96%	0%
Acidification, emissions	5%	1%	94%	0%
Volatile Organic Compounds (VOC)	1%	0%	99%	0%
Persistent Organic Pollutants (POP)	18%	2%	83%	-3%
Heavy Metals (air)	26%	5%	106%	-37%
PAHs	57%	5%	43%	-6%
Particulate Matter (PM, dust)	13%	49%	39%	-1%
Heavy Metals (water)	37%	0%	67%	-4%
Eutrophication	54%	0%	51%	-4%

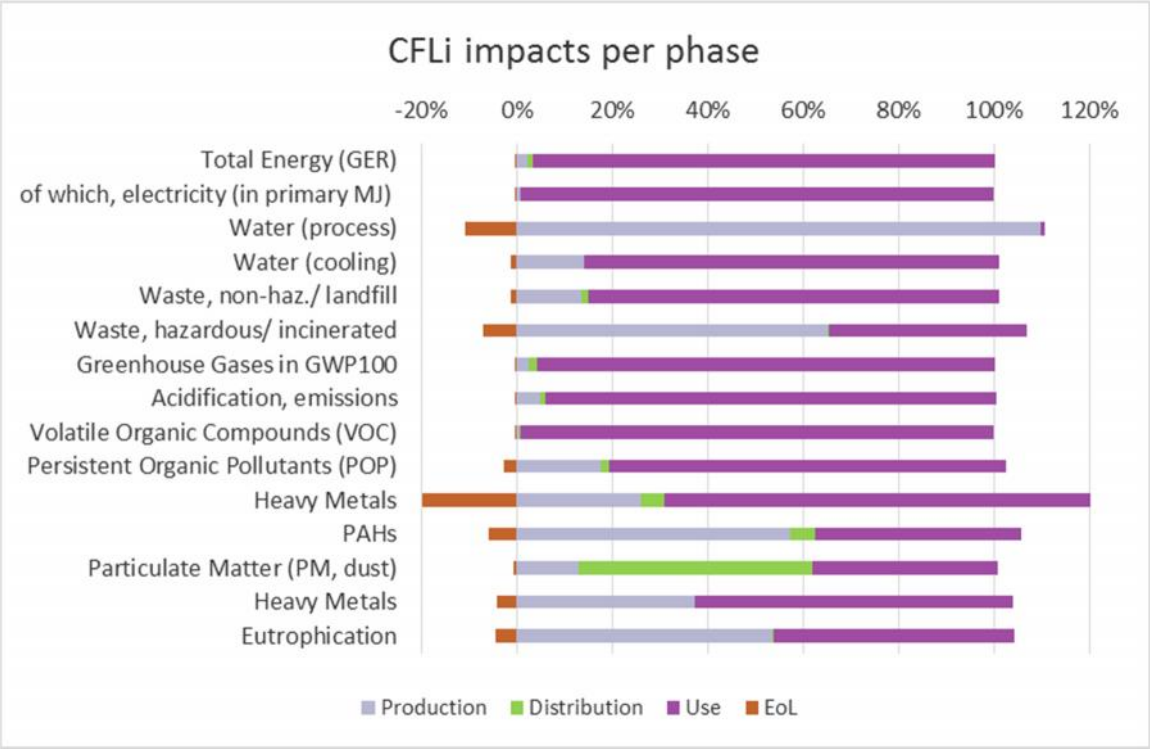

Table 33 Life Cycle Impact (per unit) of CFLni

Nr	Life cycle Impact per product:	Reference year	Author
0	CFLni (without integrated gear)	2013	vhk, izm

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Stock	
	Materials	unit									
1	Bulk Plastics	g			16		0	6	8	3	0
2	TecPlastics	g			1		0	0	0	0	0
3	Ferro	g			0		0	0	0	0	0
4	Non-ferro	g			1		0	0	1	0	0
5	Coating	g			0		0	0	0	0	0
6	Electronics	g			0		0	0	0	0	0
7	Misc.	g			79		1	17	48	14	0
8	Extra	g			0		0	0	0	0	0
9	Auxiliaries	g			0		0	0	0	0	0
10	Refrigerant	g			0		0	0	0	0	0
	Total weight	g			98		1	24	57	17	0
	Other Resources & Waste							debet	credit		
11	Total Energy (GER)	MJ	3	1	4	5	1,035	0	-1		1,044
12	of which, electricity (in primary MJ)	MJ	1	0	1	0	1,035	0	0		1,036
13	Water (process)	ltr	0	0	0	0	0	0	0		0
14	Water (cooling)	ltr	1	0	1	0	46	0	0		47
15	Waste, non-haz./ landfill	g	5	2	7	5	533	0	-1		544
16	Waste, hazardous/ incinerated	g	0	0	0	0	16	0	0		16
	Emissions (Air)										
17	Greenhouse Gases in GWP100	kg CO2 eq.	0	0	0	0	44	0	0		45
18	Acidification, emissions	g SO2 eq.	1	0	1	1	196	0	0		198
19	Volatile Organic Compounds (VOC)	g	0	0	0	0	23	0	0		23
20	Persistent Organic Pollutants (POP)	ng i-Teq	0	0	0	0	2	0	0		2
21	Heavy Metals	mg Ni eq.	0	0	0	0	10	0	-2		9
22	PAHs	mg Ni eq.	0	0	0	0	2	0	0		3
23	Particulate Matter (PM, dust)	g	0	0	0	2	4	0	0		6
	Emissions (Water)										
24	Heavy Metals	mg Hg/20	0	0	0	0	4	0	0		5
25	Eutrophication	g PO4	0	0	0	0	0	0	0		0

Table 34 Life Cycle Impact (per unit) of CFLni, percentages per phase

	Production	Distribution	Use	EoL
Total Energy (GER)	0%	0%	99%	0%
of which, electricity (in primary MJ)	0%	0%	100%	0%
Water (process)	125%	0%	1%	-26%
Water (cooling)	2%	0%	98%	0%
Waste, non-haz./ landfill	1%	1%	98%	0%
Waste, hazardous/ incinerated	0%	1%	99%	0%
Greenhouse Gases in GWP100	0%	1%	99%	0%
Acidification, emissions	1%	1%	99%	0%
Volatile Organic Compounds (VOC)	0%	0%	100%	0%
Persistent Organic Pollutants (POP)	0%	1%	99%	0%
Heavy Metals (air)	1%	2%	114%	-17%
PAHs	1%	5%	94%	0%
Particulate Matter (PM, dust)	2%	28%	70%	0%
Heavy Metals (water)	2%	0%	98%	-1%
Eutrophication	9%	0%	91%	-1%

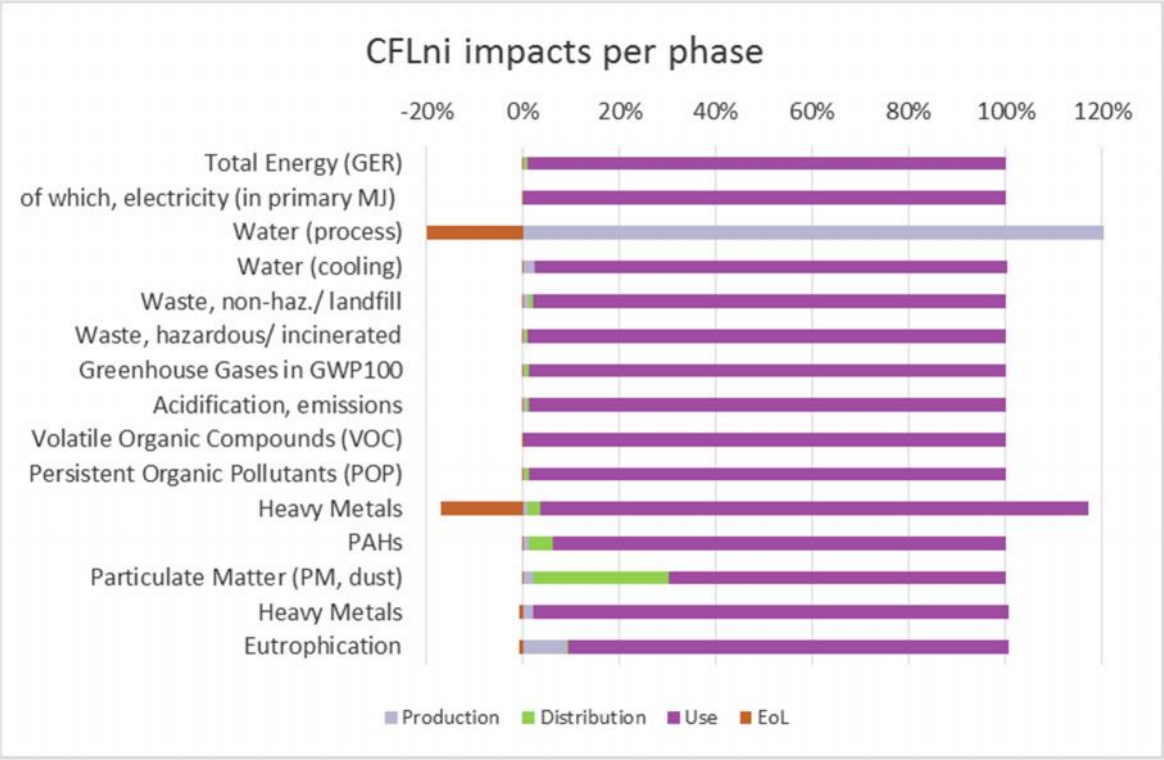

Table 35 Life Cycle Impact (per unit) of HL LV R

Nr	Life cycle Impact per product:	Reference year	Author
0	HL LV R (low voltage halogen reflector lamps)	2013	vhk, izm

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Stock	
	Materials	unit									
1	Bulk Plastics	g			3		0	2	1	0	0
2	TecPlastics	g			0		0	0	0	0	0
3	Ferro	g			0		0	0	0	0	0
4	Non-ferro	g			1		0	0	0	0	0
5	Coating	g			0		0	0	0	0	0
6	Electronics	g			0		0	0	0	0	0
7	Misc.	g			56		1	18	33	5	0
8	Extra	g			0		0	0	0	0	0
9	Auxiliaries	g			0		0	0	0	0	0
10	Refrigerant	g			0		0	0	0	0	0
	Total weight	g			60		1	20	35	5	0
	Other Resources & Waste							debet	credit		
11	Total Energy (GER)	MJ	2	0	2	5	624	0	0		630
12	of which, electricity (in primary MJ)	MJ	0	0	1	0	624	0	0		624
13	Water (process)	ltr	0	0	0	0	0	0	0		0
14	Water (cooling)	ltr	0	0	0	0	28	0	0		28
15	Waste, non-haz./ landfill	g	2	0	3	4	321	0	0		328
16	Waste, hazardous/ incinerated	g	0	0	0	0	10	0	0		10
	Emissions (Air)										
17	Greenhouse Gases in GWP100	kg CO2 eq.	0	0	0	0	27	0	0		27
18	Acidification, emissions	g SO2 eq.	0	0	0	1	118	0	0		119
19	Volatile Organic Compounds (VOC)	g	0	0	0	0	14	0	0		14
20	Persistent Organic Pollutants (POP)	ng i-Teq	0	0	0	0	1	0	0		1
21	Heavy Metals	mg Ni eq.	0	0	0	0	6	0	0		7
22	PAHs	mg Ni eq.	0	0	0	0	1	0	0		2
23	Particulate Matter (PM, dust)	g	0	0	0	1	2	0	0		4
	Emissions (Water)										
24	Heavy Metals	mg Hg/20	0	0	0	0	3	0	0		3
25	Eutrophication	g PO4	0	0	0	0	0	0	0		0

Table 36 Life Cycle Impact (per unit) of HL LV R, percentages per phase

	Production	Distribution	Use	EoL
Total Energy (GER)	0%	1%	99%	0%
of which, electricity (in primary MJ)	0%	0%	100%	0%
Water (process)	126%	0%	1%	-28%
Water (cooling)	1%	0%	99%	0%
Waste, non-haz./ landfill	1%	1%	98%	0%
Waste, hazardous/ incinerated	0%	1%	99%	0%
Greenhouse Gases in GWP100	0%	1%	98%	0%
Acidification, emissions	0%	1%	99%	0%
Volatile Organic Compounds (VOC)	0%	0%	100%	0%
Persistent Organic Pollutants (POP)	0%	2%	98%	0%
Heavy Metals (air)	1%	3%	96%	0%
PAHs	0%	8%	92%	0%
Particulate Matter (PM, dust)	1%	29%	70%	0%
Heavy Metals (water)	2%	0%	99%	-1%
Eutrophication	3%	0%	97%	0%

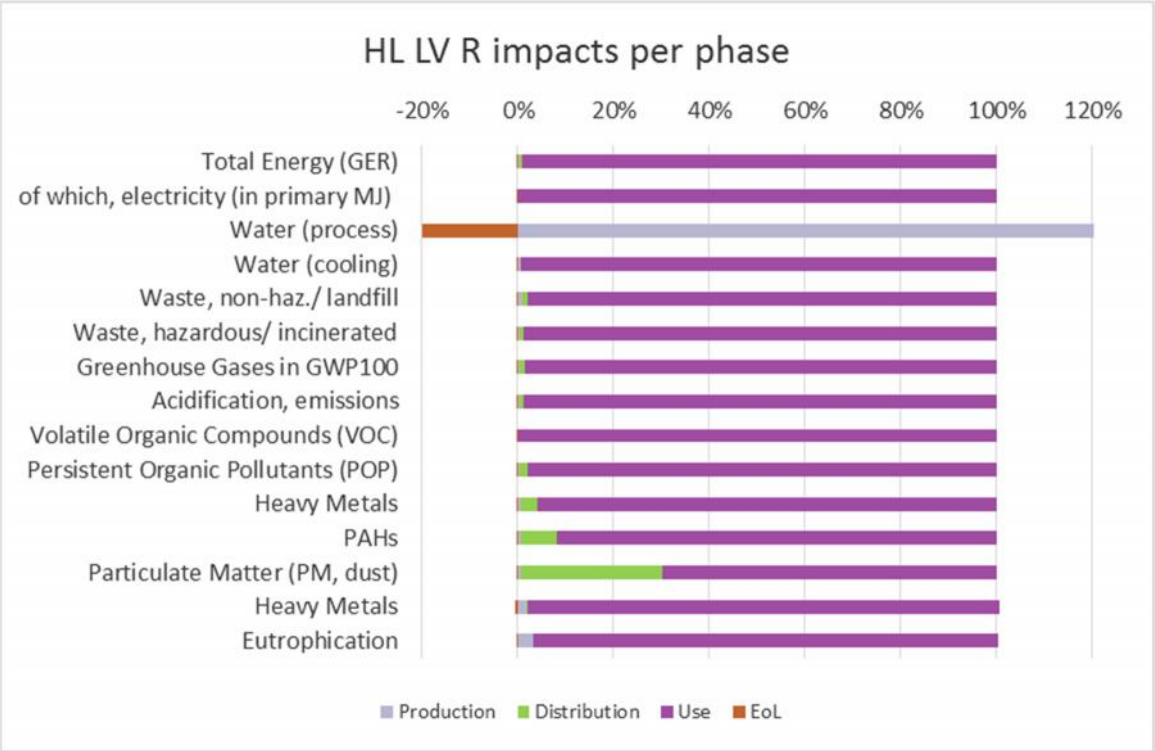

Table 37 Life Cycle Impact (per unit) of HL LV C

Nr	Life cycle Impact per product:	Reference year	Author
0	HL LV C (low voltage halogen capsules)	2013	vhk, izm

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Stock	
	Materials	unit									
1	Bulk Plastics	g			2		0	1	1	0	0
2	TecPlastics	g			0		0	0	0	0	0
3	Ferro	g			0		0	0	0	0	0
4	Non-ferro	g			0		0	0	0	0	0
5	Coating	g			0		0	0	0	0	0
6	Electronics	g			0		0	0	0	0	0
7	Misc.	g			16		0	7	13	-4	0
8	Extra	g			0		0	0	0	0	0
9	Auxiliaries	g			0		0	0	0	0	0
10	Refrigerant	g			0		0	0	0	0	0
	Total weight	g			17		0	8	14	-4	0
	Other Resources & Waste							debet	credit		
11	Total Energy (GER)	MJ	1	0	1	5	624	0	0		629
12	of which, electricity (in primary MJ)	MJ	0	0	0	0	624	0	0		624
13	Water (process)	ltr	0	0	0	0	0	0	0		0
14	Water (cooling)	ltr	0	0	0	0	28	0	0		28
15	Waste, non-haz./ landfill	g	1	0	1	4	321	0	0		327
16	Waste, hazardous/ incinerated	g	0	0	0	0	10	0	0		10
	Emissions (Air)										
17	Greenhouse Gases in GWP100	kg CO2 eq.	0	0	0	0	27	0	0		27
18	Acidification, emissions	g SO2 eq.	0	0	0	1	118	0	0		119
19	Volatile Organic Compounds (VOC)	g	0	0	0	0	14	0	0		14
20	Persistent Organic Pollutants (POP)	ng i-Teq	0	0	0	0	1	0	0		1
21	Heavy Metals	mg Ni eq.	0	0	0	0	6	0	0		7
22	PAHs	mg Ni eq.	0	0	0	0	1	0	0		2
23	Particulate Matter (PM, dust)	g	0	0	0	1	2	0	0		3
	Emissions (Water)										
24	Heavy Metals	mg Hg/20	0	0	0	0	3	0	0		3
25	Eutrophication	g PO4	0	0	0	0	0	0	0		0

Table 38 Life Cycle Impact (per unit) of HL LV C, percentages per phase

	Production	Distribution	Use	EoL
Total Energy (GER)	0%	1%	99%	0%
of which, electricity (in primary MJ)	0%	0%	100%	0%
Water (process)	130%	0%	1%	-31%
Water (cooling)	0%	0%	100%	0%
Waste, non-haz./ landfill	0%	1%	98%	0%
Waste, hazardous/ incinerated	0%	1%	99%	0%
Greenhouse Gases in GWP100	0%	1%	99%	0%
Acidification, emissions	0%	1%	99%	0%
Volatile Organic Compounds (VOC)	0%	0%	100%	0%
Persistent Organic Pollutants (POP)	0%	2%	98%	0%
Heavy Metals (air)	0%	3%	96%	0%
PAHs	0%	7%	92%	0%
Particulate Matter (PM, dust)	0%	22%	78%	0%
Heavy Metals (water)	0%	0%	100%	0%
Eutrophication	2%	0%	99%	0%

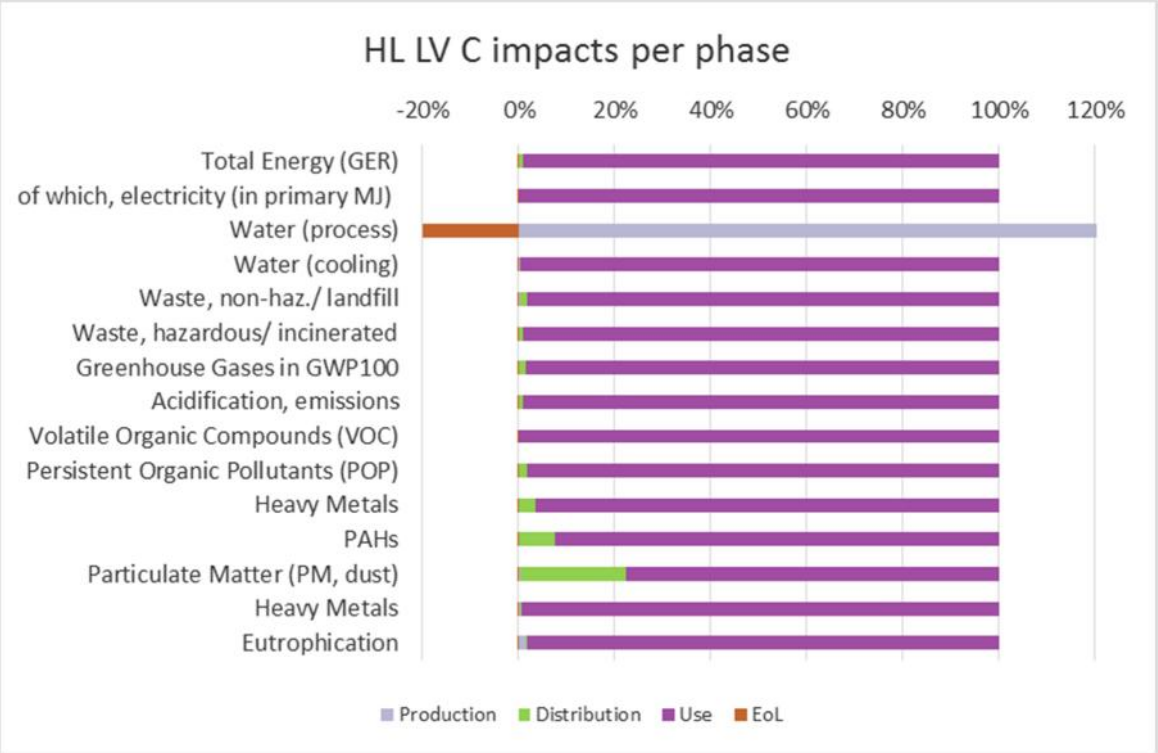

Table 39 Life Cycle Impact (per unit) of HL MV C

Nr	Life cycle Impact per product:	Reference year	Author
0	HL MV C (mains voltage halogen capsules)	2013	vhk, izm

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Stock	
	Materials	unit									
1	Bulk Plastics	g			2		0	1	1	0	0
2	TecPlastics	g			0		0	0	0	0	0
3	Ferro	g			0		0	0	0	0	0
4	Non-ferro	g			0		0	0	0	0	0
5	Coating	g			0		0	0	0	0	0
6	Electronics	g			0		0	0	0	0	0
7	Misc.	g			17		0	6	12	-1	0
8	Extra	g			0		0	0	0	0	0
9	Auxiliaries	g			0		0	0	0	0	0
10	Refrigerant	g			0		0	0	0	0	0
	Total weight	g			19		0	7	12	-1	0
	Other Resources & Waste							debet	credit		
11	Total Energy (GER)	MJ	1	0	1	5	468	0	0		473
12	of which, electricity (in primary MJ)	MJ	0	0	0	0	468	0	0		468
13	Water (process)	ltr	0	0	0	0	0	0	0		0
14	Water (cooling)	ltr	0	0	0	0	21	0	0		21
15	Waste, non-haz./ landfill	g	1	0	1	4	241	0	0		246
16	Waste, hazardous/ incinerated	g	0	0	0	0	7	0	0		7
	Emissions (Air)										
17	Greenhouse Gases in GWP100	kg CO2 eq.	0	0	0	0	20	0	0		20
18	Acidification, emissions	g SO2 eq.	0	0	0	1	88	0	0		89
19	Volatile Organic Compounds (VOC)	g	0	0	0	0	10	0	0		10
20	Persistent Organic Pollutants (POP)	ng i-Teq	0	0	0	0	1	0	0		1
21	Heavy Metals	mg Ni eq.	0	0	0	0	5	0	0		5
22	PAHs	mg Ni eq.	0	0	0	0	1	0	0		1
23	Particulate Matter (PM, dust)	g	0	0	0	1	2	0	0		3
	Emissions (Water)										
24	Heavy Metals	mg Hg/20	0	0	0	0	2	0	0		2
25	Eutrophication	g PO4	0	0	0	0	0	0	0		0

Table 40 Life Cycle Impact (per unit) of HL MV C, percentages per phase

	Production	Distribution	Use	EoL
Total Energy (GER)	0%	1%	99%	0%
of which, electricity (in primary MJ)	0%	0%	100%	0%
Water (process)	127%	0%	1%	-28%
Water (cooling)	0%	0%	100%	0%
Waste, non-haz./ landfill	0%	2%	98%	0%
Waste, hazardous/ incinerated	0%	1%	99%	0%
Greenhouse Gases in GWP100	0%	2%	98%	0%
Acidification, emissions	0%	1%	99%	0%
Volatile Organic Compounds (VOC)	0%	0%	100%	0%
Persistent Organic Pollutants (POP)	0%	2%	98%	0%
Heavy Metals (air)	0%	4%	95%	0%
PAHs	0%	10%	90%	0%
Particulate Matter (PM, dust)	0%	27%	72%	0%
Heavy Metals (water)	0%	0%	99%	0%
Eutrophication	2%	0%	98%	0%

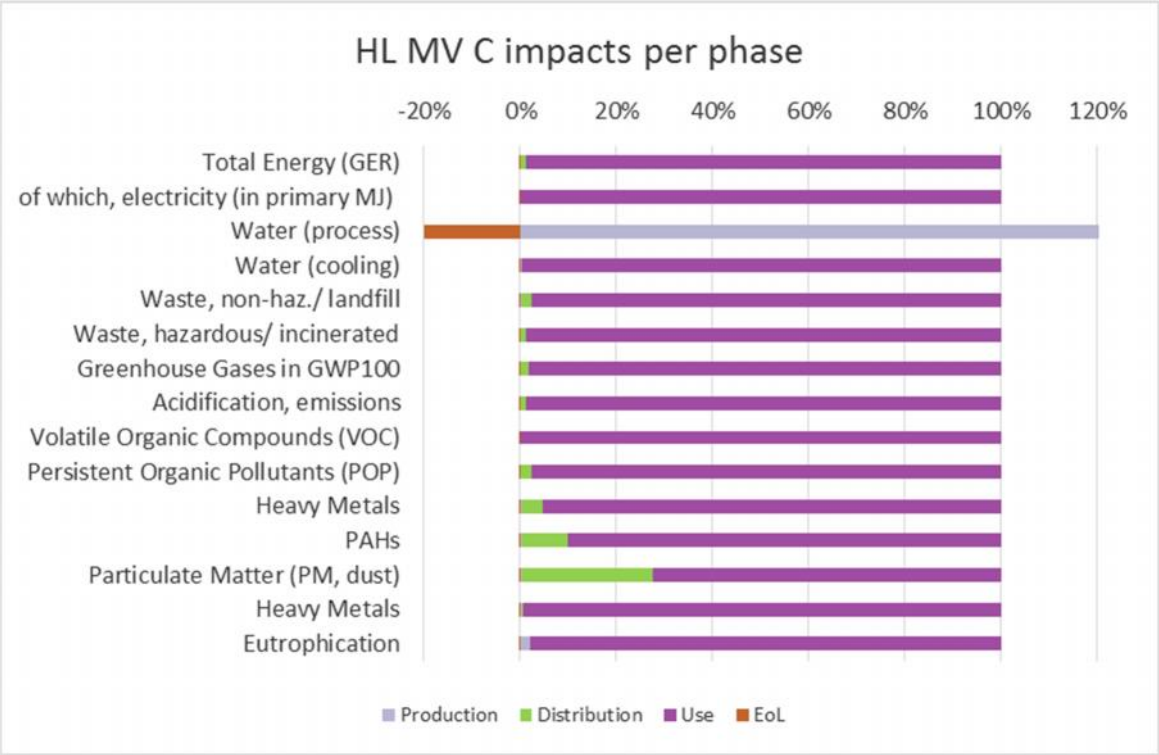

Table 41 Life Cycle Impact (per unit) of HL MV L

Nr	Life cycle Impact per product:	Reference year	Author
0	HL MV L (linear double-ended halogen R7s)	2013	vhk, izm

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Stock	
	Materials	unit									
1	Bulk Plastics	g			2		0	1	1	0	0
2	TecPlastics	g			0		0	0	0	0	0
3	Ferro	g			0		0	0	0	0	0
4	Non-ferro	g			0		0	0	0	0	0
5	Coating	g			0		0	0	0	0	0
6	Electronics	g			0		0	0	0	0	0
7	Misc.	g			27		0	10	19	-1	0
8	Extra	g			0		0	0	0	0	0
9	Auxiliaries	g			0		0	0	0	0	0
10	Refrigerant	g			0		0	0	0	0	0
	Total weight	g			29		0	11	20	-2	0
	Other Resources & Waste							debet	credit		
11	Total Energy (GER)	MJ	1	0	1		2,228	0	0		2,233
12	of which, electricity (in primary MJ)	MJ	0	0	0	0	2,228	0	0		2,228
13	Water (process)	ltr	0	0	0	0	0	0	0		0
14	Water (cooling)	ltr	0	0	0	0	99	0	0		99
15	Waste, non-haz./ landfill	g	2	0	3	4	1,148	0	-1		1,154
16	Waste, hazardous/ incinerated	g	0	0	0	0	35	0	0		35
	Emissions (Air)										
17	Greenhouse Gases in GWP100	kg CO2 eq.	0	0	0	0	95	0	0		95
18	Acidification, emissions	g SO2 eq.	0	0	0	1	421	0	0		422
19	Volatile Organic Compounds (VOC)	g	0	0	0	0	50	0	0		50
20	Persistent Organic Pollutants (POP)	ng i-Teq	0	0	0	0	5	0	0		5
21	Heavy Metals	mg Ni eq.	0	0	0	0	23	0	0		23
22	PAHs	mg Ni eq.	0	0	0	0	5	0	0		5
23	Particulate Matter (PM, dust)	g	0	0	0	1	9	0	0		10
	Emissions (Water)										
24	Heavy Metals	mg Hg/20	0	0	0	0	10	0	0		10
25	Eutrophication	g PO4	0	0	0	0	0	0	0		0

Table 42 Life Cycle Impact (per unit) of HL MV L, percentages per phase

	Production	Distribution	Use	EoL
Total Energy (GER)	0%	0%	100%	0%
of which, electricity (in primary MJ)	0%	0%	100%	0%
Water (process)	133%	0%	1%	-34%
Water (cooling)	0%	0%	100%	0%
Waste, non-haz./ landfill	0%	0%	99%	0%
Waste, hazardous/ incinerated	0%	0%	100%	0%
Greenhouse Gases in GWP100	0%	0%	100%	0%
Acidification, emissions	0%	0%	100%	0%
Volatile Organic Compounds (VOC)	0%	0%	100%	0%
Persistent Organic Pollutants (POP)	0%	0%	99%	0%
Heavy Metals (air)	0%	1%	99%	0%
PAHs	1%	2%	97%	0%
Particulate Matter (PM, dust)	0%	10%	90%	0%
Heavy Metals (water)	0%	0%	100%	0%
Eutrophication	2%	0%	99%	0%

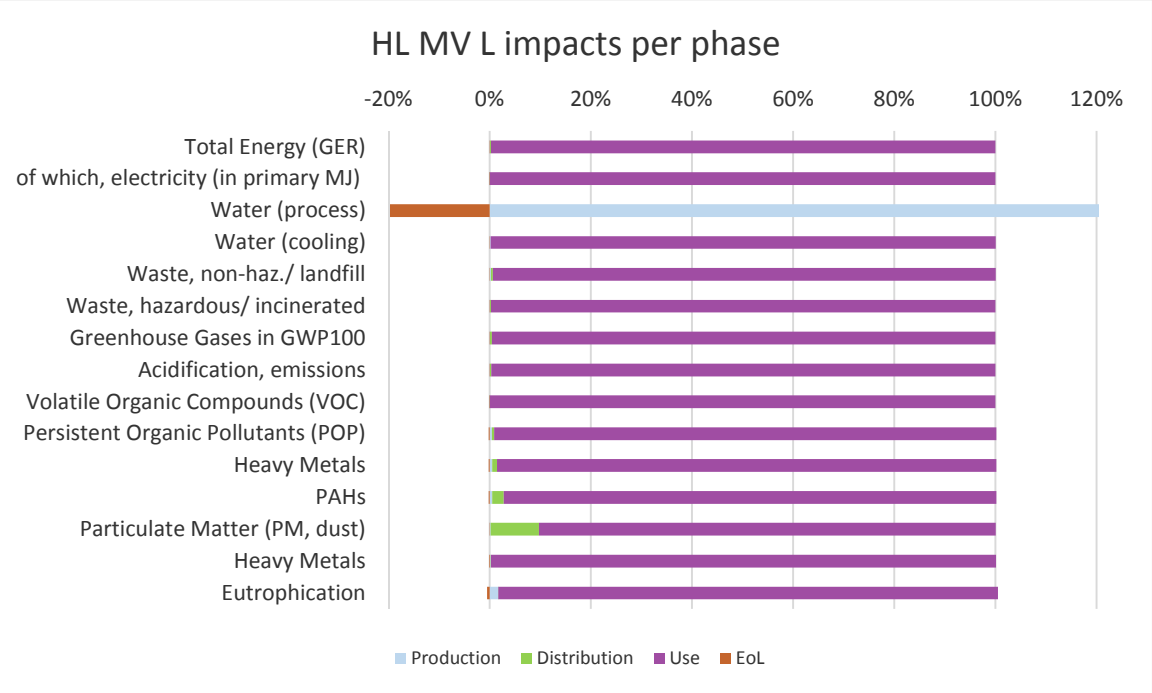

Table 43 Life Cycle Impact (per unit) of HL MV E

Nr	Life cycle Impact per product:	Reference year	Author
0	HL MV E (substitutes for GLS, with E-cap)	2013	vhk, izm

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Stock	
	Materials	unit									
1	Bulk Plastics	g			6		0	2	2	2	0
2	TecPlastics	g			0		0	0	0	0	0
3	Ferro	g			0		0	0	0	0	0
4	Non-ferro	g			1		0	0	1	0	0
5	Coating	g			0		0	0	0	0	0
6	Electronics	g			0		0	0	0	0	0
7	Misc.	g			75		1	17	31	28	0
8	Extra	g			0		0	0	0	0	0
9	Auxiliaries	g			0		0	0	0	0	0
10	Refrigerant	g			0		0	0	0	0	0
	Total weight	g			83		1	19	34	31	0
	Other Resources & Waste							debet	credit		
11	Total Energy (GER)	MJ	3	0	3	5	481	0	0		489
12	of which, electricity (in primary MJ)	MJ	1	0	1	0	481	0	0		482
13	Water (process)	ltr	0	0	0	0	0	0	0		0
14	Water (cooling)	ltr	0	0	1	0	21	0	0		22
15	Waste, non-haz./ landfill	g	7	1	8	5	248	0	-1		259
16	Waste, hazardous/ incinerated	g	0	0	0	0	8	0	0		8
	Emissions (Air)										
17	Greenhouse Gases in GWP100	kg CO2 eq.	0	0	0	0	21	0	0		21
18	Acidification, emissions	g SO2 eq.	1	0	1	1	91	0	0		93
19	Volatile Organic Compounds (VOC)	g	0	0	0	0	11	0	0		11
20	Persistent Organic Pollutants (POP)	ng i-Teq	0	0	0	0	1	0	0		1
21	Heavy Metals	mg Ni eq.	0	0	0	0	5	0	0		5
22	PAHs	mg Ni eq.	0	0	0	0	1	0	0		1
23	Particulate Matter (PM, dust)	g	0	0	0	3	2	0	0		5
	Emissions (Water)										
24	Heavy Metals	mg Hg/20	0	0	0	0	2	0	0		2
25	Eutrophication	g PO4	0	0	0	0	0	0	0		0

Table 44 Life Cycle Impact (per unit) of HL MV E, percentages per phase

	Production	Distribution	Use	EoL
Total Energy (GER)	1%	1%	98%	0%
of which, electricity (in primary MJ)	0%	0%	100%	0%
Water (process)	117%	0%	1%	-18%
Water (cooling)	2%	0%	98%	0%
Waste, non-haz./ landfill	3%	2%	96%	0%
Waste, hazardous/ incinerated	1%	1%	98%	0%
Greenhouse Gases in GWP100	1%	2%	98%	0%
Acidification, emissions	1%	1%	98%	0%
Volatile Organic Compounds (VOC)	0%	0%	100%	0%
Persistent Organic Pollutants (POP)	5%	2%	94%	-1%
Heavy Metals (air)	6%	4%	91%	-1%
PAHs	9%	10%	83%	-2%
Particulate Matter (PM, dust)	2%	56%	42%	0%
Heavy Metals (water)	4%	0%	96%	-1%
Eutrophication	18%	0%	85%	-3%

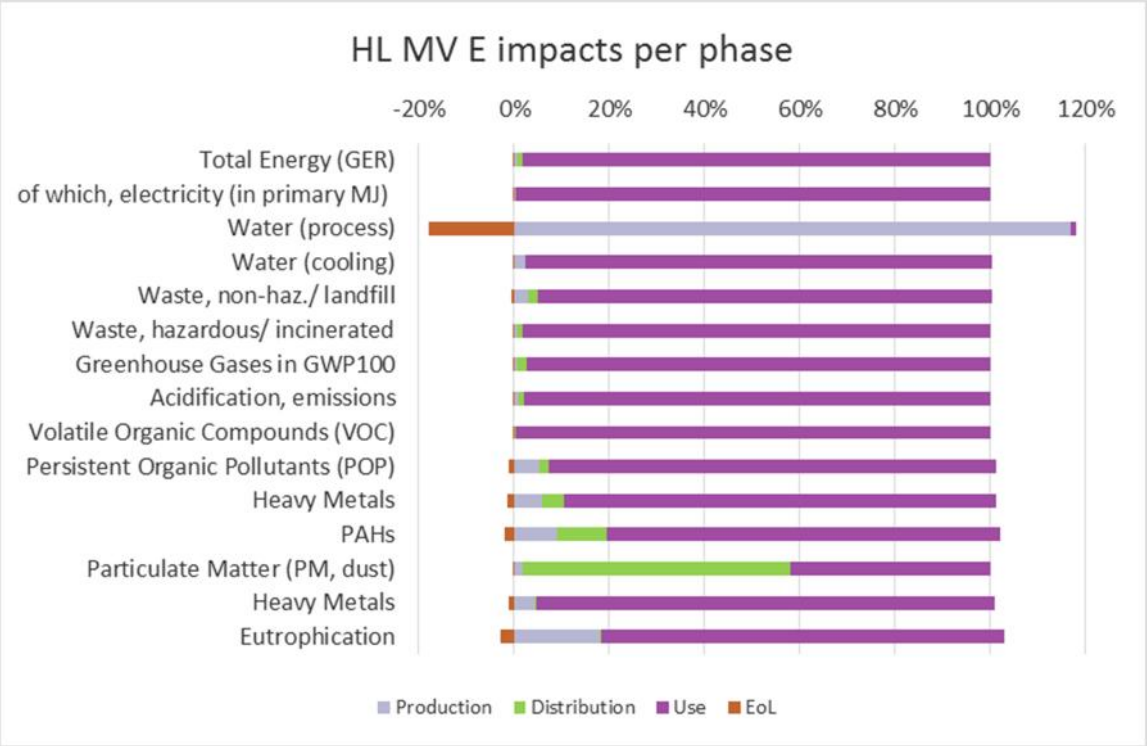

Table 45 Life Cycle Impact (per unit) of HL MV X

Nr	Life cycle Impact per product:	Reference year	Author
0	HL MV X (other, incl. reflector lamps with GU10)	2013	vhk, izm

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Stock	
	Materials	unit									
1	Bulk Plastics	g			4		0	2	2	0	0
2	TecPlastics	g			0		0	0	0	0	0
3	Ferro	g			0		0	0	0	0	0
4	Non-ferro	g			2		0	0	2	0	0
5	Coating	g			0		0	0	0	0	0
6	Electronics	g			0		0	0	0	0	0
7	Misc.	g			73		1	28	52	-5	0
8	Extra	g			0		0	0	0	0	0
9	Auxiliaries	g			0		0	0	0	0	0
10	Refrigerant	g			0		0	0	0	0	0
	Total weight	g			79		1	30	55	-6	0
	Other Resources & Waste							debet	credit		
11	Total Energy (GER)	MJ	2	0	2	5	468	0	-1		475
12	of which, electricity (in primary MJ)	MJ	1	0	1	0	468	0	0		468
13	Water (process)	ltr	0	0	0	0	0	0	0		0
14	Water (cooling)	ltr	0	0	0	0	21	0	0		21
15	Waste, non-haz./ landfill	g	3	1	3	4	241	0	-1		248
16	Waste, hazardous/ incinerated	g	0	0	0	0	7	0	0		7
	Emissions (Air)										
17	Greenhouse Gases in GWP100	kg CO2 eq.	0	0	0	0	20	0	0		20
18	Acidification, emissions	g SO2 eq.	1	0	1	1	88	0	0		90
19	Volatile Organic Compounds (VOC)	g	0	0	0	0	10	0	0		10
20	Persistent Organic Pollutants (POP)	ng i-Teq	0	0	0	0	1	0	0		1
21	Heavy Metals	mg Ni eq.	0	0	0	0	5	0	0		5
22	PAHs	mg Ni eq.	0	0	0	0	1	0	0		1
23	Particulate Matter (PM, dust)	g	0	0	0	1	2	0	0		3
	Emissions (Water)										
24	Heavy Metals	mg Hg/20	0	0	0	0	2	0	0		2
25	Eutrophication	g PO4	0	0	0	0	0	0	0		0

Table 46 Life Cycle Impact (per unit) of HL MV X, percentages per phase

	Production	Distribution	Use	EoL
Total Energy (GER)	0%	1%	99%	0%
of which, electricity (in primary MJ)	0%	0%	100%	0%
Water (process)	133%	0%	1%	-34%
Water (cooling)	1%	0%	99%	0%
Waste, non-haz./ landfill	1%	2%	97%	0%
Waste, hazardous/ incinerated	0%	1%	98%	0%
Greenhouse Gases in GWP100	0%	2%	98%	0%
Acidification, emissions	1%	1%	98%	0%
Volatile Organic Compounds (VOC)	0%	0%	100%	0%
Persistent Organic Pollutants (POP)	1%	2%	97%	0%
Heavy Metals (air)	2%	5%	94%	-1%
PAHs	1%	10%	89%	0%
Particulate Matter (PM, dust)	1%	42%	57%	0%
Heavy Metals (water)	7%	0%	96%	-3%
Eutrophication	6%	0%	95%	0%

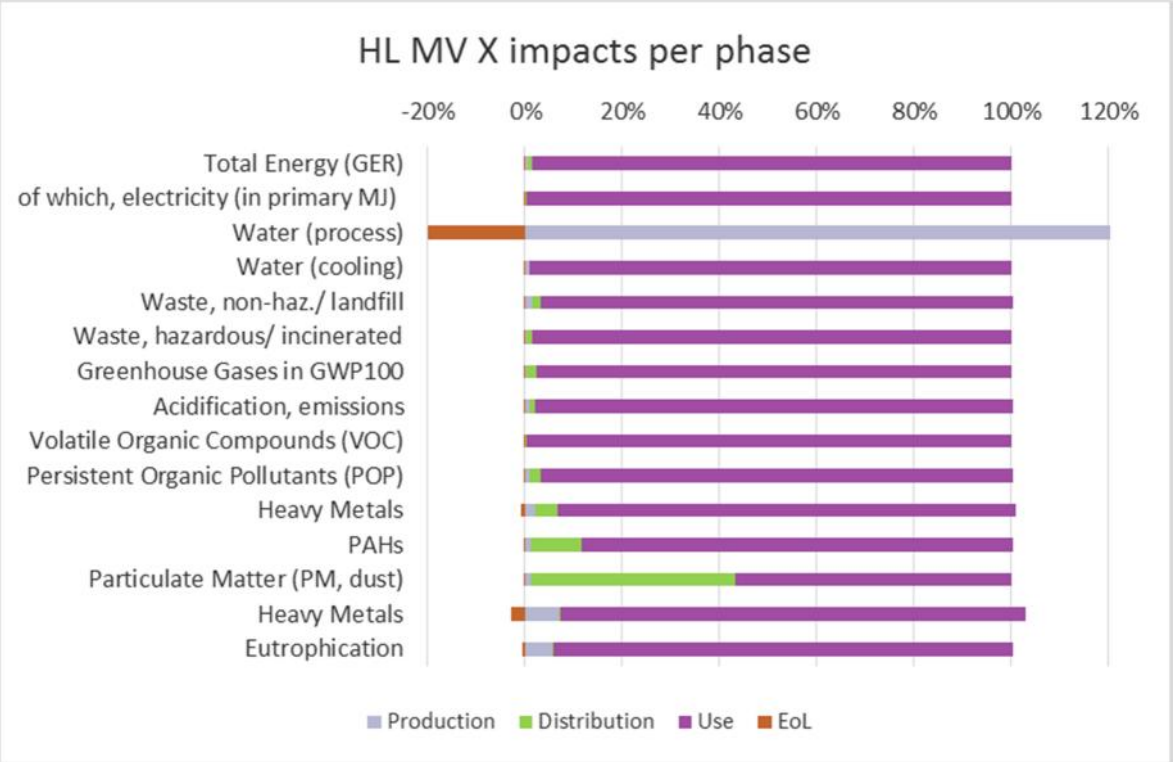

Table 47 Life Cycle Impact (per unit) of GLS R

Nr	Life cycle Impact per product:	Reference year	Author
0	GLS R (incandescent reflector lamps)	2013	vhk, izm

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Stock	
	Materials	unit									
1	Bulk Plastics	g			9		0	8	6	-5	0
2	TecPlastics	g			2		0	1	1	-1	0
3	Ferro	g			0		0	0	0	0	0
4	Non-ferro	g			1		0	0	2	-1	0
5	Coating	g			0		0	0	0	0	0
6	Electronics	g			0		0	0	0	0	0
7	Misc.	g			108		1	58	108	-58	0
8	Extra	g			0		0	0	0	0	0
9	Auxiliaries	g			0		0	0	0	0	0
10	Refrigerant	g			0		0	0	0	0	0
	Total weight	g			120		1	68	117	-64	0
	Other Resources & Waste							debet	credit		
11	Total Energy (GER)	MJ	4	0	5	6	481	0	-1		490
12	of which, electricity (in primary MJ)	MJ	1	0	1	0	481	0	0		482
13	Water (process)	ltr	0	0	0	0	0	0	0		0
14	Water (cooling)	ltr	1	0	1	0	21	0	0		22
15	Waste, non-haz./ landfill	g	8	1	9	5	248	1	-3		260
16	Waste, hazardous/ incinerated	g	0	0	0	0	8	0	0		8
	Emissions (Air)										
17	Greenhouse Gases in GWP100	kg CO2 eq.	0	0	0	0	21	0	0		21
18	Acidification, emissions	g SO2 eq.	1	0	1	1	91	0	0		93
19	Volatile Organic Compounds (VOC)	g	0	0	0	0	11	0	0		11
20	Persistent Organic Pollutants (POP)	ng i-Teq	0	0	0	0	1	0	0		1
21	Heavy Metals	mg Ni eq.	0	0	0	0	5	0	0		5
22	PAHs	mg Ni eq.	0	0	0	0	1	0	0		1
23	Particulate Matter (PM, dust)	g	0	0	0	4	2	0	0		6
	Emissions (Water)										
24	Heavy Metals	mg Hg/20	0	0	0	0	2	0	0		2
25	Eutrophication	g PO4	0	0	0	0	0	0	0		0

Table 48 Life Cycle Impact (per unit) of GLS R, percentages per phase

	Production	Distribution	Use	EoL
Total Energy (GER)	1%	1%	98%	0%
of which, electricity (in primary MJ)	0%	0%	100%	0%
Water (process)	146%	0%	1%	-47%
Water (cooling)	5%	0%	96%	-1%
Waste, non-haz./ landfill	4%	2%	95%	-1%
Waste, hazardous/ incinerated	1%	1%	98%	0%
Greenhouse Gases in GWP100	1%	2%	97%	0%
Acidification, emissions	1%	1%	98%	0%
Volatile Organic Compounds (VOC)	0%	0%	100%	0%
Persistent Organic Pollutants (POP)	3%	2%	96%	-2%
Heavy Metals (air)	3%	5%	94%	-2%
PAHs	9%	12%	84%	-5%
Particulate Matter (PM, dust)	2%	67%	31%	0%
Heavy Metals (water)	3%	0%	98%	-2%
Eutrophication	26%	0%	77%	-3%

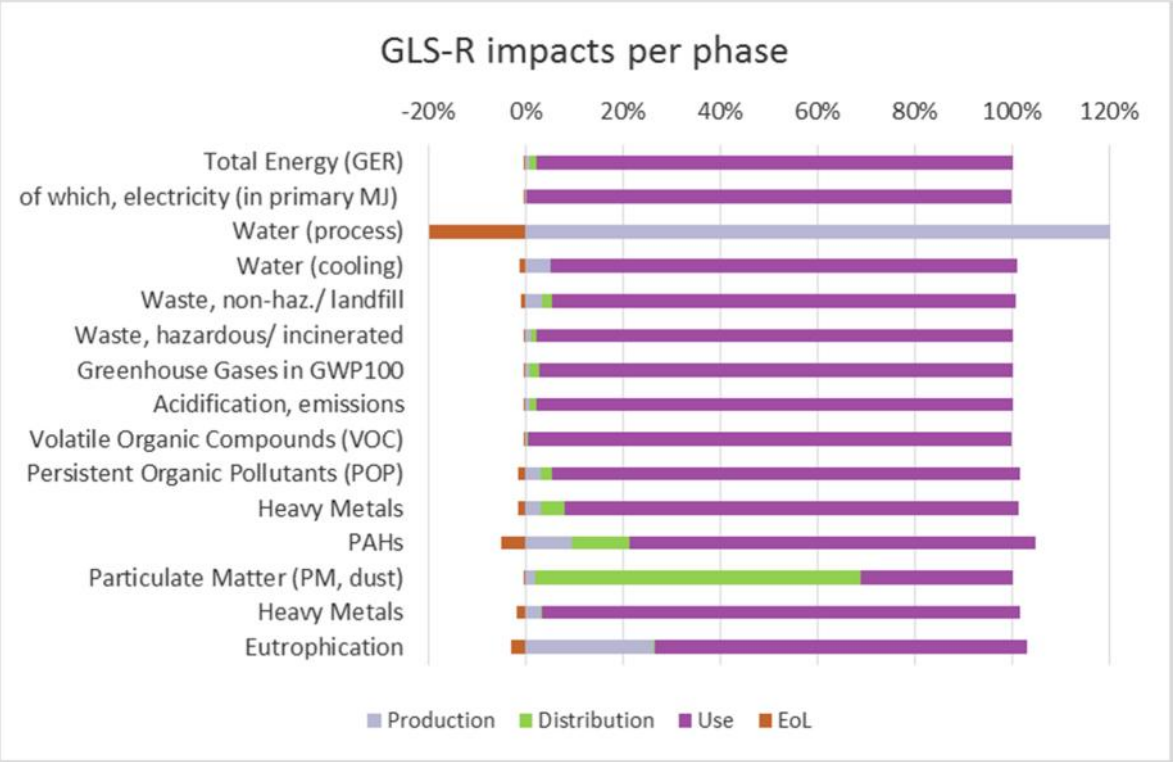

Table 49 Life Cycle Impact (per unit) of GLS X

Nr	Life cycle Impact per product:	Reference year	Author
0	GLS X (incandescent other, incl. clear/pearl, candle, coloured, decorative)	2013	vhk, izm

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Stock	
	Materials	unit									
1	Bulk Plastics	g			6		0	12	9	-15	0
2	TecPlastics	g			1		0	2	2	-3	0
3	Ferro	g			0		0	0	0	0	0
4	Non-ferro	g			1		0	0	3	-3	0
5	Coating	g			0		0	0	0	0	0
6	Electronics	g			0		0	0	0	0	0
7	Misc.	g			76		1	92	171	-186	0
8	Extra	g			0		0	0	0	0	0
9	Auxiliaries	g			0		0	0	0	0	0
10	Refrigerant	g			0		0	0	0	0	0
	Total weight	g			85		1	106	186	-206	0
	Other Resources & Waste							debet	credit		
11	Total Energy (GER)	MJ	3	0	3	5	481	0	-2		488
12	of which, electricity (in primary MJ)	MJ	1	0	1	0	481	0	-1		481
13	Water (process)	ltr	0	0	0	0	0	0	0		0
14	Water (cooling)	ltr	1	0	1	0	21	0	0		22
15	Waste, non-haz./ landfill	g	6	1	7	5	248	1	-5		255
16	Waste, hazardous/ incinerated	g	0	0	0	0	8	0	0		8
	Emissions (Air)										
17	Greenhouse Gases in GWP100	kg CO2 eq.	0	0	0	0	21	0	0		21
18	Acidification, emissions	g SO2 eq.	1	0	1	1	91	0	0		92
19	Volatile Organic Compounds (VOC)	g	0	0	0	0	11	0	0		11
20	Persistent Organic Pollutants (POP)	ng i-Teq	0	0	0	0	1	0	0		1
21	Heavy Metals	mg Ni eq.	0	0	0	0	5	0	0		5
22	PAHs	mg Ni eq.	0	0	0	0	1	0	0		1
23	Particulate Matter (PM, dust)	g	0	0	0	3	2	0	0		5
	Emissions (Water)										
24	Heavy Metals	mg Hg/20	0	0	0	0	2	0	0		2
25	Eutrophication	g PO4	0	0	0	0	0	0	0		0

Table 50 Life Cycle Impact (per unit) of GLS X, percentages per phase

	Production	Distribution	Use	EoL
Total Energy (GER)	1%	1%	99%	0%
of which, electricity (in primary MJ)	0%	0%	100%	0%
Water (process)	375%	0%	4%	-278%
Water (cooling)	4%	0%	98%	-2%
Waste, non-haz./ landfill	3%	2%	97%	-2%
Waste, hazardous/ incinerated	1%	1%	99%	-1%
Greenhouse Gases in GWP100	1%	2%	98%	0%
Acidification, emissions	1%	1%	98%	0%
Volatile Organic Compounds (VOC)	0%	0%	100%	0%
Persistent Organic Pollutants (POP)	3%	2%	98%	-3%
Heavy Metals (air)	3%	5%	96%	-3%
PAHs	8%	11%	90%	-10%
Particulate Matter (PM, dust)	2%	57%	42%	-1%
Heavy Metals (water)	3%	0%	100%	-3%
Eutrophication	22%	0%	83%	-6%

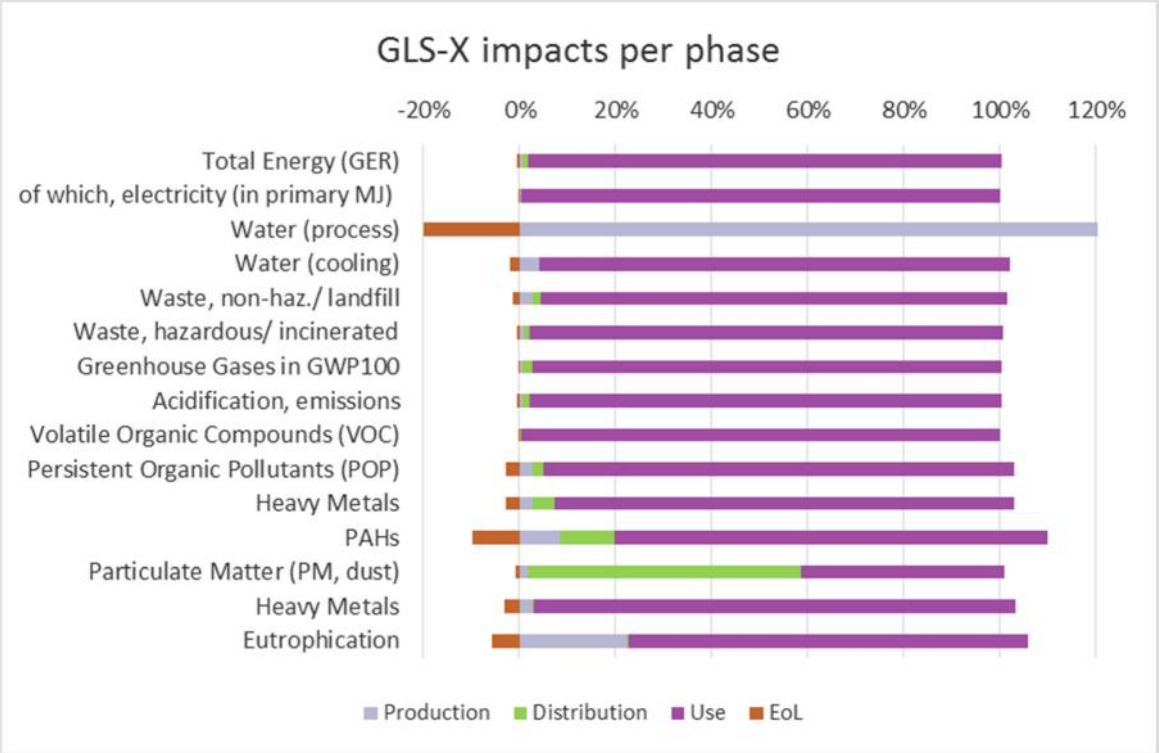

Table 51 Life Cycle Impact (per unit) of HPM

Nr	Life cycle Impact per product:	Reference year	Author
0	HPM (high-pressure mercury lamps)	2013	vhk, izm

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Stock	
	Materials	unit									
1	Bulk Plastics	g			0		0	0	0	0	0
2	TecPlastics	g			0		0	0	0	0	0
3	Ferro	g			0		0	0	0	0	0
4	Non-ferro	g			17		0	2	31	-16	0
5	Coating	g			0		0	0	1	0	0
6	Electronics	g			9		0	6	10	-8	0
7	Misc.	g			224		2	114	315	-204	0
8	Extra	g			0		0	0	0	0	0
9	Auxiliaries	g			0		0	0	0	0	0
10	Refrigerant	g			0		0	0	0	0	0
	Total weight	g			250		2	122	358	-228	0
	Other Resources & Waste							debet	credit		
11	Total Energy (GER)	MJ	8	1	9	7	18,000	0	-4		18,012
12	of which, electricity (in primary MJ)	MJ	4	0	4	0	18,000	0	-2		18,002
13	Water (process)	ltr	2	0	2	0	0	0	-1		1
14	Water (cooling)	ltr	0	0	0	0	800	0	0		800
15	Waste, non-haz./ landfill	g	9	1	10	6	9,276	1	-5		9,288
16	Waste, hazardous/ incinerated	g	0	0	0	0	284	0	0		284
	Emissions (Air)										
17	Greenhouse Gases in GWP100	kg CO2 eq.	0	0	0	1	768	0	0		769
18	Acidification, emissions	g SO2 eq.	3	0	3	2	3,400	0	-2		3,403
19	Volatile Organic Compounds (VOC)	g	0	0	0	0	402	0	0		402
20	Persistent Organic Pollutants (POP)	ng i-Teq	0	0	0	0	42	0	0		42
21	Heavy Metals	mg Ni eq.	1	0	1	0	182	109	-694		-402
22	PAHs	mg Ni eq.	0	0	0	0	42	0	0		42
23	Particulate Matter (PM, dust)	g	0	0	0	9	72	0	0		81
	Emissions (Water)										
24	Heavy Metals	mg Hg/20	1	0	1	0	77	0	0		78
25	Eutrophication	g PO4	0	0	0	0	3	0	0		3

Table 52 Life Cycle Impact (per unit) of HPM, percentages per phase

	Production	Distribution	Use	EoL
Total Energy (GER)	0%	0%	100%	0%
of which, electricity (in primary MJ)	0%	0%	100%	0%
Water (process)	195%	0%	2%	-97%
Water (cooling)	0%	0%	100%	0%
Waste, non-haz./ landfill	0%	0%	100%	0%
Waste, hazardous/ incinerated	0%	0%	100%	0%
Greenhouse Gases in GWP100	0%	0%	100%	0%
Acidification, emissions	0%	0%	100%	0%
Volatile Organic Compounds (VOC)	0%	0%	100%	0%
Persistent Organic Pollutants (POP)	1%	0%	100%	-1%
Heavy Metals (air)	0%	0%	45%	-146%
PAHs	0%	1%	99%	0%
Particulate Matter (PM, dust)	0%	11%	89%	0%
Heavy Metals (water)	1%	0%	100%	0%
Eutrophication	1%	0%	100%	0%

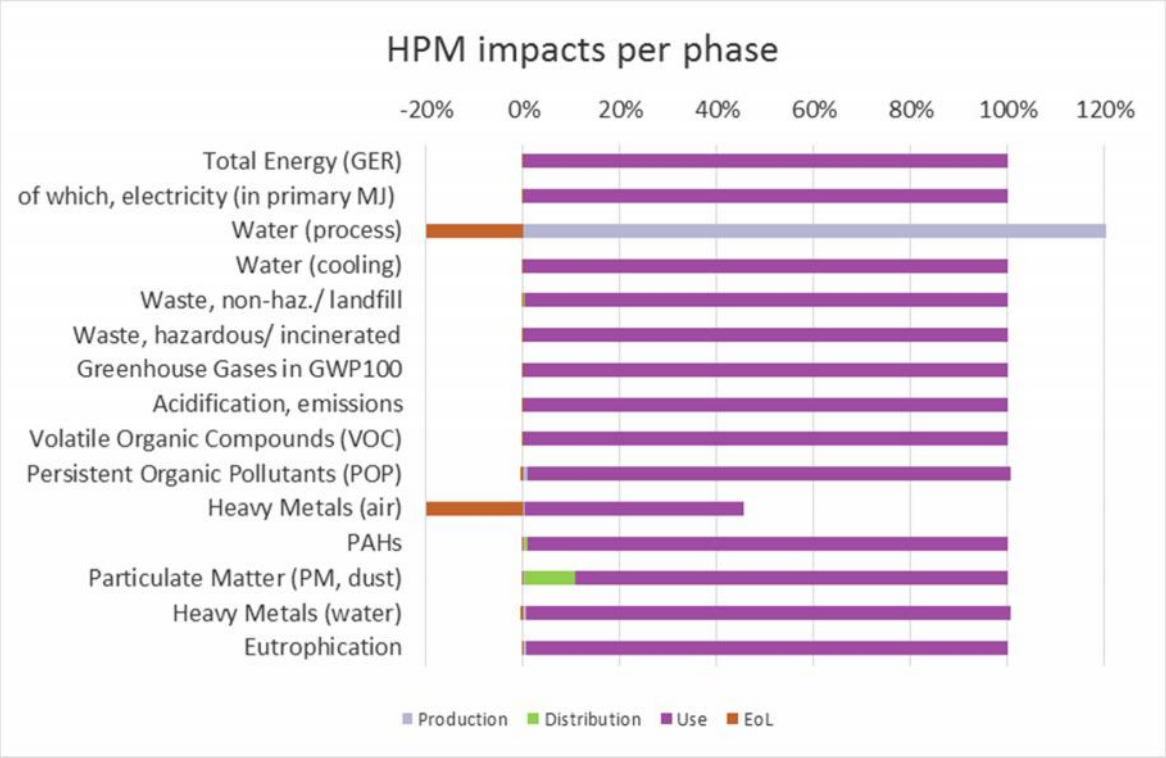

Table 53 Life Cycle Impact (per unit) of HPS

Nr	Life cycle Impact per product:	Reference year	Author
0	HPS (high-pressure sodium lamps)	2013	vhk, izm

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Stock	
	Materials	unit									
1	Bulk Plastics	g			0		0	0	0	0	0
2	TecPlastics	g			0		0	0	0	0	0
3	Ferro	g			5		0	0	6	-1	0
4	Non-ferro	g			34		0	2	36	-4	0
5	Coating	g			3		0	0	3	0	0
6	Electronics	g			4		0	2	3	0	0
7	Misc.	g			167		2	50	137	-18	0
8	Extra	g			0		0	0	0	0	0
9	Auxiliaries	g			0		0	0	0	0	0
10	Refrigerant	g			0		0	0	0	0	0
	Total weight	g			213		2	54	185	-23	0
	Other Resources & Waste							debet	credit		
11	Total Energy (GER)	MJ	16	1	17	7	15,120	0	-6		15,138
12	of which, electricity (in primary MJ)	MJ	11	0	11	0	15,120	0	-4		15,127
13	Water (process)	ltr	2	0	2	0	0	0	-1		1
14	Water (cooling)	ltr	6	0	6	0	672	0	-2		676
15	Waste, non-haz./ landfill	g	79	2	80	6	7,793	1	-32		7,847
16	Waste, hazardous/ incinerated	g	0	0	0	0	239	0	0		239
	Emissions (Air)										
17	Greenhouse Gases in GWP100	kg CO2 eq.	1	0	1	1	645	0	0		646
18	Acidification, emissions	g SO2 eq.	8	0	8	2	2,856	0	-3		2,863
19	Volatile Organic Compounds (VOC)	g	0	0	0	0	338	0	0		338
20	Persistent Organic Pollutants (POP)	ng i-Teq	2	0	2	0	35	0	-1		37
21	Heavy Metals	mg Ni eq.	9	0	9	0	153	24	-159		27
22	PAHs	mg Ni eq.	1	0	1	0	35	0	0		36
23	Particulate Matter (PM, dust)	g	0	0	0	8	60	0	0		68
	Emissions (Water)										
24	Heavy Metals	mg Hg/20	2	0	2	0	65	0	-1		66
25	Eutrophication	g PO4	0	0	0	0	3	0	0		3

Table 54 Life Cycle Impact (per unit) of HPS, percentages per phase

	Production	Distribution	Use	EoL
Total Energy (GER)	0%	0%	100%	0%
of which, electricity (in primary MJ)	0%	0%	100%	0%
Water (process)	152%	0%	1%	-54%
Water (cooling)	1%	0%	99%	0%
Waste, non-haz./ landfill	1%	0%	99%	0%
Waste, hazardous/ incinerated	0%	0%	100%	0%
Greenhouse Gases in GWP100	0%	0%	100%	0%
Acidification, emissions	0%	0%	100%	0%
Volatile Organic Compounds (VOC)	0%	0%	100%	0%
Persistent Organic Pollutants (POP)	6%	0%	97%	-2%
Heavy Metals (air)	32%	1%	562%	-495%
PAHs	2%	1%	98%	-1%
Particulate Matter (PM, dust)	1%	11%	89%	0%
Heavy Metals (water)	2%	0%	99%	-1%
Eutrophication	11%	0%	94%	-4%

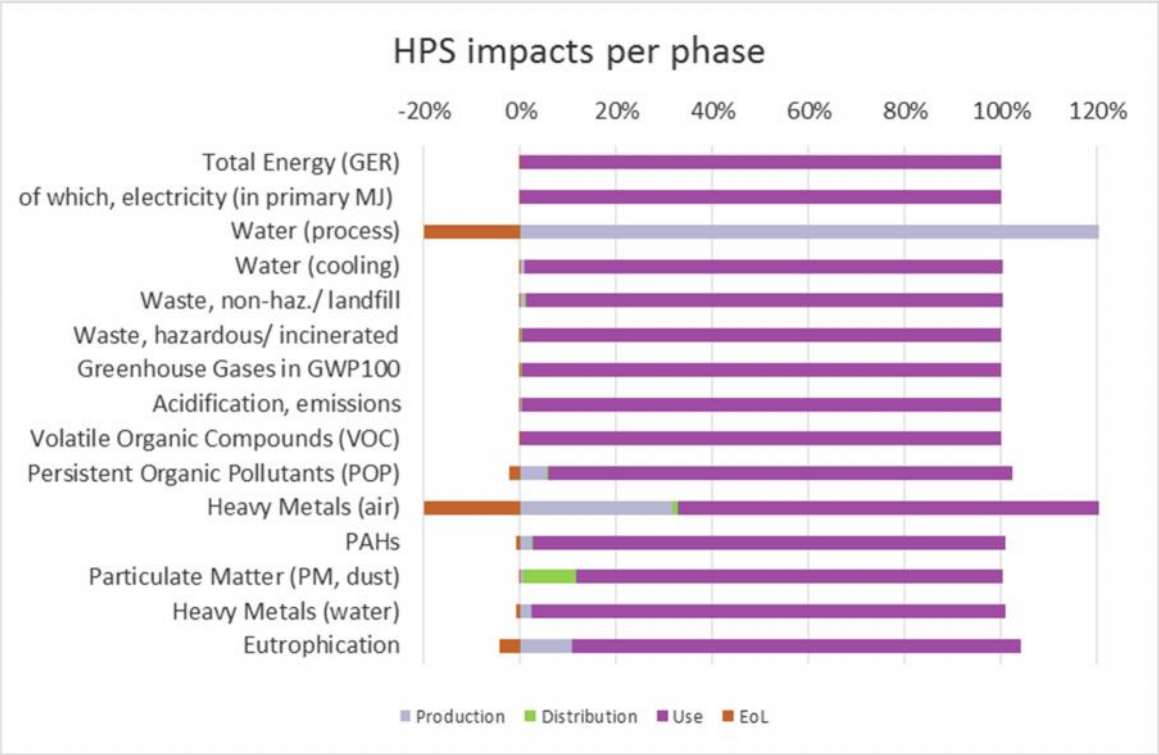

Table 55 Life Cycle Impact (per unit) of MH

Nr	Life cycle Impact per product:	Reference year	Author
0	MH (metal-halide lamps)	2013	vhk, izm

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Stock	
	Materials	unit									
1	Bulk Plastics	g			0		0	0	0	0	0
2	TecPlastics	g			0		0	0	0	0	0
3	Ferro	g			4		0	0	5	-1	0
4	Non-ferro	g			24		0	2	31	-9	0
5	Coating	g			2		0	0	3	-1	0
6	Electronics	g			2		0	1	2	-1	0
7	Misc.	g			127		1	47	131	-50	0
8	Extra	g			0		0	0	0	0	0
9	Auxiliaries	g			0		0	0	0	0	0
10	Refrigerant	g			0		0	0	0	0	0
	Total weight	g			158		2	51	172	-63	0
	Other Resources & Waste							debet	credit		
11	Total Energy (GER)	MJ	12	1	12	6	11,520	0	-6		11,532
12	of which, electricity (in primary MJ)	MJ	7	0	7	0	11,520	0	-4		11,524
13	Water (process)	ltr	1	0	1	0	0	0	-1		1
14	Water (cooling)	ltr	4	0	4	0	512	0	-2		514
15	Waste, non-haz./ landfill	g	54	1	56	5	5,937	1	-28		5,971
16	Waste, hazardous/ incinerated	g	0	0	0	0	182	0	0		182
	Emissions (Air)										
17	Greenhouse Gases in GWP100	kg CO2 eq.	1	0	1	0	492	0	0		492
18	Acidification, emissions	g SO2 eq.	5	0	6	1	2,176	0	-3		2,180
19	Volatile Organic Compounds (VOC)	g	0	0	0	0	257	0	0		257
20	Persistent Organic Pollutants (POP)	ng i-Teq	1	0	1	0	27	0	-1		28
21	Heavy Metals	mg Ni eq.	6	0	6	0	117	8	-51		79
22	PAHs	mg Ni eq.	1	0	1	0	27	0	0		27
23	Particulate Matter (PM, dust)	g	0	0	0	3	46	0	0		50
	Emissions (Water)										
24	Heavy Metals	mg Hg/20	1	0	1	0	50	0	-1		50
25	Eutrophication	g PO4	0	0	0	0	2	0	0		2

Table 56 Life Cycle Impact (per unit) of MH, percentages per phase

	Production	Distribution	Use	EoL
Total Energy (GER)	0%	0%	100%	0%
of which, electricity (in primary MJ)	0%	0%	100%	0%
Water (process)	179%	0%	2%	-80%
Water (cooling)	1%	0%	100%	0%
Waste, non-haz./ landfill	1%	0%	99%	0%
Waste, hazardous/ incinerated	0%	0%	100%	0%
Greenhouse Gases in GWP100	0%	0%	100%	0%
Acidification, emissions	0%	0%	100%	0%
Volatile Organic Compounds (VOC)	0%	0%	100%	0%
Persistent Organic Pollutants (POP)	5%	0%	98%	-2%
Heavy Metals (air)	7%	0%	148%	-55%
PAHs	3%	1%	98%	-2%
Particulate Matter (PM, dust)	1%	7%	93%	0%
Heavy Metals (water)	2%	0%	99%	-1%
Eutrophication	10%	0%	95%	-5%

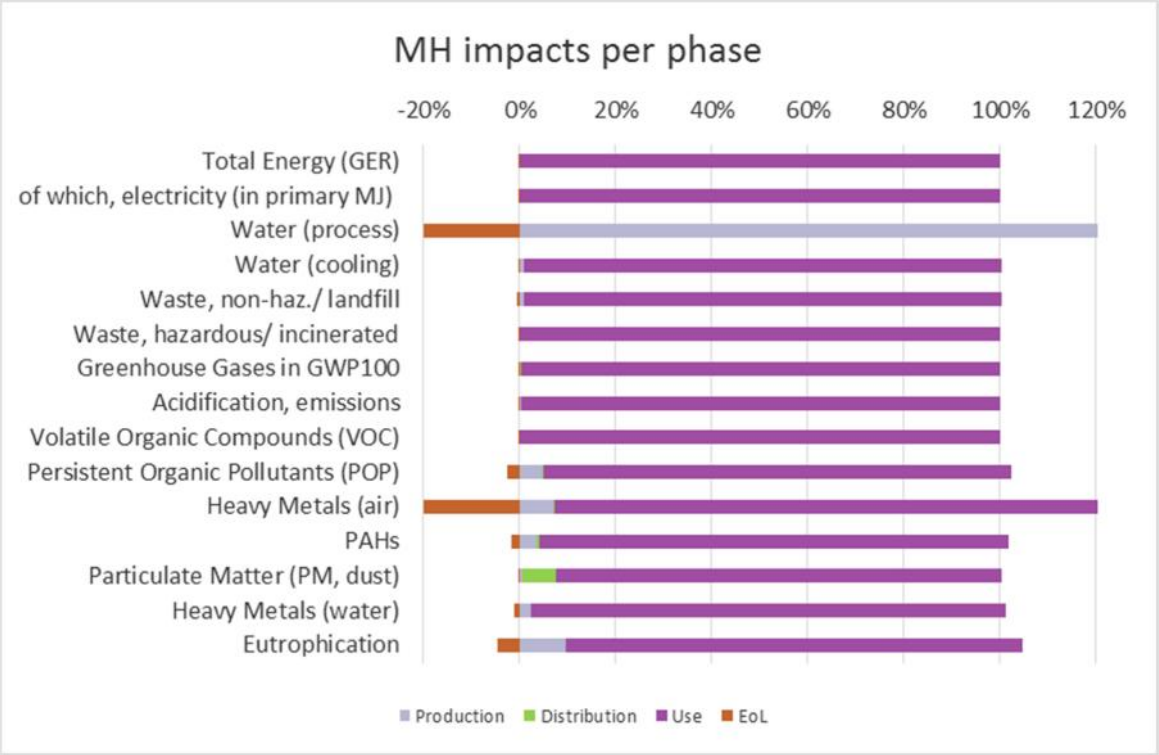

Table 57 Life Cycle Impact (per unit) of LED lamps

Nr	Life cycle Impact per product:	Reference year	Author
0	LED lamps	2013	vhk, izm

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Stock	
	Materials	unit									
1	Bulk Plastics	g			4		0	2	2	0	0
2	TecPlastics	g			30		0	13	17	0	0
3	Ferro	g			1		0	0	1	0	0
4	Non-ferro	g			77		1	4	74	0	0
5	Coating	g			0		0	0	0	0	0
6	Electronics	g			27		0	10	17	0	0
7	Misc.	g			52		1	14	39	0	0
8	Extra	g			0		0	0	0	0	0
9	Auxiliaries	g			0		0	0	0	0	0
10	Refrigerant	g			0		0	0	0	0	0
	Total weight	g			190		2	43	149	0	0
	Other Resources & Waste							debet	credit		
11	Total Energy (GER)	MJ	27	5	33	5	2,250	1	-7		2,282
12	of which, electricity (in primary MJ)	MJ	15	1	16	0	2,250	0	-4		2,263
13	Water (process)	ltr	8	0	8	0	0	0	-2		6
14	Water (cooling)	ltr	9	2	10	0	100	0	-2		108
15	Waste, non-haz./ landfill	g	93	9	102	5	1,160	3	-24		1,246
16	Waste, hazardous/ incinerated	g	41	0	41	0	36	0	-10		67
	Emissions (Air)										
17	Greenhouse Gases in GWP100	kg CO2 eq.	1	0	2	0	96	0	0		98
18	Acidification, emissions	g SO2 eq.	14	2	16	1	425	0	-4		438
19	Volatile Organic Compounds (VOC)	g	0	0	0	0	50	0	0		50
20	Persistent Organic Pollutants (POP)	ng i-Teq	2	0	2	0	5	0	-1		7
21	Heavy Metals	mg Ni eq.	3	0	3	0	23	0	-1		25
22	PAHs	mg Ni eq.	2	0	2	0	5	0	-1		6
23	Particulate Matter (PM, dust)	g	1	0	1	3	9	0	0		13
	Emissions (Water)										
24	Heavy Metals	mg Hg/20	3	0	3	0	10	0	-1		12
25	Eutrophication	g PO4	0	0	0	0	0	0	0		1

Table 58 Life Cycle Impact (per unit) of LED, percentages per phase

	Production	Distribution	Use	EoL
Total Energy (GER)	1%	0%	99%	0%
of which, electricity (in primary MJ)	1%	0%	99%	0%
Water (process)	129%	0%	1%	-31%
Water (cooling)	10%	0%	92%	-2%
Waste, non-haz./ landfill	8%	0%	93%	-2%
Waste, hazardous/ incinerated	62%	0%	54%	-15%
Greenhouse Gases in GWP100	2%	0%	98%	0%
Acidification, emissions	4%	0%	97%	-1%
Volatile Organic Compounds (VOC)	0%	0%	100%	0%
Persistent Organic Pollutants (POP)	36%	0%	77%	-13%
Heavy Metals (air)	12%	1%	90%	-3%
PAHs	25%	2%	82%	-9%
Particulate Matter (PM, dust)	11%	20%	70%	-2%
Heavy Metals (water)	24%	0%	83%	-7%
Eutrophication	39%	0%	65%	-4%