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Preparatory Studies for Eco-design Requirements of EuPs

Final Report
Lot 9: Public street lighting

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

0 EXECUTIVE SUMMARY

The aim of this preparatory study is to provide information on whether and which eco-design requirements could be set for street lighting products in order to improve their environmental performance in the framework of Directive 2005/32/EC on eco-design requirements for energy-using products. The structure of this study is according to the MEEUP methodology and contains the typical 8 chapters. In a multi-stakeholder consultation, a number of groups and experts provided comments on a preliminary draft of this report. The report was then revised, benefiting from stakeholder perspectives and input. The views expressed in the report remain those of the authors, and do not necessarily reflect the views of the European Commission or the individuals and organisations that participated in the consultation. A list of stakeholders that participated in this consultation is included in the appendix.

The MEEUP methodology report structure distinguishes 8 product specific sections:
1. Product Definition;
2. Market and economic analysis;
3. Consumer Behaviour & Local Infrastructure;
4. Technical Analysis Existing Products;
5. Definition of Base Case(s);
6. Technical Analysis of Best Available Technology(BAT) and BNAT;
7. Improvement Potential;
8. Scenario, Policy, Impact and Sensitivity Analyses.

A project report is published toghether with this study, providing more background on how the preparatory study was conceived and the process to arrive at the results.

Street lighting is without doubt an energy using product that has been installed in European cities for centuries. Since early mankind, outdoor lighting has contributed to human development by providing and improving human vision at night. The current (2005) energy consumption estimated in this study is 35 TWh for the EU25 representing about 1,3 % of the final energy consumption of electricity in the EU25 (Eurostat definition). Although outdoor lighting has been around for centuries, the lighting industry made significant technological progress in the last decades and is still committed for further innovation (see chapter 6). New installation projects are mostly related to new urbanisation of rural areas and in part to city beautification. City beautification projects are less related to vision alone. Because street lighting luminaires have an estimated lifetime of 30 years (see chapter 2), there is a considerable number of installations that are based on old, energy inefficient technology. As a consequence, the market for replacement or renovation of those installations is large. However, new energy efficient technologies are not often a known and recognised reason to speed up renovation rates. There are few incentives to improve the energy efficiency of the installed park. An additional barrier to increase the energy efficiency of existing street lighting installations is the lack of simple, energy saving, retrofit measures such as the self-ballasted Compact Fluorescent Lamp in domestic lighting. Lamps in street lighting are mostly High Intensity Discharge lamps that need an appropriate ballast and optic system. In most cases the ballast and even the luminaire in its entirety need to be replaced. Moreover, the old, less performing technology is still available on the market and even installed nowadays(see chapters 2&4).

Once street lighting products are on the market, they are used between 2500 up to 4400 h per year (see chapter 3) and there is few doubt about it.

The environmental impacts of Energy-using Products, including street lighting, take various forms, such as energy consumption and related negative contribution to climate change, consumption of materials and natural resources, waste generation and release of hazardous substances that are quantified according to the MEEUP methodology (see chapters 5 and 7). Much as artificial lighting provides a very useful service, it has also initiated a side-effect known as 'light pollution' (see chapter 4). Pressure groups, e.g. the International Dark-Sky Association, have been addressing the matter in recent years. Initially these pressure groups focused on star visibility but there is a growing concern for the direct impact of outdoor lighting that alters natural light regimes in terrestrial and aquatic ecosystems. Light pollution is therefore treated as an environmental aspect in the context of this study but not quantified because of the absence of sufficient scientific evidence that would allow to quantify its significance.

This study points out that the largest environmental impact comes from the use of electricity according to the MEEUP methodology applied to all quantified parameters (see chapter 5). If products placed on the market relied on the latest best available technology, a significant reduction on environmental impact could be realised as pointed out in this study. New technologies and product features (see chapter 4 and 6) can also significantly reduce 'light pollution' in combination with energy savings (see chapters 6 and 7). However, if the focus is only on low astronomical light pollution there is a risk of sub-optimisation of energy efficiency (see chapter 6).

Finally, the following eco-design options are recommended for further consultation (see chapter 8) by the EC on the implementation of Directive 2005/32/EC:

- Generic Eco-design requirements for the supply of information for lamps, luminaires and ballasts;
- Generic eco-design requirement for reducing light pollution;
- Specific eco-design requirement for excluding the application of High Pressure Mercury lamps;
- Specific eco-design requirements for increasing the lamp efficacy of High Pressure Sodium lamps;
- Specific eco-design requirements for increasing lamp efficacy and lamp lumen maintenance of Metal Halide lamps;
- Specific eco-design requirements for minimum ballast efficiency for all HID lamp ballasts, HID stands for High Intensity Discharge lamps and is a group name;
- Specific eco-design requirements required to increase the luminaire maintenance factor (LMF), e.g. by higher Ingress Protection (IP-rating);
- Specific eco-design requirements for increasing the optic efficiency and decreasing upward light flux;

- Specific eco-design requirements for the application of electronic, dimming ballasts.

Complementary to this study, calculation spreadsheets are published that include the MEEUP EcoReport and input data.
There are additional recommendations in chapter 8 for the appropriate putting into service of street lighting luminaires, for the development of a new measurement standard for HID ballasts and additional research.

The scenarios in chapter 8 point out that excluding the application of High Pressure Mercury lamps in street lighting in 2010 can reduce energy consumption in 2020 from 39 TWh in Business as Usual to 35 TWh and that implementing all formulated specific eco-design requirements can reduce energy consumption in 2020 further to 31 TWh. The impact on global warming potential (GWP) is almost proportional, wherein 39.4 TWh electricity use (Business as Usual scenario) is equivalent to 17.7 Mt CO_2 eq (GWP).
This measure would have the additional advantage that there will be a significant amount of lamp-mercury that is withdrawn from circulation.
These scenarios take into account a 30 year product life. An accelerated replacement of the installed park of luminaires with outdated technology will also accelerate the beneficial impact on energy consumption (see chapter 8).

1 PRODUCT DEFINITION

The goal of this task is to define the product category and define the system boundaries of the ‘playing field’ for eco-design. It is important for a realistic definition of design options and improvement potential and it is also relevant in the context of technically defining any legislation or voluntary measure (if any).

In this study the product definition and classification are derived from existing European standards and official classification schemes. A more detailed overview and discussion of the existing test standards, product legislation and official classification schemes is included in chapters 1.2 and 1.3. The most broadly accepted definitions for road lighting classes, performance criteria and measuring methods can be found in the EN 13201 standard series. 'Lighting equipment' parts comprising 'luminaires', 'ballasts' and 'lamps' are defined in standard EN 12665 and 'particular luminaire requirements for road and street lighting' are defined in standard EN 60598-2-3. There is no specific definition for lamps and ballasts for road lighting, because these parts can also be used for other lighting applications. Also, a functional-oriented classification of street lighting road classes and performance criteria can be derived from the EN 13201 standard series (see 1.1.2). The Prodcom classification (see chapter 2) defines street lighting as according to two functions: ‘pedestrian’ and ‘other roads’, and at a more disaggregated level according to lamp technology: ‘incandescent’, ‘fluorescent’, ‘other lamps’. The PRODCOM level of aggregation is generally too high and too outdated (lamp types) for the purpose of this study (see 1.1.4). The approach in this study uses the function-based classes in line with EN 13201-2 and a further technology-based segmentation in accordance with lamp and ballast types defined in EN and IEC standards.

1.1 Product category and performance assessment

1.1.1 Product definition and scope of products

According to the definition of Energy-Using Products, Article 2.1 of the EuP Directive; lamps, ballasts and luminaires are EuP’s; they can be considered at “part"-level and/or at “product"-level.

The following definition of (public) street lighting equipment can be derived from EN 13201:

“fixed lighting installation intended to provide good visibility to users of outdoor public traffic areas during the hours of darkness to support traffic safety, traffic flow and public security”.

A street lighting product system can more generally be considered a 'lighting equipment' as defined in standard EN 12665 (Light and lighting - Basic terms and criteria for specifying lighting requirements) and EN 60598-2-3 (Luminaires Part 2-3: particular requirements - luminaires for road and street lighting), containing:

1. A “*lamp”* as *“source made in order to produce an optical radiation, usually visible*”(fig.1);

Figure 1: Typical street lighting lamps

2. A “*ballast”* as *“device connected between the supply and one or more discharge lamps which serves mainly to limit the current of the lamp(s) to the required value”* Note that in this study, a ballast also includes means for transforming the supply voltage, correcting the power factor and, either alone or in combination with a starting device, provide the necessary conditions for starting the lamp(s). (fig.2);

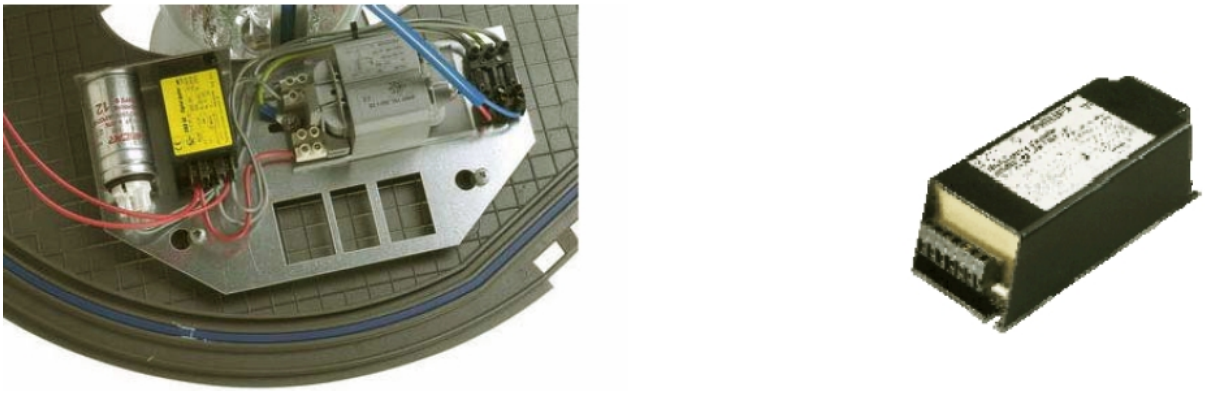

Figure 2: Typical street lighting ballast

3. A *”luminaire*” as *“apparatus which distributes, filters or transforms the light transmitted from one or more lamps and which includes, except the lamps themselves, all parts necessary for fixing and protecting the lamps and, where necessary, circuit auxiliaries together with the means for connecting the lamps to the electric supply” (fig. 3).*

 

Figure 3: Typical street lighting luminaire.

In this study; ballasts, lamps and luminaires are considered the main products within street lighting equipment. It is important to notice that most lamps and ballasts defined in this study are not exclusively used for public street lighting; they could for example also be used in sports field lighting or industrial outdoor and indoor lighting.

In general, it is important for this eco-design study that the definition of outdoor lighting scopes products with similar characteristics in order to be able to derive meaningful conclusions regarding design options and improvement potential.

Many other types of outdoor lighting or products used outdoors containing lights (i.e. signal lighting) can be thought of. However, products falling out of the scope of this study 'may' benefit from the conclusions of this study but should also be evaluated for their own proper application.

Following the previous product definition for public street lighting, the products below are not in the scope of this study:

- Traffic signs (fig. 4) and road signalisation products: their function is not "to provide good visibility…during hours of darkness" and they consequently have different characteristics from street lighting.

Figure 4: Traffic signs (outside the product boundary)

- Tunnel lighting (fig. 5) can be considered a very specific type of street lighting with various different and complementing performance requirements, measuring methods etcetera. For this reason, separate standards on tunnel lighting exist (e.g. BS 5489-2, ..standards per EU country), apart from those on outdoor street lighting. Also, annual sales of tunnel lighting is marginal compared to outdoor street lighting and is expected to be lower than the criterion of 200.000 units annual sales given in the EuP Directive, article 15.

Figure 5: Tunnel lighting (outside the product boundary)

- Lighting installations for 'city beautification' for which the function is:
    - to light monuments, building facades, trees, hills, other objects or subjects, (fig. 6)
    - to light the surrounding space of the public areas in order to create a good appearance of the context,
    - to be itself as a subject to look for.

  Their function is completely different from the functions given in the definition of the standard and by consequence these products can have different characteristics.

Figure 6: Monument lighting (outside the product boundary)

- Products such as private outdoor car park lighting, domestic and commercial outdoor lighting, lighting of sports fields, industrial sites, etcetera…because they are non-public street lighting (fig. 7) applications. As mentioned before, this does not exclude that they can benefit from the similar conclusions of this study (see 8.2.1).

Figure 7: Non-public lighting applications (outside the product boundary)

The following parts, typical for a public street lighting installation (or product system), are not or only partly considered in the scope of this study:

- The "Bill Of Materials" (BOM) and cost of the supports (e.g. lighting poles, ..) and it's fixation parts are only partly considered. Consequently, the related production and disposal impacts of the poles are not accounted for. There are several reasons for this omission:
  First, the poles have a typical technical and economical lifetime from 30 till more than 50 years. This timescale makes them part of the system (infrastructure) in which the products: lamps , ballasts and luminaires operate. The important relation between the products and the wider system in which they operate is treated in the technical analysis related to the system use phase in chapter 4. Moreover, there exist many alternative luminaire support methods for lighting poles such as: building mountings, catenaries and existing electricity distribution poles... Lighting supports (e.g. poles, ..) will also be assessed in chapter 3 as local infrastructure.
  Second, a luminaire is almost never brought on the market together with lighting poles. Lighting poles are therefore a separate product group (defined in standard EN 40 series) not dependent on energy input to work as intended , nor do they generate, transfer, measure energy. They do therefore not fulfil the definition of an EuP product definition. The impact is assessed in 8.1.3.4.
- The cost of installing the luminaire at a particular position and height is included in the study, as this is an important economic factor to be considered while evaluating options for improvement. This cost represents an average of many existing variations in positioning a luminaire at the desired place and height: one or more luminaires connected to one pole, catenaries, steel, wood or aluminium or other material poles, luminaires connected to existing infrastructure i.e. houses, infrastructure for electricity distribution, etcetera… The result on "installation costs" thus includes the cost of materials, manpower and equipment necessary for installing the armatures.

1.1.2 Performance requirements and street lighting categories

Performance requirements for new street lighting installations are drawn up by CEN TC 169/226 JWG in standard EN 13201-2. Note that in the installed base or stock of street lighting, older equipment do not necessarily meet these relatively new performance requirements e.g. lighting level, uniformity etc.. Determination of real-life performance versus standard performance is part of this study (chapter 3).

Guideline CEN/TR 13201-1 specifies the selection of lighting classes for road lighting. This guideline considers the lighting classes set out in EN 13201-2 and provides guidance on the application of these classes. To do this, it includes a system to define an outdoor public traffic area in terms of parameters relevant to lighting. To assist in the application of classes, it suggests a practical relationship between the various series of lighting classes, in terms of comparable or alternative classes.
The standard EN 13201-2 contains performance requirements in defined classes (ME1..ME6, MEW1..MEW6, CE0..CE5, S1..S6, ES1 .. ES6, A1 .. A6). A lighting class is characterized by a set of photometric requirements aiming at the visual needs of certain road users in certain types of road areas and environment.

Because the number of classes specified in the standard is relatively extensive, a simplified and more aggregated classification of 3 road categories (see figure 8) is followed in this study.. These categories with the same lighting levels and more corresponding with the classes used in European statistics for road lengths are defined hereafter:

1. Category F "fast traffic" with fast motorized traffic use only, having only luminance requirements (cd/m²). Also corresponding to classes ME1 to ME5 or MEW1 to MEW5 for new installations.

2. Category M "mixed traffic" with motorized traffic, slow moving vehicles, and possibly cyclists and pedestrians with only luminance requirements (cd/m²). Also corresponding to classes ME2 to ME5 or MEW2 to MEW5 for new installations.

3. Category S "slow traffic" for mainly urban and pedestrian areas, with illuminance requirements only (lx). Corresponding to classes CE0 to CE5, S1 to S6 and ES, EV and A classes for new installations.

Figure 8: Example of Fast Traffic (category F), Mixed Traffic (category M) and Slow Traffic situations (category S)

This classification of street lighting serves right for the study and is according to the MEEuP Methodology (VHK, 2005) as we are looking for product groupings that are functionally similar. And by consequence a similar group of design options would apply to improve its environmental performance. In the following tables, an overview is given of the classes used in this study and their related performance requirements.

Guideline EN/TR 13201-1 and standard EN 13201-2 are summarised hereafter (simplified version) in table 1.

Table 1: Simplified version of guideline CEN/TR 13201-1 and standard EN 13201-2

Simplified version of selection according to EN/TR 13201-1 guideline and standard EN 13201-2 performance classes						
		Luminance concept (objective = vision of road surface)				
Road type	**typical situation**	**EN 13201 class**	**Lavg Cd/m²**	**U_O**	**U_l**	**TI %**
category **'F'** fast traffic only (e.g. motorways,..)	busy and fast	ME1	2	0,4	0,7	10
	busy and normal speed	ME2	1,5	0,4	0,7	10
	not busy and rain	ME3a	1	0,4	0,7	15
	few traffic	ME4a	0,75	0,4	0,6	15
category **'M'** mixed traffic	busy	ME2	1,5	0,4	0,7	10
	normal	ME3a	1	0,4	0,7	15
	few traffic	ME4a	0,75	0,4	0,6	15

Simplified version of selection according to EN/TR 13201-1 guideline and standard EN 13201-2 performance classes					
		Illuminance concept (objective = light levels to see persons and cars)			
Road type	**typical situation**	**EN 13201 class**	**Eavg illuminance (Avg) lx**	**Umin Uniformity**	**Emin Illuminance(min)**
category **'S'** slow traffic	busy	CE2	20	0,4	
	normal	CE3	15	0,4	
	few traffic	CE4	10	0,4	
	busy	S2	10		3
	normal	S4	5		1
	few traffic	S6	2		0,6

Where:
- L [Cd/m2] is minimum maintained average road surface luminance;
- U_O is minimum overall uniformity (of road surface luminance, illuminance on a road area or hemispherical illuminance);
- U_l is minimum longitudinal uniformity (of road surface luminance);
- TI is maximum threshold increment: measure of loss of visibility caused by the disability glare of the luminaires of a road lighting installation
- E [lx] is minimum maintained average illuminance (on a road area);
- E_{min} is minimum illuminance (on a road area).

Please note that there also exist the following classes that are less frequently used:
- The ES classes are intended as additional classes for pedestrian areas for the purposes of reducing crime and suppressing feelings of insecurity.
- The EV classes in Table 6 are intended as additional classes in situations where vertical surfaces need to be seen, e.g. interchange areas, roundabouts etc.
- The MEW series corresponds to the ME series but also includes U_O specifications for wet road conditions.
- Class A can be used complementary to class S and uses 'hemispherical illuminance' as unit.

From this summary of performance requirements can be concluded that:
1. there is a large difference between minimum illuminance (E_{min}) and minimum maintained illuminance (E) for category **'S'** street lighting;
2. there is a large spread within minimum maintained luminance (L) for category **'F'** and **'M'**, while the other parameters e.g. U_O, U_l and TI are rather constant.
3. the primary functional unit of street lighting can be considered as luminance L (cd/m2) for categories **'F'** and **'M'**, and illuminance E (lx) for category **S'**.

For all street lighting luminaires we assume they are designed to meet these performance requirements, all options resulting in inferior performance are not considered.

1.1.3 Functional unit for street lighting

Knowing the functional product segmentation used in this study for street lighting and the related performance requirements, we now further explain what is called the "functional unit" of street lighting. In standard ISO 14040 on life cycle assessment (LCA) the functional unit is defined as "the quantified performance of a product system for use as a reference unit in life cycle assessment study". The primary purpose of the functional unit in this study is to provide a calculation reference to which environmental impact such as energy use, costs, etcetera can be related and to allow for comparisons between functionally equal street lighting luminaires with and without options for improvement. Reducing the functional unit to light output alone would reduce the perspective mainly to parts (lamp and ballast) which can not be individually assessed for street lighting alone.

The functional unit (FU) for street lighting in this study can be defined as:

"The maintained useful luminous flux (lumen) from the luminaire according to the performance requirements as set out in EN13201-2 for these respective classes. 'Maintained' means that performance depreciation parameters are taken into account (e.g. the luminaire maintenance factor LMF and the lamp lumen maintenance factor LLMF, ...) and 'useful' means that only the useful flux received by the road surface is taken into account."

FU [lumen] = UF x LMF x LLMF x Lamp Lumen Output (see 4.3.1.1)

Remarks:

- This approach allows to compare equal performing street lighting luminaires.
- In section 4.3.1.1, the corresponding formulas will be further pointed out but the relationship with illuminance on the road is obvious when knowing the useful road surface between luminaires: illuminance [lx] = luminous flux [lm] / surface [m²].
- This approach will allow to evaluate implementing measures at four levels in street lighting (luminaire, ballast and lamp seperatly and then the three togheter).
- An advantage of using this functional unit is that it can be directly linked to road infrastructure statistics expressed in km roads of various types and from which total EU energy consumption, environmental impacts and costs can be calculated. This is discussed in more detail in the next chapter on economic and market analysis.

1.1.4 Detailed product segmentation

As explained in the introduction of chapter 1, a further technology-based segmentation in accordance with lamp, ballast type and luminaire is required for the eco-design analysis in this study.

The Prodcom classification (see also chapter 2) defines street lighting as according to two functions: 'pedestrian' and 'other roads, and at a more disaggregated level according to lamp technology: 'incandescent', 'fluorescent', 'other lamps'. The Prodcom level of aggregation is generally too high and too outdated (lamp types) for the purpose of this study.
Therefore a further technology-based segmentation in accordance with lamp and ballast types compliant with European standards (EN) will be followed or, in case of absence of EN standards, IEC standards will be used.

1.1.4.1 Segmentation of Lamps

Lamp categories that are used in street lighting are mainly the lamps that are generally categorized by the European Lamp Companies Federation (ELC) as High Intensity Discharge lamps (HID)*(in American classifications and also in the IEA-study (2006), Low Pressure Sodium lamps are not classified as HID lamps*):

- High pressure sodium lamps,
- Low pressure sodium lamps,
- Metal halide lamps with quartz arc tube,
- Metal halide lamps with ceramic arc tube,
- High pressure mercury lamps,

In many countries, also the low pressure mercury or fluorescent lamps were and are still utilized in street lighting; subdivision can be made into following categories:

- Linear fluorescent lamps,
- Compact fluorescent lamps with integrated ballast,
- Compact fluorescent lamps with non integrated ballast.

General remarks:

- Note that none of the above mentioned lamp categories are exclusively used for street lighting. The wide range of lamp applications are often cited in the lamp manufacturers catalogue, for instance:
    - HID lamps are also used in industrial and commercial indoor and outdoor lighting
    - (Ceramic) metal halide lamps with low wattages are often used in indoor commercial lighting as replacement for halogen, incandescent lamps
    - (Quartz) metal halide lamps are often used for outdoor and indoor sport field and work place lighting
    - HID lamps are also used in monument lighting for city beautification, on parking areas etc.
    - High pressure sodium lamps are also used for plant growing in green houses
    - Fluorescent lamps are mainly used in indoor lighting for offices and commercial areas.
- LEDs are actually rarely applied in street lighting, they will be considered and discussed as Best Not yet Available Techniques(BNAT) in chapter 6.
- In each category, several lamp power ratings, socket type (e.g. plug or screw), outer glass envelope(e.g. tubular, ovoid, clear, frosted, fluorescent, etc.), colour blend, .. exist.
- Lamp manufacturers also use proprietary brand names and abbreviations in their catalogues
- In order to provide compatibility between manufacturers the ILCOS-code was created that defines exactly the lamp category, type, wattage, socket, dimensions,... This code is quite complicated and therefore seldom used by end users and in literature.
- In street lighting, mainly the metal halide-lamps with E27/E40 socket are used and are consequently considered in this study.
- Also compact fluorescent lamps with non integrated ballast for outdoor temperature ranges (street lighting versions) are considered.

Specific lamp typology and abbreviations used in this study:

The first two characters indicate the *discharge gas*; if available, the *scientific* denomination is used:

- *Na* for Sodium
- *Hg* for mercury
- *MH* for metal halide (not scientific)

The two following characters indicate the *internal pressure* of the discharge tube:

- *HP* for high pressure
- *LP* for low pressure

The fifth character indicates the *outer bulb form*:

- *B* for balloon form (ellipsoid, ovoid)
- *T* for tubular form.

The sixth character indicates the *outer bulb treatment:*

- *F* for fluorescent or frosted
- *C* for clear.

e.g. *a clear tubular high pressure sodium lamp is indicated as type: NaHP-TC*
a high pressure mercury lamp is indicated as type: HgHP-BF
a tubular fluorescent lamp is indicated as type: HgLP-TF
an ovoid metal halide lamp is indicated as type: MHHP-BF

(For metal halide lamps, there can also be made a subdivision based on the material of the arc tube: quartz or ceramic '*cer*'.
For fluorescent lamps a subdivision is made between straight linear lamps and compact types '*comp*'.)

An overview of lamp types with acronyms and related standards is included in Table 2 below:

Table 2: Overview of lamp types with acronyms and related standards

Specific code in this study	ILCOS-code	English literature	Manufacturers	Standard
NaHP-TC 	ST-70/20/4-H-E27-37/156 ST-150/20/4-H-E40-46/211 etc.	HPS	LU_/HO/T, NAV T_SUPER, SHP-TS, SON-T-PLUS, LUCALOX_XO, etc.	EN 60662
NaHP-BF 	SE-70/20/4-H/I-E27-70/156 SE-150/20/4-H-E40-90/226 etc.	HPS	LU_/HO/D, NAV E_SUPER, SHP-S, SON-S, SON-PLUS, etc.	EN 60662
NaHP-BF retrofit (retrofit for HgHP-ballast) 	SEQ-110/20/4-H-E27-75/170 SEQ-210/20/4-H-E40-90/226 etc.	HPS	LUH_/D/EZ, NAV E, NAV, SHX, SON-H, SPX EcoArc, etc.	EN 60662
NaLP-TC 	LS-36-BY22d-54/425/H110 etc.	LPS	SOX, SOX-E, SOX-PLUS, SLP, etc.	EN 60192

HgHP-BF 	QE/R-125/40/3-H-E27-75/170 QE/R-250/39/3-H-E40-90/226 etc.	HPM	MBF, H, HPL-N, HQL, HSL-BW, MBFSD, H_DX, HPL-COMFORT, HQL de LUXE, HSL-SC, etc.	EN 60188
MHHP-TC 	MT/UB-70/30/1B-H-E27-30/150 MT/UB-150/30/1B-H-E40-46/204 etc.	MH, QMH, CMH	HPI-T, HQI-T,HSI-T, CMI_TT, CDO-TT, HCI-T, HCI-T/P, etc.	EN 61167
MHHP-BF 	MES/UB-70/30/1B-H-E27-70/156 MES/UB-100/30/1B-H-E40-75/18 6 etc.	MH, QMH, CMH	HQI, HPI, HSI, CMI-E, CDO-ET, HCI-E, etc.	EN 61167
HgLP-TF comp 	FSD-24/L/30/1B-E-2G11 FSD-36/30/1B-E-2G11 etc.	CFL non integrated	DULUX L SP, PL-L Polar, etc.	EN 60901

General lamp performance specification parameters (according to EN 12655):

Each lamp has its own specific characteristics; the important performance assessment parameters are (EN 12665(2002)):

- Rated luminous flux (Φ): value of the initial luminous flux of the lamp, declared by the manufacturer or the responsable vendor, the lamp being operated under specified conditions and after a short ageing period of 100 hours. The belonging unit: lumen [lm].
- Lamp power (P_{lamp}): the power consumed by the lamp, unit Watt [W].
- Lamp Survival Factor (LSF): fraction of the total number of lamps which continue to operate at a given time under defined conditions and switching frequency.
- Lamp Lumen Maintenance Factor (LLMF): ratio of the luminous flux emitted by the lamp at a given time in its life to the initial luminous flux.
- CIE 1974 general colour rendering index (Ra).

Luminous efficacy of a lamp (η_{lamp}): quotient luminous flux emitted by the power consumed by the source, unit lumen per Watt [lm/W].
The following performance parameters will also be adressed:

General lamp performance assessment provided by the sector (according to CIE 154):

Publication CIE 154(2003): Maintenance of outdoor lighting systems

During the life of a lighting installation, the available light progressively decreases. The reduction rates are a function of environmental, operating and age conditions. In lighting design we must take into account this fall by the use of a maintenance factor and must plan suitable maintenance schedules to limit the decay. This CIE guide provides information on suggested maintenance factors and the selection of suitable equipment. It describes the parameters influencing the depreciation process and develops the procedure for estimating the economic maintenance cycles for outdoor electric lighting installations and gives advice on servicing techniques.

Important performance parameters included:
Lamp Lumen Maintenance Factors (LLMF) .
Lamp Survival Factor (LSF)

Remarks:

- The LLMF and LSF values are average values according to lamp type.
- Individual lamp manufacturers can bring products on the market with significantly deviated Lumen Output; it is more than likely that also LLMF and LSF will deviate. Therefore ELC provided new data, adapted to their present product range (see chapter 6).

1.1.4.2 Segmentation of Ballasts

Discharge lamps (fluorescent, HID, ..) and solid state lamps can not be connected directly to the mains and need in some cases a lamp starting aid. Therefore lamp control gear is needed.
Control gear conventionally consists of three parts: a ballast (coil), a capacitor and an ignitor. Commonly the control gear is called ballast.
Alternatively, electronic gear is used in some cases, also commonly indicated as electronic ballast.

There is an existing EuP directive 2000/55/EC on 'energy efficiency requirements for ballasts for fluorescent lighting'. The purpose of this directive is to improve the efficiency of the systems by limiting the ballast losses. For this purpose, CELMA developed a classification system that takes both parts of the system into account, the lamp and the ballast and that is compliant with the directive. Ballasts are given an energy efficiency index (EEI) classification. The label on the product will indicate the class defined through the Energy Efficiency Index (EEI). The corrected total input power of the lamp-ballast circuit is defined as the ''Energy Efficiency Index'' (EEI) of the ballast-lamp combination. The grading consists of different classes defined by a limiting value. There are seven classes of efficiency: A1, A2, A3, B1, B2, C and D. The classes have no direct correlation to a specific technology; every class is defined by a limiting value of total input power related to the corresponding ballast lumen factor (BLF). This directive bans ballast classes C and D from the European market, but is only legitimate and applicable for fluorescent lamps; there is no comparable directive for HID lamps. So there is a gap in legislation on energy efficiency requirements for ballasts used in street lighting, because in public street lighting mainly HID-lamps are used.

Ballast categories used in this study are:

- Ferromagnetic or electromagnetic ballasts for discharge lamps. The parts are: a magnetic ballast coil, an ignitor (not for HgHP-lamps) and a power factor capacitor. There exists also dimmable or 'bi-level' ferromagnetic ballasts (see chapter 6).

- Electronic ballasts for discharge lamps::
    - Electronic ballasts non-dimmable
    - Electronic ballasts dimmable
- Electronic power supply for solid state lamps (SSL)

General ballast performance specification parameters:

There are no applicable ballast standards for HID lamps that include energy efficiency criteria (under development according to stakeholder consultation).
In this study, the next performance assessment parameters will be used: ballast efficiency, ballast maintenance factor and ballast gain factor.

Ballast efficiency ($\eta_{ballast}$): ratio between output power (to lamp) and total input power in standard conditions.
For lack of applicable standard, the following 'standard' conditions for magnetic ballasts are assumed (a better definition by stakeholders is welcome):

- standard line voltage (e.g. 230 VAC)
- mounted on a blank aluminium support plate 20x20 cm
- after 1h warming up
- a reference lamp with according lamp voltage and lamp power must be used.

For the purpose of this study, also a *Ballast Maintenance Factor* (BMF) will be used (more information see chapter 3). This BMF is the ratio of the worst ballast efficiency at a given time in its life to the initial ballast efficiency in standard conditions.

(In chapter 3 also a 'Ballast Gain Factor' will be defined that takes energy savings from dimming into account).

1.1.4.3 Segmentation of Luminaires

General luminaire performance specification parameters (according to EN 12665):

Each luminaire has its own specific characteristics. The important performance assessment parameters are (EN 12665 (2002)):

- *Light Output Ratio (LOR):* ratio of the total flux of the luminaire, measured under specified practical conditions with its own lamps and equipment, to the sum of the individual luminous fluxes of the same lamps when operated outside the luminaire with the same equipment, under specified conditions (see IEC 50 (845/CIE 17.4).
- *Downward Light Output Ratio (DLOR):* ratio of the downward flux of the luminaire, measured under specified practical conditions with its own lamps and equipment, to the sum of the individual luminous fluxes of the same lamps when operated outside the luminaire with the same equipment, under specified conditions (see IEC 50 (845/CIE 17.4).
- *Upward Light Output Ratio (ULOR):* ratio of the upward flux of the luminaire, measured under specified practical conditions with its own lamps and equipment, to the

sum of the individual luminous fluxes of the same lamps when operated outside the luminaire with the same equipment, under specified conditions (see IEC 50 (845/CIE 17.4).

- *Utilance (of an installation, for a reference surface)(U)): ratio of the luminous flux received by the reference surface to the sum of the individual total fluxes of the luminaires of the installation (IEC 50/CIE 17.4).*
- *Utilization Factor (of an installation, for a reference surface)(UF=UxLOR):* ratio of the luminous flux received by the reference surface to the sum of the individual total fluxes of the lamps of the installation (IEC 50/CIE 17.4). The reference surface in street lighting is of course the road surface

  .

  Note that the UF is not only dependent on the luminaire itself but also on the accordance between the light distribution and the geometry of the road and especially on the exact installation of the luminaire (putting into service).

Specific ULOR performance street lighting luminaire categories required for reducing light pollution (according to CIE 126-1997):

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CIE 126-(1997): 'Guidelines for minimizing sky glow' proposes limitations to the ULOR depending on the 4 environmental zones. The ULOR limitations are varying between 0% and 25%. This technical report is only a guideline.

Specific LMF luminaire performance assessment provided by the sector (according to CIE 154):

CIE 154 (2003): The maintenance of outdoor lighting systems

During the life of a lighting installation, the light available progressively decreases. The reduction rates are a function of environmental, operating and age conditions. In lighting design we must take account of this fall by the use of a maintenance factor and plan suitable maintenance schedules to limit the decay. This guide provides information on suggested maintenance factors and the selection of suitable equipment. It describes the parameters influencing the depreciation process and develops the procedure for estimating the economic maintenance cycles for outdoor electric lighting installations and gives advice on servicing techniques

Important performance parameter included:
Luminaire Maintenance Factor (LMF) is defined as the ratio of the light output ratio of a luminaire at a given time to the initial light output ratio.

Luminaire segmentation:
It depends strongly on environmental pollution and the quality of the optical system, especially on the protection class (IP-rating) of the optical compartment. The IP-ratings are defined in standard EN 60529 : 'Degrees of protection provided by enclosures (IP Code)'. So an important segmentation will be made by distinction of the IP-rating.

The specific IP ratings for luminaires and the related specific test methods for defining these ratings for luminaries are described in standard EN 60598-1.
A complementary performance segmentation can be made, based on the material of the outer glazing, e.g. glass attracts less dust than synthetic material and has consequently a higher LMF. The LMF is taken into account in the selection of representative luminaires and consequent modelling of the performance, impacts and costs (see chapter 4).

1.2 Lighting test standards or guidelines

This section identifies and shortly describes the 'test standards or guidelines' that are related to the functional unit, resource use (energy, materials, ..), safety and other lighting product specific standards.
A “test standard or guideline” is defined in the context of this study as a standard or guideline that sets out a test method, but that does not indicate what result is required when performing that test. Therefore, strictly speaking, a test standard can be different from a “technical standard”. Especially 'technical standards' that are a specification against which all others may be measured are not discussed hereafter(e.g. the measurement of power, luminous flux, ..). In addition to “official” test standards, there are other sector specific procedures for product testing that are compiled by industry associations or other stakeholders for specific purposes included in this chapter. Also ongoing work for the development of new standards or guidelines is discussed together with recommendations for new ones.

The following references are made to:

- EN, European standard ratified by either CEN (European Committee for Standardization) or CENELEC (European Committee for Electrotechnical Standardization),
- IEC, International Electrotechnical Commission,
- CIE, International Commission on Illumination.

1.2.1 Standards and guidelines directly related to the functional unit

EN 13201-3: *Road Lighting. Calculation of performance.*

Scope:

The standard defines and describes the conventions and mathematical procedures to be adopted in calculating the photometric performance of road lighting installations designed in accordance with EN 13201-1 and EN 13201-2.

EN 13201-4: *Road Lighting. Methods of measuring lighting performance.*

Scope:

This part of the European Standard specifies the procedures for making photometric and related measurements of road lighting installations. Examples are given of the form of the test report.

CIE 144(2001): Road surface and road marking reflection characteristics

Scope:

This standard is required to calculate the luminance value from illumination conditions for various types of surface (see chapter 3).

Sector specific standard method: Professional light planning, calculation and visualisation software

Examples:

- free downloads:
  - http://www.dialux.com
  - http://www.relux.biz
- manufacturers specific software.

Scope:

These software are intended for light planning, calculation and visualization of outdoor (and indoor) lighting systems (fig. 9). Some softwares are free and some softwares have the ability to import from and export to CAD programmes and include photorealistic visualization with an integrated ray tracer.
Most major manufacturers provide also free luminaire data for users. Most of these softwares aim to take the latest standards into consideration as well as planning regulations and customs of the specific country.

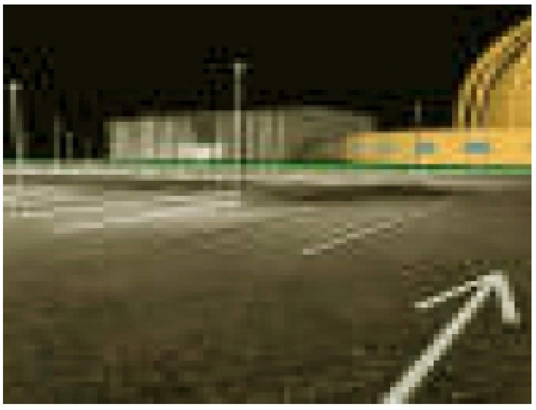

Figure 9: Photorealistic visualization of street lighting.

Identified gaps:

- Compliance with new EN 13201- standard series is not always guaranteed.

- At this moment, different file formats for luminaire data are used, but most of the programmes (free download) can not calculate with all formats. As there is actually a standardized format, the CEN-file format, it would be preferable that every programme could use this file format. Most common file formats are:
  - EULUMDAT
  - IES
  - CIBSE
  - CEN.

1.2.2 Other test standards and guidelines

Other *CEN documents* concerning street lighting

CEN/TR 13201-1: Road lighting - Part 1: Selection of lighting classes

Scope:

This technical report specifies the lighting classes set out in EN 13201-2 and gives guidelines on the application of these classes. To do this, it includes a system to define an outdoor public traffic area in terms of parameters relevant to lighting. To assist in the application of classes, it suggests a practical relationship between the various series of lighting classes, in terms of comparable or alternative classes. It also gives guidelines on the selection of the relevant area to which the lighting classes from EN 13201-2 and the calculation grids and procedure from EN 13201-3 should be applied. As mentioned before, this document is only a technical report, not a standard.

EN 13201-2: Road lighting - Part 2: Performance requirements.

Scope:

This part of this European Standard defines, according to photometric requirements, lighting classes for road lighting aiming at the visual needs of road users, and it considers environmental aspects of road lighting.

Non-limitative list of *CENELEC documents* concerning street lighting

EN 50294: Measurement Method of Total Input Power of Ballast-Lamp Circuits

Scope:

This Standard gives the measurement method of the total input power for ballast-lamp circuits when operating with their associated fluorescent lamp(s). This standard applies to electrical ballast-lamp circuits comprised solely of the ballast and of the lamp(s). NOTE: Requirements for testing individual ballasts during production are not included. It specifies the measurement method for the total input power for all ballasts sold for domestic and normal commercial purposes operating with the following fluorescent lamps: linear lamps with power equal to or greater than 15 W; single ended (compact) lamps with power equal to or greater than 18 W; other general purpose lamps. This standard does not apply to: ballasts which form an integral part of the lamp; ballast-lamp circuits with capacitors connected in series; controllable wire-wound magnetic ballasts; luminaires, which rely on additional optical performance aspects.

EN 60598-1: *Luminaires Part 1 : General requirements and tests*

Scope:

This Part 1 specifies general requirements for luminaires, incorporating electric light sources for operation from supply voltages up to 1 000 V. The requirements and related tests of this standard cover: classification, marking, mechanical construction and electrical construction.

EN 60598-2-3: *Luminaires –Part 2-3 : Particular requirements –Luminaires for road and street lighting*

Scope:

This part of IEC 60598 specifies requirements for

- luminaires for road, street lighting and other public outdoor lighting applications
- tunnel lighting
- column-integrated luminaires with a minimum total height above normal ground level of 2,5 m and for use with electrical lighting sources on supply voltages not exceeding 1 000 V.

EN 50102: *Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code)*

Scope :

This standard refers to the classification of the degrees of protection provided by enclosures against external mechanical impacts when the rated voltage of the protected equipment is not greater than 72,5 kV. This standard is only applicable to enclosures of equipment where the specific standard establishes degrees of protection of the enclosure against mechanical impacts (expressed in this standard as impacts). The object of this standard is to give: the definitions for degrees of protection provided by enclosures of electrical equipment as regards protection of the equipment inside the enclosure against harmful effects of mechanical impacts; the designations for the degrees of protection; the requirements for each designation; the tests to be performed to verify that enclosures meets the requirements of this standard

EN 60529: *Degrees of protection provided by enclosures (IP Code)*

Scope :

Applies to the classification of degrees of protection provided by enclosures for electrical equipment with a rated voltage not exceeding 72,5 kV. Has the status of a basic safety publication in accordance with IEC Guide 104.

Degree of protection code IP X_1X_2:

X_1 indicates the degree that persons are protected against contact with moving parts (other than smooth rotating shafts, etc.) and the degree that equipment is protected against solid foreign bodies intruding into an enclosure;

- $X_1 = 0$ means *no special protection*
- $X_1 = 1$ means *protection against penetration by large foreign bodies, d>50 mm No protection against intentional access*
- $X_1 = 2$ means *protection against small foreign bodies, d>12mm, exclusion of fingers or similar objects*
- $X_1 = 3$ means *protection against small foreign bodies, d>2.5 mm, exclusion of tools, wires or similar objects*
- $X_1 = 4$ means *protection against grainy foreign bodies, d>1 mm, exclusion of tools, wires or similar objects*
- $X_1 = 5$ means *protection against dust deposits (dust protected), complete exclusion of access*
- $X_1 = 6$ means *totally protection against dust deposits (dust protected), complete exclusion of access.*

X_2 indicates the degree of protection of the equipment inside the enclosure against the harmful entry of various forms of moisture (e.g. dripping, spraying, submersion, etc.);

- $X_2 = 0$ means *no special protection*
- $X_2 = 1$ means *protection against drops of water falling vertically*
- $X_2 = 2$ means *protection against water falling at an angle (water drop), inclined at 15° to the normal operating position*
- $X_2 = 3$ means *protection against water spray, up to 60° from the vertical*
- $X_2 = 4$ means *protection against water splashes from any direction*
- $X_2 = 5$ means *protection against water jet from any direction*
- $X_2 = 6$ means *protection against heavy sea or strong water jet*
- $X_2 = 7$ means *protection against submersion in water at a certain pressure and for a certain period*
- $X_2 = 8$ means *protection against continuous submersion in water.*

Example: IP65 means totally protection against dust deposits (dust protected), complete exclusion of access and protection against water jet from any direction.

Non-limitative list of *CENELEC documents* concerning lamps and ballasts

EN 60662: *High pressure sodium vapour lamps – Performance*

Scope :

Specifies the lamp dimensions, electrical characteristics for lamp starting and operation together with information for ballast, ignitor and luminaire design purposes. This is a loose-leaf publication. Amendments containing new and revised sheets are issued periodically. This consolidated version of IEC 60662 is based on the first edition (1980) and its amendments 1(1986), 2(1987), 3(1990), 4(1992), 5(1993), 6(1994), 7(1995), 8(1995), 9(1997) and 10(1997). It bears the edition number 1.10

EN 60901: *Single-capped fluorescent lamps – Performance specifications*

Scope :

Specifies the performance requirements for single-capped fluorescent lamps for general lighting service.
The requirements of this standard relate only to type testing. Conditions of compliance, including methods of statistical assessment, are under consideration.

EN 60921: *Ballasts for tubular fluorescent lamps – Performance requirements*

Scope :

This standard specifies performance requirements for ballasts, excluding resistance types, for use on a.c. supplies up to 1 000 V at 50 Hz or 60 Hz, associated with tubular fluorescent lamps with pre-heated cathodes operated with or without a starter or starting device and having rated wattages, dimensions and characteristics as specified in IEC 60081 and 60901. It applies to complete ballasts and their component parts such as resistors, transformers and capacitors.

EN 60923: *Auxiliaries for lamps – Ballasts for discharge lamps (excluding tubular fluorescent lamps) – Performance requirements*

Scope :

This International Standard specifies performance requirements for ballasts for discharge lamps such as high-pressure mercury vapour, low-pressure sodium vapour, high-pressure sodium vapour and metal halide lamps. Clauses 12 through 15 each detail specific requirements for a particular type of ballast. This standard covers inductive type ballasts for use on a.c. supplies up to 1 000 V at 50 Hz to 60 Hz associated with discharge lamps, having rated wattage, dimensions and characteristics as specified in the relevant IEC lamp standards.

EN 60927: *Specification for auxiliaries for lamps. Starting devices (other than glow starters). Performance requirements*

Scope :

Specifies performance requirements for starting devices (starters and ignitors) for tubular fluorescent and other discharge lamps for use on a.c. supplies up to 1 000 V at 50 Hz or 60 Hz which produce starting pulses not greater than 5 kV. Should be read in conjunction with IEC 60926.

EN 60929: *AC-supplied electronic ballasts for tubular fluorescent lamps – Performance requirements*

Scope :

This standard specifies performance requirements for ballasts, excluding resistance types, for use on a.c. supplies up to 1 000 V at 50 Hz or 60 Hz, associated with tubular fluorescent lamps with pre-heated cathodes operated with or without a starter or starting device and having rated wattages, dimensions and characteristics as specified in IEC 60081 and 60901. It applies to complete ballasts and their component parts such as resistors, transformers and capacitors.

EN 61048 : *Auxiliaries for Lamps - Capacitors for Use in Tubular Fluorescent and Other Discharge Lamp Circuits - General and Safety Requirements*

Scope :

This International Standard states the requirements for both self-healing and non-self-healing continuously rated a.c. capacitors of up to and including 2,5 kVAr, and not less than 0,1 μF, having a rated voltage not exceeding 1 000 V, which are intended for use in discharge lamp circuits operating at 50 Hz or 60 Hz and at altitudes up to 3 000 m.

EN 61049 : *Capacitors for Use in Tubular Fluorescent and Other Discharge Lamp Circuits Performance Requirements*

Scope :

Specifies the requirements for both self-healing and non-self- healing continuously rated a.c. capacitors of up to and including 2,5 kvar, and not less than 0,1 F, having a rated voltage not exceeding 1 000 V, which are intended for use in discharge lamp circuits operating at 50 Hz or 60 Hz and at altitudes up to 3 000 m. Does not cover radio-interference suppressor capacitors, the requirements for which are given in IEC 60384-14. This publication supersedes IEC 60566.

EN 61167: *Metal halide lamps –Performance*

Scope :

This International Standard specifies the methods of test to be used for determining the characteristics of metal halide lamps, both single-ended and double-ended, operated on a.c. mains, 50 Hz or 60 Hz, with ballasts satisfying the requirements of IEC 923. These requirements relate only to type testing. The standard specifies lamp dimensions, electrical characteristics for lamp starting and operation together with information for ballast, ignitor and luminaire design and colour characteristics.

EN 62035: *Discharge Lamps (Excluding Fluorescent Lamps) - Safety Specifications*

Scope :

Specifies the safety requirements for discharge lamps (excluding fluorescent lamps) for general lighting purposes.
This International Standard is applicable to low-pressure sodium vapour lamps and to high-intensity discharge (HID) lamps, i.e. high-pressure mercury vapour lamps (including blended lamps), high-pressure sodium vapour lamps and metal halide lamps. It applies to single- and double-capped lamps.

The following non- limitative list summarises the *CIE documents* concerning street lighting (for a scope please consult CIE website on www.cie.co.at):

01-1980:	Guide lines for minimizing urban sky glow near astronomical observatories (Joint publication IAU/CIE)
17.4-1987:	International lighting vocabulary, 4th ed. (Joint publication IEC/CIE)
23-1973:	International recommendations for motorway lighting
31-1976:	Glare and uniformity in road lighting installations
32-1977:	Lighting in situations requiring special treatment (in road lighting)
33-1977:	Depreciation of installation and their maintenance (in road lighting)
34-1977	Road lighting lantern and installation data: photometrics, classification and performance
47-1979:	Road lighting for wet conditions
66-1984:	Road surfaces and lighting (joint technical report CIE/PIARC)
84-1989:	Measurement of luminous flux
93-1992:	Road lighting as an accident countermeasure
100-1992:	Fundamentals of the visual task of night driving
115-1995:	Recommendations for the lighting of roads for motor and pedestrian traffic
121-1996:	The photometry and goniophotometry of luminaires
126-1997:	Guidelines for minimizing sky glow
129-1998:	Guide for lighting exterior work areas
132-1999:	Design methods for lighting of roads
136-2000:	Guide to the lighting of urban areas
140-2000:	Road lighting calculations
144:2001:	Road surface and road marking reflection characteristics
154:2003:	Maintenance of outdoor lighting systems

General comment on standards

Standard EN 50294 has no performance requirements for HID-ballasts.
There is a lack of European bench mark data for street lighting at installation level.
There is no verification protocol for (photometric) data provided by the manufacturers.

1.3 Existing Legislation and EU Voluntary Agreements

In this section the relevant legislation and EU voluntary agreements are described.

1.3.1 Legislation and Agreements at European Community level

1.3.1.1 Environmental directives (RoHS, WEEE)

Directive 2002/95/EC on Restriction of the use of certain Hazardous Substances in electrical and electronic equipment (RoHS)

Scope:

The RoHS Directive stands for "the restriction of the use of certain hazardous substances in electrical and electronic equipment". This Directive bans the placing on the EU market of new electrical and electronic equipment containing more than agreed levels of lead, cadmium, mercury, hexavalent chromium, polybrominated biphenyl (PBB) and polybrominated diphenyl ether (PBDE) flame retardants.
Exception for lamps: TBD
Exception requested by ELC: TBD

Directive 2002/96/EC on waste electrical and electronic equipment (WEEE)

Scope:

The WEEE Directive aims to:

- reduce waste arising from electrical and electronic equipment (EEE);
- make producers of EEE responsible for the environmental impact of their products, especially when they become waste.
- encourage separate collection and subsequent treatment, reuse, recovery, recycling and sound environmental disposal of EEE .
- improve the environmental performance of all those involved during the lifecycle of EEE.

Exception for lamps: TBD
Exception requested by ELC: TBD

1.3.1.2 Minimum efficiency directives

Directive 2000/55/EC on energy efficiency requirements for ballasts for fluorescent lighting

Scope:

The purpose of this Directive is to improve the efficiency of the systems by limiting the ballast losses. For this purpose, CELMA developed a classification system that takes both parts of the system into account, the lamp and the ballast and that is compliant with the directive.

Exceptions for lamps: this directive is reviewed in detail in the preparatory study on office lighting.

Directive 98/11/EC on Energy labelling of household lamps

Scope:

This Directive, which was published on 10th March 1998, applies the energy labelling requirements to household electric lamps supplied directly from the mains and to household fluorescent lamps. The Directive sets out the design and content of the label, as well as the colours that may be used.
The label must include the following information:
• the energy efficiency class of the lamp;
• the luminous flux of the lamp in lumens;
• the input power (wattage) of the lamp; and
• the average rated life of the lamp in hours.
The Directive also sets out how the energy efficiency class of a lamp will be determined.

Albeit these lamps are not usual for streetlighting, this directive can be an example of lamp labeling for street lighting.

There is a ' European CFL QUALITY CHARTER'
see ' http://energyefficiency.jrc.cec.eu.int/CFL/index.htm'

Scope:

This is dedicated to self ballasted CFL lamps or CFL-i, by consequence they are out of the scope of this study.

1.3.1.3 Other product related directives

Directive 2006/32/EC on energy end-use efficiency and energy services (repealing Council Directive 93/76/EEC)

Scope:

According to the Directive the Member States shall adopt and aim to achieve an overall national indicative energy savings target of 9 % for the ninth year of application of the Directive, to be reached by way of energy services and other energy efficiency improvement measures. Member States shall take cost-effective, practicable and reasonable measures designed to contribute towards achieving this target.

Directive 98/11/EC of 27 January 1998 implementing Council Directive 92/75/EEC with regard to energy labelling of household lamps

Scope:

This Directive shall apply to household electric lamps supplied directly from the mains (filament and integral compact fluorescent lamps), and to household fluorescent lamps (including linear, and non-integral compact fluorescent lamps), even when marketed for non-household use.

Electromagnetic Compatibility (EMC) Directive 2004/108/EEC

Scope:

The Council Directive *2004/108/EEC* of 15 December 2004 on the approximation of the laws of the Member States relating to electromagnetic compatibility (EMC Directive) governs on the one hand the electromagnetic emissions of this equipment in order to ensure that, in its intended use, such equipment does not disturb radio and telecommunication as well as other equipment. In the other the Directive also governs the immunity of such equipment to interference and seeks to ensure that this equipment is not disturbed by radio emissions normally present used as intended.

Low Voltage Directive (LVD) 73/23/EEC

Scope:

The Low Voltage Directive (LVD) 73/23/EEC seeks to ensure that electrical equipment within certain voltage limits both provides a high level of protection for European citizens and enjoys a Single Market in the European Union. The Directive covers electrical equipment designed for use with a voltage rating of between 50 and 1000 V for alternating current and between 75 and 1500 V for direct current. It should be noted that these voltage ratings refer to the voltage of the electrical input or output, not to voltages that may appear inside the equipment. For most electrical equipment, the health aspects of emissions of Electromagnetic Fields are also under the domain of the Low Voltage Directive

1.3.2 Existing legislation at member state or local level

In several member states and regions there exist legislation to restrict light pollution that can be more or less product related, an overview is enclosed hereafter:

Legislation against light pollution in Spain:

Canary Islands (Teneriffa an La Palma) 1988/1992:
Ley 31/1988 del 31 OCTUBRE. BOE NUM 264 DE 3 NOVIEMBRE.
R.D. 243/1992 DE 13 MARZO. BOE NUM 96 DEL 21 ABRIL 1992
more info: www.iac.es/proyect/otpc/pages/ley.html
These laws implies restrictions to luminaires in the defined region.

Catalonia 2001:
'LLEI 6/2001, de 31 de maig, d'ordenació ambiental de l'enllumenament per a la protecció del medi nocturn' (Catalan)
more info: www.gencat.net/mediamb/cast/sosten/eluminica.htm

Legislation against light pollution in Italy:

The law of Lombardy (Lombardia LR17/00 and LR38/04) is clearly product related.
This law is valid in Lombardy since 2000 with amendments from 2004. Five other provinces of Italy have similar laws (Marche LR10/02, Emilia Romagna LR19/03, Abruzzo LR12/05, Puglia LR15/05, Umbria LR20/05).
The law of Lombardy has the following demands for all new outdoor lighting installations and reconstructions of the existing lighting systems, whenever the old luminaries are changed to new ones (free translation):

1. each luminaire is to have zero specific luminous intensity horizontally and upwards (I read 0 cd/klm over 90°); exceptions are only for special architectural buildings if no other possibility
2. level of luminance and illuminance shall be no more than the minimum defined by European technical norms (UNI10439, DIN5044, EN 13201, etc..); and should be equipped by devices able to reduce by midnight, the light emissions until but no under 30% of the full capacity of light emissions Lighting flux reducer systems are mandatory - there is to be a possibility to reduce the full luminous flux until 30% of the full capacity, in a way that security is not compromised.

Requirement 1 is product-related and 2 is system-related but can be fulfilled at the product level, using a programmable ballast
The law has also an explicit requirement to manufacturers, importers and sellers (non-compliant products are not allowed to enter the market in these provinces), the text reads:
8.Manufacturers, importers and sellers have to certify, together with other technical parameters of the offered products, the compliance of the product with the present law and its implementing standards; this is to be done by including a declaration of conformity issued by national or international institutes working at the field of safety and product quality, and instructions for correct installation and use.
Furthermore there are requirement applicable to producers only to demonstrate the conformity of the luminaires to the law:
The producers are obliged (always) to furnish, for each product installed in Lombardy, photometric data on paper and on file Eulumdat CERTIFIED and SIGNED by the laboratory manager that made the measurements.

1.3.3 Third Country Legislation

This section again deals with the subjects as above, but now for legislation and measures in Third Countries (extra-EU) that have been indicated by stakeholders (NGOs , industry, consumers) as being relevant for the product group.

Australia and New Zealand are preparing minimum energy performance standards for HID lamps and HID ballasts (IEA (2006)).

Mexico has lighting power density limitations for exterior lighting of pavements, bus stops, plazas and main squares. Lamps must have an efficacy of > 40lm/W (IEA (2006)).
NOM-013-ENER-1996 (External Lighting Systems):
NOM-013-ENER-1996 is used to set illuminance levels and set efficacy levels (lumens per watt) for outdoor lighting on roadways and buildings. It is based on the IES LEM-6 but also sets values for car parks and areas illuminated by tower lights. Details of the test method are not available in English.

INMETRO is a Brazillian Labeling Program for Public Lighting Fixtures:
The Brazilian program is based on the bar style energy label. It contains an efficiency rating along with energy consumption and freezer temperature information. The program is conducted by PROCEL, the national energy efficiency program and the government agency INMETRO (Instituto Nacional de Metrologia, Normalizacao e Qualidade Industrial (INMETRO - National Institute of Metrologia) is responsible for verifying the manufacturers data.

China has limited the lighting power density for roadways between 0.4 and 0.8 W/m² (IEA (2006)).

Turkey recently approved 2 directives on public lighting with date of obligation on 01 September 2006 for new installations of public street lighting.
The first obligation is to use tubular, clear high pressure sodium lamps (NaHP-TC) with enhanced lumen output.
The second obligation is to use efficient luminaires with an IP-rating of at least IP 65.
(see: http//www.tedas.gov.tr). (IP65 means totally protection against dust deposits (dust protected), complete exclusion of access and protection against water jet from any direction).

Japan has a 'Top Runner Programme' for the efficiency of Energy using Products. For lighting, this programme imposes burdens but only for fluorescent lighting (see: http://www.eccj.or.jp/top_runner/).

In the next tables existing international legislation on labels and minimum performance (Table 3, Table 4, Table 5, Table 6, Table 7, Table 8)related to fluorescent ballasts is included, they are equivalents of the existing EC legislation (source www.apec-esis.org):

Table 3: Mandatory Label for Ballasts (Electronic)

No.	Economy	Title
1.	Argentina	Programa de Calidad de Artefactos Electricos para el Hogar (PROCAEH) - Fluorescent Ballasts (22-12-2003)
2.	Colombia	Programa Colombiano de NormalizaciÃ³n, AcreditaciÃ³n, CertificaciÃ³n y Etiquetado de Equipos de Uso Final de EnergÃa (CONOCE) - Ballasts (2002)
3.	Costa Rica	Plaqueo Energetico - Ballasts (1996)
4.	El Salvador	Mandatory Standard (NSO) No. 29.39.01:03, Energy Efficiency of Double-Capped Fluorescent Lamps. Energy Performance and Labelling Requirements - Electronic Ballasts (2004)
5.	Israel	Energy Label for Ballasts for Fluorescent Lamps - Israel (--)
6.	Philippines	Label for Electronic Ballasts For Fluorescent Lamps (--)
7.	Republic of Korea	Energy Efficiency Rating Labelling Program for Electronic Ballasts (01-07-1994)
8.	USA	EnergyGuide - Electronic Ballasts For Fluorescent Lamps (1994)

Table 4: Voluntary Label for Ballasts (Electronic)

No.	Economy	Title
1.	Canada	Environmental Choice Program (ECP) - Ballasts Electronic (1988)
2.	China	China Energy Conservation Product Certification - Electronic Ballasts For Fluorescent Lamps (--)
3.	Germany	Blue Angel (Umweltzeichen) - Ballasts (--)
4.	Hong Kong, China	The Hong Kong Voluntary Energy Efficiency Labelling Scheme for Electronic Ballasts (23-12-2004)
5.	New Zealand	Electronic Ballasts For Fluorescent Lamps - New Zealand (--)
6.	Republic of Korea	Certification of high energy efficiency appliance program for Electronic Ballasts (1997)
7.	Singapore	Green Labelling Scheme - Electronic Ballasts - Singapore (2000)
8.	Thailand	Green Label Scheme - Electronic Ballasts For Fluorescent Lamps (08-1994)
9.	Viet Nam	Label for Electronic Ballasts - Viet Nam (--)

Table 5: Minimum Energy Performance Standard - Mandatory for Ballasts (Electronic)

No.	Economy	Title
1.	Australia	AS/NZS 4783.2:2002 : Performance of electrical lighting equipment - Ballasts for fluorescent lamps - Energy labelling and minimum energy performance standard requirements (2003)
2.	Canada	Mandatory MEPS for Fluorescent Lamp Ballasts - Electronic (03-02-1995)
3.	China	GB 17896-1999 - The limited values of energy efficiency and evaluating values of energy conservation of ballasts for tubular fluorescent lamps (--)
4.	Colombia	Programme for the Rational and Efficient Use of Energy and Other Non-Conventional Energy Forms (Programa de Uso Racional y Eficiente de la energia y d (1998)
5.	Israel	MEPS for Ballasts for Fluorescent Lamps - Israel (--)
6.	New Zealand	NZHB 4783.2:2001 - Performance of electrical lighting equipment - Ballasts for fluorescent lamps Part2: Energy labelling and minimum energy performanc (01-02-2003)
7.	Republic of Korea	MEPS for Electronic Ballasts - Korea (01-07-1994)
8.	Thailand	Electronic Ballasts For Fluorescent Lamps - Thailand (10-02-2004)
9.	USA	10 CFR Part 430: Energy Conservation Program for Consumer Products: Electronic Ballasts For Fluorescent Lamps (--)
10.	Viet Nam	MEPS for Electronic Ballasts - Viet Nam (--)

Table 6: Mandatory Label for Ballasts (Magnetic)

No.	Economy	Title
1.	Australia	Labeling Program for Fluorescent Lamp Ballasts - Australia (--)
2.	Philippines	Label for Ballasts (Magnetic) - Philippines (2002)
3.	Republic of Korea	Energy Efficiency Rating Labelling Program for Magnetic Ballasts (01-07-1994)

Table 7: Voluntary Label for Ballasts (Magnetic)

No.	Economy	Title
1.	Brazil	Stamp Procel de Economia de Energia (Energy Efficiency Stamp) - Ballasts (1993)
2.	Brazil	INMETRO Brazillian Labeling Program (PBE) for Magnetic p/Sodium Reactors (--)
3.	Canada	Environmental Choice Program (ECP) - Ballasts Magnetic (1988)
4.	China	China Energy Conservation Product Certification - Magnetic Ballasts For Fluorescent Lamps (--)
5.	New Zealand	Magnetic Ballasts For Fluorescent Lamps - New Zealand (--)
6.	Republic of Korea	Certification of high energy efficiency appliance program for Magnetic Ballasts (1997)
7.	Singapore	Green Labelling Scheme - Magnetic Ballasts - Singapore (2000)
8.	Sri Lanka	Labels for Ballasts - Sri Lanka (--)
9.	Thailand	Energy Efficient Ballast Program - Magnetic Ballasts For Fluorescent Lamps (1998)

Table 8: Minimum Energy Performance Standard - Mandatory for Ballasts (Magnetic)

No.	Economy	Title
1.	Australia	AS/NZS 4783.2:2002 : Performance of electrical lighting equipment - Ballasts for fluorescent lamps - Energy labelling and minimum energy performance standard requirements - Ferromagnetic Ballasts (2003)
2.	Canada	Mandatory MEPS for Fluorescent Lamp Ballasts (03-02-1995)
3.	China	GB 17896-1999 - The limited values of energy efficiency and evaluating values of energy conservation of ballasts for tubular fluorescent lamps (Magnetic) (--)
4.	Costa Rica	National Energy Conservation Programme (Programa Nacional de ConservaciÃ³n de EnergÃa - PRONACE) - Ballasts (1996)
5.	EU Member Countries	Directive 2000/55/EC of the European Parliament and of the Council (2004)
6.	Malaysia	Magnetic Ballasts For Fluorescent Lamps - Malaysia (1999)
7.	New Zealand	NZHB 4783.2:2001 - Performance of electrical lighting equipment - Ballasts for fluorescent lamps Part2: Energy labelling and minimum energy performanc (01-02-2003)
8.	Philippines	PNS 12-3:1999: Lamp and related equipment: Electromagnetic ballasts - Energy standards and labeling requirements (2002)
9.	Republic of Korea	MEPS for Magnetic Ballasts - Korea (01-07-1994)
10.	Thailand	Magnetic Ballasts For Fluorescent Lamps - Thailand (10-02-2004)
11.	USA	10 CFR Part 430: Energy Conservation Program for Consumer Products: Fluorescent Lamp Ballasts Energy Conservation Standards (--)

There is one country that has limiting values related to HPS ballasts reported:

China: GB 19574-2003: Limiting values of energy efficiency and evaluating values of energy conservation of ballast for high-pressure sodium lamps

There is one country that has minimum energy performance values related to HPS lamps reported:

China: GB 19573-2003, MEPS for high-pressure sodium vapour lamps

There are various minimum standards and labeling programs applied worldwide (Table 9) compact fluorescent lamps (CFL). Please note that they are almost without exception applicable to CFL-i or CFL with integrated ballasts and CFL-i is outside the scope of this study. CFL-i lamps are mainly used in domestic applications and also called 'energy saving lamps'.

country	Minimum Standard	Labelling	National test standard	Reference test standard
Argentina		Yv(1)		
Australia	U(1)	Yv(1)		
Brazil	Ym(1)	Yv(2)	PROCEL 01 RESP/010-LUZ	
Canada	Ym(1)	Yv(1)	CAN/CSA-C 861-95	IES LM 66
Chile		Ym(1)	NCh 2695: 2002 NCh 3020: 2006	
China	Ym(1)	Yv(1)	GB/T 17263-2002 GB 19044-2003	
Colombia	Ym(1)		NTC 5101 NTC 5103 NTC 5102 NTC 5109	
Czech Republic		Yv(1)		
Ghana	Ym(1)	Ym(1)	GS 323:2003	
Hong Kong, China		Yv(1)	CIE 84-1989 IEC 60901 IEC 60969	
Hungary		Yv(1)		
Indonesia		Yv(1)		
Latvia		Yv(1)		
Mexico	Ym(1)	Yv(1)	NOM-017-ENER-1997	
New Zealand	U(1)			
Peru		Yv(1)		
Philippines	Ym(1)	Ym(1) Yv(1)	PNS 603-2-Amd.1:2001	
Poland		Yv(1)		
Republic of Korea	Ym(1)	Ym(1) Yv(1)	KS C 7621-99	
Singapore		Yv(1)	CIE 84-1989	
South Africa		Yv(1)		
Sri Lanka		Yv(1)	SLS 1225:2002	
Thailand	U(1)	Yv(2)	TIS 236-2533	IEC 60081
UK		Yv(1)		
USA	Ym(1)	Yv(1)	10 CFR Part 430 Subpar US Energy Star	IES LM 66
Viet Nam	U(1)	U(1)		

Table 9: Minimum standards and labeling programs applied worldwide for CFL (source www.apec-esis.org).

2 MARKET AND ECONOMIC ANALYSIS

The aim of the economic and market analysis is to place the product group street lighting within the total of EU industry and trade policy (chapter 2.1), to provide market and cost inputs for the EU-wide environmental impact of the product group (chapter 2.2), to provide insight in the latest market trends so as to indicate the place of possible eco-design measures in the context of the market-structures and ongoing trends in product design (chapter 2.3), and finally, to provide a practical data set of prices and rates to be used in the Life Cycle Cost calculation (LCC) (chapter 2.4).

2.1 Generic economic data

2.1.1 Sources and Limitations of the Eurostat production and trade data

To investigate the volume of sales and trade of a product group, it makes sense to consult Eurostat's product-specific statistics. For trade and production figures, these are the so-called Europroms[1]-Prodcom[2] statistics. As an example, these data enable to check whether the product complies with the eligibility criterion of Art. 15, par. 2, sub a, of the EuP Directive. In the MEEUP Methodology Report the general advantages, flaws and limitations of these official EU statistics are discussed extensively[3].

Reliable market data are essential for the development of effective lighting policies. However, any such assessment can only be as comprehensive and systematic as the available data itself. For street lighting; this data is scattered and only partially available. Unfortunately, much of the data that would be necessary for a thorough analysis has not been collected or reported in the past, or is protected for reasons of manufacturing trade secrets. Although we attempt to focus on the specific attributes of the street lighting market, much of our analysis could only be performed at the level of the EU total lighting market, as data were only available in an aggregated form.

In this report, our comparisons of imports, exports, and EU production and apparent consumption, give the reader a sense of the relative scales within the lighting market. For numerous reasons[4], these data comparisons should only be considered as approximations.

[1] Europroms is the name given to published Prodcom data. It differs from Prodcom in that it combines production data from Prodcom with import and export data from the Foreign Trade database.
[2] Prodcom originates from the French "PRODuction COMmunautaire"
[3] MEEUP Methodology Report (VHK, 2005), pages 120, 121
[4] Eurostat data shop Handbook (part 6.4.2. Europroms-Prodcom data, version 29/08/2003)

2.1.2 Volume and value of European lamp production, trade and consumption: Europroms results

A query was submitted on the website of Eurostat[5] for extra-EU trade[6] and production of lamp types applicable in street lighting (as defined in Table 136, in ANNEX A); in physical volume and monetary units for all EU-25 Member States, for the years 1995 and 2000 up to 2004[7].
The results of the Prodcom queries for the different lamp types that can be used in street lighting are shown in Table 139 up to Table 143 in ANNEX B. Some production figures are missing, most likely due to confidentiality[8], and some of the reported production figures are estimated by Eurostat. As production figures (both in volume and in value) are not available for several years, it is not always possible to identify apparent domestic consumption (total sales within the EU).

For the two lamp types most frequently used in street lighting; mercury vapour discharge lamps and sodium vapour discharge lamps, the Europroms results for 2003-2004 are presented in Figure 10 and
Figure 11.

In 2003 the net balance of imported and exported volumes of mercury and sodium vapour discharge lamps is in equilibrium (imported volumes are only slightly smaller than the exported volumes). By consequence the apparent EU-25 consumption of these lamp types runs parallel to the EU-25 production.

Figure 10 shows that the apparent consumption of sodium vapour discharge lamps in EU-25 is about 1,6 to 1,3 times as high as that of mercury vapour discharge lamps in 2003 respectively 2004. Whereas the apparent consumption of mercury vapour lamps increases by 33% from 2003 to 2004 and originates from the EU-25 net import in 2004[9], the annual growth of sodium vapour discharge lamps from 2003 to 2004 only amounts up to 5% and is not due to a change of the net balance of imported versus exported goods but can be explained by a (slightly) higher EU-25 production.

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[5] http://epp.eurostat.ec.europa.eu/portal/page?_pageid=0,1136195,0_45572097&_dad=portal&_schema=PORTAL

[6] When comparing production with trade figures we consider all the trade passing the external borders of the territory in question. For individual Member States this means all external trade, i.e. the sum of the trade with all Intra-EU and all Extra-EU partners. However for EU totals we are only interested in trade leaving and entering the EU as a whole, so the sum of trade with all Extra-EU partners is displayed.

[7] At time of study, no data for 2005 was available

[8] Very big manufacturers with a high market share, as is the case in the lamp market (see ANNEX H "the Big Three"), are sometimes exempt from reporting their data publicly because it would reveal confidential company information. However if several countries declare their production for a heading to be confidential, an EU total can be published because the data for an individual country cannot be inferred (Eurostat data shop Handbook, part 6.4.2. Europroms-Prodcom data, version 29/08/2003).

[9] while they were exporting more lamps in 2003 than importing

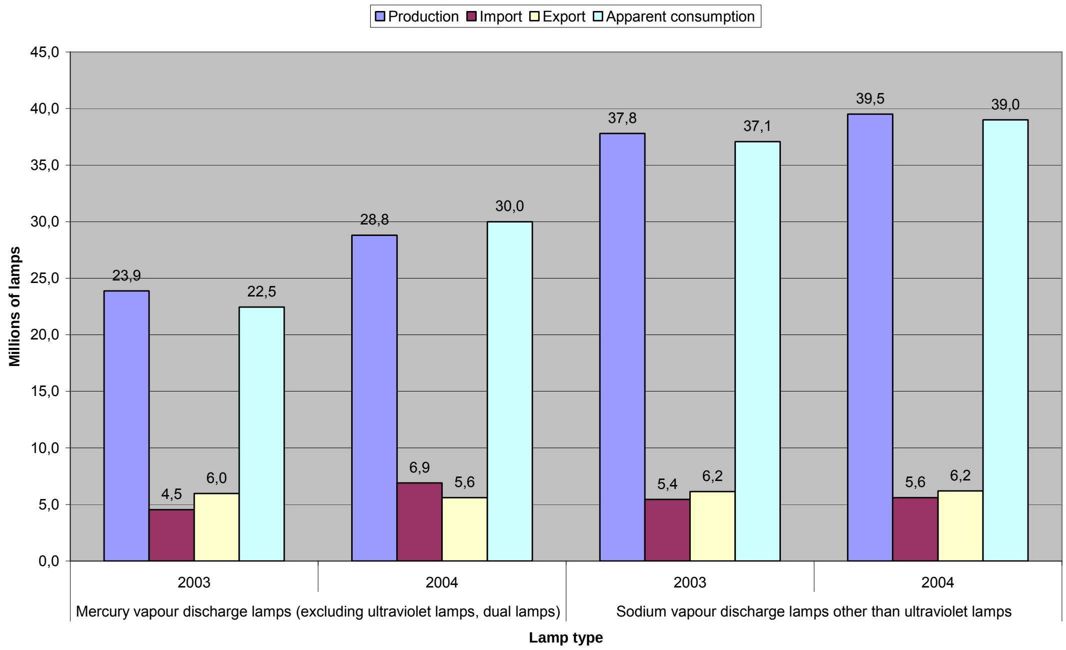

Figure 10: EU-25 lamp volume: Production, trade and consumption profile in 2003-2004 (Source: Europroms)

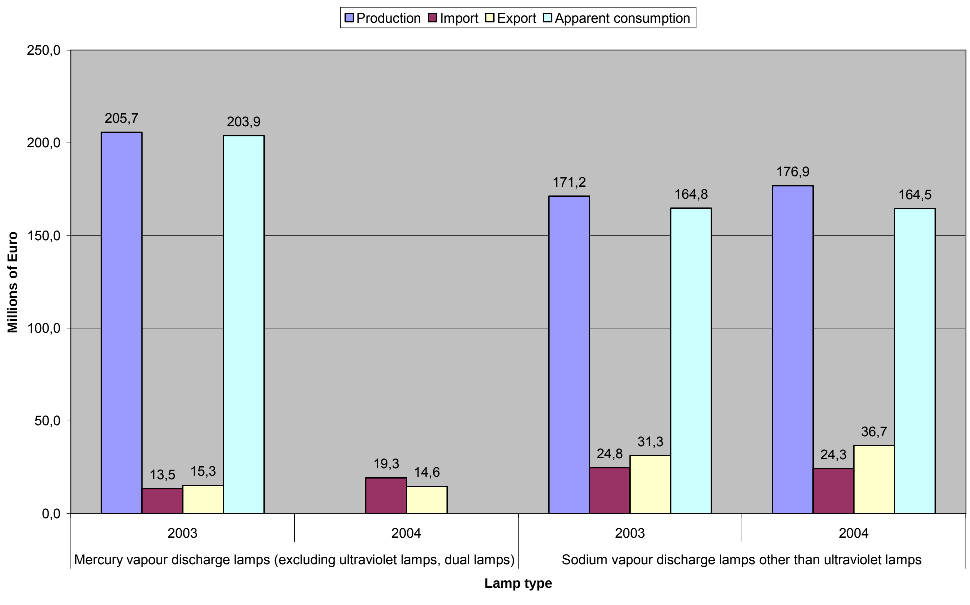

Figure 11: EU-25 lamp value: Production, trade and consumption profile in 2003-2004 (Source: Europroms)

Table 144-Table 145 in ANNEX C give an overview of production and trade data for the two main lamp types applicable in street lighting and express export as a share of EU manufacturer

sales[10], and import as a share of EU net supply[11]. Table 144 shows that in 2003 only a small fraction (7,4%) of the EU manufacturer sales of mercury vapour discharge lamps are exported (sold on a foreign market), implying that the remainder of 92,6% are sales on the EU-25 market. The same table indicates that imports represent only a minor part (6,6%) of the EU net supply of mercury vapour lamps, and thus the apparent consumption of mercury vapour lamps is to a large extent produced in the EU-25.

Compared to mercury vapour discharge lamps, the share of the EU manufacturer sales of sodium vapour discharge lamps that are exported is higher, up to about 20% in 2003-2004 (Table 145). Imported sodium lamps represent 15% of the EU-25 net supply in 2003-2004, implying that the share of EU-production of sodium lamps (85%) in the total net supply is slightly lower compared to that of mercury lamps (93,4%).

One must bear in mind that these results hold for the total of all lighting applications and not only for the lamps used in street lighting. As the (exact) proportion of street lighting lamps is not known, it is hard to say whether these general findings also apply to the case of street lighting.

2.1.3 Volume and value of European ballasts and ballast parts- production, trade and consumption: Europroms results

A query was submitted on the website of Eurostat[12] for extra-EU trade and production of ballasts and ballast parts applicable in street lighting (as defined in Table 137 in ANNEX A), in physical volume and monetary units for all EU25 Member States, for the years 1995 and 2000-2004.

The query of the Prodcom database resulted in fragmented data on production and an almost complete overview of foreign trade data. As production figures (both in volume and in value) are not available for several years, it is not always possible to identify apparent domestic consumption (total sales within the EU) of specific lighting products. Results of the queries for the different ballasts and ballast parts applicable in street lighting are presented in Table 146-Table 148 of ANNEX D.

For the two types of ballasts most frequently used in street lighting (i.e. ferromagnetic[13] versus electronic[14] ballasts) the Europroms results for 2003-2004 are summarised in
Figure ***12:*** EU-25 ballasts and ballast parts volume: Production, trade and consumption profile in 2003-2004 (Source: Europroms)
and Figure 13. Another ballasts and ballast parts category that can be found in Europroms is "Parts (excluding glass or plastics) of lamps and lighting fittings"[15]. However, for this class of

[10] Corresponds to Europroms "Production"
[11] Corresponds to Europroms "Apparent consumption" (= EU Manufacturer sales + Imports – Exports)
[12] http://epp.eurostat.ec.europa.eu/portal/page?_pageid=0,1136195,0_45572097&_dad=portal&_schema=PORTAL
[13] The Prodcom category 'Inductors for discharge lamps or tubes' corresponds to ferromagnetic ballasts
[14] The Prodcom category 'Ballasts for discharge lamps or tubes (excluding inductors)' corresponds to electronic ballasts

parts no information on production and trade volumes can be retrieved from the Eurostat database[16]. Only import and export values are listed for several years.
Figure ***12:*** EU-25 ballasts and ballast parts volume: Production, trade and consumption profile in 2003-2004 (Source: Europroms)
shows that the apparent consumption of ferromagnetic ballasts is about 5,5 to 5,8 times as high as that of electronic ballasts in 2003 respectively 2004. The apparent consumption of ferromagnetic ballasts increases with 14,8% from 2003 to 2004- originating from an increased EU-25 production, whereas the increase of apparent consumption of electronic ballasts only amounts up to 8,6% and is due to a higher net import into EU-25.

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[15] The sub categorisation of this class of parts into "Tracks for electric lighting and parts thereof", "Lamps-shades in paper cardboard" and "Other parts (excl. glass or plastics) of lamps and lighting fittings" is too detailed as the Europroms results (presented in Table 148 in ANNEX D) comprise no information (neither on production, nor on import/export).
[16] This might be due to the fact that the market of electrotechnical parts for luminaires is formed by many SME's and these very small manufacturers are sometimes allowed not to report annually (but it is sufficient to do this only with large census questionnaires). So these data can lag more than 3 years behind or not be a part of the statistics at all.

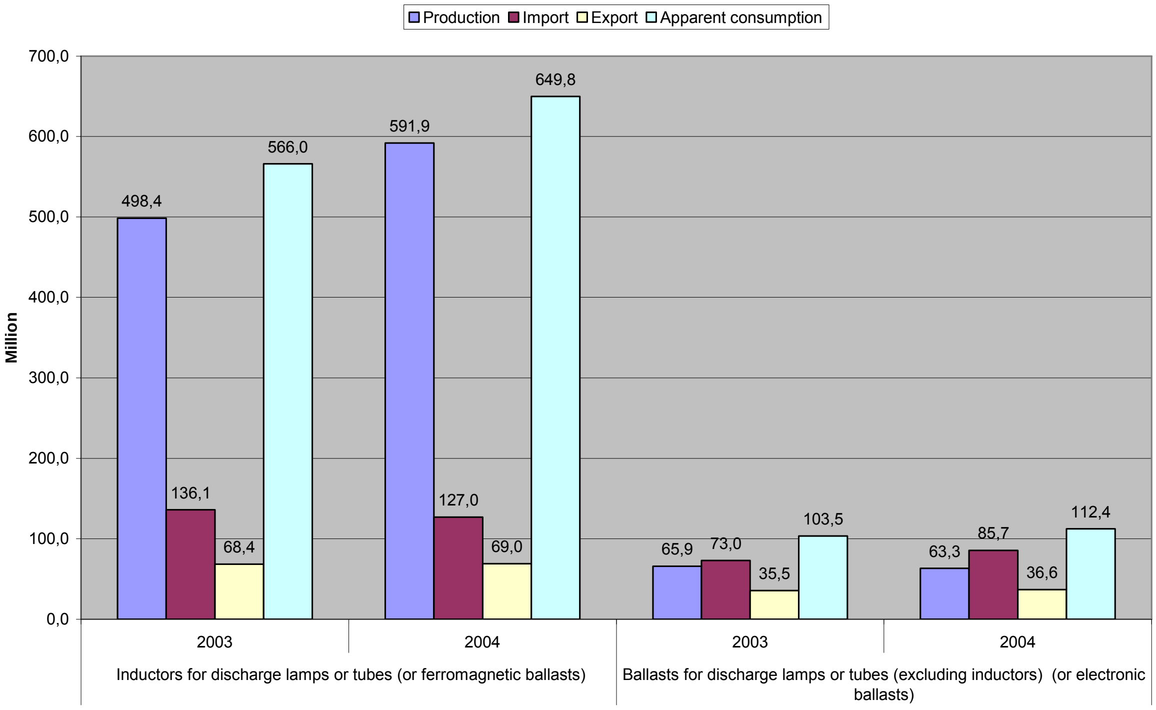


Figure 12: EU-25 ballasts and ballast parts volume: Production, trade and consumption profile in 2003-2004 (Source: Europroms)

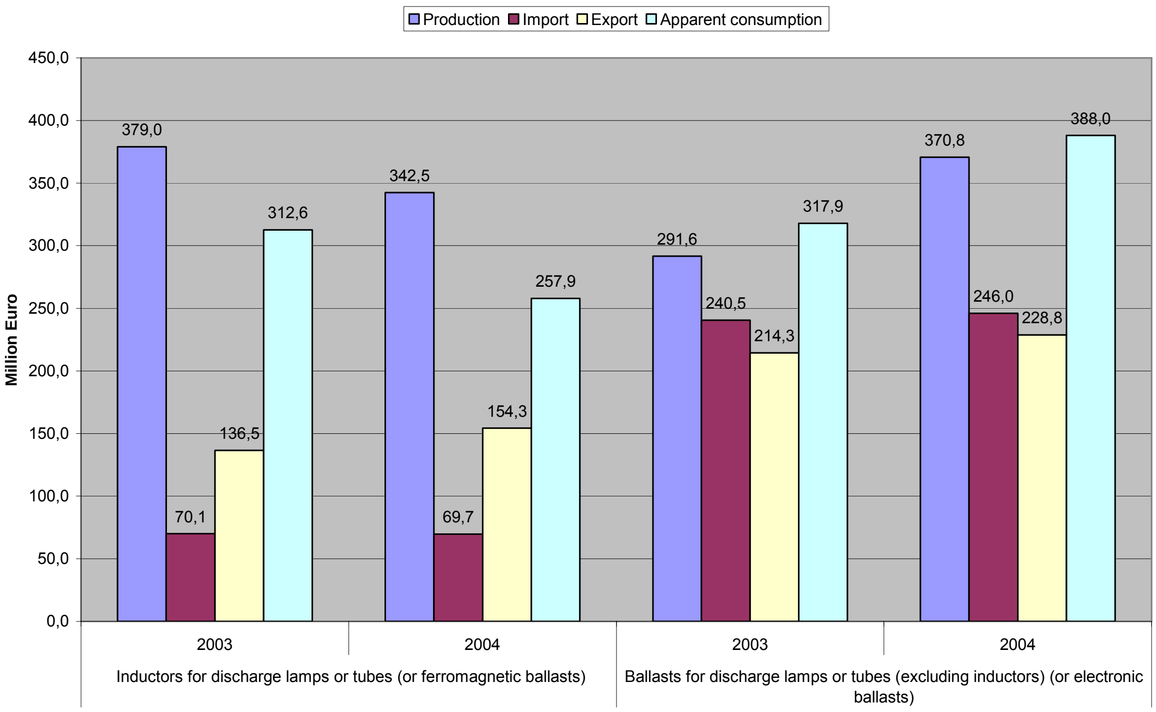


Figure 13: EU-25 ballasts and ballast parts value: Production, trade and consumption profile in 2003-2004 (Source: Europroms)

Table 149 and Table 150 in ANNEX E give an overview of production, trade and consumption data for ballasts and ballast parts applicable in street lighting and express export as a share of EU manufacturer sales[17], and import as a share of EU net supply[18]. Table 149 shows that after a decrease of the share of export of the total EU manufacturer sales of ferromagnetic ballasts to 26% in 2002 (in EU-15), the relative share of export has increased strongly from 2002 onwards to reach 45% in 2004 (in EU-25). While in 2001-2002 imports of ferromagnetic ballasts represented only 10,5 to 11,5% of EU net supply, in 2004 approximately 1 out of 4 ferromagnetic ballasts consumed in Europe is imported.

In 2001 the proportion of EU manufacturer sales of electronic ballasts being exported (50,3%) was well balanced with the proportion being sold on the EU-market (49,7%). After a sharp increase to about 75% of EU manufacturer sales being exported in 2003, this proportion started decreasing from 2003 onwards. The same trend (balance in 2001, followed by a sharp increase to 75% in 2003, and then a slight decline from 2003 onwards) is observed in the comparison of imports expressed as a part of EU net supply (Table 150).

It can thus be concluded that (for the European market) ferromagnetic ballasts are produced mainly (approximately 75%) in EU-25, whereas electronic ballasts are produced both in Europe (approximately 60%) and abroad.

Again the same caution as for the interpretation of the lamp shipment data applies: One must bear in mind that the Europroms results hold for the total of all lighting applications and not specifically for street lighting. As globally far more fluorescent lamps are used than HID lamps, fluorescent ballasts account for the bulk of the ballast market. This together with the fact that the Europroms results describe the global lighting market and not specifically the street lighting situation one must be careful to extrapolate these general findings to the street lighting case. The Europroms results can thus only be considered as indicative.

2.1.4 Volume and value of European luminaires for different street lighting categories production, trade and consumption: Europroms results

A query was submitted on the website of Eurostat[19] for extra-EU trade and production of luminaires for different street lighting categories (as defined in Table 138 in ANNEX A) in physical volume and monetary units for all EU25 Member States, for the years 1995 and 2000-2004.

Although for this product category (luminaires) the categorisation in Europroms was detailed at the level of street lighting, the Eurostat query did not yield results of production and trade data for EU-15/EU-25 (years 1995, 2000, 2004 and 2005). Neither aggregated data for EU-15/EU-25, nor (scattered) data per Member State are recorded in the Prodcom database.

[17] Corresponds to Europroms "Production"
[18] Corresponds to Europroms "Apparent consumption" (= EU Manufacturer sales + Imports – Exports)
[19] http://epp.eurostat.ec.europa.eu/portal/page?_pageid=0,1136195,0_45572097&_dad=portal&_schema=PORTAL

Apparently no data at all is available in the Prodcom database at this particular level of detail. Results of the queries for luminaires for different street lighting categories are shown in ANNEX F.
This illustrates some of the shortcomings of the Europroms data source: The Prodcom sub categorisation was designed for customs use and is not conform the sub categorisation normally used by industry and other stakeholders. Besides this (very) small manufacturers (SME) are sometimes not required to report annually but it is sufficient to do this only with large census questionnaires. So these data can lag more than 3 years behind or not be a part of the statistics at all.

2.1.5 Overview of lamp and ballast production, trade and consumption profile in EU-25

Table 10 presents an overview of all the above information and indicates that far more ferromagnetic and electronic ballasts are imported than exported. The imported ballasts tend to be less expensive than the ballasts that are domestically manufactured. In 2003 about twice as much ballasts were imported as exported and while the imported inductors for discharge lamps or tubes (ferromagnetic ballasts) accounted for about 24% of total domestic consumption, the imported electronic ballasts made up to 75% of the domestic consumption volume.

On the other hand sodium vapour and mercury vapour discharge lamps are exported 1,1 to 1,3 times more than imported in 2003. While the imported sodium vapour discharge lamps accounted for about 15% of total domestic consumption, both in volume as in value - indicating little price difference between the domestically (EU-25) produced and imported sodium lamps- the imported mercury vapour discharge lamps accounted for 20% of total domestic consumption volume, but only for about 7% of the value of domestic consumption of mercury lamps – indicating imported mercury lamps are cheaper then the ones being domestically produced.

An indication of the prices per item for the most common lighting parts used in street lighting can be calculated by dividing the values of production, imports and exports reported in Europroms by their corresponding volumes (Table 10).

Figure 70 - Figure 70 in ANNEX G compares EU-25 exports, imports and domestic consumption for the different types of lamps and ballasts presented in Table 10.

Table 10: Overview of lamp and ballast shipments in EU-25 in 2003 (Source: Calculated based on Europroms results)

	Units	Total EU-25 shipments[20]	EU-25 exports	EU-25 shipments for domestic consumption ("domestic production")	EU-25 Imports	Total shipments for domestic consumption[21]
Lamp types applicable in street lighting						
Mercury vapour discharge lamps (HgHP)						
Volume	Millions	23,88	5,97	17,91	4,54	22,45
Value	Million of 2003 Euros	205,74	15,35	190,39	13,52	203,91
Price per item (calculated)	2003 Euro	8,6	2,6		3,0	
Sodium vapour discharge lamps (NaHP + NaLP)						
Volume	Millions	37,79	6,15	31,64	5,44	37,08
Value	Million of 2003 Euros	171,24	31,25	139,99	24,77	164,76
Price per item (calculated)	2003 Euro	4,5	5,1		4,6	
Ballast and lamp ballast parts applicable in street lighting						
Inductors for discharge lamps or tubes-ferromagnetic ballasts						
Volume	Millions	498,36	68,41	429,95	136,07	566,02
Value	Million of 2003 Euros	379,03	136,50	242,53	70,06	312,59
Price per item (calculated)	2003 Euro	0,8	2,0		0,5	
Ballasts for discharge lamps or tubes (excluding inductors)-electronic ballasts'						
Volume	Millions	65,94	35,46	30,48	72,98	103,46
Value	Million of 2003 Euros	291,64	214,31	77,33	240,53	317,86
Price per item (calculated)	2003 Euro	4,4	6,0		3,3	

2.1.6 Conclusion data retrieval from Europroms

From the preceding sections, it can be concluded that data retrieval on street lighting from this publicly available data source is limited because, although for lamps and ballasts the volume of

[20] This corresponds to Europroms "Production"
[21] This corresponds to Europroms 'Apparent consumption'
= Total EU-25 shipments + Imports - Exports

sales can be derived from the “Apparent consumption[22]” (for which it provides the necessary data - both in physical and monetary units), it does not provide data on the stock of products already in use (or “Installed Base”), nor does it say anything about the average product life, which would help in calculating that stock. Furthermore an important shortcoming of the use of Europroms as data source is that production and trade data on lighting parts (such as lamps and ballasts) are not available at the desired level of detail (i.e. only data available at a very high level of aggregation, thus including other lighting categories). Last but not least, for several technical reasons, the Prodcom data have a limited reliability and –if one wants a reasonable coverage of data of all Member States—runs several years behind.

For these reasons we will have to estimate the total street lighting market using other indirect sources of information. The detailed approach in described in section 2.2.

[22] One of the most important indicators provided by Europroms is “Apparent consumption” - the estimation of the amount of each product consumed in a country based on the amount produced plus the amount imported minus the amount exported. This is the rationale for combining Prodcom and Foreign Trade data in Europroms (Eurostat Data Shop Handbook, part 6.4.2 Europroms-Prodcom data, version 29/08/2003).

2.2 Market and stock data

To overcome the data gap (discussed in section 2.1) several approaches for retrieving more data were explored.

1. ***Literature review:*** first, an overview of existing publicly available data on the market and stock of street lighting at the level of individual Member States was generated by a literature review and an inquiry of experts from individual Member States and other lighting related organizations.

2. ***Consultation of EU industry federations ELC and CELMA:*** a request for lamp and luminaire market data and any other relevant information was launched at the first stakeholder expert meeting (10/04/2006). ELC is the European Lamp Companies federation and CELMA is the federation representing 16 National Manufacturers Associations for Luminaires and Electrotechnical Parts for luminaires in the European Union. Mainly market data on sales of lamps (i.e. differentiated per market segment) and luminaires was asked for. Based on sales data and average luminaire lifetime, results regarding installed base can be estimated. ELC provided their sales data for lamps. Because there were no sales data available for luminaires, CELMA provided an estimation of installed street lighting luminaires for EU25.

3. ***Inquiry of experts from individual Member States and other lighting related organizations ("Expert-inquiry")***: a questionnaire was sent to: among others, industry experts from CIE (Commité International Éclairage) at Member State level and other lighting-related organisations such as Eurocities, Energie-cités, AIE-elec, CCRE-CEMR, … Besides data on installed base, questions were also posed on other street lighting-related aspects, such as the performance of street lighting, the application of standards and legislation, disposal aspects, etcetera.
   Only few answers were received, even after many personal telephone calls (filled out inquiry for Belgium, Ireland, United Kingdom and Sweden, data by e-mail forDenmark, Greece, Netherlands and Poland see Table 16). Also most of the answers were not complete.

4. ***Calculated estimations based on Eurostat road infrastructure statistics*** (total km): this, Combining this data with estimations on 'share of road lit' and 'average pole distances', the amount of street lighting luminaires installed in the EU25 can be deduced. This base data is also used to make projections regarding future installed base and annual sales of street lighting products (up to 2025). This is discussed in detail in chapter 3.

Market and stock data are required for the following 4 time periods:

- 1990 (Kyoto reference)
- 2003-2005 (most recent real data)
- 2010-2012 (forecast, end of Kyoto phase 1)

- 2020-2025 (forecast, year in which all new eco-designs of today will be absorbed by the market

The following sections mainly describe the present situation (based on the most recent real data) and the parameter (the foreseen growth of the road network) that determines the forecasts for the future situation (see scenario model results in chapter 5).
For an assessment of the past situation in the scenario model we will have to assume a linear trend of the available data of the present situation as no information on the street lighting situation in the past was retrieved from the consulted sources (the Expert-inquiry to a.o. CIE representatives in the different Member States only produced answers for Belgium, ELC only started compiling detailed sales statistics from 1999 onwards, and Europroms data only go back to 1995).

2.2.1 Market

An overview of consulted literature in the search of street lighting market data is included in the reference list. Next to consulting ELC and CELMA publications, SAVE projects were scanned. SAVE studies covering street lighting are: PROST (Public Procurement of Energy Saving Technologies in Europe), Greenlight, Enlight and more recently E-street (Intelligent road and street lighting in Europe). Other initiatives related to street lighting under the IEE programme are: ButK (Bottom up to Kyoto) and The Buy Bright Initiative.
At present, scattered data on the number of lighting points, road width, distance between lighting poles and energy consumption of street lighting are retrieved from the literature review for several Member States. These data are complemented with the results of the "Expert inquiry".

Recently the report of Work Package 2 'Market assessment and review of energy savings' of the E-street Initiative was finalised. Their data from specific countries indicate a relation between the number of inhabitants and number of light points for street and road lighting. The most accurate data came from Germany where the total number of outdoor light points is known (approximately 9 million street light luminaires installed for 82 million inhabitants). An extrapolation for Europe was made based on this ratio of 0,11 luminaires/capita resulting in an estimate of a total of 91 million light points in Europe (with 820 million inhabitants). The authors of the report of WP2 point out themselves that (based on the information from other countries) this ratio is found to be a too high number to apply to all of Europe since other countries (and cities) show lower numbers of luminaires per person (For the underpinning of our assumptions of installed luminaries/capita see Table 16).

For an outline of the global trade in lamps and lighting products and the global market value and trends we refer to the recently published IEA Light's Labour's Lost (IEA, 2006).

An Expert-inquiry was sent to amongst others the CIE-representatives in different EU-Member States. Although the CIE is a rather scientific organisation, most of the representatives are strongly related to the lighting associations in their countries and often even use the same secretariat.

An introduction message explained the objective of the inquiry and asked for appropriate contacts in case the addressee could not complete the questionnaire himself.
After a short description of the methodology and the road types for the scenario model, the inquiry asked for various data regarding street lighting in the concerned Member State:

- installed power and energy consumption
- installed lamp types and luminaires
- application of European standards
- road infrastructure and roads lit
- burning hours
- maintenance.

This questionnaire was also sent to a number of organisations representing European cities, European action groups and a federation of contractors that might dispose of additional interesting information about street lighting.
Furthermore, the questionnaire, which can be found in ANNEX H, was placed on the project website (http://www.eup4light.net) and could be completed by every registered stakeholder.
The contacts of the "Expert inquiry" and the responses received are presented in Table 155 in ANNEX I.

➢ **Total sales-real EU-consumption**

The objective is to define the actual consumption as reliably as possible for the categories defined in task 1.1 for the latest full year for which data could be retrieved.

A request for market data and any other relevant information was launched at the first stakeholder expert meeting on 10/04/2006 at EC DG TREN. Industry associations for luminaires and parts (CELMA) and lamps (ELC) have set up a task force to supply information.

Lamp market
ELC provided generic sales data for all types of lamps for the Western European market place[23] for the period 1999-2004. As the scope of this study is EU-25, the original ELC sales figures were rescaled based on population[24]. Further input was asked from the lamp industry experts (through ELC) to provide, per different lamp type, reliable estimates on the share of these sales figures intended for application in street lighting, and on the further subdivision[25] of the street lighting lamp sales according to defined road categories (i.e. fast traffic, mixed traffic or slow traffic see section 1.1.2 "Performance requirements and street lighting categories"). No response was received to these last two questions. Therefore, we needed to make our own assumptions (see "new sales" section).

[23] ELC supplied global European sales figures for EU-25 + Switzerland, Norway, Bulgaria, Romania, Turkey, Belarus, Russian federation, Ukraine, Yugoslavia. They divide the European region in 4 groups of countries: Central and Eastern Europe, Southern Europe, Middle Europe, and Nordic Europe. This division is not useful to this study as the scope is EU-25.
[24] EU-25 population only represented 58,5% of the total population of the countries to which the original ELC sales data related.
[25] This subdivision of street lighting lamp sales according to road category San possibly be done according to the wattage

Table 156 (in ANNEX J) and Figure 14 provide an overview of the total lamp sales in EU-25 from 1999 to 2004.

ELC splits up its total lamp sales according to the following 5 main lamp types:

1. Linear fluorescent and Special fluorescent products
2. Compact fluorescent lamps
3. Tungsten halogen lamps
4. Incandescent lamps
5. High Intensity Discharge lamps

As mentioned earlier in 1.1.4.1 "Segmentation of lamps" the main lamp type used in street lighting is the High Intensity Discharge lamp (HID). Also fluorescent lamps (Low Pressure Mercury) and Low Pressure Sodium (LPS) lamps are used.

ELC subdivides its HID sales into:

a. Mercury (incl. mixed)
b. Sodium, low and high pressure
c. Metal halide – All types including ceramic

As discussed in 1.1.4.1 and 2.1 none of these lamps are exclusively used for street lighting.

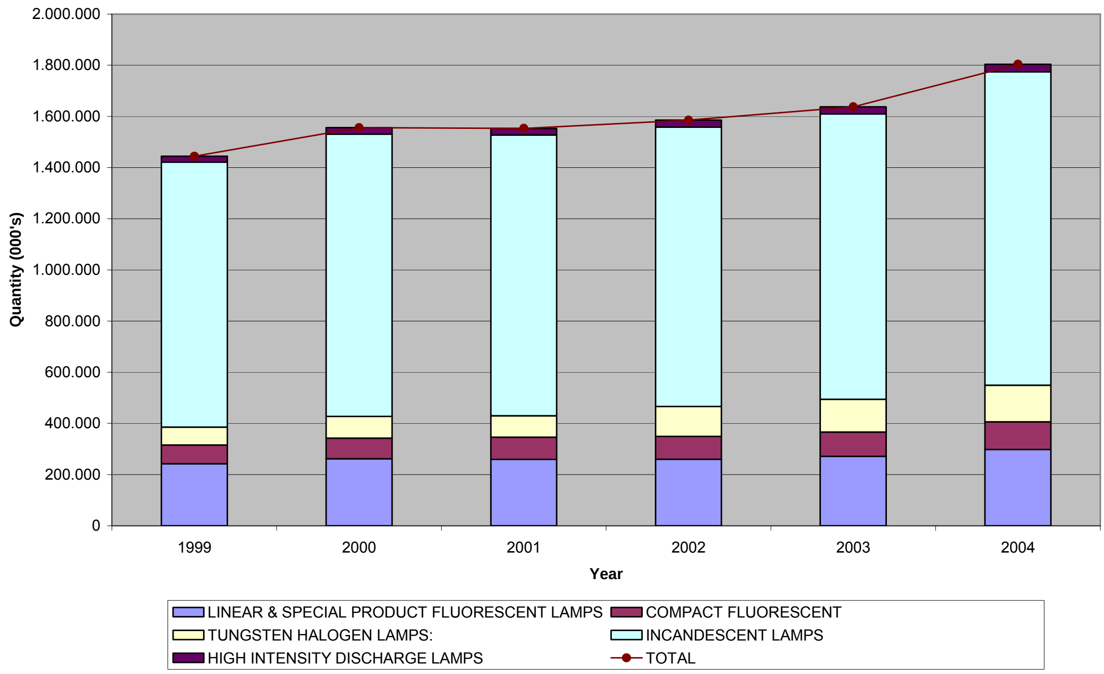


Figure 14: Volume of EU-25 lamp sales, 1999-2004 (Source: rescaled based on population from original ELC sales data for the Western European market)

Table 156 and Figure 14 indicate that HIDs only account for a very small share (1,6–1.7%) of the total EU-25 lamp sales volume. The average efficiency of HID lamps varies considerably between national markets depending on the relative share of low-efficacy mercury vapour lamps compared to the high-efficacy metal halide and high-pressure sodium lamps (IEA, 2006). In Europe mercury vapour lamp sales account for 27% of all HID lamps at present (Figure 15).

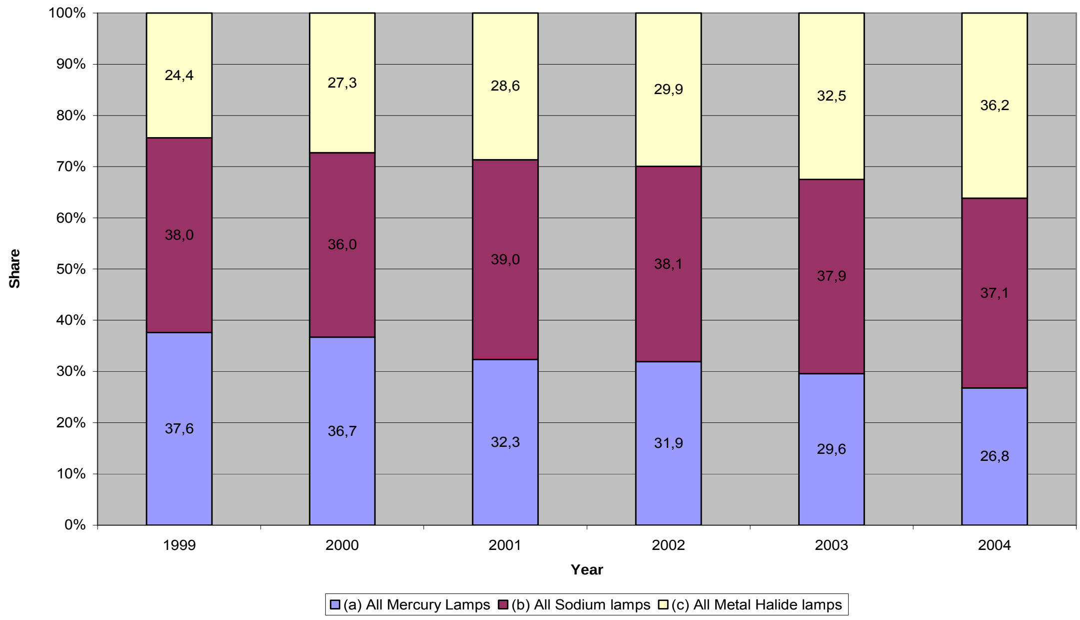


Figure 15: Evolution of share of High Intensity Discharge lamps in EU-25, 1999-2004 (Source: rescaled based on population from original ELC sales data for the Western European market)

Similar to the volume of ELC lamp sales the total value of ELC sales was rescaled to EU-25 based on population (Figure 16). While the volume of total ELC lamp sales in EU-25 is augmenting in the period 1999-2004, the corresponding total value of the ELC EU-25 lamp market is declining on average with 0,4% every year in the same period due to price erosion.

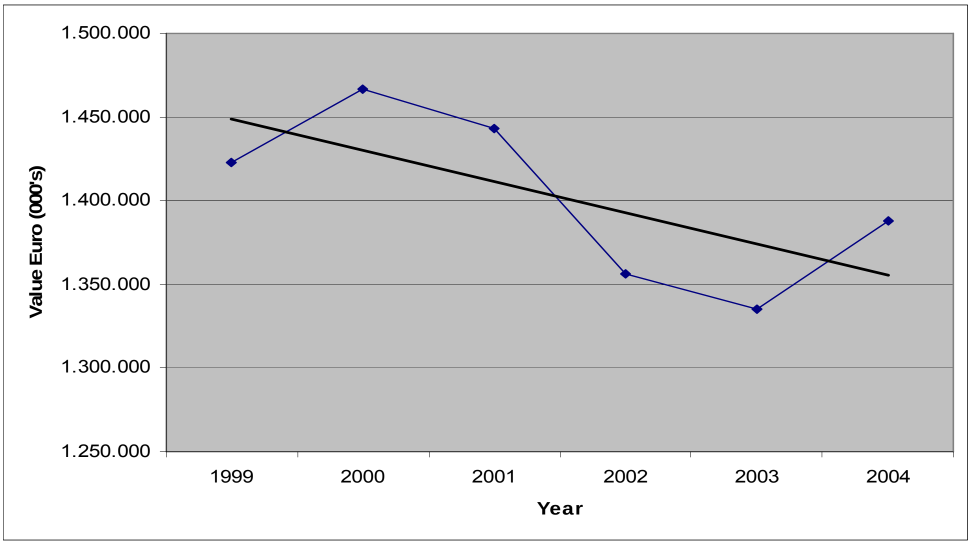


Figure 16: Value of lamp sales in EU-25 (Source: rescaled based on population from original ELC data)

Comparison of the apparent consumption figures retrieved from Eurostat with the ELC sales figures[26] gives a somewhat conflicting view (ANNEX K).
One must bear in mind that the figures from these two data sources can not be interpreted straightforward for several reasons:

- ELC sales figures do not include lamps for vehicles or lamps for projectors.
- ELC sales of 'metal halide lamps' are reported in Prodcom as 'Mercury vapour discharge lamps' (pers. Comm.. of Mr. B. Kenis from Philips on 04/08/2006)
- Furthermore extra-EU-25 imports should be added to the ELC sales figures for a more univocal comparison with the calculated "Apparent consumption" from Eurostat.

To get a more univocal comparison of the "Apparent consumption" with EU-25 ELC sales figures, the sold volumes of metal halide lamps are added to the sold volumes of mercury lamps reported by ELC. Furthermore the extra-EU imports (retrieved from Europroms) are added to the ELC EU-25 sales figures to get a better indication of the "Actual consumption" in Europe.

Table 157 to Table 160 in ANNEX K present the calculations and results of the comparison of "Apparent consumption" with "Actual consumption" for the different types of lamps used in street lighting.
For linear and special product fluorescent lamps the apparent consumption almost equals the EU-25 sales in 2003 and 2004, but for 2001 and 2002 the apparent consumption corresponds better to the actual consumption figures. For compact fluorescent lamps the apparent consumption seems to be rather consistent with the actual consumption (Percentage difference ranging from -13% to -23%).
While for mercury lamps the relative difference between apparent and actual consumption in 2000-2004 ranges between 3,7-32,8%, the difference for sodium lamps is much more

[26] Rescaled to EU-25 based on population

pronounced, i.e. the apparent consumption of sodium lamps is more than twice as high as the actual consumption indicates (133,2%-134,3% in 2003-2004).

As the MEEuP report (VHK, 2005) states, significant differences between the actual consumption and the apparent consumption may occur.

ELC will be asked if they have a further explanation for this discrepancy.

- **Annual sales growth rate**

Total ELC EU-25 sales figures Table 156 (ANNEX J) indicate an average annual growth rate of 4,62% in the period 2000-2004 for all lamp types.

Looking into more detail at lamp types applicable in street lighting, i.e. the HID sales data, Table 11 shows that globally the HID's grow at a somewhat faster pace than the average of the total lamp market: 5,1% annually. Differences in annual growth rates occur though between the different HID lamp types: while the sodium lamps grow at a rate close to the global HID sales, metal halide lamps display a much stronger growth rate (+13,8% on average in 2000-2004), while the mercury lamp sales exhibit a mean decline of 1,7% over the same period.

Note these observed annual growth rates apply to the global HID lamp market and as the exact share of HIDs applied in street lighting is not known these figures can only be regarded as indicative. The absolute numbers serve as an upper limit for the annual sales of lamps for street lighting.

Table 11: Annual growth rate (AGR) of EU-25 High Intensity Discharge lamps annual sales (Source: Calculated based on rescaled ELC lamp sales figures)

Lamp type		**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**Average annual growth rate**
All Mercury Lamps (HgHP)(including mixed)[27]	000's	8.711	9.333	8.501	8.542	8.151	7.938	
AGR	%		7,1	-8,9	0,5	-4,6	-2,6	-1,7
All Sodium lamps (NaHP + NaLP)	000's	8.801	9.151	10.265	10.206	10.457	10.982	
AGR	%		4,0	12,2	-0,6	2,5	5,0	4,6
All Metal Halide lamps	000's	5.649	6.935	7.531	8.011	8.958	10.714	
AGR	%		22,8	8,6	6,4	11,8	19,6	13,8
TOTAL	**000's**	**23.161**	**25.418**	**26.297**	**26.759**	**27.566**	**29.633**	
Annual growth rate	**%**		**9,74**	**3,46**	**1,75**	**3,02**	**7,50**	**5,1**

[27] HgHP mixed is a self ballasted HgHP lamp, thus with an incorporated incandescent filament that replaces the ballast

➢ **New sales**

The total of "new sales" of lighting products are formed on the one hand by new sales intended for lighting of newly constructed roads and on the other hand by new sales of lighting products intended for the lighting of existing roads which were previously unlit.
From the combination of the known road length in 2004-2005 with the percentage of roads that are lit[28] and the distance between lighting points (45m for Cat F, 30m for Cat M and 25m for Cat S roads) the number of lighting points in 2004 and 2005 can be derived. The increase in lighting points from 2004 to 2005 represents the total "new sales" of 1.019.000 lamps (Table 12). For each of the three defined road categories these new sales figures can be deduced likewise. We assume that the 23 million new lamp sales of category F are all sodium lamps[29], while the 135 million new lamp sales for category M roads will be a combination of 20% mercury lamps and 80% sodium lamps; and the 861 million new lamp sales intended for category S roads will consist of 30% mercury lamps, 50% sodium lamps, 5% metal halide lamps and 15% fluorescent lamps. This results in the number of new sales per lamp type (Table 13)

[28] We currently assumed that 10% of category F roads, 15% of category M roads and 30% of category S roads were lit in 1990, increasing linear to 15% Cat F, 17,5% Cat M and 40% Cat S roads lit in 2025.
[29] 90% high pressure sodium lamps and 10% low pressure sodium lamps

Table 12: Derivation of "New sales" in 2004

Road category	Road length in 2004	Share of road categories	Share of roads lit in 2004	Road length lit in 2004 (km)	Avg distance between lighting points	Number of lighting points in 2004	Road length in 2005	Share of roads lit in 2005	Road length lit in 2005	Number of lighting points in 2005	New sales in 2004
	km	%	%	km	m	000's	km	%	km	000's	000's
	Eurostat		Assumption	Calculated	Assumption	Calculated	Eurostat	Assumption	Calculated	Calculated	Calculated
Cat F	232.398	4,5	12	27.888	45	620	239.211	12,1	28.945	643	23
Cat M	1.870.830	35,5	16	299.333	30	9.978	1.884.321	16,1	303.376	10.113	135
Cat S	3.160.140	60,0	34	1.074.448	25	42.978	3.195.235	34,3	1.095.966	43.839	861
Total	**5.263.368**	**100**		**1.401.668**		**53.576**	**5.318.766**		**1.428.287**	**58.904**	**1.019**

➢ **Replacement sales**

From a combination of this "new sales" figure for 2004 with the corresponding total lamp sales data from ELC (rescaled to EU-25) and assuming that 7,5 % of mercury and sodium lamps are intended for indoor use while 90% of metal halide sales and 98% of compact fluorescent lamp sales are used for other purposes than street lighting, the replacement sales volume in 2004 can be derived: 19.719.000 units. The majority (95%) of lamp sales for street lighting are thus replacement sales.

Table 13: Overview of total EU-25(street lighting) lamp sales in 2004, split up in "new sales" versus "replacement sales"

Lamp type	Total EU-25 lamp sales	Share applied in street lighting	Total EU-25 street lighting lamp sales		New street lighting lamp sales		Replacement street lighting lamp sales	
	Rescaled from ELC	Own Assumption[30]	Calculated		Calculated		Calculated	
	(000's)	%	(000's)	%	(000's)	%	(000's)	%
Mercury lamps (HgHP)	7.938	92,5	7.343	35,4	285	28,0	7.058	35,8
Sodium lamps (NaHP+NaLP)	10.982	92,5	10.158	49,0	562	55,1	9.596	48,7
Metal halide lamps	10.714	10	1.071	5,2	43	4,2	1.028	5,2
Compact fluorescent lamps	108.286	2	2.166	10,4	129	12,7	2.037	10,3
Total			**20.738**	**100**	**1.019**	**100**	**19.719**	**100**

These figures of street lighting lamp sales (and the proportion between different lamp types) will be used as input in the scenario model. A sensitivity analysis will be performed using the apparent consumption figures retrieved from Europroms instead of the ELC EU-25 sales data (see chapter 8 section 8.3)

Luminaire market

CELMA could not provide accurate statistics for luminaires due to the specific structure of the lighting luminaires market (many companies in different countries with different statistical reporting systems). No reliable global EU-25 data exist[31]. They did deliver their estimations on the installed base of street lighting luminaires in Europe (and per Member State) and the share of mercury lamps (see Table 161 in ANNEX L). In case no data were available from literature or the Expert inquiry, these estimations were used (for certain Member States) to complete the calculation of the total installed base of luminaires in EU-25 (see 2.2.2).
The uncertainty about the number of installed luminaires is discussed in the sensitivity analysis (see 8.1.3.3).

[30] An estimate of this share per lamp type was asked from ELC but until now no response to this question was received, so we had to make our own assumption, based on expert opinion.
[31] Pers. Comm. of Mrs S. Mittelham, managing director CELMA, during the second stakeholder meeting on 12/05/2006

For luminaires we can conclude that no useful data are available in the Prodcom database but that this data gap can be overcome with a combination of data from literature and the Expert inquiry and input (estimations) from the European sector federation, CELMA.

The IEA Light's Labours' Lost study mentions that according to the Freedonia forecasts (Freedonia, 2004 in IEA, 2006) there will be a greater rate of growth in the global lighting-fixture market up to 2008 than occurred in 1998–2003, as a result of increased manufacturing and construction activity triggered by global economic growth, continuous urbanisation and the expansion of electricity grids in rural areas. Not surprisingly, the rate of growth is projected to be highest in the developing areas of Asia-Pacific, Eastern Europe, Africa, the Middle East and Latin America. Demand for lighting fixtures in Western Europe is projected to grow by 4.0% per annum, which is well above the 2.9% growth rate registered over the period of 1998 to 2003.

2.2.2 Stock

➢ **Average product life**

<u>Lamps</u>

The lifetime of a lamp is always expressed in service time i.e. burning hours and is dependent on lamp family. Moreover different definitions of lifetime are used.

One definition of the average lifetime of a lamp family is the burning hours after which only 50% of the installed lamps survive; this is the time that manufacturers generally display in their catalogues. In the technical report CIE154:2003, this lifetime corresponds with a LSF=0,5.

Table 14: Lamp survival factor (LSF) for the three main lamp types used in street lighting (Source: CIE 154:2003)

		Differences	Burning hours				
			100	10.000	12.000	20.000	30.000
Fluorescent tri-phosphor magn. ballast	LLMF	moderate	1	0.9	0.9	0.9	
	LSF	moderate	1	0.98	0.92	0.5	
Mercury (HgHP)	LLMF	moderate	1	0.79	0.78	0.76	
	LSF	moderate	1	0.86	0.79	0.5	
Metal halide	LLMF	big	1	0.6	0.56		
	LSF	big	1	0.8	0.5		
High pressure sodium (NaHP)	LLMF	moderate	1	0.97	0.97	0.94	0.9
	LSF	moderate	1	0.99	0.97	0.92	0.5

This 'survival' lifetime does not take into account the decrease in light output of a lamp during its lifetime. Because all lighting standards mention "*maintained*" lighting levels, this decrease must be taken into account when performing the calculations for the dimensioning of new lighting installations. Allowing a decrease of more than 30% causes an over dimensioned installation and thus an excessive power consumption. The values of light output decrease in function of the burning hours also differ between lamp families and are given in CIE154:2003 as a ratio LLMF. For NaHP-lamps, HgHP-lamps and ceramic MHHP-lamps, they are included in Table 14.

Taking into account both factors (LSF and LLMF), a commonly used economic lifetime or replacement time (t_{group}) of lamps in street lighting can be found in Table 15. For practical maintenance reasons[32], this lifetime is given as replacement time in years for lamps functioning the entire night (about 4000 hours per year). If lamps are switched off after curfew, lifetime in years must be adjusted accordingly.
A more detailed analysis of LLMF and LSF parameters for current products available on the market will be included chapter 4.3. The lifetime in years is used as input in the formulas in chapter 4.3. for calculating the lamp consumption.

Table 15: Commonly used practice for lifetime of the main lamp type families (Source: based on combination of LSF and LLMF data provided in CIE154:2003)

Lamp family	**Lifetime - t_{group}**	
	Years	**Service hours**
HgHP	3	12.000
HgLP (linear and compact non integrated)	3	12.000
HgLP (compact integrated)	2	8.000
NaHP	4	16.000
NaLP	3	12.000
MHHP	1.5	8.000

<u>Ballasts</u>
A discharge lamp needs a ballast for its functioning. This gear has mainly two functions: ignition of the lamp and control of the functioning by supplying the right lamp voltage and limiting the electric current.
Two types of ballast exist: electromagnetic[33] and electronic. A classical electromagnetic ballast has different parts: an electromagnetic ballast, an ignitor (not for HPM-lamps) and a capacitor. An electronic ballast is mostly one unit that provides both ignition and good functioning (by supplying the right lamp voltage and limiting the electric current) of the lamp.

The ballast lifetime depends on service hours. Normally, magnetic ballasts last as long as the luminaires if they are placed inside the luminaire (and thus are protected against rain).
For electronic ballasts, lifetimes of 40.000 to 60.000 hours (10 to 15 years) are considered as realistic by the manufacturers. Real data, based on experience in public lighting, can not be given as the introduction of electronic ballasts in public lighting was only in the late 1990's[34].
The lifetime of electronic ballasts decreases strongly if the working temperature in reality exceeds the indicated working temperature.
The lifetime of ignitors associated with magnetic ballasts does not depend on hours in service but on the number of times that the lamps are switched on. Experiences show that the lifetime of an ignitor can match the lifetime of a luminaire with an acceptable survival rate. An electronic ballast includes an ignition device and does not have a separate ignitor.
With electromagnetic gear, in addition to a ballast and ignitor, a capacitor has to be used to improve the power factor ($\cos \varphi$) of the lighting installation. An unsatisfactory power factor

[32] group replacement
[33] Synomym of ferromagnetic
[34] Personal experience with a pilot installation of 60 dimmable electronic ballasts in Zele, Belgium confirms a lifetime without trouble of already more than 32.000 hours or 8 years. Source: Pers. Comm. of Mr. L. Vanhooydonck on 08/08/2006

causes higher currents and by consequence higher cable losses. The quality of a capacitor and thus the amelioration of the power factor decreases over service time. A maximum useful lifetime declared by capacitor manufacturers is 10 years.
An electronic gear is designed to have a power factor of at least 0.97 and has no additional capacitor.

Luminaires
The average overall lifetime for luminaires is expressed in years after placement. Because the lifetime is only influenced by local conditions as weather (humidity, wind…), pollution, vibrations caused by traffic density, etc., time in service must not be taken into account. A lifetime of 30 years is common practice. This figure is based on practical experiences and is confirmed by the first responses to our inquiry. The variation can be considerable. Whereas in the centre of municipalities and in shopping streets -where public lighting is an element of street furniture- replacement times can be much shorter e.g. 15 years, in rural areas -with very low traffic density- luminaires with an age of 35 years and even more can be encountered. Many installations of 20 years and older are of course no longer complying with the standards on illumination, depending on the applied maintenance. Regular cleaning of the luminaire is necessary. This cleaning necessity depends strongly on the characteristics of the luminaire. Where the reflector of an open luminaire needs at least every 10 years a new polish and anodizing; a cleaning of the outer glazing at lamp replacement can be sufficient for luminaires with IP65 optical compartment.

- **Installed base ("stock")**

ELC EU-25 street lighting sales of 20,7 million and an average product life of 3 years renders an installed base of some 62,2 million lamps in 2004.

This number corresponds well to the calculated installed base of 56,1 million street lighting luminaires in EU-25 from the combination of data from the Expert inquiry and literature with CELMA market estimations[35] (when figures for a certain Member State were missing). The full compilation of data (and their sources) that were used to derive this estimate of the total EU-25 installed base of street lighting luminaires is presented in Table 16.

Table 16 illustrates that one must keep in mind that considerable variations exist between different EU Member States when the installed lamp mix is considered. While in Germany almost half (45%) of the installed base of street lighting is composed out of mercury lamps, this lamp type forms only 5% of the installed base in Belgium, and is not used at all in the UK. Although both in the UK and Belgium about 80% of the stock of street lighting is formed by sodium lamps, there is a clear distinction between this 2 Member States: in the UK the installed base of sodium lamps is balanced between HPS and LPS, while in Belgium the HPS lamps are dominant.

In ANNEX L Figure 71 shows a ranking of the 25 EU Member States according to increasing number of luminaires per capita, while Figure 72 presents an overview of the total installed luminaires per Member State in EU-25, ranging from 45.000 in Malta to 9.120.000 in Germany.

[35] The market estimations provided by CELMA are shown in Table 161 in ANNEX L

Table 16: Market data on installed base of street lighting luminaires in EU-25 (Source : data from literature and expert inquiry completed with CELMA market data estimations for missing Member States)

	Literature and expert inquiry (CELMA for missing MS)														
2005	**Luminaires TOTAL**	**%EU25**	**Capita ('000)**	**Luminaires /capita**	**HPM**	**HPS**	**LPS**	**MH**	**FL**	**%HPM**	**%HPS**	**%LPS**	**%MH**	**%FL**	**Source**
Austria	1.000.000	1,8%	8.207	0,12	300.000					**30%**	*67%*	*0%*	*3%*	*0%*	CELMA
Belgium	2.005.000	3,6%	10.446	0,19	105.000	1.015.000	632.000	59.000	148.000	**5%**	**51%**	**32%**	**3%**	**7%**	Filled out inquitry with lamp data from SYNERGRID (2005)
Czech republic	300.000	0,5%	10.221	0,03	120.000	168.000	0	6.000	6.000	**40%**	*56%*	*0%*	*2%*	*2%*	CELMA
Denmark	780.000	1,4%	5.411	0,14	312.000	273.000	19.500	19.500	156.000	**40%**	35%	3%	3%	20%	Mr. Thomas Christoffersen, based on data for city of Copenhagen
Finland	400.000	0,7%	5.237	0,08	160.000	220.000	10.000	10.000	0	**40%**	*54%*	*3%*	*3%*	*0%*	CELMA
France	8.570.000	15,3%	60.561	0,14	2.805.000	5.313.400	0	428.500	0	**33%**	*62%*	*0%*	*5%*	*0%*	ADEME (2006) and %HgHP adapted based on feedback Mr. Fourtune (email, 3/10/2006)
Germany	9.120.000	16,3%	82.501	0,11	4.110.000	3.100.000	0	270.000	1.640.000	**45%**	**34%**	**0%**	**3%**	**18%**	Philips AEG Licht GmbH/WestLB AG/ WestKC GmbH (2003)
Greece	900.000	1,6%	11.076	0,08	450.000	378.000	0	27.000	45.000	**50%**	*42%*	*0%*	*3%*	*5%*	CELMA and email Mr. Paissidis (15/06/2006): most commonly used lamp types: 400W NaHP for cat. F roads, HgHP 125, 80W for cat. M roads, HgHP 125W and (but minority)

2005	Literature and expert inquiry (CELMA for missing MS)														
	Luminaires TOTAL	**%EU25**	**Capita ('000)**	**Luminaires /capita**	**HPM**	**HPS**	**LPS**	**MH**	**FL**	**%HPM**	**%HPS**	**%LPS**	**%MH**	**%FL**	**Source**
															100, 150W NaHP for cat. S roads. Some roads are over lit (e.g. cat. F roads about 6 cd/m2) other roads are not or poorly lit (even in cat. S).
Hungary	600.000	1,1%	10.098	0,06	200.000	402.000	0	0	0	**33%**	*67%*	*0%*	*0%*	*0%*	CELMA
Italy	9.000.000	16,0%	58.462	0,15	5.760.000	2.520.000	45.000	450.000	135.000	**64%**	*28%*	*0,5%*	*5%*	*2%*	ASSIL
Netherlands	2.500.000	4,5%	16.306	0,15	125.000	1.175.000	750.000	75.000	500.000	**5%**	*47%*	*30%*	*3%*	*20%*	Projectbureau energiebesparing Grond-, Weg- en Waterbouw (GWW) (2005); ECN (2000) Partly filled out inquiry by B. Hamel, RWS
Poland	4.200.000	7,5%	38.174	0,11	2.060.000	2.100.000	0	42.000	0	**49%**	*50%*	*0%*	*1%*	*0%*	Email Mr. R.Zwierchanowski and Mr. J. Grzonkovski.
Portugal	1.100.000	2,0%	10.529	0,10	330.000	715.000	0	0	55.000	**30%**	*65%*	*0%*	*0%*	*5%*	CELMA
Sweden	2.500.000	4,5%	9.011	0,28	125.000	2.250.000	62.500	62.500	0	**5%**	*90%*	*3%*	*3%*	*0%*	Filled out inquiry Mr. Frantzell
Spain	4.200.000	7,5%	43.038	0,10	840.000	2.940.000	0	0	420.000	**20%**	*70%*	*0%*	*0%*	*10%*	IDAE (2005)
Slovakia	200.000	0,4%	5.385	0,04	80.000	112.000	0	4.000	4.000	**40%**	*56%*	*0%*	*2%*	*2%*	CELMA
UK	7.851.000	14,0%	60.035	0,13	0	3.181.000	3.454.000	0	1.193.000	**0%**	**41%**	**44%**	**0%**	**15%**	Filled out inquiry and extra data Ms. Hillary Graves
Latvia	85.000	0,2%	2.306	0,04	34.000	47.600	0	1.700	1.700	**40%**	*56%*	*0%*	*2%*	*2%*	CELMA

	Literature and expert inquiry (CELMA for missing MS)														
2005	**Luminaires TOTAL**	**%EU25**	**Capita ('000)**	**Luminaires /capita**	**HPM**	**HPS**	**LPS**	**MH**	**FL**	**%HPM**	**%HPS**	**%LPS**	**%MH**	**%FL**	**Source**
Lithuania	125.000	0,2%	3.425	0,04	50.000	70.000	0	2.500	2.500	**40%**	*56%*	*0%*	*2%*	*2%*	CELMA
Estonia	50.000	0,1%	1.347	0,04	20.000	28.000	0	1.000	1.000	**40%**	*56%*	*0%*	*2%*	*2%*	CELMA
Malta	45.000	0,1%	403	0,11	15.000	28.800	0	1.350	0	**33%**	*64%*	*0%*	*3%*	*0%*	CELMA
Cyprus	88.000	0,2%	775	0,11	42.000	43.120	0	2.640	0	**48%**	*49%*	*0%*	*3%*	*0%*	CELMA
Luxembourg	61.000	0,1%	455	0,13	15.000	43.310	610	1.830	0	**25%**	*71%*	*1%*	*3%*	*0%*	CELMA
Ireland	401.000	0,7%	4.109	0,09	12.261	167.000	222.000	0	0	**3%**	*42%*	*55%*	*0%*	*0%*	Filled out inquiry, Mr. M. Perse (ESB)
Slovenia	74.000	0,1%	1.998	0,04	30.000	41.440	0	1.480	1.480	**41%**	*56%*	*0%*	*2%*	*2%*	CELMA
Total EU25	**56.155.000**	**100%**	**459.514**	0,12	**18.100.261**	**26.331.670**	**5.195.610**	**1.466.000**	**4.308.680**	**32%**	**47%**	**9%**	**3%**	**8%**	

As will be explained in chapter 3 on the local infrastructure the length of European roads is one of the determining factors of our model to forecast the installed base (stock) in the future.

Data of European road lengths retrieved from Eurostat (see section 3.3.3 “Consumer behaviour and local infrastructure - Total EU-25 road network: 1990-2005” and Table 162- Table 165 (in ANNEX N) indicate a mean annual growth rate of the road infrastructure of 0,85%. Linear regression would be a (very) rude (over)simplification of reality as passenger and freight transport activity (and thus the corresponding road infrastructure) are determined by a variety of factors (as will be explained in the following sections). To derive a more realistic projection of the European road infrastructure the EC DG TREN publication “EU Energy and Transport trends to 2030” (January 2003) was used as input.

This publication describes the Baseline scenario being a projection of energy supply and demand in the European Union for the short, medium and long term (up to 2030). It was developed with the use of the PRIMES[36] model. ANNEX O gives a more elaborated description of the Baseline scenario and its main assumptions.

Under Baseline scenario assumptions passenger transport activity in EU-25 is projected to increase at a rate of 1,5% pa in 2000-2030, whereas EU-25 freight transport activity increases by 2,1% pa in the same period. More specifically EU-25 energy related transport activity per capita is projected to reach 18.653 km pa in 2030 compared to 12.174 km pa in 2000. Combining these per capita transport activity indicators with their corresponding population[37] results in a total transport activity (km pa) of 5.519.813 in 2000 and 8.546.058 in 2030. Taking into account the known total EU-25 road length in 2000 of 5.087.077 km, a transport indicator of 1,08 is derived. With this transport indicator an estimation can be made of the projected road length in 2030: 7.913.017 km, representing an annual growth rate of the EU road infrastructure of 1,53% in the period 2000-2030.

The projected growth of transport activity, both in terms of passenger and freight transport, in the EU-15 strongly dominates the overall picture at the EU-25 level. In 2000, the EU-15 accounted for 91% of overall passenger activity and 87% of freight transport activity. The evolution of transport activity in the EU-25 indicates a moderate decoupling between transport activity and economic growth. The decoupling between passenger transport activity, growing by 1,5% pa in 2000-2030, and economic growth is much more pronounced and starts from the beginning of the projection period. This can be explained by the rather stable EU population and by the fact that, at some stage, human mobility (either for necessity or for recreational reasons) is expected to experience some saturation effects in the long run. On the other hand, the decoupling of freight transport activity (growing by 2,1% pa under Baseline assumptions in 2000-2030) and overall economic activity is projected to be significantly less pronounced, occurring mainly in the long run. The structural shifts of the EU-25 economy towards services and high value added manufacturing activities are the main drivers for this trend. This is

[36] PRIMES is a partial equilibrium model for the European Union energy system developed by, and maintained at, the National Technical University of Athens, E3M-Laboratory led by Prof. Capros. The most recent version of the model used in the EC DG TREN Trends to 2030-study covers all EU Member States, uses Eurostat as the main data source and is updated with 2000 being the base year. PRIMES is the result of collaborative research under a series of projects supported by the Joule programme of the Directorate General for Research of the European Commission.

[37] 453,41 million inhabitants in 2000 versus 458,16 million in 2030 (Source: Eurostat. Global Urban Observatory and Statistics Unit of UN-HABITAT. PRIMES. ACE in EC DG TREN, see Table 168 in ANNEX O)

because these sectors are less freight intensive than the more traditional basic manufacturing and extraction activities.

From the preceding sections we can conclude that the observed annual growth of the European road network of the past (i.e. 0,85% in the period 1995-2005) does not increase proportional to the projected increase of transport activity of 1,53% in the period 2000-2030. Simply extrapolating the observed growth rate of the road infrastructure to the period 2005-2025 is thus not realistic. Assuming that the truth lies somewhere in between and thus working with an average annual growth rate of 1,19% for the European road infrastructure makes more sense. We further split up this growth rate according to road category Fnd assume an annual growth of 2,95% for category F, 0,53% for category M and 1,4% for category S roads[38]. A sensitivity analysis will be performed using the observed annual growth rate of the past.

[38] These Percentages per road category Fre found by applying the same factor of 1,77 (1,5% projected average annual increase of transport activity in period 2000-2030/0,85% observed average annual increase of EU road infrastructure in period 1995-2005) to the observed annual growth rates per road category, and assuming that reality will be in between those two values.

2.3 Market trends

2.3.1 General trends in product design an features from marketing point of view

Lamps

Lamps are currently replacement parts for a luminaire because lamp life is typically 3 years while luminaires are used for typically 30 years. LEDs could change this problem by making light sources that last as long as the luminaire.

There is also a new trend to promote more white light sources for outdoor lighting.

Recently Solid State Lamps(SSL or LEDs) are introduced on the market. Up till now they are rarely used in street lighting because of the actual high price and lower efficacy, but technology is changing. Traffic lights use this technology because it has high efficacy for coloured light. Life time of SSL is also high up to 50.000 hours.

We will consider the LED technology behind these developments under the BNAT section in chapter 6.

Ballasts

There is a new trend to introduce electronic ballasts for street lighting that offer more power control and dimming. Large and small companies are introducing this technology. Also voltage stabilisers to control the line voltage and thus lamp power are sold for this purpose.

Each defined lamp type and wattage needs its own ballast. A consequence of this is that once the ballast is installed in the luminaire, it is very difficult to change lamp power or type. There is a new trend in electronic ballast to make 'multi-watt' and 'multi-lamp' ballast, making distribution and stock more easy.

Another new trend is to develop more preferment lamp types that can only be operated by electronic ballast, they benefit from a better lamp-ballast compatibility (e.g. more accurate power and lamp voltage control).

Luminaires

In the luminaire market product differentiation arises from technological innovations, design and price. Technological innovations will be described in the BAT chapter later in this report. An important new trend is to pay more attention to luminaire design in order to fit better in city beautification projects.

2.3.2 Description of market and production structure and identification of major players

Street lighting purchase process

The purchase process of 'public street lighting products' is controlled by public authorities and is a typical ‘Business to Business’ (B2B) market. Exploitation can be done by the authorities themselves or can be subcontracted to ESCO's (Energy Services Companies).

In general the market is a so called 'specifiers market' and uses public tenders. In many cases public tenders require a second source supplier, especially for replacement lamps. The reason is that lamps are current replacement parts for a luminaire because lamp life is typically 3 years while luminaires are used for typically 30 years.

For sales of new installations lighting designers or engineers with good lighting knowledge are often involved. They need these skills to implement the various public lighting requirements.

Sales of luminaries for replacement are limited because the lighting equipment is used for typical 25 or more years. A consequence is that a lot of the equipment in use has a low performance compared to the performance of new equipment. Luminaires are often sold for totally new street lighting projects and not for replacement in old street lighting installations.

Global lighting production market

The global lighting-product manufacturing industry is made up of many enterprises ranging from large multinational public companies that manufacture a broad range of lighting products to small single-product firms, which may be publicly or privately owned. (IEA Light's Labour's Lost, 2006).

When viewed as a region, the European Union is the world's largest producer of lighting equipment in terms of value, although China now probably surpasses it in terms of volume (IEA Light's Labour's Lost, 2006). The European lighting manufacturing industry has annual revenues of about EUR 13 billion, of which EUR 5 billion (USD 6.2 billion) is from lamp manufacture (ELC, 2005 in IEA, 2006) and EUR 8 billion from luminaires, ballasts and associated electrotechnical equipment (CELMA, 2005 in IEA, 2006). Lamp manufacturers are represented by the European Lamp Companies Federation (ELC), which includes among its members[39] Philips Lighting, OSRAM, GE Lighting, Aura Lighting Group, BLV, Leuci, Narva and Sylvania Lighting International (SLI). The European activity of these companies employs roughly 50 000 people, produces annual revenue of EUR 5 billion[40] and supplies about 90%[41] of the lamps sold on the European market (IEA Light's Labour's Lost, 2006).
Manufacturers of luminaires and electrotechnical parts for luminaires are represented by a European federation of national industry associations called CELMA. The 16 national member associations of CELMA represent some 1 200 companies in 11 European countries. These producers, which include many SMEs, directly employ some 100 000 people and generate EUR 8 billion annually. CELMA claims to supply more than 90% of luminaires and associated electrotechnical parts for the EU market (IEA Light's Labour's Lost, 2006).

Market shares and competition

The extent to which an industry's market share is dominated by relatively larger firms is referred to as "market concentration". Market share can represent financial power in the marketplace; typically, the mark-ups that firms pass on to consumers increase as the concentration of the market increases (Atkinson et al. 1992 in Vorsatz et al., 1997). In general, the lamp and ballast market is highly concentrated, with a limited amount of players, whereas the luminaire market is very fragmented. Although for street lighting, the number of players in the luminaire market is also more limited.
Below, we discuss the number of manufacturers, as well as market share, for lamps, ballasts, fixtures, and controls.

Lamp market:

Lamps are a globally traded commodity and there is a high degree of standardisation between international lighting markets. For several decades three major multinational lamp

[39] ELC, Make the switch: The ELC roadmap for deploying energy efficient lighting technology across Europe http://www.elcfed.org/uploads/documents/-3-01elc_a5report_6_05.pdf
[40] http://www.elcfed.org/index.php?mode=0
[41] This claimed market share of ELC is brought into question by the "indicative ELC market share" (calculated by comparing ELC reported sales figures to the apparent consumption derived from official production and foreign trade figures reported in Eurostat. See next paragraph

manufacturers have dominated the international lamp market: Philips, based in the Netherlands; OSRAM, based in Germany; and General Electric, based in the United States. Sylvania is another large multinational lamp manufacturer whose North American operations were merged with OSRAM's in the 1990s but is a separately owned brand elsewhere. While these companies have a strong presence in almost all global markets their strength in any one sector or region varies appreciably. (IEA Light's Labour's Lost, 2006).

European lamp manufacturers are grouped in the ELC (The European Lamp Companies Federation), they have 8 members and claim 95 % of the total European lamp production.

Ballast market
Most of the large lamp manufacturers also sell ballast. There is also a large group of manufacturers that only produces ballast ranging from SMEs to large companies.
For street lighting the market was dominated up till now by ferromagnetic ballasts, but there is a new trend to introduce electronic ballast. Large and small companies are introducing this technology. Also voltage stabilisers are sold that can control the lamp power with ferromagnetic ballast. They are installed at the distribution transformer. Some companies might experience/suffer severe competition if electronic ballast technology takes over the old ferromagnetic ballast technology because other production lines and technological competences are needed. The switch of ferromagnetic to electronic ballast will also affect the copper and silicon steel industry because lower volumes of this material are needed in this technology. In general more copper or magnetic material is good for the energy efficiency in any technology because of lower copper and magnetic losses but a switch from technology can cause a decrease of copper use with a status quo or even increase of energy efficiency.

Luminaire market
There is a large import of lighting products from China (IEA Light's Labour's Lost, 2006) but it is unlikely that they are imported for public street lighting applications (no dealers of these products in the EU-25 could be found or are known).
The number of street lighting luminaire manufacturers is limited because they must fulfil the high demanding technical specifications from public tenders which cause a high development cost.

2.3.3 Duration of redesign cycle of the EuP

The duration of the redesign cycle for a street lighting product can range from several months to many years. A new technology for light production can need tens of years from first idea to functioning technology and working prototype. New lamps and new ballasts based on the same or similar existing basic technology can need redesign cycles up to several years, mainly depending on the needed long term reliability testing cycle. A simple modification in luminaire design can sometimes be done in months. Totally new luminaire designs changing all functional and optical parameters can require a design cycle from 6 months up to two years.

2.3.4 Latest consumer tests

The Belgian federation of network operators for electricity and gas (Synergrid) has a type street lighting luminaire procurement specification called 'Prescriptions relatives à la fourniture d'appareils d'éclairage public' (Synergrid, 2004 for download at www.synergrid.be).

Luminaires are evaluated for energy performance on a similar manner as proposed in this study. A list of evaluated luminaires with energy performance number called 'efficiency factor' is also publicly available (Equipements d'éclairage public: Liste des appareils agréés (Synergrid, 2006). The system is operational and luminaires that are not compliant are charged by some network operators with a 30% higher installation cost.

2.4 Consumer expenditure data

2.4.1 Product prices

Eurostat data are not suitable to define part costs of street lighting because there are no data on luminaire prices. Moreover the amount of ballast and lamps for street lighting only accounts for a small share in the general lighting sales data so Eurostat does not give reliable prices for street lighting applications.
In accordance with the WEEE Directive manufacturers of lamps, ballasts and luminaries are responsible for the end of life treatment of their products. They include this cost in the price of new products but mention this separately as a contribution. As the prices used in this study take into account this contribution, end-of-life costs are intrinsically included.

For prices of materials, we therefore used catalogues of manufacturers. Taking into account that the prices displayed in manufacturers catalogues are for retail trade, we made realistic assumptions for the prices of different lighting parts based on our own experience of the market, e.g. 60% of the retail price for luminaires and ballast and 45% for the lamps. These derived price assumptions are listed in Table 17 and are used in chapter 4.3 (Technical analysis of existing products-Use phase).

Table 17: Price assumptions (Euro) for different lighting parts (Source: Assumptions based on a combination of own experience and retail prices displayed in manufacturer catalogues)

Type Lamp	**Lamp**	**Electronic ballast**	**Magnetic gear**	**Luminaire** (magn.gear incl)	**Luminaire** (BAT)
HgHP-BF-80W	3.6	n.a.	12.4	157	
HgHP-BF-125W	3.6	n.a.	21.7	157	
HgHP-BF-250W	8.2	n.a.	20.8	239	
HgHP-BF-400W	11.5	n.a.	29.8	321	
NaHP-BF-110 (RF)	18.4	n.a.	21.7	157	
NaHP-BF-220 (RF)	22.5	n.a.	20.8	239	
NaHP-BF-350 (RF)	25.1	n.a.	29,8	321	
NaHP-TC-50W	14.7	n.a.	29.6	159	
NaHP-TC-70W	14.7	120	32.4	163	
NaHP-TC-100W	17.4	123	33.6	177	
NaHP-TC-150W	18.8	126	39.3	186	460
NaHP-TC-250W	20.2	n.a.	43.3	220	475
NaHP-TC-400W	22.0	n.a.	59.3		
MHHP-TC-70W	22.3	120	32.4	163	
MHHP-TC-100W	27.0	123	33.6	177	
MHHP-TC-150W	27.0	126	39.3	186	
MHHP-TC-250W	54.0	n.a.	43.3	220	
MHHP-TC-60	40.1		n.a.	**electron* 243	
MHHP-TC-140	47.3		n.a.	**electron* 266	
NaLP-TC 131W	48.2	n.a.	76.8	565	
HgLP-TF 36W single capped 4pin	4.0		5.0	150	

2.4.2 Electricity rates

Electricity consumption accounts for the most important part in lighting costs[42], also in public lighting. Electricity rates (euro/kWh) are subject to fluctuations due to recent market liberalisation.

Eurostat reports every 6 months on electricity prices for final domestic household consumers and for industrial consumers and distinguishes several user categories (defined in footnotes 43 and 44) of which results of two categories are reported in Table 18.

Table 18: Electricity prices for household and industry consumers (Source: Eurostat)

	Overall price (euro/ kWh)	
Member State	**Domestic[43] consumers**	**Industrial consumers[44]**
Austria	0,1391	0,0964
Belgium	0,1429	0,1014
Cyprus	0,1203	0,1147
Czech Republic	0,0871	0,0693
Denmark	0,2320	0,1099
Estonia	0,0713	0,0555
Finland	0,1038	0,0669
France	0,1194	0,0691
Germany	0,1801	0,1081
Greece	0,0694	0,0703
Hungary	0,1147	0,0951
Ireland	0,1436	0,1056
Italy	0,2010	0,1236
Latvia	0,0829	0,0482
Lithuania	0,0718	0,0588
Luxembourg	0,1502	0,0902
Malta	0,0769	0,0746
Poland	0,1059	0,0664
Portugal	0,1380	0,0772
Slovak Republic	0,1330	0,0828
Slovenia	0,1049	0,0734
Spain	0,1097	0,0836
Sweden	0,1333	0,0544
The Netherlands	0,1960	0,1071
United Kingdom	0,0926	0,0781
EU-25 average	**0,1363**	**0,0904**

[42] In general lighting it would amount up to 79% of the total cost (Source: IEA, 2006)
[43] Eurostat collects data every 6 months for 5 categories of household consumption, ranging between 600 kWh to 20.000 kWh. Table 18 refers to 'medium sized household' (annual consumption of 3.500 kWh of which 1300 during night)
[44] Eurostat collects data every 6 months for 9 categories of industry consumption (defined by a combination of annual consumption (in MWh), maximum demand (in kW) and annual load (hours)) ranging from Ia: 30 MWh annual consumption, 30kW maximum demand and 1000h annual load; to Ii: 70.000 MWh annual consumption, 10.000 kW maximum demand and 7000h annual load. Table 19 refers to 'medium sized industry' (annual consumption of 2.000 MWh, maximum demand 500 kW and annual load of 4.000hours)

Public street lighting is mainly operated by municipalities, national and regional authorities and the prices that they pay are not collected by Eurostat.
These authorities usually negotiate a contract for several years and they pay a lower price than the final domestic and sometimes lower than industrial consumers.
Evidently street lighting is needed during the night. Night tariffs are lower but the starting hour can differ between countries and electricity vendors.
From our Expert inquiry to a.o. CIE representatives in EU-25 Member States we have received the following answers so far :

Table 19: Estimated electricity rate per kWh for public street lighting (Source: Expert inquiry)

Country	**(Estimated) Electricity rate per kWh for public street lighting in €**		
Belgium (2005)	0,09	Excl VAT	
Ireland (2005)	0,1038		
Poland (2005)	0,08		
Sweden (2004)	0,045		
The Netherlands	0,09	Incl VAT	National authorities
	0,11-0,16	Incl VAT	Regional authorities
United Kingdom (2005)	0,08		

We still have to check whether the taxes (VAT) are included for some countries. In case we do not receive more information from the inquiry for the remaining countries we will use a price of 0,08 Euro per kWh excl.VAT. This is evidently lower than the EU -25 average of 0,136 Euro for medium sized households.

2.4.3 Repair, maintenance and installation costs

For estimating the maintenance and installation labour cost we use the average hourly labour cost of €21.22 from Eurostat (EU-25) in 2004 multiplied by 1.5 because an electrician for public lighting has overhead costs including an tower waggon. So the applied hourly labour cost is €31,83. Results from the Expert inquiry indicate an hourly labour cost in street lighting maintenance and installation of €50-60 (feedback from Belgium, Sweden and the U.K.)
The required installation and maintenance time was estimated based on 25 years of experience in Belgium (L. Vanhooydonck) and is included in Table 20.

Table 20:Estimation of maintenance and installation cost related parameters

EU25 average hourly labour cost including overhead	€31,83
Time required for installing one luminaire (group installation)	20 min.
Time required for lamp replacement (group replacement)	10 min.
Time required for lamp replacement (spot replacement)	20 min.
Time required for maintenance including ballast replacement	30 min.

2.4.4 Interest and inflation rate

As regards the discount rates, which is the difference between interest and inflation, there will only be small differences in the EU. The official inflation rate is 2% and the interest rate (for consumer loans[45]) is around 4%. This leads to a discount rate of 2% (VHK, 2005).

[45] Not the ECB long-term rate, which is around 2%, but the interest rate a consumer theoretically would have to pay for lending money to pay for a more expensive product.

3 CONSUMER BEHAVIOUR AND LOCAL INFRASTRUCTURE

Consumer aspects can -in part- be influenced by product design but overall it is a very relevant input for the assessment of the environmental impact and the Life Cycle Costs of a product. One aim is to identify barriers and restrictions to possible eco-design measures, due to social, cultural or infra-structural factors. A second aim is to quantify relevant user-parameters that influence the environmental impact during product-life and that are different from the standard test conditions as described in chapter 1. The parameters that are quantified in this chapter are relevant for the calculation of environmental impacts and costs in the use phase of street lighting (see 4.3).

3.1 Real Life Efficiency and quantification of relevant parameters

3.1.1 Street lighting, colour and the sensitivity of the human eye and nature

It is important in the context of street lighting that the actual standard performance requirements on photometric values as defined in chapter 1 (lumen, lux, candela) are defined for photopic vision only. There are however studies that indicate that white light is optically beneficial compared to more yellowish light at similar but very low illuminance levels, when also considering scotopic and mesopic vision.

Photopic vision (Figure 17) is the scientific term for human colour vision under normal lighting conditions during the day.
The human eye uses three types of cones to sense light in three respective bands of colour. The pigments of the cones have maximum absorption values at wavelengths of about 445 nm (blue), 535 nm (green), 575 nm (red). Their sensitivity ranges overlap to provide continuous (but not linear) vision throughout the visual spectrum. The maximum efficacy is 683 lumens/W at a wavelength of 555 nm (yellow).
Scotopic vision (Figure 17) is the scientific term for human vision "in the dark".
In that range, the human eye uses rods to sense light. Since the rods have a single absorption maximum of about 1700 lumens/W at a wavelength of 507 nm, scotopic vision is colour blind. The sensitivity range of the rods makes the eye more sensitive to blue light at night, while red light is almost exclusively perceived through photopic vision.
Mesopic vision is the scientific term for a combination between photopic vision and scotopic vision in low (but not quite dark) lighting situations.
The combination of the higher total sensitivity of the rods in the eye for the blue range with the colour perception through the cones results in a very strong appearance of bluish colours (e.g. flowers) around dawn.

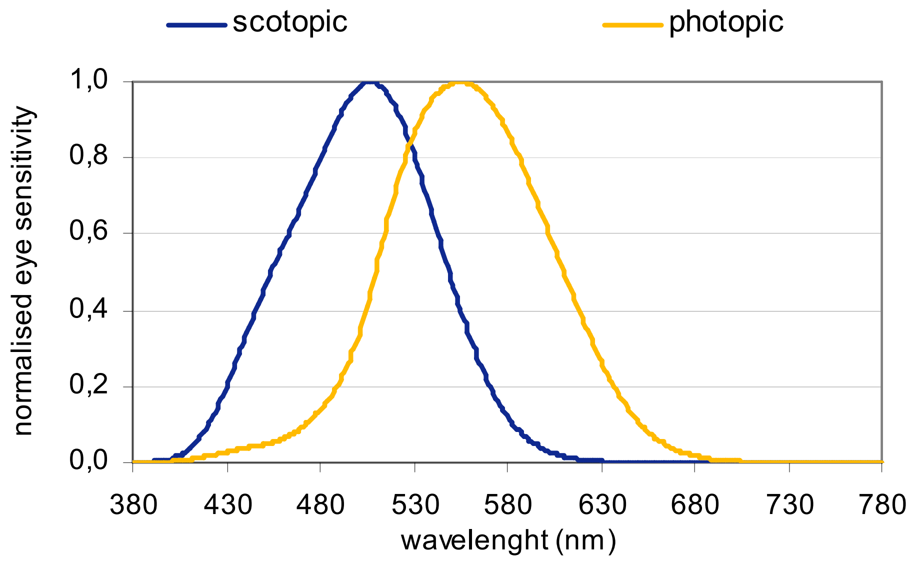


Figure 17: Normalised eye sensitivity for scotopic and photopic vision.

Please note that the assessment of the advantages/disadvantages of more white light in road lighting is complicated and subject of ongoing research studies (e.g. EU Growth Project 'MOVE: Mesopic Optimization of Visual Efficiency') coordinated by the CIE Technical Committee on 'Visual Performance in the Mesopic Range' (1-58)).
By consequence, at low light levels or so called 'mesopic view conditions' and photometric values such as lamp efficacy or luminance should be corrected (Narisada K. & D. Schreuder (2004)) in function of colour and luminance level. Therefore the lamp efficacy should be corrected for different lamp types when they have a different colour spectrum in function of photopic luminance (see Table 21). Please note that Low Pressure Sodium lamps produce orange light, Metal Halide lamps produce white light and High Pressure Sodium lamps appear golden-white. The relationship with illuminance can also be derived when a reflection coefficient for road objects is assumed (e.g. ρ =0.3) (Table 22). Therefore a relationship with illuminance requirements in defined road classes (standard EN 13201-2) is possible.

Table 21: Corrections for lamp efficacy at mesopic luminance (Source: 'Opstelten, 1984 in Narisada K. & D. Schreuder, 2004).

Photopic luminance(Cd/m²)		10	1	0.5	0.1	0.01	0.001
Lamp type	Lamp power (W)	% apparent efficacy(lm/W)					
Low Pressure Sodium (LPS)	90	100	96	95	75	34	24
High Pressure Sodium (HPS)	250	100	98	96	86	68	62
Metal Halide (MH)	400	100	103	105	116	138	144

Table 22: Relationship between photopic luminance and illuminance of road objects calculated with 30 % reflection (formula see 1.2 ρ =0.3, R = 0.1)

Photopic luminance(Cd/m²)	10	1	0.5	0.1	0.01	0.001
Illuminance (lx) with ρ =0.3	100	10	5	1	0.1	0.01

Conclusions related to this study are:
- Metal halide lamps or white light lamps have an advantage in apparent luminance compared to High Pressure Sodium when photopic road illuminance (Table 22) is low (+10 % at 5 lx and +30 % at 1 lx). Please note that there are many new colour blends in High Pressure Sodium lamps, by consequence this advantage will only be allocated +10 % for road classes S5 (3 lx) and +15 % for road classes S6.
- White light can decrease the contrast between road objects at high photopic luminance levels (e.g. 1 Cd/m² in Table 22) versus the road surroundings at much lower level (e.g. 0.1 Cd/m² in Table 22).
- White light has an increased contribution to visible (human) 'sky glow' because sky glow luminance is around 0.001 Cd/m² (Narisada K. & D. Schreuder (2004)). This effect on light pollution is not considered neither here nor below in LGF because of the reasons explained in section 4.3.1.3.
- It is also not recommended to overly promote white light at road classes above S5 and S6 (EN 13201-2) because insects are more attracted (Steck, B. (1997)) by blue light and UV. By consequence luminaires with white light that have blue light as colour component (e.g. High Pressure Mercury or Metal Halide lamps) will also become more polluted by insects than luminaires with golden white light (e.g. High Pressure Sodium). Especially UV attracts insects (Steck, B. (1997)). High Pressure Mercury lamps have a high UV content and are therefore not recommended in open luminaires.

For judging improvement options in different road classes with different lighting requirements we can take into account a correction factor for lamp efficacy (Lamp Gain Factor, LGF).

Table 23: Lamp Gain Factor (LGF): parameter values applied in this study according to road class category distinguished in EN 13201-2

Road class (EN 13201-2)	LGF
S6 (2 lx)	1.2
S5 (3 lx)	1.1
All other	1

3.1.2 Influence of user and local conditions on switching schemes

Globally the dark period is 4000 h per year. Seasonal changes between winter and summer increase with distance from the equator. Nordic countries have daylight during almost the whole day in summer and are dark (almost) all day in winter. At equinox (21 March and 21 September) day and night are equal everywhere over the globe. By consequence 4000 operating hours per year (as suggested by ELC and found in different literature sources) is the universal default value for street lighting.

Switching off street lighting after curfew is rarely applied and there are several arguments for this explained below.

Public lighting requirements are traditionally dominated by road traffic safety concerns and the perceived security feeling especially in densely populated areas. The absolute *reduction of crime* by public lighting is not proven and controversial. There are no large-scale studies available but it sounds logic that criminality cannot be cured by lighting alone, social control is also an important factor. But good lighting can lead to higher perceived security and social activities. Several studies show that lighting can displace criminality from higher lit places with social control to lower lit places. This is explained by the fact that at low light levels the eye needs long (typical 5 to 10 minutes) to adapt and some criminals try to exploit this as an advantage. An opposite criminality shift from poor lit places to well lit places without social control also seems to be possible. This is explained by the fact that light is simply helpful for the selection of the crime location and the execution of criminal activities. If no social control or surveillance is present this lighting will only help criminals.

Switching off 50 % of the lamps in alternating patterns causes bad uniformity in the illumination of the street, one of the important performance requirements for public lighting, and is controversial. Partly switching off of public lighting could also cause a criminality displacement effect as explained in the previous section.

The Expert inquiry (see chapter 2) showed that complete or partial switch off is rarely applied in the 25 EU-countries, for a maximum of only 5% of the roads.

The lamp survival factor LSF of a discharge lamp is negatively influenced by the number of switching cycles during its lifetime, due to the high voltage peak that the ignitor generates to start the lamp. If the number of cycles is doubled, in case of switching off after curfew and restart in the early morning, the normal lifetime of a discharge lamp is shortened by 30%.
The LSF declared by the lamp manufacturers is based on a test cycle of 11 hours operating and 1 hour off. This cycle approaches the average operating cycle in reality.
If a lamp is switched off and on during the night, the LSF has to be corrected by 0,7 to obtain the adapted LSF. In this study we apply no correction because partial switch off after curfew is rarely applied. The impact on savings in electricity consumption in the use phase is directly proportional to the hours of switch off.
For further calculations we assume 4000 street lighting hours yearly for all road categories.

3.1.3 User and infrastructure influence on energy saving potential by light dimming

Light dimming or light level control can only be used when dimming ballasts are used. This technology is state of art and will be described in chapter 6 dedicated to best available technology (BAT). The technology of electronic dimmable ballast is subject of the 'E-Street' SAVE project on intelligent street lighting.

In general there are four relations that justify dimming according to local conditions:

1. Dimming related to traffic density, e.g. dimming of street light after curfew.
2. Dimming related to local weather conditions.
3. Maximum power point fine tuning adapted to local parameters (e.g.: pole distance, lamp luminous flux, road reflection, installed luminaire position, shading, .).

4. Dimming to compensate for Lamp Lumen Maintenance Factor (LLMF).

The first relation could be justified when using CEN/TR 13201-1 as a guideline (see also chapter 1), in this case traffic density should be interpreted on an hourly basis and light levels could be adapted accordingly. This new practice is not yet incorporated in this guideline and traffic density is expressed on a daily basis resulting in one road class connected to a particular road. It is also clear that road classes with high light levels (e.g. CE2 (20 lx) and CE3 (15 lx)) selected on daily basis can benefit more from dimming compared to lower level classes (e.g. CE4(10 lx)-CE6). One objective of the 'E-street' SAVE project is to contribute to the development of standards and guidelines adapted to intelligent dimming. The technology is relatively new, few data are available and research is ongoing. Therefore we assume in this study that lighting in categories F and M can be dimmed to a 70 % power level with bilevel ballast (approx. 60% light level) and 60 % level with an electronic ballast (approx. 50 % light level) during 6h out of typical 11 h daily operation (e.g. from 23h until 5h), this results in a total energy saving of around 16 % with magnetic ballasts and 22 % with electronic ballasts. A work group CIE 40.44 is working on this subject anno 2006.
The second relation varies strongly on the local climate and few data is available, therefore we will assume a minimum saving of approx. 5% only when stepwise electronic dimming ballasts are provided.
The third relation allows at least to adjust to the required light level using the standard lamp types that are only available in a limited number of power values (example : for category S typical a 70 W HPS versus 100 W HPS lamp). New electronic ballast technology can allow 'multi-watt' luminaires (actually mainly available for fluorescent lamps), this means that a lamp of a lower power rating can be installed in an existing luminaire without modification (e.g.; switch ballast for another power rating). Therefore we assume in this study that with dimmable electronic ballasts 10 % energy can be saved.
The fourth relation is only useful for lamp types with variable LLMF over lifetime (see chapter 2 table 5) and therefore most useful for Metal Halide lamps. When assuming lamp replacement at LLMF =0.8 the saving is 10 % in energy. This can only be taken into account for metal halide lamps and this saving is therefore not included in the table below.

<u>Parameter Ballast Gain Factor (BGF):</u>
Because the energy savings by dimming are related to a feature in the ballast type, a correction factor ‘Ballast Gain Factor’ can be introduced.

As $P_{dim} = P_{normal} / BGF$

and $P_{dim} < P_{normal}$

it is obvious that $BGF > 1$ for dimmable ballasts.
(For non dimmable ballasts BGF = 1.)

Table 24: Ballast Gain Factor (BGF) parameter values applied in this study

	Cat. F			Cat. M			Cat. S		
	non dim ballast	bi-level dim ballast	electronic dim ballast	non dim ballast	bi-level dim ballast	electronic dim ballast	non dim ballast	bi-level dim ballast	electronic dim ballast
BGF	1	1.2 (1/0.84)	1.6 (1/0.63)	1	1.2 (1/0.75)	1.6 (1/0.55)	1	1.2 (1/0.90)	1.6 (1/0.70)

3.1.4 Influence of lamp and ballast operation under non-standard conditions

The performance parameters defined in chapter 1 are obtained under standard test conditions. Photometric data is obtained under test conditions specified in standard CIE 121-1996 on 'The Photometry and Goniophotometry of Luminaires'. An important parameter that can deviate in real life is temperature (the default test temperature is 25 °C).
Electrical data (e.g. power, ..) are also obtained under test conditions specified in standard EN 60598-1: 2004 on 'Luminaires. General requirements and tests'. An important parameter that can deviate in real life is line voltage, the default line voltage in EU 25 is 230 VAC with an exception for the UK (240 VAC).

Hereafter we will discuss four factors that can influence energy consumption of luminaires in real life, they are: temperature, line voltage, lamp voltage and the ageing of the power factor compensating capacitor. None of these power consumption-influencing factors are taken into account when dimensioning a lighting installation according to standard EN 13201-3.
It is important to realise that electronic ballasts are far less sensitive to these influences and therefore a compensation factor will be introduced in this study.

1. Temperature:
Lamp efficacy and power consumption of fluorescent lamps are influenced by temperature. Therefore fluorescent lamps are not often used for outdoor lighting.

2. Line voltage:
Power consumption and light output of gas discharge lamps vary with line voltage when electromagnetic ballasts are used, typical +/- 20 % power variation with +/- 10 % variation of line voltage. Line voltage variations of +/- 10 % are not exceptional in the public grid and are standard allowed, moreover in street lighting voltage drop over long lines can occur. Electronic ballasts with power control features can reduce these variations. By consequence it could be justified to equip lamps with this power control feature at a lower power set point (e.g. 90 %) because they still guarantee more minimum maintained light than ferromagnetic control gear. At present there is no clear standard that already enables this.

3. Lamp voltage:
Power consumption and light output of gas discharge lamps vary also with lamp voltage when electromagnetic ballasts are used. Lamp voltage can vary with production variations and generally increases with aging. By consequence power consumption over lamp life (with electromagnetic ballasts) is not constant. Taking lamp and line voltage variations into account together, lamp power can vary strongly (+/- 30 %) with ferromagnetic ballasts. Only electronic ballast with power control features could overcome this problem.

4. Power factor compensating capacitor aging:
Power factor compensation capacitors are used with ferromagnetic control gear. The capacitance decreases with capacitor age. Poor performance of this capacitor is causing an increase of useless currents in the distribution grid and additional power losses in this distribution grid. Moreover discharge lamps are causing third harmonic currents that cannot be compensated in ferromagnetic control gear with capacitors. These third harmonic currents (limited by EN 61000-3-2) can cause increased magnetic losses in distribution transformers. Only electronic ballast with pure sine wave electronic power factor correctors

can overcome this problem. This power factor corrector feature is standard for electronic control gear with lamp power above 22 Watt as required by EN 61000-3-2.
According to a study in France (ADEME (2006)) 9% additional energy loss can be caused in the distribution grid by aged power factor capacitors.

Parameter 'Ballast Maintenance Factor' BMF (see chapter 1):
This parameter takes into account that magnetic ballasts are ageing (capacitor) and cause higher power consumption. So BMF < 1 for magnetic ballasts. For electronic ballasts BMF = 1.
(BMF does not yet take other benefits of electronic ballasts into account as power stabilization and longer lamp lifetime, see also 6.1.7.)

Table 25: Ballast Maintenance Factor (BMF): parameter values applied in this study

	Cat. F		Cat. M		Cat. S	
	magnetic ballast	electronic ballast	magnetic ballast	electronic ballast	magnetic ballast	electronic ballast
BMF	0.95	1	0.95	1	0.95	1

3.2 End-of Life behaviour related to consumers

As mentioned in chapter 2.2.2, a product life of 30 years for a luminaire is common practice, but the standard deviation on this lifetime is significant (Table 26).
In the centre of municipalities and in shopping streets, public lighting installations are an element of street furniture and therefore often have shorter replacement times.

Table 26: Luminaire life time: parameter values applied in this study

	Cat. F			Cat. M			Cat. S		
	min.	avg.	max	min.	avg.	max	min.	avg.	max
life time (y)	25	30	35	25	30	35	15	30	35

For lamps, the commonly used replacement time is also mentioned in chapter 2.2.2. This lifetime takes into account the lamp survival factor (LSF), combined with the lamp lumen maintenance (LLMF). If the survival rate becomes too low, the cost of repair becomes too high.

The lifetime of control gear can also be found in chapter 2.2.2.
Control gear is only replaced in case of failure.

All replaced parts of a lighting installation (posts and brackets excluded) should be treated according to the constraints of the WEEE Directive.

Maintenance and/or repair of the street lights takes place only when lamps or ballasts need to be exchanged or the lamppost suffer from vandalism or traffic accidents. This means, according to the service life of lamps, every 2 to 4 years. In between these periods, no additional maintenance takes place. According to the type of luminaire, the following operations usually take place:

1. Closed luminaires (IP66): cleaning of the outer glazing, outside only.
2. Closed luminaires (IP54): cleaning of the outer glazing, outside and inside.
3. Open luminaires: cleaning of the reflector and every 10 years, the reflector 'should' be repolished and anodized to remove dirt and insects and re-establish its properties. However, no information is available regarding the actual practice regarding the latter.

Recycling and disposal of the luminaire, ballast, lamps and other electronic parts is the responsibility of the manufacturers according to the WEEE Directive. Manufacturers can choose between organizing the collection themselves or join a collective initiative such as Recupel (Belgium), RecOlight (U.K.), Recylum (France), Ecolamp (Italy),…. These organizations provide in the collection and recycling for the manufacturers and collect the waste from installers or companies doing technical maintenance & repair in street lighting. In practice, installers or companies doing technical maintenanance & repair, remove and collect the luminaires and already separate the lamps.

When evaluating the environmental effects of disposing of lamps at the end of life, the real driver for lamp recycling, as opposed to other forms of disposal, is the need to recover the mercury and the neutralization of sodium metal. Note that a typical mercury content of HPM is 20-25 mg, HPS 10-15 mg and CMH 1-5 mg. Although the quantity of mercury in the present generation of gas discharge lamps is very small, the lamp industry has been encouraging the development of cost effective, practical and environmental sound methods for managing the disposal of EoL gas discharge lamps since early 90s. In Belgium all HID lamps from public lighting are collected and mercury is recovered. We assume that given the date of obligation for recovery rates under the WEEE Directive (i.e. 31 December 2006) the same practice is or will be applied in the other member states.

In most European countries where specific waste legislation is in force a technical infrastructure is in operation regarding the separate recycling of EoL mercury containing gas discharge lamps.

Table 27: Countries with a recycling infrastructure for EoL gas discharge lamps in Europe (ELC)

Lamp Types	*End User*	*With Infrastructure*[1]	*Without Infrastructure*[1]
GAS DISCHARGE LAMPS	Professional	Belgium Austria Denmark France[2] Germany Netherlands Nordic countries Spain[2] Switzerland United Kingdom[2]	Rest of Europe

1: Countries are included here if sufficient capacity is available to recycle at least 50% of the EoL lamps
2: Starting Scheme

Additional information at: www.recupel.be, www.ear-project.de, www.zvei.org, www.uba.de, www.bmu.de, www.altgeraete.org, www.bitkom.org, www.Eco-Lamp.sk, www.dti.gov.uk.
Regarding hazardous substances in the other parts, PCB's can still be found in capacitors of old equipment (approximately >20yrs). The use in new equipment is forbidden and in practice no longer the case. In Belgium, these capacitors are always removed from the luminaire for separate hazardous waste treatment (incineration). We assume the same practice in the other member states.

3.3 Local infra-structure and facilities

3.3.1 'Lock-in effect' for new products due to limitations imposed by existing infrastructure or equipment

Previous investments in infrastructure (lamp poles, grids) can obviously lead to 'lock in' effects. Usually, pole distances can not be changed without substantial infrastructural changes and related costs. By the consequence the maximum obtainable energy savings can not always be realized without additional investments.

Figure 18: Street lighting luminaire attached to cables(left) and to electricity distribution (right).

Figure 19: Street lighting luminaires attached to poles(left) and to a house (right)

Examples:

- Luminaires can be attached to poles for electricity distribution, to poles for public lighting only, to houses or on cables above a street (see Figure 18 and Figure 19). It is clear that light point locations cannot be changed without great infrastructural changes and related costs. Therefore in re-lighting projects (with more efficient luminaires and/or more efficient lamps) the pole distance usually can not be changed. If the new installation supplies a useful luminous flux that is higher than necessary, the maximum energy savings will not be reached.

- Public lighting can be connected together with the residential electrical distribution grid or have a separate grid. A separate grid is sometimes required for telemanagement systems.
- Lamps are only sold in a defined and limited power series (e.g. 50-70-100-150 Watt). This implies that in real circumstances an overpowering can occur to meet the minimum required light levels. Fine tuning of the maximum lamp power set point by using lamp power dimmable ballasts or installing line voltage regulators can adjust the light output to the required levels.
- The HID lamp power is regulated by the integrated ballast in the luminaire. This means that when replacing a lamp with a more efficient one, there is no energy saving but only more light output from the lamp. The only solution for this is again fine tuning of the maximum lamp power set point with dimmable ballasts or installing line voltage regulators.

3.3.2 Lack of interest by authorities

Public street lighting has to provide good visibility to users of outdoor public traffic areas (the consumers?) during the hours of darkness to support traffic safety, traffic flow and public security. On the other hand, the public authorities are responsible for procurement and management of public lighting installations. If the public lighting installations provide the required visibility, investments in energy saving projects that do not give quick earnings are not a priority.

Examples:

- There exist many compromising motivating factors that can prevail at the design stage of public lighting installations: budget and planning for investments in new street lighting (infrastructure), pay back period for new investments, risk for quality complaints for new technology, general resistance to change, etc…
- A new trend called 'city beautification' can be identified. The main objective is to make city centres more attractive and install decorative street lighting luminaires with designs that fit with historical buildings or the city character. The most important parameter here is the aesthetic one and might compromise eco-design of street luminaires. In many cases design architects are dominating projects and it will be important that these people are aware of environmental impact (see also limitation in 3.3.4) and advantages of new eco-designed products.

3.3.3 Limitations imposed by local light colour preferences

It is possible that the local population, or the local authority purchasing the equipment, has preference for a certain light colour blend (gold, cold white, yellow, ..) that fits most there perception of comfort according to: local climate (warm, cool, rainy, snow,..), colour of street surrounding buildings, ...

Examples:

- CIE defines a chromaticity diagram and provides a sense of the visual appearance of the light sources and an indication (colour temperature) of how visually a 'warm' or 'cool' lamp appear (1976 CIE chromaticity diagram).
- (IEA (2006) p. 106): 'Lamp sales around the world reveals an apparent user preference for 'cooler' light sources the closer the illuminated locations is to the equator.
- The high energy efficient High Pressure Sodium lamp have a warmer (gold) colour compared to the energy inefficient High Pressure Mercury lamp ('cool white').

3.3.4 Lack of skilled work force

The proliferation of more advanced lighting energy saving techniques can require additional skills that people responsible for design and installation might be lacking.

Examples:

- Especially lighting energy saving techniques where complex telemanagement technologies are used (e.g.: traffic density and weather related dimming, fine tuning of maximum power point according to real street lighting surroundings, special lamp versus ballast requirements, ..).
- Optic systems that require fine tuning related to the real surroundings.
- Calculation programs, 'easy to use', give the impression that anybody can design street lighting installations. This fact hides the lack of design skills, discernment and scrutiny on the results.
- When urban architects are more involved in street lighting they need technical lighting designer skills.

3.3.5 Influence of the road reflection on luminance

Description:

CIE 144(2001): Road surface and road marking reflection characteristics

Scope:

The luminance of the road surface depends on the optical characteristics of the road surface. They are defined in standard CIE 144(2001) on 'Road surface and road marking reflection characteristics'. This standard is required to calculate the luminance value from illumination conditions for various types of surface. Please note also that real road reflection can vary strong on local conditions (dust, wet, ..) from -40 % up to 60 % (Memphis project (2006)).

Applicable parameter:

Average luminance coefficient (Q0) as defined in CIE 144: 'A measure for the lightness of a road surface being defined as the value of the luminance coefficient q averaged over a specified solid angle of light incidence', with,

$Lav = Q_O \times E_{avg}$

Table 28: Average luminance coefficient (Q0): parameter values applied in this study

Class	Q_0	description	mode of reflection
R1	0.1	concrete road or asphalt with minimum 12 % of artificial brightener	mostly diffuse
R2	0.07	Asphalt (more info see standard)	mixed
R3	0.07	Asphalt (more info see standard)	slightly specular
R4	0.08	Asphalt (more info see standard)	mostly specular

Results from the Expert inquiry are:

Table 29: Expert inquiry results

	Cat. F		Cat. M		Cat. S	
	% high Q_0 reflection (concrete)	% low Q_0 reflection (asphalt)	% high Q_0 reflection (concrete)	% low Q_0 reflection (asphalt)	% high Q_0 reflection (concrete)	% low Q_0 reflection (asphalt)
%	5	95	5	95	5	95
Typical Q_0	0.075		0.075		0.075	

3.3.6 Road width

The road width is an important parameter for defining the road surface to be lit.

In order to have an overview of EU25 this question was included in the Expert inquiry (see chapter 2).

- The received answers indicate almost the same (standardized) width for traffic lanes in the different categories; for cat F we found 3,50 to 3,75m, for cat M 3,50m and for cat S 2,50m to 3,00m.
- The number of traffic lanes per direction was also asked for.

For category F, there are mostly 2 traffic lanes per direction (rarely 3, 4 or more lanes), for category M and S mostly 1 lane per direction.

<u>Conclusions from the Expert inquiry:</u>

- For category F:
  - 2 x 3,75m for the traffic lanes
  - 1 x 2,5m for the hard shoulder.

This results in a total width to be lit in one direction of 10m.

- For category M:
  - 2 x 3,50m for the fast traffic lanes
  - 2 x 1,50m for the cyclists / pedestrians

what results in an overall width of 10m to be lit.

- For category S:

The width of the traffic lanes is rather constant.

The public surrounding space next to the traffic lanes can differ strongly in residential areas: separate parking lanes or not, separate footpaths or not, green strips between traffic lanes and footpaths or not etc.

Many commercial areas only allow traffic during the night and the early morning. As a consequence they do not have separate traffic lanes and footpaths.

In our model, we assume a space to be lit in category S:

  - 2 x 3,00m for the traffic lanes
  - 2 x 1,00m for the footpaths

and this results in an overall width of 8m.

For this study, following simplified assumptions are made:

Table 30: Road width assumptions made in this study

	Cat. F	Cat. M	Cat. S
Average number of lanes	2 x 2	2 x 1	2 x 1
Average overall width in m	20	10	8

3.3.7 Lighting point spacing and spacing to height ratio (SHR)

The spacing between lighting poles or lighting points and the height of them are largely different.

In order to have an overview of EU25 this question was included in the Expert inquiry (see chapter 2). dimension.

Summary of the Expert inquiry:

For roads in category F there is a very large difference in spacing between countries going from 40 to 90m but the spacing/height ratio is approximately the same: 4 (e.g. 90/20, 60/15, 48/12, 40/13).

For the roads in category M the spacing/height ratio varies between 4,5 and 3 (e.g. 45/10, 50/12,5, 35/11).

For the roads in category S the divergence of the spacing/height ratio is between 5 and 4 (e.g. 40/8, 36/8, 25/5, 30/7, 20/4).

It is logical that the SHR varies between the categories. In cat. F and M, the European standard imposes severe limitations on the glare caused by the luminaires. This means that the luminaires can not have very extensive optical systems and so the spacing is limited to about 4 times the height. In category S, the limitations on glare are lower and commonly lamps with smaller wattages are used so the risk of glare also decreases; implying that the luminaires can be more extensive and the spacing can be higher. In residential areas there is mostly a limitation on the pole height, but with a higher SHR the spacing can be adjusted to reasonable values.

These values retrieved from the enquiry are only based on a few countries and on the present local practices.

Table 31: Pole distance: Conclusions from the Expert inquiry

	Cat. F	Cat. M	cat. S
Pole distance (m)	35-80	25-50	15-50
Typical assumed (m)	45	30	25

3.3.8 Total EU-25 road network: 1990-2005

The local road network is, as described in 2.2, one of our key parameters for the calculation of the installed stock of street lighting in Europe. Figures for the road length of different types of roads[46] were obtained from Eurostat[47] and are presented in Table 162-Table 165, in ANNEX N. Note: For an estimation of the figures for the missing years an extrapolation was made based on the average growth rate of the preceding/coming years. These are shown in italic format.

The Economic Commission for Europe of the United Nations publishes yearly its "Annual bulletin of transport statistics for Europe and North-America". The figures (for the year 1990, 2001 and 2002) listed in their most recent (2005) edition were used as a benchmark for the Eurostat road infrastructure data and overall seem to correspond well for the 4 distinguished road categories (Motorways, State roads, Provincial roads, and Communal roads).

Another source for information on the lengths of different road types in the different EU-25 Member States is "European Road Statistics 2005" of the European Road Federation[48]. A check of the ERF reported figures for the year 2002[49] with the figures from Eurostat gave rise to (large) discrepancies between these two sources. In compiling this year's data, and those in previous years, ERF's researchers have found that gathering reliable data on Europe's road sector is no simple task. Once again, ERF is struck by the differences between the data found here and the more limited data found in official sources such as the European Commission, which consistently underestimate the size and importance of the road sector. "It has always been a firmly held belief of ERF that available transport data neither reflect economic and social realities nor enable adequate and informed decision-making." (ERF, 2005).
IRF World Road Statistics claims to be the only global compilation of road and vehicle statistics. "It is based on data compiled from official sources within national statistics offices and national road administrations in more than 185 countries. It also benefits from increased

[46] Motorways, State roads, Provincial roads, Communal roads
[47] http://epp.eurostat.ec.europa.eu/portal/page?_pageid=0,1136228,0_45572945&_dad=portal&_schema=PORTAL
[48] http://www.erf.be/images/stat/ERF_stats.pdf
[49] Reported sources are: European Commission and IRF (International Road Federation)

IRF cooperation with international institutions such as Eurostat and Afristat, and the UN Economic Commissions for Europe and for Africa." (IRF[50], 2006).
The questionnaires which was sent out to among others CIE (the Expert inquiry) to gather information on the use/application of street lighting in (the different countries of) Europe was sent to ERF together with the question if they have an explanation for the differences between their reported road infrastructure statistics and Eurostat. Until now neither the questionnaire nor an answer to this question was received.

Our proposal is to work with the official reported figures for road length in Eurostat when these do not differ more than 10% with the figures reported in the "Annual Bulletin of Transport Statistics for Europe and North-America" of The Economic Commission for Europe of the United Nations. In case neither Eurostat nor the UN Economic Commission for Europe reports figures for certain road categories in a Member State, the ERF figures will be used as input parameter for the scenario model.

As explained in chapter 2, the length of European roads is one of the determining factors of our model to forecast the installed base (stock) for street lighting in the future.

European road lengths retrieved from Eurostat (Table 162-Table 165 in ANNEX N) indicate a mean annual growth rate of the road infrastructure of 0,85%. Linear regression would be a (very) rude (over)simplification of reality as passenger and freight transport activity (and thus the corresponding road infrastructure) are determined by a variety of factors (see chapter 2.2.2 Stock). To derive a more realistic projection of the European road infrastructure, the EC DG TREN publication "EU Energy and Transport trends to 2030" (January 2003) was used as input.

From 2.2.2. we can conclude that the observed annual growth of the European road network of the past (i.e. 0,85% in the period 1995-2005) does not increase proportional to the projected increase of transport activity of 1,53% in the period 2000-2030. Simply extrapolating the observed growth rate of the road infrastructure to the period 2005-2025 is thus not realistic. Assuming that the truth lies somewhere in between and thus working with an average annual growth rate of 1,19% for the European road infrastructure makes more sense. We further split up this growth rate according to road category and assume an annual growth of 2,95% for category F, 0,53% for category M and 1,4% for category S roads[51]. A sensitivity analysis will be performed using the observed annual growth rate of the past.

3.3.9 Share of lit roads

We currently assumed that 10% of category F roads, 15% of category M roads and 30% of category S roads were lit in 1990[52], increasing linear to 15% cat F, 17,5% cat M and 40% cat S roads lit in 2025. Main driving forces for this growth in road lighting are a.o.: increase of road infrastructure, increased passenger and freight transport activity, the high cost of accidents, the

[50] http://www.irfnet.org/cms/pages/en/ViewPage.asp?id=21&mTitre=%20-%20World%20Road%20Statistics
[51] These Percentages per road category are found by applying the same factor of 1,77 (1,5% projected average annual increase of transport activity in period 2000-2030/0,85% observed average annual increase of EU road infrastructure in period 1995-2005) to the observed annual growth rates per road category, and assuming that reality will be in between those two values (See chapter 2.2.2).
[52] The number of luminaires per capita (and the total number of luminaires) per Member State are presented in Figure 12 and Figure 13 of Annex 2-13)

ageing of the overall population with diminished visual capacities,… An extensive overview of the input parameters regarding road infrastructure for the scenario model are given in Table 167 in ANNEX N.

The methodology for the projections of the road infrastructure (and thus of the installed base of street lighting luminaires) up to 2025, is described in the preceding section (and in detail in chapter 2.2.2). The total road length and the total road length lit per capita obtained in this manner is presented graphically in Figure 20.

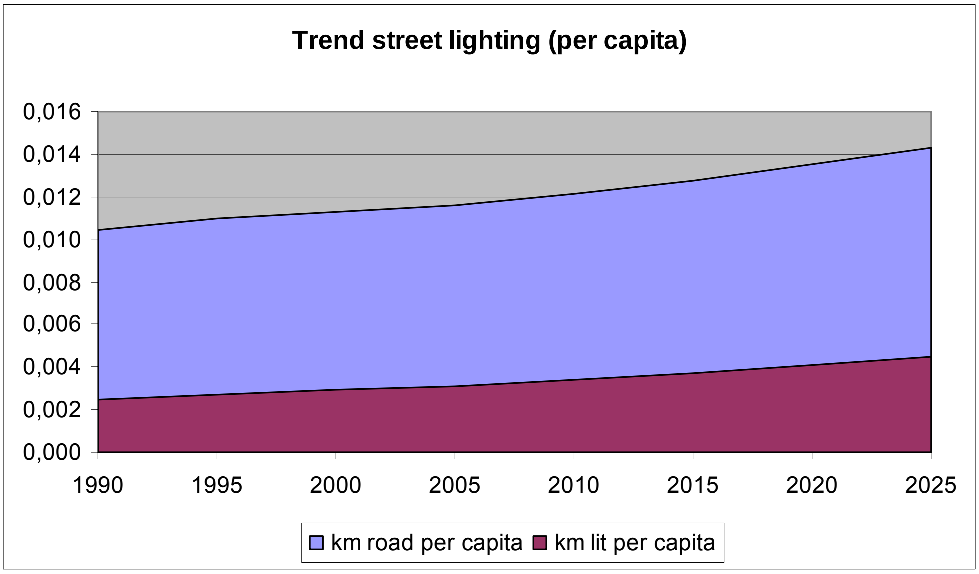


Figure 20: Trend street lighting per capita: 1990-2025

3.3.10 Summary

All parameters will be taken into account in chapter 4 as mentioned there. The improvement of LGF due to white light in the mesopic view range (3.1.1) is not taken into account because it is part of ongoing research and the assumed base case illumination levels are higher in category S and even much more in category F.

4 TECHNICAL ANALYSIS EXISTING PRODUCTS

This task is a general technical analysis of current products on the EU-market and provides general inputs for the definition of the Base case (chapter 5) as well as the identification of part of the improvement potential (chapter 7), i.e. the part that relates to better performing products on the market.

In this chapter a product segmentation with 8 product categories is used in line with the product segmentation that was defined in chapter 1 and for product groups that have significant impact in volume of sales according to the market study in chapter 2. The purpose of this segmentation is not to be complete up to the last lighting point installed in the EU-25 but to allow a realistic simulation for the base case environmental impact assessment in chapter 5 and for further impact assessment of improvement options in chapter 7 at EU-25 level.

This resulted in 8 product categories (see also table 1) for the 3 defined road categories (**F** (fast), **M** (mixed traffic), **S** (slow traffic)). There are 2 product categories allocated to category F, 2 in category M and 4 in category S. The 8 identified product categories have their own lamp type and lamp power. The lamp power fits the requirements imposed by the existing infrastructure and current practices according to the analysis in chapter 3.

In each of these 8 product categories a series of luminaires is analysed with a detailed performance analysis in the use phase (chapter 4.3).
BOM's (Bill of Materials) and cost data are retrieved for:

1. Different types of representative lamps
2. Different types of representative control gears that can be used in combination with particular lamps: magnetic ballast (applicable for all above lamp types) and electronic ballast (not applicable for HPM or HgHP).
3. Different representative luminaires that are used in combination with these lamps and gears.

These BOM's are used as input data for calculating the production, distribution and end-of-life phase impacts and costs according to the VHK eco-design model, in other words: all material-related aspects of the street lighting installation. Also for this purpose, the VHK excel spreadsheet is used (one spreadsheet for each separate BOM lamp, gear, luminaire).

4.1 Production phase

4.1.1 Introduction

The table below summarizes the types of lamp, gear and luminaire that are taken into account as most relevant for this part of the project. This list is based on the types of lamp and control gear that are currently installed on European roads and the types that are expected to be installed in the near future.

Table 32: Overview of lamps, control gear and luminaires subjected to an environmental analysis

LAMPS	CONTROL GEAR		LUMINAIRE
High pressure sodium lamps (HPS)			Luminaire 1: housing mix aluminum and polyester; aluminum reflector Luminaire 2: housing mix aluminum and polyester; aluminum reflector Luminaire 3: aluminum housing; aluminum reflector
70 W	electromagnetic ballast 70W, capacitor, ignitor	electronic ballast 70-250W	
150 W	electromagnetic ballast 150W, capacitor, ignitor		
250 W	electromagnetic ballast 250W, capacitor, ignitor		
Low pressure sodium lamps (LPS)			
131 W	electromagnetic ballast 131W, capacitor, ignitor		
High pressure mercury lamps (HPM)			
125 W	electromagnetic ballast 125W, capacitor		
400 W	electromagnetic ballast 400W, capacitor		
Low pressure mercury lamps (CFL)			
36 W	electromagnetic ballast 36W, capacitor	electronic ballast 36W	
High pressure ceramic metal halide lamps (CMH)			
70 W	electromagnetic ballast 70W, capacitor, ignitor	electronic ballast 70W	

For these typical lamp types and their respective control gears and luminaires product data are collected compliant with the VHK model. The production phase is modelled according to the MEEUP methodology report. Detailed information on environmental impact is included in chapter 3 of this MEEUP methodology report. This method focuses on seven environmental impact parameters (Total Gross Energy Requirement, Electricity, Feedstock energy (for plastics only), Process Water, Cooling Water, Hazardous Solid Waste, Non-Hazardous Waste). This method satisfies the requirement set out in article 15 section 4 (a) of the eco-design directive (2005/32/EC): ' Considering the life cycle of the EuP and all its significant environmental aspects, inter alia, energy efficiency. The depth of analysis of environmental aspects and of the feasibility of their improvement shall be proportionate to their significance. The adoption of eco-design requirements on the significant environmental aspects of an EuP shall not be unduly delayed by uncertainties regarding the other aspects'. In order to satisfy these requirements the most relevant products were chosen and sometimes an available similar process or material (based on physical or chemical similarity) was used when it was not directly available in the MEEUP methodology. These requirements often allow to follow a simple and straightforward approach.

Mercury for example is an important hazardous element found in many lamp types and could contribute significantly to the hazardous solid waste indicator if not recovered. In this study a simple and straightforward approach is used that covers about 90% of the weight of mercury in

lamps. It is unlikely that this will lead to important aberrations on environmental impact indicators according to the MEEUP methodology because a case study was carried out for a street lighting product together with the elaboration of this MEEUP methodology and this already indicated that the use phase was far more important in terms of hazardous waste production. Therefore we will adopt this method and evaluate the potential total environmental impact later in chapter 8 with the required sensitivity analysis. In the case that the impact is large the mercury content in lamps will be reconsidered.
In this study types of lamp and control gear were chosen with a certain band width between weight of parts and power (except for the ignitor). This bandwidth will also allow the assessment of aberrations on the potential environmental impact of other lamp, luminaire and ballast parts in chapter 8 with the required sensivity analysis. But here again, one can expect a very low total environmental impact for street lighting by the 'production phase' according to the case study that was carried out together with the elaboration of the MEEUP methodology.
The environmental assessment with the VHK method is performed for one part, i.e. one lamp, control gear for one lamp, one luminaire. In this part of the study the different parts (lamp, gear and luminaire) are analyzed on part-level, independent from each other. The results of this assessment on part-level serve as input for the assessment of the base-case, which is discussed in the next chapter.

4.1.2 Bill of Materials (BOM)

The Bill of Materials for the respective products (lamps, gear and luminaires) has been composed based on information retrieved from on the one hand the VHK Case Study on Street Lighting (Kemna et al, 2005) where ELC and CELMA have provided these data and on the other hand data from specific producers. If relevant and possible, comparable data sets are checked on their consistency. In case stakeholders provide additional relevant information , this could still be included in the sensitivity analysis in chapter 8.
The BOM is used as input for modelling the production phase in the VHK-model. The input tables are included in the following sections. The discussion of the end-of-life phase is referred to in section 2.6.

4.1.3 Lamps

4.1.3.1 Typical high pressure mercury lamps (HPM)

► HPM 125W lamp
The Bill of Materials (BOM) for the HPM 125W lamp is based on data from ELC. The weight is compared with and corresponds to an identical type of lamp from specific producers. The BOM is shown in the following table, and is as such used as input for calculation of the environmental impacts during the production phase.

Some remarks about this input table:

- Coating of bulb with metal oxides (Y, V, P and B) resp. MgO, Ni, Cu and Mo is modelled as Cu/Ni/Cr plating. We assume that this parameter approaches better the reality than not taking it into account. In the MEEUP database this material/process comes closest to the mix of materials.
- The environmental impacts of the filling gasses for the bulb (Argon and Neon) resp. the burner (Argon) are not modelled, since these gases are not considered environmentally

relevant and also amounts are substantially low. Both are noble gasses that are present in the earth atmosphere. Argon as well as Neon are not poisonous, flammable nor explosive. Environmental databases (a.o. Eco-Invent v.1.3) show negligible energy requirements for the production of Argon. Based on this additional information it can be acceptable to not take their environmental impact into account for the environmental assessment.

- Looking at the total weight, the bulb is the most important component of the lamp (almost 80wt%), followed by the lamp base (15wt%). The most important weight contributing material of the bulb is the glass, followed by the brass and solder in the lamp base.

More than 99wt% is modelled, the remaining materials are left blank in the last two columns of the table below and are expected not to have a major environmental impact. So we only expect a minor underestimation of the total environmental impact of the lamp.

Table 33: Input data for the materials extraction and production of the HPM 125W lamp

MATERIALS Extraction & Production	Weight	Category	Material or Process
Description of component	**in g**	**Click &select**	**select Category first !**
BULB_Outer bulb _Lead-free glass	49,67	7-Misc.	**54-Glass for lamps**
BULB_Stem tube_Lead-free glass	4,33	7-Misc.	**54-Glass for lamps**
BULB_Lead-in_Ni, Fe, Cu, W	1,17	4-Non-ferro	**28-Cu winding wire**
BULB_Coating_Y, V, P & B-Oxides	0,13	5-Coating	**40-Cu/Ni/Cr plating**
BULB_Resistor_MgO, Ni, Cu, Mo	0,43	5-Coating	**40-Cu/Ni/Cr plating**
BULB_Filling Gas_Argon, Neon	0		
BURNER_Envelope_Quartz Glass	3,87	7-Misc.	**54-Glass for lamps**
BURNER_Lead-in_Molybdene	0,013		
BURNER_Electrode&Emittor_Tungsten&Ba.Ca Y-Oxide	0,2		
BURNER_Filling_Mercury	0,02		
BURNER_Inert gas filling_Argon	0,0002		
LAMP BASE (E27)_Cap_Brass and glass-frit	7,1	4-Non-ferro	**31-CuZn38 cast**
LAMP BASE (E27)_Solder_Sn, Pb, Sb	4,67	6-Electronics	**52-Solder SnAg4Cu0.5**

The table below gives the other inputs that refer to the production (manufacturing processes) of the lamps. No specific significant differences in the production parameters exist among the different lamp types to our knowledge. Following the VHK case study we take into account that for the production of 1 kg sheet metal for lamps, 1.25 kg sheet metal is needed as input material (25% sheet metal scrap).

Table 34: Input data for the manufacturing of the HPM 125W lamp

MANUFACTURING Description	Weight in g	Percentage Adjust
OEM Plastics Manufacturing (fixed)	0	
Foundries Fe/Cu/Zn (fixed)	7	
Foundries Al/Mg (fixed)	0	
Sheet metal Manufacturing (fixed)	0	
PWB Manufacturing (fixed)	5	
Other materials (Manufacturing already included)	59,83	
Sheet metal Scrap (Please adjust percentage only)	0	**25%**

► **HPM 400W lamp**

For this lamp, we dispose of specific producer data. Based on available data for HPM lamps of different power, we found that the relation between power and weight of this type of lamp is fixed between a specific band width. If this relation is applied for calculating the weight of the 400W lamp, the result corresponds to the producer-specific data. Therefore, the BOM starts from the total weight of the lamp and assumes an identical material composition (in terms of percentage of weight) as the HPM 125W lamp. Exceptions on this calculation method are made for the mercury-content in the lamp, which is in absolute value taken over from company-specific data, and on the lamp base, which is an E40 type for the 400W lamp (instead of E27 for the 125W lamp).

The table below shows the BOM as it is taken into account for the environmental assessment.

Table 35: Input data for the materials extraction and production of the HPM 400W lamp

MATERIALS Extraction & Production	Weight	Category	Material or Process
Description of component	**in g**	**Click &select**	**select Category first !**
BULB_Outer bulb _Lead-free glass	166,35	7-Misc.	**54-Glass for lamps**
BULB_Stem tube_Lead-free glass	14,50	7-Misc.	**54-Glass for lamps**
BULB_Lead-in_Ni, Fe, Cu, W	3,92	4-Non-ferro	**28-Cu winding wire**
BULB_Coating_Y, V, P & B-Oxides	0,44	5-Coating	**40-Cu/Ni/Cr plating**
BULB_Resistor_MgO, Ni, Cu, Mo	1,44	5-Coating	**40-Cu/Ni/Cr plating**
BULB_Filling Gas_Argon, Neon	0		
BURNER_Envelope_Quartz Glass	12,96	7-Misc.	**54-Glass for lamps**
BURNER_Lead-in_Molybdene	0,040		
BURNER_Electrode&Emittor_Tungsten&Ba.Ca Y-Oxide	0,7		
BURNER_Filling_Mercury	0,07		
BURNER_Inert gas filling_Argon	0,0002		
LAMP BASE (E27)_Cap_Brass and glass-frit	17,4	4-Non-ferro	**31-CuZn38 cast**
LAMP BASE (E27)_Solder_Sn, Pb, Sb	11,44	6-Electronics	**52-Solder SnAg4Cu0.5**

The BOM's for both lamps indicate that the mercury-content of the high pressure mercury lamps increases with the power of the lamps. This could be an important factor in the environmental assessment, especially with regard to the potential release of mercury in the end-of-life phase. This increasing relation between mercury-content and power of high pressure mercury lamps is confirmed by data for lamps of different power.
Other remarks about the input table are identical to the HPM 125W lamp and as such the discussion of this lamp is referred to for more details. Again, the environmental impact of more than 99wt% of all materials is modelled and the remaining materials (of which the last two columns in the table above are left blank) are not expected to cause major environmental effects.

The table below gives the other inputs that refer to the production (manufacturing processes) of the lamps. We assume no specific differences in the production parameters among the different lamp types. Following the VHK case study we assume that for the production of 1 kg sheet metal for lamps, 1.25 kg sheet metal is needed as input material (25% sheet metal scrap).

Table 36: Input data for the manufacturing of the HPM 400W lamp

MANUFACTURING Description	Weight in g	Percentage Adjust
OEM Plastics Manufacturing (fixed)	0	
Foundries Fe/Cu/Zn (fixed)	17	
Foundries Al/Mg (fixed)	0	
Sheet metal Manufacturing (fixed)	0	
PWB Manufacturing (fixed)	11	
Other materials (Manufacturing already included)	200,39	
Sheet metal Scrap (Please adjust percentage only)	0	**25%**

4.1.3.2 Typical high pressure sodium lamps (HPS)

In this study 3 types of high pressure sodium lamps are subject to an environmental assessment.

► HPS 70W lamp
The bill of materials for the HPS 70W lamp is delivered by ELC and is also used in the VHK-study on street lighting.
The BOM is shown in the following table, and is as such used as input for the VHK-model for calculation of the environmental impacts.

Table 37: Input data for the materials extraction and production of the HPS 70W lamp

MATERIALS Extraction & Production	**Weight**	**Category**	**Material or Process**
Description of component	**in g**	**Click &select**	**select Category first !**
BULB_Envelope_Glass	35,33	7-Misc.	**54-Glass for lamps**
BULB_Stem tube_Glass	3,80	7-Misc.	**54-Glass for lamps**
BULB_Lead wires_Low carbon steel	2,00	3-Ferro	**25-Stainless 18/8 coil**
BULB_Tube_Si, B, Al, Na, K, Mg, Ca, Ba, -oxides	1,17	5-Coating	**40-Cu/Ni/Cr plating**
BULB_Getter_Zr, Al, Fe	0,14	4-Non-ferro	**27-Al diecast**
BURNER_PCA (Poly Crystallyne Aluminium Oxide)	2,47	4-Non-ferro	**26-Al sheet/extrusion**
BURNER_Amalgam_Hg, Na	0,02		
BURNER_Electrode&Emittor_Tungsten&Ba,Y,W-oxides	0,29	4-Non-ferro	
BURNER_Frit ring_Ca, Ba, Al-oxides	0,02	4-Non-ferro	
BURNER_Niobium Tube	0,53	4-Non-ferro	
LAMP BASE (E27)_Cap_Brass and glass-frit	9,4	4-Non-ferro	**31-CuZn38 cast**
LAMP BASE (E27)_Solder_Sn, Pb, Sb	1,50	6-Electronics	**52-Solder SnAg4Cu0.5**
LAMP BASE (E27)_Capping cement_CaCO3	1,1	7-Misc.	

More than 96wt% of the materials are modelled in the environmental assessment, which indicates that the environmental impact of the production phase is not largely underestimated.

Some remarks about these input data:

- Oxides of alkaline earth metals (Si, B, Al, Na, K, Mg, Ca, Ba) for the tube are modelled as Cu/Ni/Cr plating. We assume that this parameter approaches better the reality than not taking it into account. In the MEEUP database this material/process comes closest to the mix of materials.
- For the production of amalgam (mercury and sodium, resp 0.015g Hg and 0.005g Na) detailed data are not available. The efforts to include the impact of mercury in the production phase do not outweigh the results since a rough assessment already shows that the impact of the production phase is not significant compared to the use phase of a lamp.
- The production of the electrode and emitter (burner), the frit ring, the niobium tube and the capping cement in the lamp base are not accounted for because data are not available. We don't expect that the environmental impact of these materials outweighs the negligible weight share of these materials in the lamp.
- Similar to the HPM lamps the most important parts in terms of material composition are the bulb (envelope and stem tube, together 70wt%) and the lamp base (20wt%).

The mercury content in the HPS 70W lamp is 0.015g (and 0.005g Na).

The table below gives the other inputs that refer to the production (manufacturing processes) of the lamp. We assume no specific differences in the production parameters among the different lamp types. Following the VHK case study we assume that for the production of 1 kg sheet metal for lamps, 1.25 kg sheet metal is needed as input material (25% sheet metal scrap).

Table 38: Input data for the manufacturing of the HPS 70W lamp

MANUFACTURING Description	Weight in g	Percentage Adjust
OEM Plastics Manufacturing (fixed)	0	
Foundries Fe/Cu/Zn (fixed)	9	
Foundries Al/Mg (fixed)	0	
Sheet metal Manufacturing (fixed)	4	
PWB Manufacturing (fixed)	2	
Other materials (Manufacturing already included)	42,23	
Sheet metal Scrap (Please adjust percentage only)	1	**25%**

► **HPS 150W lamp**

Based on available data for HPS lamps of different power, we found that the relation between power and weight of this type of lamp is fixed between a specific band width (like the HPM lamps). If this relation is applied for calculating the weight of the 150W lamp, the result corresponds to producer-specific data. Therefore, the BOM starts from the total weight of the lamp and assumes an identical material composition (in terms of percentage of weight) as the HPS 70W lamp. Exceptions on this calculation method are made for the mercury-content in the lamp, which is a fixed amount and thus independent of the lamp power (based on company-specific data), and for the lamp base, which is an E40 type for the 150W lamp (instead of E27 for the 70W lamp). The BOM that is composed this way was compared with BOMs of specific suppliers and showed no significant discrepancies.

The table below shows the BOM as is taken into account for the environmental assessment.

Table 39: Input data for the materials extraction and production of the HPS 150W lamp

MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
BULB_Envelope_Glass	96,55	7-Misc.	**54-Glass for lamps**
BULB_Stem tube_Glass	10,39	7-Misc.	**54-Glass for lamps**
BULB_Lead wires_Low carbon steel	5,47	3-Ferro	**25-Stainless 18/8 coil**
BULB_Tube_Si, B, Al, Na, K, Mg, Ca, Ba, -oxides	3,20	5-Coating	**40-Cu/Ni/Cr plating**
BULB_Getter_Zr, Al, Fe	0,38	4-Non-ferro	**27-Al diecast**
BURNER_PCA (Poly Crystallyne Aluminium Oxide)	6,75	4-Non-ferro	**26-Al sheet/extrusion**
BURNER_Amalgam_Hg, Na	0,02		
BURNER_Electrode&Emittor_Tungsten&Ba,Y,W-oxides	0,79	4-Non-ferro	
BURNER_Frit ring_Ca, Ba, Al-oxides	0,05		
BURNER_Niobium Tube	1,45		
LAMP BASE (E40)_Cap_Brass and glass-frit	25,7	4-Non-ferro	**31-CuZn38 cast**
LAMP BASE (E40)_Solder_Sn, Pb, Sb	4,10	6-Electronics	**52-Solder SnAg4Cu0.5**
LAMP BASE (E40)_Capping cement_CaCO3	2,9		

The general remarks about this input table are identical to the HPS 70W lamp. We refer to the section above for this discussion.
Over 96wt% of the materials are modelled in this environmental assessment, which indicates that the environmental impact of the production phase is not largely underestimated. This lamp contains 0.015g mercury (and 0.005g Na), which is the same as the 70W lamp.

The table below gives the other inputs that refer to the production (manufacturing processes) of the lamp. We assume no specific differences in the production parameters among the different lamp types. Following the VHK case study we assume that for the production of 1 kg sheet metal for lamps, 1.25 kg sheet metal is needed as input material (25% sheet metal scrap).

Table 40: Input data for the manufacturing of the HPS 150W lamp

MANUFACTURING	Weight	Percentage
Description	**in g**	**Adjust**
OEM Plastics Manufacturing (fixed)	0	
Foundries Fe/Cu/Zn (fixed)	26	
Foundries Al/Mg (fixed)	0	
Sheet metal Manufacturing (fixed)	12	
PWB Manufacturing (fixed)	4	
Other materials (Manufacturing already included)	115,37	
Sheet metal Scrap (Please adjust percentage only)	3	**25%**

► HPS 250W lamp

For the HPS 250W lamp an identical method is used to compose the BOM as for the HPS 150W lamp. The table below shows the BOM as it is taken into account for the environmental assessment.

Table 41: Input data for the materials extraction and production of the HPS 250W lamp

MATERIALS Extraction & Production	Weight	Category	Material or Process
Description of component	**in g**	**Click &select**	**select Category first !**
BULB_Envelope_Glass	143,18	7-Misc.	**54-Glass for lamps**
BULB_Stem tube_Glass	15,40	7-Misc.	**54-Glass for lamps**
BULB_Lead wires_Low carbon steel	8,11	3-Ferro	**25-Stainless 18/8 coil**
BULB_Tube_Si, B, Al, Na, K, Mg, Ca, Ba, -oxides	4,74	5-Coating	**40-Cu/Ni/Cr plating**
BULB_Getter_Zr, Al, Fe	0,57	4-Non-ferro	**27-Al diecast**
BURNER_PCA (Poly Crystallyne Aluminium Oxide)	10,10	4-Non-ferro	**26-Al sheet/extrusion**
BURNER_Amalgam_Hg, Na	0,02		
BURNER_Electrode&Emittor_Tungsten&Ba,Y,W-oxides	1,18	4-Non-ferro	
BURNER_Frit ring_Ca, Ba, Al-oxides	0,08		
BURNER_Niobium Tube	2,15		
LAMP BASE (E40)_Cap_Brass and glass-frit	25,7	4-Non-ferro	**31-CuZn38 cast**
LAMP BASE (E40)_Solder_Sn, Pb, Sb	4,10	6-Electronics	**52-Solder SnAg4Cu0.5**
LAMP BASE (E40)_Capping cement_CaCO3	2,9	7-Misc.	

For the general remarks with this input table is referred to the discussion of the HPS 70W lamp. Over 97wt% of the materials are modelled, which is acceptable and indicates that the environmental impact of the production phase is not largely underestimated

The HPS 250W lamp has a mercury content of 0.015g (and 0.005g Na). The BOMs for the different HPS lamps show a fixed mercury-content for all lamps, independent of their power. This is due to the fact that for HPS-lamps mercury serves only as a carrier.

The table below gives the other inputs that refer to the production (manufacturing processes) of the lamp. We assume no specific differences in the production parameters among the different lamp types. Following the VHK case study we assume that for the production of 1 kg sheet metal for lamps, 1.25 kg sheet metal is needed as input material (25% sheet metal scrap).

Table 42: Input data for the manufacturing of the HPS 250W lamp

MANUFACTURING Description	Weight in g	Percentage Adjust
OEM Plastics Manufacturing (fixed)	0	
Foundries Fe/Cu/Zn (fixed)	26	
Foundries Al/Mg (fixed)	1	
Sheet metal Manufacturing (fixed)	18	
PWB Manufacturing (fixed)	4	
Other materials (Manufacturing already included)	599,80	
Sheet metal Scrap (Please adjust percentage only)	5	**25%**

4.1.3.3 Typical low pressure sodium lamps (LPS)

► LPS 131W lamp

The input data for the low pressure sodium lamp are specific data for one type of lamp. No general data were available. Table 43 summarizes the input data that are taken into account for the environmental assessment.

Table 43: Input data for the materials extraction and production of the LPS 131W lamp

MATERIALS Extraction & Production	Weight	Category	Material or Process
Description of component	**in g**	**Click &select**	**select Category first !**
Outer bulb_Soda lime glass	740,00	7-Misc.	**54-Glass for lamps**
Diachroic coating_Indium-Tin-oxide layer	0,01	5-Coating	**40-Cu/Ni/Cr plating**
Mirror_Barium metal	0,03	4-Non-ferro	
Discharge tube_Ply glass	250,00	7-Misc.	**54-Glass for lamps**
Ignition gas_Neon-Argon penning mixture	0,00	7-Misc.	
Discharge material_Sodium metal	2,90	4-Non-ferro	
Cathode_Tungsten spiral with metal oxide coating	0,14		
Leg protector_Stainless steel	3,00	3-Ferro	**25-Stainless 18/8 coil**
Top plate_Stainless steel	10,60	3-Ferro	**25-Stainless 18/8 coil**
Foot plate_natural mica	2,10		
Foot assembly_Soda lime glass	3,0	7-Misc.	**54-Glass for lamps**
Foot assembly_copper wires	3,00	4-Non-ferro	**29-Cu wire**
Cap adhesive_Resin cement	4,9		
Lamp cap_Brass skirt MouldingStyrene-free unsaturated polyester resin	17,2	4-Non-ferro	**31-CuZn38 cast**
Solder contacts_Copper-Tin solder	1,0	6-Electronics	**52-Solder SnAg4Cu0.5**
Footpinch Clip_Stainless steel	0,7	3-Ferro	**25-Stainless 18/8 coil**
Catalyst_Ceramic-Pt	0,1		

99wt% of the materials are modelled in the environmental assessment.
Some remarks about these input data:

- Oxides of Indium and Tin for the diachronic coating are modelled as Cu/Ni/Cr plating since specific data are not available. We assume that this parameter approaches better the reality than not taking it into account. In the MEEUP database this material/process comes closest to the mix of materials.
- This is also true for some metals (Barium metal, Sodium metal etc.)
- For the ignition gas, the cathode, the footplate, cap adhesive and catalyst: the environmental impact of these materials does not outweigh the negligible share of these materials in the lamp.
- The lamp bulb is responsible for over 97% of the total lamp weight, which is opposite to the high pressure lamps, where also the lamp cap has a significant share in the total weight.

The low pressure sodium lamp does not contain mercury, which implies that glass is the most important material, in terms of environmental impact, for this type of lamp.

The table below gives the other inputs that refer to the production (manufacturing processes) of the lamp. We assume no specific differences in the production parameters among the different lamp types. Following the VHK case study we assume that for the production of 1 kg sheet metal for lamps, 1.25 kg sheet metal is needed as input material (25% sheet metal scrap).

Table 44: Input data for the manufacturing of the LPS 131W lamp

MANUFACTURING Description	Weight in g	Percentage Adjust
OEM Plastics Manufacturing (fixed)	0	
Foundries Fe/Cu/Zn (fixed)	17	
Foundries Al/Mg (fixed)	0	
Sheet metal Manufacturing (fixed)	14	
PWB Manufacturing (fixed)	1	
Other materials (Manufacturing already included)	3073,25	
Sheet metal Scrap (Please adjust percentage only)	4	25%

4.1.3.4 Typical high pressure ceramic metal halide lamps (CMH)

► CMH 70W

The bill of materials for the CMH 70W lamp is supplied by ELC and is also used for the VHK case study on street lighting. A comparison of the provided average ELC-data with data from specific suppliers showed a maximum difference of 30% in the total weight of the lamp. This difference is mostly due to differences in the weight of the bulb. We use the ELC-data since these represent a good average of all lamps that are on the market.

The BOM is shown in the following table, and is as such used as input for the VHK-excel model for calculation of the environmental impacts.

Some remarks about these input data:

- Filling gasses for the burner (Argon and Krypton) are not modelled. Argon and Krypton are both noble gasses that are present in the earth atmosphere. Argon as well as Krypton are not poisonous, flammable nor explosive. Environmental databases (a.o. Eco-Invent v.1.3) show negligible energy requirements for the production of Argon, the production of Krypton requires a more significant amount of energy. Based on this information and on the negligible amount of both gasses present in the lamp, it can be justified to not take both gasses into account for the environmental assessment.
- For the salt mix in the burner, the electrode and the niobium pen: the environmental impact of these materials outweighs the negligible share of these materials in the lamp.
- From a perspective of weight, the important components are similar to the other types of lamps, being the bulb and the lamp base. The environmental impact of 94wt% of the materials is taken into account.

Table 45: Input data for the materials extraction and production of the CMH 70W lamp

MATERIALS Extraction & Production	**Weight**	**Category**	**Material or Process**
Description of component	**in g**	**Click &select**	**select Category first !**
BULB_Envelope_Quartz Glass	19,17	7-Misc.	**54-Glass for lamps**
BULB_Getter_Zr, Al, Fe	0,12	4-Non-ferro	**27-Al diecast**
BULB_Lead wires_Mo	2,03		
BURNER_PCA (Poly Crystallyne Aluminium Oxide)	7,77	4-Non-ferro	**26-Al sheet/extrusion**
BURNER_Metal filling_Hg	0,002		
BURNER_Gas_ArKr	0,0001		
BURNER_Salt mix_salt, including Tl, rare earths	0,003		
BURNER_Electrode_NbZr	0,20		
BURNER_Frit ring_AlDySi	0,01	4-Non-ferro	**26-Al sheet/extrusion**
BURNER_Niobium pen	0,23		
LAMP BASE (E27)_Clamping plate_steel	2,4	3-Ferro	**25-Stainless 18/8 coil**
LAMP BASE (E27)_Shell_stainless steel	3	3-Ferro	**25-Stainless 18/8 coil**
LAMP BASE (E27)_Ceramic_ceramic	5,77	7-Misc.	**24-Ferrite**
LAMP BASE (E27)_Pins_ni plated steel	0,67	5-Coating	**40-Cu/Ni/Cr plating**

The table below gives the other inputs that refer to the production (manufacturing processes) of the lamp. We assume no specific differences in the production parameters among the different lamp types. Following the VHK case study we assume that for the production of 1 kg sheet metal for lamps, 1.25 kg sheet metal is needed as input material (25% sheet metal scrap).

Table 46: Input data for the manufacturing of the CMH 70W lamp

MANUFACTURING	**Weight**	**Percentage**
Description	**in g**	**Adjust**
OEM Plastics Manufacturing (fixed)	0	
Foundries Fe/Cu/Zn (fixed)	0	
Foundries Al/Mg (fixed)	0	
Sheet metal Manufacturing (fixed)	19	
PWB Manufacturing (fixed)	0	
Other materials (Manufacturing already included)	22,31	
Sheet metal Scrap (Please adjust percentage only)	5	**25%**

4.1.3.5 Typical fluorescent lamps (CFL)

In this study the compact fluorescent 36W lamp with non integrated ballast is considered a relevant fluorescent lamp for street lighting, as it is used in some specific countries. We have requested but not received BOM-data from the stakeholders and as such we have used the BOM for the equivalent linear fluorescent lamp (LFL) T8-36W as composed for office lighting. The main difference between these lamps concerns the cap(s).

Table 40: Input data for the manufacturing of the CFL lamp, modelled as the LFL T8-36W

MATERIALS Extraction & Production	Weight	Category	Material or Process
Description of component	**in g**	**Click &select**	**select Category first !**
Float glass	133,00	7-Misc.	**54-Glass for lamps**
Aluminium sheet for caps	4,20	4-Non-ferro	**26-Al sheet/extrusion**
Residual_rare earth metals and gas	2,80	5-Coating	
Metal Mercury	0,005		

The table below gives the other inputs that refer to the production (manufacturing processes) of the lamp. We assume no specific differences in the production parameters among the different lamp types. Following the VHK case study we assume that for the production of 1 kg sheet metal for lamps, 1.25 kg sheet metal is needed as input material (25% sheet metal scrap).

Table 41: Input data for the manufacturing of the CFL lamp, modelled as the LFL T8-36W

MANUFACTURING	Weight	Percentage
Description	**in g**	**Adjust**
OEM Plastics Manufacturing (fixed)	0	
Foundries Fe/Cu/Zn (fixed)	0	
Foundries Al/Mg (fixed)	0	
Sheetmetal Manufacturing (fixed)	4	
PWB Manufacturing (fixed)	0	
Other materials (Manufacturing already included)	135,81	
Sheetmetal Scrap **(Please adjust percentage only)**	1	**25%**

4.1.4 Ballast (control gear)

For street lighting the most commonly used ballasts nowadays are the electromagnetic ballasts including a capacitor and ignitor (except for HPM lamps). Electronic ballasts are not yet frequently used, however may not be neglected in this study because of their future potential. In this study the environmental assessment is performed for the control gear as a whole, not for the individual subparts. Distinction is made between electromagnetic ballast and electronic ballast. The weight of electromagnetic ballasts differs depending on the lamp power. This is not the case for electronic ballasts.

With regard to the different parts and the respective composition of the control gear with electromagnetic ballast, we dispose of CELMA-data for the HPM 125W lamp, the HPS 70W lamp and the CMH 70W lamp. The CELMA-data are checked for the electromagnetic (EM) ballast, the capacitor and the ignitor (if relevant) with producer specific data. This comparison showed that the weight of the EM ballast varies largely with the lamp power, the weight of the capacitor and ignitor varies also but the variations are insignificant compared to the EM ballast. Therefore the bill of materials for the electromagnetic control gear is specified according to the lamp power and type of lamp, the only difference between identical lamp types with different power is the weight of the ballast. The weight of the ballast is taken from CELMA-data or the average of specific suppliers (in case of no available CELMA-data). The composition of the ballast is based on data from literature (Hermann C. et al, 2005) but simplified according to the most important materials. The composition of the other control gear is assumed to be identical for different lamp power.
With respect to the control gear with electronic ballast we assume an identical composition of the gear for all subparts except the ballast, capacitor and ignitor. The last two subparts are included in the electronic ballast. The weight of the electronic ballast is taken as an average of different suppliers (checked by measurements), the composition of the ballast is derived from literature (Hermann C. et al, 2005). Producer data showed that the weight of an electronic ballast is not dependent on the lamp power. So, for each type of lamp one type of control gear is modelled, independent of the lamp power. For HPM-lamps no electronic ballasts exist.

The following tables present the bill of materials for the control gear as the basis for the environmental assessment.

4.1.4.1 Ballast for high pressure mercury lamps

► Electromagnetic ballast

The bill of materials for the electromagnetic control gear for the HPM lamps is based on the CELMA-data as used in the VHK case study on street lighting. In the framework of this study these data are used as a basis, but the BOMs are diversified with respect to the ballast related to the different lamp power. The ballast is modelled according to the most important materials, being the steel (85%) and the copper wiring (15%). The weight of the ballast is based on producer specific data, that match the CELMA-data for the 125W lamp.
The following tables present the input data as they are modelled in the VHK model for the environmental assessment.

Table 47: Input data for the materials extraction and production of the electromagnetic ballast for the HPM 125W lamp

MATERIALS Extraction & Production	Weight	Category	Material or Process
Description of component	**in g**	**Click &select**	**select Category first !**
HOUSING_Encapsuled EM copper/iron ballast	1105,00	3-Ferro	**21-St sheet galv.**
HOUSING_Encapsuled EM copper/iron ballast	195,00	4-Non-ferro	**28-Cu winding wire**
BASE PLATE_steelplate Sendsimir geartray on steel lackered frame	1000,00	3-Ferro	**21-St sheet galv.**
WIRING MAG_orthocyclic winding	10,00	4-Non-ferro	**28-Cu winding wire**
CONNECTORS_screw terminalbloc	25,00	1-BlkPlastics	**4-PP**
WIRING CONNECTION_Plastic terminationbloc	25	1-BlkPlastics	**4-PP**
PASSIVE COMPONENTS_capacitor	70,00	4-Non-ferro	**26-Al sheet/extrusion**
PASSIVE COMPONENTS_capacitor	30,000	2-TecPlastics	**14-Epoxy**

Table 48: Input data for the materials extraction and production of the electromagnetic ballast for the HPM 400W lamp

MATERIALS Extraction & Production	Weight	Category	Material or Process
Description of component	**in g**	**Click &select**	**select Category first !**
HOUSING_Encapsuled EM copper/iron ballast	2465,00	3-Ferro	**21-St sheet galv.**
HOUSING_Encapsuled EM copper/iron ballast	435,00	4-Non-ferro	**28-Cu winding wire**
BASE PLATE_steelplate Sendsimir geartray on steel lackered frame	1000,00	3-Ferro	**21-St sheet galv.**
WIRING MAG_orthocyclic winding	10,00	4-Non-ferro	**28-Cu winding wire**
CONNECTORS_screw terminalbloc	25,00	1-BlkPlastics	**4-PP**
WIRING CONNECTION_Plastic terminationbloc	25	1-BlkPlastics	**4-PP**
PASSIVE COMPONENTS_capacitor	70,00	4-Non-ferro	**26-Al sheet/extrusion**
PASSIVE COMPONENTS_capacitor	30,000	2-TecPlastics	**14-Epoxy**

4.1.4.2 Ballast for high pressure sodium lamps

► Electromagnetic ballast

The bill of materials for the electromagnetic control gear for the HPS lamps is based on the CELMA-data as used in the VHK case study on street lighting. In the framework of this study these data are used as a basis, but the BOMs are diversified with respect to the ballast related to the different lamp power. The ballast is modelled according to the most important materials, being the steel (85%) and the copper wiring (15%). The weight of the ballast is based on producer specific data, that match the CELMA-data for the 70W lamp.

The following tables present the input data as they are modelled in the VHK model for the environmental assessment.

Table 49: Input data for the materials extraction and production of the electromagnetic ballast for the HPS 70W lamp

MATERIALS Extraction & Production	Weight	Category	Material or Process
Description of component	**in g**	**Click &select**	**select Category first !**
HOUSING_Impregnated EM copper/iron ballast	1020,00	3-Ferro	**21-St sheet galv.**
HOUSING_Impregnated EM copper/iron ballast	180,00	4-Non-ferro	**28-Cu winding wire**
BASE PLATE_geartray sendsimir steelplate	400,00	3-Ferro	**21-St sheet galv.**
CONNECTORS_plug_in connectors	25,00	1-BlkPlastics	**4-PP**
WIRING CONNECTION_plug socket 5-pole	25	1-BlkPlastics	**4-PP**
PASSIVE COMPONENTS_capacitor	70,00	4-Non-ferro	**26-Al sheet/extrusion**
PASSIVE COMPONENTS_capacitor	30,000	2-TecPlastics	**14-Epoxy**
ACTIVE COMPONENTS_Timed ignitor	100,000	6-Electronics	**51-PWB 6 lay 2 kg/m2**

Table 50: Input data for the materials extraction and production of the electromagnetic ballast for the HPS 150W lamp

MATERIALS Extraction & Production	Weight	Category	Material or Process
Description of component	**in g**	**Click &select**	**select Category first !**
HOUSING_Impregnated EM copper/iron ballast	1700,00	3-Ferro	**21-St sheet galv.**
HOUSING_Impregnated EM copper/iron ballast	300,00	4-Non-ferro	**28-Cu winding wire**
BASE PLATE_geartray sendsimir steelplate	400,00	3-Ferro	**21-St sheet galv.**
CONNECTORS_plug_in connectors	25,00	1-BlkPlastics	**4-PP**
WIRING CONNECTION_plug socket 5-pole	25	1-BlkPlastics	**4-PP**
PASSIVE COMPONENTS_capacitor	70,00	4-Non-ferro	**26-Al sheet/extrusion**
PASSIVE COMPONENTS_capacitor	30,000	2-TecPlastics	**14-Epoxy**
ACTIVE COMPONENTS_Timed ignitor	100,000	6-Electronics	**51-PWB 6 lay 2 kg/m2**

Table 51: Input data for the materials extraction and production of the electromagnetic ballast for the HPS 250W lamp

MATERIALS Extraction & Production	Weight	Category	Material or Process
Description of component	**in g**	**Click &select**	**select Category first !**
HOUSING_Impregnated EM copper/iron ballast	2465,00	3-Ferro	**21-St sheet galv.**
HOUSING_Impregnated EM copper/iron ballast	435,00	4-Non-ferro	**28-Cu winding wire**
BASE PLATE_geartray sendsimir steelplate	400,00	3-Ferro	**21-St sheet galv.**
CONNECTORS_plug_in connectors	25,00	1-BlkPlastics	**4-PP**
WIRING CONNECTION_plug socket 5-pole	25	1-BlkPlastics	**4-PP**
PASSIVE COMPONENTS_capacitor	70,00	4-Non-ferro	**26-Al sheet/extrusion**
PASSIVE COMPONENTS_capacitor	30,000	2-TecPlastics	**14-Epoxy**
ACTIVE COMPONENTS_Timed ignitor	100,000	6-Electronics	**51-PWB 6 lay 2 kg/m2**

► **Electronic ballast**

The general subparts of the control gear (base plate, wiring, etc.) are taken over from the electromagnetic control gear. The data for the composition of the electronic ballast come from literature (Hermann C. et al, 2005) and are simplified according to the most important materials. The data we dispose of with regard to the electronic ballast are not specific for street lighting, but for the regular fluorescent lamps. We know that the basic technology for ballasts is the same for streetlighting applications compared to other applications and therefore we have used the same composition of the electronic ballast for street lighting. Producer data showed no differences in weight of the ballast according to the lamp power.

The following table presents the input data as they are modelled in the VHK model for the environmental assessment.

Table 52: Input data for the materials extraction and production of the electronic ballast for the HPS lamps

MATERIALS Extraction & Production	Weight	Category	Material or Process
Description of component	**in g**	**Click &select**	**select Category first !**
E-BALLAST_PCB	70,00	6-Electronics	**49-PWB 1/2 lay 3.75kg/m2**
E-BALLAST_housing steel sheet	385,00	3-Ferro	**21-St sheet galv.**
BASE PLATE_geartray sendsimir steelplate	400,00	3-Ferro	**21-St sheet galv.**
CONNECTORS_plug_in connectors	25,00	1-BlkPlastics	**4-PP**
WIRING CONNECTION_plug socket 5-pole	25	1-BlkPlastics	**4-PP**
E-BALLAST_THT surface_coil	182,00	6-Electronics	**44-big caps & coils**
E-BALLAST_THT surface_metal film capacitor	24,500	4-Non-ferro	**26-Al sheet/extrusion**
E-BALLAST_THT surface_metal film capacitor	10,5	2-TecPlastics	**14-Epoxy**
E-BALLAST_PET film	14,0	1-BlkPlastics	**2-HDPE**
E_BALLAST_solder paste	14,0	6-Electronics	**52-Solder SnAg4Cu0.5**

4.1.4.3 Ballast for low pressure sodium lamps

► **Electromagnetic ballast**

The bill of materials for the electromagnetic control gear for the LPS lamp is based on the BOM for the electromagnetic control gear for the high pressure lamps, but specified according to the specific ballast that is related to the LPS 131W lamp. The ballast is modelled according to the most important materials, being the steel (85%) and the copper wiring (15%). The weight of the ballast is based on producer specific data.

Table 53 presents the input data as they are modelled in the VHK model for the environmental assessment.

Table 53: Input data for the materials extraction and production of the electronic ballast for the LPS 131W lamp

MATERIALS Extraction & Production	Weight	Category	Material or Process
Description of component	**in g**	**Click &select**	**select Category first !**
HOUSING_Impregnated EM copper/iron ballast	2677,50	3-Ferro	**21-St sheet galv.**
HOUSING_Impregnated EM copper/iron ballast	472,50	4-Non-ferro	**28-Cu winding wire**
BASE PLATE_geartray sendsimir steelplate	400,00	3-Ferro	**21-St sheet galv.**
CONNECTORS_plug_in connectors	25,00	1-BlkPlastics	**4-PP**
WIRING CONNECTION_plug socket 5-pole	25	1-BlkPlastics	**4-PP**
PASSIVE COMPONENTS_capacitor	70,00	4-Non-ferro	**26-Al sheet/extrusion**
PASSIVE COMPONENTS_capacitor	30,000	2-TecPlastics	**14-Epoxy**
ACTIVE COMPONENTS_Timed ignitor	100,000	6-Electronics	**51-PWB 6 lay 2 kg/m2**

► Electronic ballast

No electronic control gear exists for the LPS lamp 131W, only for the 36W lamp.

4.1.4.4 Ballast for ceramic metal halide lamps

► Electromagnetic ballast

The bill of materials for the electromagnetic control gear for the CMH lamp is based on the CELMA-data as used in the VHK case study on street lighting and is confirmed by producer-specific data. The material for the base plate is changed from plastic (CELMA) into steelplate (in conformity with the other lamps). The ballast is modelled according to the most important materials, being the steel (85%) and the copper wiring (15%).

Table 54 presents the input data as they are modelled in the VHK model for the environmental assessment.

Table 54: Input data for the materials extraction and production of the electromagnetic ballast for the CMH 70W lamp

MATERIALS Extraction & Production	Weight	Category	Material or Process
Description of component	**in g**	**Click &select**	**select Category first !**
HOUSING_Impregnated EM copper/iron ballast	1105,00	3-Ferro	**21-St sheet galv.**
HOUSING_Impregnated EM copper/iron ballast	195,00	4-Non-ferro	**28-Cu winding wire**
BASE PLATE_geartray sendsimir steelplate	700,00	3-Ferro	**21-St sheet galv.**
WIRING MAG_orthocyclic winding	12,00	4-Non-ferro	**28-Cu winding wire**
CONNECTORS_screw terminalbloc	35,00	1-BlkPlastics	**4-PP**
WIRING CONNECTION_3-pole safety switch	60	1-BlkPlastics	**4-PP**
PASSIVE COMPONENTS_capacitor	70,00	4-Non-ferro	**26-Al sheet/extrusion**
PASSIVE COMPONENTS_capacitor	30,000	2-TecPlastics	**14-Epoxy**
ACTIVE COMPONENTS_Timed ignitor	100,000	6-Electronics	**51-PWB 6 lay 2 kg/m2**

► **Electronic ballast**

The general components of the control gear (base plate, wiring, etc.) are taken over from the electromagnetic control gear. The data for the composition of the electronic ballast come from literature (Hermann C. et al, 2005) and are simplified according to the most important materials. The data we dispose of with regard to the electronic ballast are not specific for street lighting, but for the regular fluorescent lamps. We assume that no severe differences exist in composition of the electronic ballast for street lighting. The weight of the ballast is based on producer data.

The following table presents the input data as they are modelled in the VHK model for the environmental assessment.

Table 55: Input data for the materials extraction and production of the electronic ballast for the CMH 70W lamp

MATERIALS Extraction & Production	Weight	Category	Material or Process
Description of component	**in g**	**Click &select**	**select Category first !**
E-BALLAST_PCB	70,00	6-Electronics	**49-PWB 1/2 lay 3.75kg/m2**
E-BALLAST_housing steel sheet	385,00	3-Ferro	**21-St sheet galv.**
BASE PLATE_geartray sendsimir steelplate	700,00	3-Ferro	**21-St sheet galv.**
WIRING MAG_orthocyclic winding	12,00	4-Non-ferro	**28-Cu winding wire**
CONNECTORS_screw terminalbloc	35,00	1-BlkPlastics	**4-PP**
WIRING CONNECTION_3-pole safety switch	60	1-BlkPlastics	**4-PP**
E-BALLAST_THT surface_coil	182,00	6-Electronics	**44-big caps & coils**
E-BALLAST_THT surface_metal film capacitor	24,500	4-Non-ferro	**26-Al sheet/extrusion**
E-BALLAST_THT surface_metal film capacitor	10,5	2-TecPlastics	**14-Epoxy**
E-BALLAST_PET film	14,0	1-BlkPlastics	**2-HDPE**
E_BALLAST_solder paste	14,0	6-Electronics	**52-Solder SnAg4Cu0.5**

4.1.4.5 Ballast for fluorescent lamps

► Electromagnetic ballast

The bill of materials is based on the gear for the high pressure mercury lamp, with a different weight for the ballast. Data on weight of the ballast are taken from literature (Hermann C. et al, 2005).

Table 56 presents the input data as they are modelled in the VHK model for the environmental assessment. Like for the other electromechanical ballast, the composition is simplified into 85% steel and 15% copper. This is validated by literature (Hermann C. et al, 2005).

Table 56: Input data for the materials extraction and production of the electromagnetic control gear for the CFL 36W lamp

MATERIALS Extraction & Production	Weight	Category	Material or Process
Description of component	**in g**	**Click &select**	**select Category first !**
HOUSING_Encapsuled EM copper/iron ballast	552,50	3-Ferro	**21-St sheet galv.**
HOUSING_Encapsuled EM copper/iron ballast	97,50	4-Non-ferro	**28-Cu winding wire**
BASE PLATE_steelplate Sendsimir geartray on steel lackered frame	1000,00	3-Ferro	**21-St sheet galv.**
WIRING MAG_orthocyclic winding	10,00	4-Non-ferro	**28-Cu winding wire**
CONNECTORS_screw terminalbloc	25,00	1-BlkPlastics	**4-PP**
WIRING CONNECTION_Plastic terminationbloc	25	1-BlkPlastics	**4-PP**
PASSIVE COMPONENTS_capacitor	70,00	4-Non-ferro	**26-Al sheet/extrusion**
PASSIVE COMPONENTS_capacitor	30,000	2-TecPlastics	**14-Epoxy**

► **Electronic ballast**

The bill of materials for the ballast is entirely based on literature (Hermann C. et al, 2005). A simplification is performed according to the most important materials/components. The other components of the control gear are taken over from the HPM lamps.

The following table presents the input data as they are modelled in the VHK model for the environmental assessment.

Table 57: Input data for the materials extraction and production of the electronic ballast for the CFL 36W lamp

MATERIALS Extraction & Production	Weight	Category	Material or Process
Description of component	in g	Click &select	select Category first !
E-BALLAST_PCB	20,00	6-Electronics	**49-PWB 1/2 lay 3.75kg/m2**
E-BALLAST_housing steel sheet	110,00	3-Ferro	**21-St sheet galv.**
BASE PLATE_steelplate Sendsimir geartray on steel lackered frame	1000,00	3-Ferro	**21-St sheet galv.**
WIRING MAG_orthocyclic winding	10,00	4-Non-ferro	**28-Cu winding wire**
CONNECTORS_screw terminalbloc	25,00	1-BlkPlastics	**4-PP**
WIRING CONNECTION_Plastic terminationbloc	25	1-BlkPlastics	**4-PP**
E-BALLAST_THT surface_coil	52,00	6-Electronics	**44-big caps & coils**
E-BALLAST_THT surface_metal film capacitor	7,000	4-Non-ferro	**26-Al sheet/extrusion**
E-BALLAST_THT surface_metal film capacitor	3,0	2-TecPlastics	**14-Epoxy**
E-BALLAST_PET film	4,0	1-BlkPlastics	**2-HDPE**
E_BALLAST_solder paste	4,0	6-Electronics	**52-Solder SnAg4Cu0.5**

The modelling of the manufacturing stage of the control gear is identical to the manufacturing of the lamps. We assume no specific differences in the production parameters among the different control gear. Following the VHK case study we assume that for the production of 1 kg sheet metal, 1.25 kg sheet metal is needed as input material (25% sheet metal scrap). The environmental impacts related to the manufacturing stage are automatically generated based on the input data with regard to the used materials. Therefore the tables with regard to the manufacturing stage of the control gear are not included in this report.

4.1.5 Luminaires

Every manufacturer of street lighting luminaires produces different models (e.g. historical design, modern design, futuristic design etcetera) and in every model, there are different sizes for different lamps. Out of this enormous number of different luminaires, CELMA provided the BOM's for three types, representing the most selled on the market. These three types are closed luminaires with medium or good optics.
As demonstrated later in chapter 5, the materials of the luminaire are far less important for the impact assessment than the electricity consumption in the use phase.
Therefore it is not useful to calculate the BOM's for open luminaires and all other types. In the calculation of the energy consumption in the use phase, also open luminaires and luminaires with poor optics will be taken into account (see 4.3.1.4). These 3 defined types of luminaires

are not directly related to a specific type of lamp (interchangeability). The most important parameters that determine the selection of the luminaire are the size of lamp and ballast. The BOMs as defined by CELMA are used as input for the impact assessment model.

The following tables present the input data as they are modelled in the VHK model for the environmental assessment.

Table 58: Input data for the materials extraction and production of the luminaire type 1

MATERIALS Extraction & Production	**Weight**	**Category**	**Material or Process**
Description of component	**in g**	**Click &select**	**select Category first !**
HOUSING_Glassfiber reinforced polyester	1300,00	2-TecPlastics	**18-E-glass fibre**
HOUSING_aluminium	1400,00	4-Non-ferro	**26-Al sheet/extrusion**
REFLECTOR_high purity anodised Aluminium	280,00	4-Non-ferro	**26-Al sheet/extrusion**
LAMP SOCKET/CONNECTOR_E-27 porcelan	360,00	2-TecPlastics	
WIRING_Single core PVC-copper	45,00	4-Non-ferro	**29-Cu wire**
FRONT COVER_Polycarbonat	500	2-TecPlastics	**12-PC**

Table 59: Input data for the materials extraction and production of the luminaire type 2

MATERIALS Extraction & Production	**Weight**	**Category**	**Material or Process**
Description of component	**in g**	**Click &select**	**select Category first !**
HOUSING_Aluminium	4000,00	4-Non-ferro	**26-Al sheet/extrusion**
REFLECTOR_deep drawn anodised Aluminium 3-D reflector	700,00	4-Non-ferro	**26-Al sheet/extrusion**
LAMP SOCKET/CONNECTOR_E-27 porcelan	420,00	7-Misc.	
WIRING_Radox single core copper	40,00	4-Non-ferro	**29-Cu wire**
FRONT COVER_Glass thermally toughened	600	7-Misc.	**54-Glass for lamps**

Table 60: Input data for the materials extraction and production of the luminaire type 3

MATERIALS Extraction & Production	**Weight**	**Category**	**Material or Process**
Description of component	**in g**	**Click &select**	**select Category first !**
HOUSING_Glassfiber reinforced polyester	2300,00	2-TecPlastics	**18-E-glass fibre**
HOUSING_aluminium	800,00	4-Non-ferro	**26-Al sheet/extrusion**
REFLECTOR_deep drawn anodised Aluminium	800,00	4-Non-ferro	**26-Al sheet/extrusion**
LAMP SOCKET/CONNECTOR_E-27 porcelan	450,00	7-Misc.	
WIRING_Single core PVC-copper	45,00	4-Non-ferro	**29-Cu wire**
FRONT COVER_Polycarbonat	300	2-TecPlastics	**12-PC**

Over 90wt% of the materials are included in the environmental assessment, so no significant underestimation is expected.

We assume no specific differences in the production parameters among the different luminaires. Following the VHK case study we assume that for the production of 1 kg sheet metal, 1.25 kg sheet metal is needed as input material (25% sheet metal scrap). The environmental impacts related to the manufacturing stage are automatically generated based on the input data with regard to the used materials. Therefore the tables with regard to the manufacturing stage of the luminaires are not included in this report.

For the base case assessment in chapter 5 an average luminaire will be defined which is based on an equal share of the 3 luminaires as defined here.

4.2 Distribution phase

The environmental impact of the distribution of the lamps, control gear and luminaires is modelled according to the VHK-model. The input parameters are shown in the table below and are assumed identical for all lamp types resp. all control gear and all luminaires. The volume of packed final product is set at 0.002m³ for lamps and control gear and 0.045m³ for luminaires.

Table 61: Input data for the environmental assessment of the distribution of the lamps, control gear and luminaires

DISTRIBUTION (incl. Final Assembly)		Answer
Description		
Is it an ICT or Consumer Electronics product <15 kg ?		YES
Is it an installed appliance (e.g. boiler)?		NO
Volume of packaged final product in m^3	in m3	0.002-0,045

4.3 Use phase (product)

In this section, an overview is included of the calculation of the annual resources consumption and the direct emissions related to the defined performance parameters in chapter 1 and 3 under standard and non-standard conditions. This section also includes a representative overview of the performance parameters found for products on the market anno 2006. In chapter 6 dedicated to the Best Available Technology (BAT) and Best Not Yet Available Technology (BNAT) upcoming products are considered with more improved performance parameters but with a high actual price and/or a low actual trade volume or products that are only in the R&D phase. Also 'light pollution' is introduced in this section as an important factor related to the products direct emissions.

4.3.1 Rated annual resources consumption (energy, lamps) and direct emissions (light pollution) during product life according to the test standards defined in chapter 1

4.3.1.1 Formulas related to energy consumption

The annual energy consumption of a luminaire and lamp in standard conditions is straightforward and related to the lamp power, control gear losses and burning hours per year.

The power consumption (P) per luminaire can be calculated from the equipment performance parameters defined in chapter 1:

$$P\ [W] = P_{lamp} / \eta_{ballast}$$

Where,

- P_{lamp} and $\eta_{ballast}$ are defined in chapter 1.

The annual energy consumption (E_y) per product can be calculated:

$$E_y\ [kWh] = P_{lamp}/(\eta_{ballast}) \times h$$

Where,

- h = burning hours per year (as discussed in chapter 3)

The functional unit (FU) as defined in chapter 1 can be calculated from the lamp, ballast and luminaire performance parameters as defined in chapter 1 following the definition of these parameters:

$$FU\ [lumen] = UF \times LMF \times LLMF \times \text{Lamp Lumen Output}$$

By definition 1 lux equals 1 lumen per m² and therefore the following relationship exists with road illuminance performance requirements as discussed in chapter 1:

$$E\ [lx] = FU / A$$

Where,

- A is street area surface [m²] by multiplying street width with average distance between light points. Street width includes also pedestrian and cyclists area (if any). Average distance between light points is best determined by light points per km, since one pole does not necessarily contain only one luminaire or one light point.

When taking into account the reflection of the road surface the relationship between the FU and luminance requirements can be calculated:

$$L\ [cd/m^2] = FU \times Q_0 / A$$

Where,

- Q_0 is the average luminance coefficient as defined in 3.3.5.

4.3.1.2 Formulas related to lamp consumption per luminaire

The annual consumption of lamps per luminaire in standard conditions is straightforward and related to the lamp survival factor (LSF) and the time period for group replacement (t_{group}) in years:

$$N_y = 1 / t_{group} + (1 - LSF) / t_{group}$$

Where:

- LSF is defined in chapter 1
- t_{group} is discussed in chapter 2.

4.3.1.3 Remark on 'Light pollution'

Much as artificial lighting provides a very useful service, it has also initiated a side-effect known as 'light pollution'. For example, in most of our urban environments it is no longer possible to see any but the brightest stars as a consequence of light emitted by outdoor lighting illumination.

Light pollution is defined in guideline CIE 126(1997) on 'Guidelines for minimizing sky glow' as 'a generic term indicating the sum-total of all adverse effects of artificial light'.

In the next sections a short summary is included on adverse effects of artificial light that could be identified in literature.

Sky glow' (fig. 1.a) is defined (CIE 126(1997)) as:
'the brightening of the night sky that results from the reflection of radiation (visible and non-visible), scattered from constituents of the atmosphere (gas molecules, aerosols and particulate matter), in the direction of the observation. It comprises two separate components as follows:

(a) Natural sky glow – That part of the sky glow which is attributed to radiation from celestial sources and luminescent processes in the Earth's upper atmosphere.
(b) Man-made sky glow – That part of the sky glow which is attributable to man-made sources of radiation (e.g. outdoor electric lighting), including radiation that is emitted directly upwards and radiation that is reflected from the surfaces of the Earth'.

Potential obtrusive effects from outdoor lighting are described in technical guide CIE 150 (2003) on 'The limitation of the effects of obtrusive light from outdoor lighting installations'.. Obtrusive light is defined (CIE 150) as 'spill light which because of quantitative, directional or spectral attributes in a given context, gives rise to annoyance, discomfort, distraction or a reduction in the ability to see essential information' (CIE 150 (2003)).

There are also adverse effects of outdoor lighting reported on (CIE 150 (2003), Narisada K. & D. Schreuder (2004), Steck (1997))): the natural environment (e.g. insect, disruption of bird habitats, ..), residents (e.g. light trespass in bedrooms), on transport system users (e.g. glare(fig.1.a)), sightseeing and astronomical observation (e.g. fig. 1a).

It is therefore also possible to distinguish 'astronomical light pollution' that obscures the view of the night sky, from 'ecological light pollution', that alters natural light regimes in terrestrial and aquatic ecosystems. 'The more subtle influences of artificial night lighting on the behaviour and community ecology of species are less well recognized, and could constitute a new focus for research in ecology and a pressing conservation challenge' (T. Longscore & C. Rich (2004)).
.

Figure 21: Examples of light pollution: sky glow (left) and glare (right)

Sky glow has been quantified by maps of the artificial sky brightness derived from DMSP satellite measurements (Cinzano et al. (2000, 2004), (Figure 22)). Its reduction is part of ongoing research. Pressure groups, such as the International Dark-Sky Association (see www.savethenight.eu), have been addressing the matter and in recent years several local and national ordinances have been issued that aim to reduce "light pollution" (see also chapter 1.3). For what concerns street lighting luminaires research shows that the emission angle of the upward light flux plays a role in reducing sky glow (Cinzano et al. (2000a)). It was found that if the distance from the city increases, the effects of the emission at high angles above the horizontal decrease relatively to the effects of emission at lower angles above the horizontal. Outside some kilometers from cities or towns, the light emitted by luminaires between the horizontal and 10 degrees above is as important as the light emitted at all the other angles in producing the artificial sky luminance (Cinzano et al. (2000a)). Therefore to reduce the light emitted between the horizontal and 10 degrees above by street lighting luminaires could be an objective in fighting light pollution.

Until now, existing scientific evidence or research have not lead to national or international legislation aiming at mitigating effects of "light pollution". Though not identified in the Annex I of the 2005/32/EC Directive "light pollution" is treated as an environmental aspect in the context of this study. However in the absence of scientific evidence that would allow quantifying possible adverse effects of "light pollution", we are not in a position to consider "light pollution" as a significant environmental impact under the terms of Article 15 of the directive (2005/32/EC). This means that the quantification of light pollution impacts will not be part of the environmental impact analysis of chapter 5. In the chapters discussing the improvement potential (6-8), it will be considered whether the design options aiming at improving other environmental aspects of street lighting have an impact on light pollution as well. Design options whose only aim would be to reduce light pollution will be mentioned in chapter 6, but their impact cannot be quantified in chapter 7.
It is expected that measures aiming at increasing the energy efficiency will reduce the amount of wasted light and have a positive effect on mitigating"light pollution" .

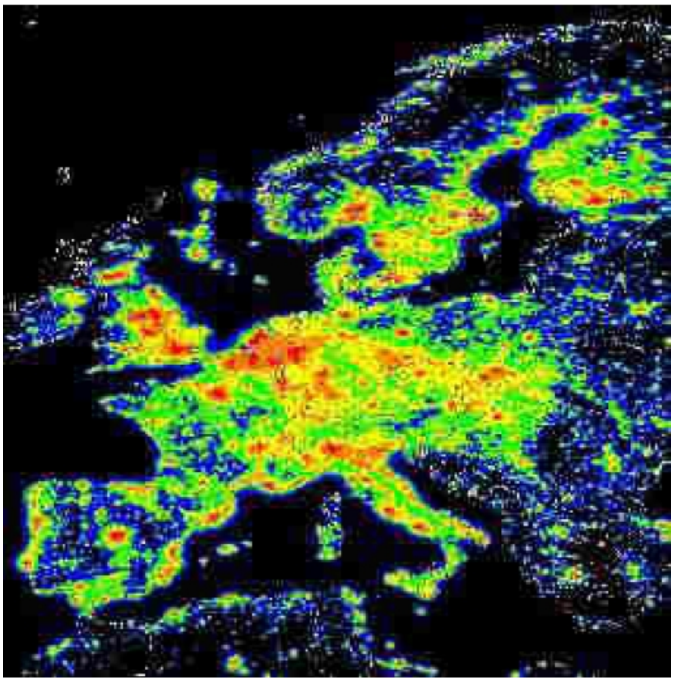


Figure 22: Artificial Night Sky Brightness in Europe, Colours correspond to ratios between the artificial sky brightness and the natural sky brightness of: <0.11 (black), 0.11-0.33 (blue), 0.33-1 (green), 1-3 (yellow), 3-9 (orange), >9 (red). (Cinzano et al. (2000))

4.3.1.4 Assessment of relevant product performance parameters per road category and per product category

In the next tables an overview of performance parameters for products on the market is enclosed per road category defined in this study and per lamp type. For commercial reasons brand names were not mentioned. The last column (AVG) includes the average values that will be used in chapter 5 for the Business As Usual (BAU) scenario. For street lighting, price informations are sometimes difficult to obtain because in a B2B market high price discounts are common practice. In this study, prices that are common for large custumers (personal experience from a team member as former responsible for over 750,000 street lighting points) were compaired with catalogue prices. Taking into account that most custumers are smaller, a weighed average was proposed in an expert meeting with European sector organisations. The sector experts agreed with this proposal.

The LMF values in the tables are chosen in accordance with technical report CIE 154 and are related to the ingress (IP-rating) and 'defined pollution categories'.
For road categories F (fast traffic) and M (mixed traffic) in this study the 'medium pollution' category is used, defined as: “Moderate smoke or dust generating activities nearby - Moderate to heavy traffic - The ambient particulate level is no more than 600 micrograms per cubic metre”.
For road category S (slow traffic) the 'low pollution' category is used, defined as: “No nearby smoke or dust generating activities and a low ambient contaminant level - Light traffic - Generally limited to residential or rural areas - The ambient particulate level is no more than 150 micrograms per cubic metre”.

The LLMF values in the tables are chosen in accordance with technical report CIE 154 (2003), adapted to the new values presented by ELC.

The factor UF results from photometric calculations.
For this calculations, road geometry and pole distances were taken in accordance with typical values in chapter 3.
The average illuminance E_{avg} [lx] on the road was calculated for different luminaires.
For the illuminated area one section between poles, A [m²] = road width [m] x pole distance [m] was taken and accordingly the luminous flux emitted by one lamp [lm].
Because:

$$E_{avg} \text{ [lx]} = \text{Useful luminous flux [lm] / A [m}^2\text{]}$$

we can calculate the useful luminous flux.
So UF can be calculated as:

$$UF = \text{Useful luminous flux / Luminous flux emitted by the lamp.}$$

Putting into service was taken into account for some luminaires where optics can be regulated (e.g. by changing the position of the lamp in the reflector or by changing inclination angle); those luminaires are identified in OM, CM or CH as stated below. Some softwares can calculate the most energy-economical position and consequently this position was applied. For some luminaires in OM and CM (partly) and for all luminaires in GO, GH, DR and OP, no regulation is possible and the standard position was applied.

For the analysis of the performance parameters in this study, the following luminaire types are considered:

- Globes with omni-directional diffuser (GO) (only in category S)
- Globes or street lanterns with hemispherical diffuser (GH) (only in category S)
- Decorative luminaire with reflector and no diffuser (DR) (only in category S)
- Open luminaire with poor reflector (OP) (only in category S and M)
- Open luminaire with medium reflector (OM)
- Closed luminaire with medium reflector (CM)
- Closed luminaire with advanced optic reflector (CH)

The energy efficiency in the use-phase is included in the parameter "Ey/FU (kWh/(y.lumen))" which reflects the yearly energy use (4000 h operation) per functional lumen.

Different lamps found on the market within each family (e.g. HPS) were used with corresponding parameters.

Table 62: Category F (Fast traffic) luminaires with HPS lamp

parameter						**AVG**
lamp type	**HPS (BF)**	**HPS (BF)**	**HPS (TC)**	**HPS (TC)**	**HPS (TC)**	**HPS**
Plamp (W)	250	250	250	250	250	250
tgroup (y)	4	4	4	4	4	4
light point distance (m) type.	50	50	50	50	50	50
ηlamp (lm/W)	124	124	132	104	132	123
LLMF	0,95	0,95	0,95	0,95	0,95	0,95
LSF	0,94	0,94	0,94	0,94	0,94	0,94
ηballast	91%	91%	91%	91%	91%	91%
Lamp unit cost €	20	20	20	18	20	20
Ballast unit cost €	40	40	40	40	40	40
luminaire type	**OP**	**OM**	**OM**	**CH**	**CH**	
IP	22	54	54	65	65	
UF	0,37	0,40	0,40	0,54	0,54	0.45
LMF	0,51	0,78	0,78	0,85	0,85	0.75
ULOR	1,5%	2,8%	2.8%	1,5%	1,5%	
DLOR	68,4%	66,6	66.6%	83,5%	83,5%	
Luminaire unit cost €	180	200	205	220	220	205
Ey/FU (kWh/(y.lumen))	0,21	0,13	0,12	0,10	0,08	

Table 63: Category F (Fast traffic) luminaires with LPS lamp

parameter			**AVG**
lamp type	**LPS**	**LPS**	**LPS**
Plamp (W)	131	131	131
tgroup (y)	3	3	3
light point distance (m) type.	35	35	35
ηlamp (lm/W)	198	198	198
LLMF	0,87	0,87	0,87
LSF	0,62	0,62	0,62
ηballast	87%	87%	87%
Lamp unit cost €	48	48	48
Ballast unit cost €	77	77	77
luminaire type	**CM**	**CM**	
IP	54	65	
UF	0,33	0,33	0.33
LMF	0,82	0,87	0.84
ULOR	3,6	3,6	3,6
DLOR	66,4	66,4	66,4
Luminaire unit cost	505	565	535
Ey/FU (kWh/(y.lumen))	0,10	0,10	

Table 64: Category M (mixed traffic) luminaires with HPS lamp

parameter						**AVG**
lamp type	**HPS (BF)**	**HPS (BF)**	**HPS (TC)**	**HPS (TC)**	**HPS (TC)**	**HPS**
Plamp (W)	150	150	150	150	150	150
tgroup (y)	4	4	4	4	4	4
light point distance (m) type.	30	30	30	30	30	30
ηlamp (lm/W)	113	113	117	100	117	112
LLMF	0,95	0,95	0,95	0,95	0,95	0,95
LSF	0,94	0,94	0,94	0,94	0,94	0,94
ηballast	89%	89%	89%	89%	89%	89%
Lamp unit cost €	19	19	19	17	19	
Ballast unit cost €	39	39	39	39	39	
luminaire type	**OP**	**OM**	**CM**	**CH**	**CH**	
IP	22	22	54	65	65	
UF	0.3	0.35	0.4	0.45	0.45	0.39
LMF	0,51	0,51	0,78	0,85	0,85	0.7
ULOR	2,1	2,5%	0,2%	0,2%	0,2%	
DLOR	71,4	70,7%	81,6%	81,6%	81,6%	
Luminaire unit cost €	140	160	170	187	187	169
Ey/FU (kWh/(y.lumen))	0,29	0,25	0,14	0,13	0,11	

Table 65: Category M (mixed traffic) luminaires with HPM lamp

parameter				**AVG**
lamp type	**HPM**	**HPM**	**HPM**	**HPM**
Plamp (W)	400	400	400	400
tgroup (y)	3	3	3	3
ηlamp (lm/W)	55	55	60	57
light point distance (m) type.	25	25	25	25
LLMF	0,76	0,76	0,76	0.76
LSF	0,76	0,76	0,76	0.76
ηballast	95%	95%	95%	95%
Lamp unit cost €	11,5	11,5	13	12
Ballast unit cost €	30	30	30	30
luminaire type	**OP**	**CM**	**CM**	
IP	22	54	54	
UF	0,25	0,27	0,3	0.27
LMF	0,53	0,82	0,82	0.72
ULOR	2,5	2,8	2,8	
DLOR	67,0	66,6	66,6	
Luminaire unit cost €	180	220	250	650
Ey/FU (kWh/(y.lumen))	0,80	0,48	0,40	

Table 66: Category S (slow traffic) luminaires with HPM lamp

parameter						**AVG**
lamp type	**HPM**	**HPM**	**HPM**	**HPM**	**HPM**	**HPM**
Plamp (W)	125	125	125	125	125	125
tgroup (y)	3	3	3	3	3	3
light point distance (m) type.	15	15	15	15	15	15
ηlamp (lm/W)	50	50	50	54	54	51
LLMF	0.78	0.78	0.78	0.78	0.78	0.78
LSF	0.76	0.76	0.76	0.76	0.76	0.76
ηballast	89%	89%	91%	91%	91%	91%
Lamp unit cost	3.5	3.5	4	4	4	3.8
Ballast unit cost	18	18	21	21	21	20
luminaire type	**OP**	**GO**	**GH**	**OM**	**CM**	
IP	22	43	43	22	43	
UF	0.23	0.11	0.18	0.3	0.3	0.22
LMF	0.78	0.84	0.84	0.78	0.84	0.82
ULOR	1%	39%	21%	-%	-	
DLOR	60%	30%	51%	-%	-	
Luminaire unit cost	140	150	160	150	165	153
Ey/FU (kWh/(y.lumen))	0,68	1,31	0,78	0,47	0,44	

Table 67: Category S (slow traffic) luminaires with HPS lamp

parameter								**AVG**
lamp type	**HPS**	**HPS**	**HPS**	**HPS**	**HPS**	**HPS**	**HPS**	**HPS**
Plamp (W)	70	70	70	70	70	70	70	70
tgroup (y)	4	4	4	4	4	4	4	4
light point distance (m) type.	30	30	30	30	30	30	30	30
ηlamp (lm/W)	83	83	94	83	83	94	94	88
LLMF	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
LSF	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
ηballast	83%	83%	83%	83%	85 %	85 %	85 %	84%
Lamp unit cost	15	15	15	15	15	15	15	15
Ballast unit cost	28	28	32	28	28	32	32	30
luminaire type	**GO**	**GH**	**DR**	**OP**	**OM**	**CM**	**CH**	
IP	43	43	65	22	22	43	65	
UF	0.11	0.18	0.32	0.23	0.3	0.3	0.49	0.27
LMF	0.84	0.84	0.89	0.78	0.78	0.84	0.89	0.84
ULOR	39%	21%	2%	1%	-%	-	1%	
DLOR	30%	51%	69%	60%	-%	-	82%	
Luminaire unit cost	160	170	210	140	160	175	210	175
Ey/FU (kWh/(y.lumen))	0,66	0,4	0,19	0,34	0,26	0,21	0,12	

Table 68: Category S (slow traffic) luminaires with MH lamp

parameter								**AVG**
lamp type	**CMH**	**CMH**	**CMH**	**CMH**	**CMH**	**CMH**	**CMH**	**CMH**
Plamp (W)	70	70	70	70	70	70	70	70
tgroup (y)	2	2	2	2	2	2	2	2
light point distance (m) type.	20	20	20	20	20	20	20	20
ηlamp (lm/W)	90	90	90	90	90	90	90	90
LLMF (TBC)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
LSF (TBC)	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
ηballast	83%	83%	83%	83%	85 %	85 %	85 %	84%
Lamp unit cost	22	22	22	22	22	22	22	22
Ballast unit cost	28	28	32	28	28	32	32	30
luminaire type	**GO**	**GH**	**DR**	**DR**	**DR**	**CM**	**CH**	
IP	43	43	65	54	43	43	65	
UF	0.11	0.18	0.32	0.32	0.32	0.3	0.49	0.27
LMF	0.84	0.84	0.91	0.9	0.85	0.84	0.89	0.84
ULOR	39%	21%	2%	2%	2%	-	1%	
DLOR	30%	51%	69%	69%	69%	-	82%	
Luminaire unit cost	160	170	210	210	210	175	210	192
Ey/FU (kWh/(y.lumen))	0,83	0,51	0,26	0,27	0,27	0,3	0,17	

Table 69: Category S (slow traffic) luminaires with CFL lamp

parameter				**AVG**
lamp type	**CFL**	**CFL**	**CFL**	**CFL**
Plamp (W)	36	36	36	36
tgroup (y)	3	3	3	3
light point distance (m) typ.	15	15	15	15
ηlamp (lm/W)	80	80	80	80
LLMF	0.9	0.9	0.9	0.9
LSF	0.96	0.96	0.96	0.96
ηballast	80%	80%	80%	80%
Lamp unit cost	4	4	4	4
Ballast unit cost	5	5	5	5
luminaire type	**GH**	**GH**	**CM**	
IP	54	54	65	
UF	0.1	0.1	0.2	0.14
LMF	0.88	0.88	0.89	0.88
ULOR			5%	
DLOR			68%	
Luminaire unit cost	150	150	150	150
Ey/FU (kWh/(y.lumen))	0,79	0,79	0,39	

4.3.2 Assessment of resources consumption (energy, lamps) during product life in off-standard conditions (i.e. at variable load)

The relevant parameters are defined in chapter 3 and are: BMF (Ballast Maintenance Factor), BGF (Ballast Gain Factor) and LGF (Lamp Gain Factor).
The quantitative assessment of these parameters (BMF, BGF, LGF) was also done in chapter 3 and only the applicable formulas are enclosed hereafter.

The real power consumption (P_{real}) per luminaire is related to the standard power consumption by:

$$P_{real}\ [W] = P\ /\ (BMF \times BGF \times LGF)$$

The real annual energy consumption (E_{yreal}) per luminaire is related to the standard energy consumption by:

$$E_{yreal}\ [kWh] = E_y\ [kWh]\ /\ (BMF \times BGF \times LGF)$$

4.4 Use phase (system)

This task is important to understand the limitations that are imposed by the outdoor street environment and also aspects related to 'putting into service of street lighting equipment'. This section identifies and describes the functional system to which the product in question belongs and identifies and quantifies to the extent possible those product features that can reduce the environmental impact not only of the product but of the system as a whole. Please note that the scope of the system analysis is wider than the scope of the EuP Directive. The question that should be posed during the analysis is whether and how the system performance could be improved leading to environmental benefits with measures that are restricted only to issues that can be influenced by technical features or additional information of the product under investigation as defined in chapter 1. Furthermore, the system analysis serves as an addition to the more traditional product-specific analysis in section 4.3, i.e. to design product specific legislation (if any) in such a way that it would not make system-oriented innovations impossible.

General description of product system interference

Any functional lighting system has a large product-system interference because the luminaire should direct the light towards the surface or objects that need to be lit. This is not always the case e.g. in street lighting when light is directed toward the sky (see Figure 23).

Figure 23: More than half of the light is directed to the sky or sea and is wasted

Even the most efficient luminaires can lead to a waste of light when they are not properly used due to a wrong tilt angle orientation or optics of the luminaire, therefore proper lighting design and installation is of equal importance to obtain energy efficient street lighting (Figure 24).

Figure 24: A high amount of light is directed to the houses and is wasted

For street lighting the lighting performance requirements are imposed by European standards per road class (EN 13201-2: Road lighting) (see also chapter 1). These performance requirements are quality requirements related to light levels, uniformity and glare but does not include any energy performance requirements.

The performance of energy consumption for street lighting with illuminance requirements (defined category S in chapter 1) is mainly dependent on 2 factors:
1. Configuration (implantation) of light points.
   This is also very diverse in Europe because of different local conditions. Luminaires can be attached to own poles, walls, cables or electricity distribution poles. Poles can also be installed in many different configurations (single side, middle, zigzag,..) (see also chapter 3) with many heights and interdistances.
2. The luminaire performance itself.

The performance of energy consumption for street lighting with luminance requirements (category F and M in chapter 1) is mainly dependent on 3 factors:
1. The road surface reflection.
2. Configuration (implantation) of light points.
   Configurations in Europe are also very diverse because of different local conditions. Luminaires can be attached to own poles, walls, cables or electricity distribution poles. Poles can also be installed in many different configurations (single side, middle, zigzag,..) with many heights, interdistances, luminaire tilt angles. Also the road or surface to be lit can vary.
3. The luminaire performance itself.

(Marc Gillet (MG), Schréder expert consultation on 3/4/06): 'Because of the many variations in factors 1,2 and 3' one luminaire can be tuned in up to 32 configurations with different optical configurations in his product portfolio. This is according to MG required to suit a particular environment (factor 1 and 2) and road class requirements (EN 13201-1) with the lowest energy consumption. Also simply chosing between the few CIE road surface classes in the design phase of the project can lead to important errors in road luminance after installation (-40 up to 60 %). In countries with wet climate this should be taken into account (more reflection). Because of the wide variety of combinations, the best fit solution should, according to MG, be part of a detailed photometric study.'

The lighting system is also linked to the electricity grid. The impact is limited to line voltage variations (see also chapter 3) and separate grid shared with residential distribution grid. A separate distribution grid offers more possibilities for telemanagement, switch off or dimming systems.

<u>Formulas related to energy efficiency at installation level:</u>

To measure street lighting energy efficiency the parameter "Lighting Power Density" (LPD) is introduced (see also reference (IEA (2006)).

For category F and M with luminance requirements:

$$LPD_l\ [W/((cd/m^2).m^2)] = P / (L \times A)$$

For category S with illuminance requirements:

$$LPD_i\ [W/(lx.m^2)] = P / (E \times A)$$

Where,

- A is street area surface (m²) by multiplying street width with average distance between light points. Street width includes also pedestrian and cyclists area (if any). Average distance between light points is best determined by light points per km, since one pole does not necessarily contain only one luminaire or one light point.
- E and L are defined in chapter 1.

As a consequence, the lighting power density can be calculated from the defined equipment (lamp, ballast, luminaire) performance parameters:

$$LDP_i\ [W/(lx.m^2)] = 1 / \{(UF \times LMF) \times (\eta_{lamp} \times LLMF) \times (\eta_{ballast})\}$$

When taking into account the reflection of the road (parameter Q_0 as defined in chapter 3) LPDl can also be calculated:

$$LDP_l\ [W/\{(cd/m^2).m^2\}] = LDPi \times Q_0$$

Where,

- Q_0 is defined in chapter 3.

The real "Lighting Power Density" ($LPDi_{real}$, $LPDl_{real}$) is related to the Lighting Power Density (LPD_l, LPD_i) under standard conditions by:

$$LPDl_{real}\ [W/((cd/m^2).m^2)] = LPDl / (BMF \times BGF \times LGF)$$

and

$LPDi_{real}$ [W/(lx.m²)] = P / LPDi / (BMF x BGF x LGF)

Preliminary conclusions:

1. The system impact described on our analytical energy performance model (defined LPD_i and LPD_l) is enclosed in the utilization factor(UF).
   This utilization factor (UF) for a luminaire is the result of a calculation with the photometric data of the luminaire and the light point configuration, road reflection and dimensions and thus taking the 'system' into account (see also 4.3.1.4).
2. Possible product related policy options that are related to UF are restricted by this system relationship.
3. An energy efficiency requirement could be linked to the performance requirements (EN 13201 standards series), e.g. in $LPDl_{real}$ or $LPDi_{real.}$
4. We will have to make a difference in our study for identifying and evaluating policy options between "total new street lighting system" design where there exists freedom to lighting point heights and/or distances and "partial system innovations" where only certain parts (lamps, lamps + ballast, lamps + ballast + luminaire) can be changed.

4.5 End-of-life phase

The environmental impact of the end-of-life phase of the lamps is modelled according to the VHK-model. The parameters used as input for this environmental assessment are shown in the following table and are identical for all types of lamps, control gear and luminaires. Most input data in the end of life phase are directly related to the input parameters for the production. An important factor that must be defined here is the percentage of mercury content that is not captured during the processing of the waste lamps. It is assumed that 10% of the mercury present in lamps is emitted during the end of life phase due to non-perfect collection. We have not found any public information on this average percentage of fugitive mercury in EU-25 and the consulted stakeholders could not provide us with better data. We assume that public data will become available in the near future due to the WEEE requirements.

Table 70: Input data for the environmental assessment of the end of life processing of the lamps, control gear and luminaires

DISPOSAL & RECYCLING		**unit**
Description		
Substances released during Product Life and Landfill		
Refrigerant in the product (Click & select)	0	g
Percentage of fugitive & dumped refrigerant	0%	
Mercury (Hg) in the product	0 to 0.07	g Hg
Percentage of fugitive & dumped mercury	10%	
Disposal: Environmental Costs perkg final product		
Landfill (fraction products not recovered) in g en %		5%
Incineration (plastics & PWB not re-used/recycled)		g
Plastics: Re-use & Recycling ("cost"-side)		g
Re-use, Recycling Benefit	**in g**	**% of plastics fraction**
Plastics: Re-use, Closed Loop Recycling (please edit%)		1%
Plastics: Materials Recycling (please edit% only)		9%
Plastics: Thermal Recycling (please edit% only)		90%
Electronics: PWB Easy to Disassemble ? (Click&select)		**NO**
Metals & TV Glass & Misc. (95% Recycling)		

The parameters that are taken into account for the modelling of the environmental impact of the lamps, control gear and luminaires are assumed to be identical. According to the VHK default values it is assumed that 5% of the materials go to landfill, 90% of the plastics is incinerated, 9% is recycled and 95% of the metals and glass is recycled.

5 DEFINITION OF THE BASE CASE AND ENVIRONMENTAL IMPACT ASSESSMENT

This chapter describes the modelling of the base case that is the reference for the environmental and technical/economical improvements to be established in chapter 7. The base case is a theoretical approximation of ‘the average’ products in: the installed base of street lighting (or ‘stock’) and new sales of street lighting.

Before explaining the modelling procedures, the following definition of terms should be clearly kept in mind.

Stock : for a given year is the total of the installed base

New Sales : new sold luminaires (including lamp, ballast) in a given year, and one should clearly distinguish:

1. **Replacement sales :** new luminaires for replacement of old luminaires at their end of life, and subject to the lock-in effect, meaning that the old poles and existing infrastructure are not changed;

2. **New project sales :** new luminaires to lit new streets, previously unlit existing streets, or previously lit streets where also poles are at their end of life. New project sales is thus always accompanied with new infrastructure (poles, power grid, etc). While improvement options for replacement sales are limited by the ‘lock-in effect’ (see section 3.3.1), this is not the case for new project sales where luminaire/ lamp/ ballast selection takes place in function of complete optimized installations (pole distance, pole height, etc…)

$$\mathbf{STOCK_{2006} = STOCK_{2005} + NEW\ SALES_{2006}}$$

$$\mathbf{NEW\ SALES_{2006} = REPLACEMENT\ SALES_{2006} + NEW\ PROJECT\ SALES_{2006}}$$

All results are generated using the EuP EcoReport, described in Chapter 5 of the MEEuP Methodology Report. It is based on input data from chapter 4 regarding the Bill of Materials (BOM), estimations regarding packaging and packaged volume, energy consumption during the use phase and finally a default scenario of the recycling/disposal phase. These inputs are then multiplied with the Unit Indicators supplied in chapter 5 of the MEEuP Methodology Report. On the project website www.eup4light.net, the EcoReports for the different BaseCases can be consulted.

Figures on EU sales, stock, growth, come primarily from chapter 2 as do the financial data on product prices, energy rates, etc. that serve to make a financial Life Cycle Cost assessment. In 2005, 56 mio. luminaires in the stock are assumed (CELMA & expert inquiry). Given the average pole distances from the technical analysis (see chapter 4); the share of the total road network in the EU25 that is lit can be calculated (approximately 22%). Assuming this share to be constant over time; street lighting growth is then only related to road network growth (1,2% annual growth, see chapter 3). When assuming the ratio pole life versus luminaire life to be 2, the share of new luminaire sales to be locked-in existing infrastructure (power grid, pole, …) is approximately 40%. This results in calculated data on annual stock and sales.

As suggested by the MEEuP report and Case Study on Street Lighting (VHK, 2005), the modelling on the improvement ratio Stock vs. New Products is expanded. On one hand the long lifetime of luminaires (average 30 yrs) makes that the 'average' characteristics and composition of stock-equipment are substantially different from that of new sold equipment. On the other hand, as mentioned above, a share of the new sales serves to replace existing old products but are often 'locked-in' an existing infrastructure. For the improvement options (chapter 7), this distinction is important to consider.

From chapter 3 it can be concluded that there are no substantial differences between Standard conditions and Real-Life conditions that are relevant regarding the environmental impact assessment and life cycle cost calculation of the "Business-As-Usual" (BAU) BaseCase (see table below). The only parameter that has some influence on the results of the environmental impact assessment and life cycle costs (but only on electricity use) is the Ballast Maintenance Factor or BMF (see chapter 3, section 3.1.4) that is introduced in this study to compensate for the influence of non-standard (testing) temperature-, and line voltage conditions and also the influence on power consumption due to lamp- and capacitor ageing. For the BaseCase calculations in this section, this correction factor is taken into account.

In chapter 8, sensitivity analysis on the BaseCase results is done for aspects on luminaire lifetime (BaseCase = 30 yrs) and share of road infrastructure lit (BaseCase = 15%, 23%, 23% for respectively road categories F, M, S).

Table 71 : Difference in inputs Real-Life versus Standard

Parameter	Standard	Real-Life	Improvement Options
(section 3.1.1) Lamp Gain Factor (LGF)	1 for road categories F, M, S	Only relevant for CFL and CMH luminaires in road classes S5 and S6 (EN 13201-2) as part of class C in this study and are resp.: 1,1 and 1,2. Because these CFL, CMH luminaires represent only marginal market/stock-share, this difference is considered negligible.	Might become relevant for options where shifting to more CFL, CMH luminaires in road class C.
(section 3.1.2) Burning hours	4000 hrs / yr for road categories F, M, S	=	=
(section 3.1.3) Ballast Gain Factor (BGF)	1 for road categories F, M, S	1 since no BAU-use of electronic ballasts	Might become relevant for options where shifting to bi-level dim ballast (1,33) or electronic dim ballast (1,8)
(section 3.1.4) Ballast Maintenance Factor (BMF)	1 for road categories F, M, S	0,95 for magnetic ballasts, for road classes A,B,C	For options where shifting to electronic ballasts, this BMF is 1.

This results in the following EuP EcoReports that are further elaborated in this chapter 5:

- calculation of production/distribution/'end-of-life'-related impacts for 'part-level EuP products' (see chapter 1.1.1. for definition):
  - Section 5.1: BaseCase lamps with their related electromagnetic BaseCase ballasts.
  - Section 5.2: BaseCase luminaire (excluding lamp & ballast), based on data for 3 'average' luminaires with different material compositions.
- the life cycle impacts, including the use phase-related impacts of street lighting, thus taking into account the energy consumption of the lamps, efficiency of ballasts, efficiency of luminaires, etc, are considered in the following BaseCases at 'product-configuration level':
  - Section 5.3: BaseCase for the average new sales, distinguishing new project sales (no lock-in effect) and replacement sales (lock-in effect).
  - Section 5.4: BaseCase for the existing installed base and EU25 totals.

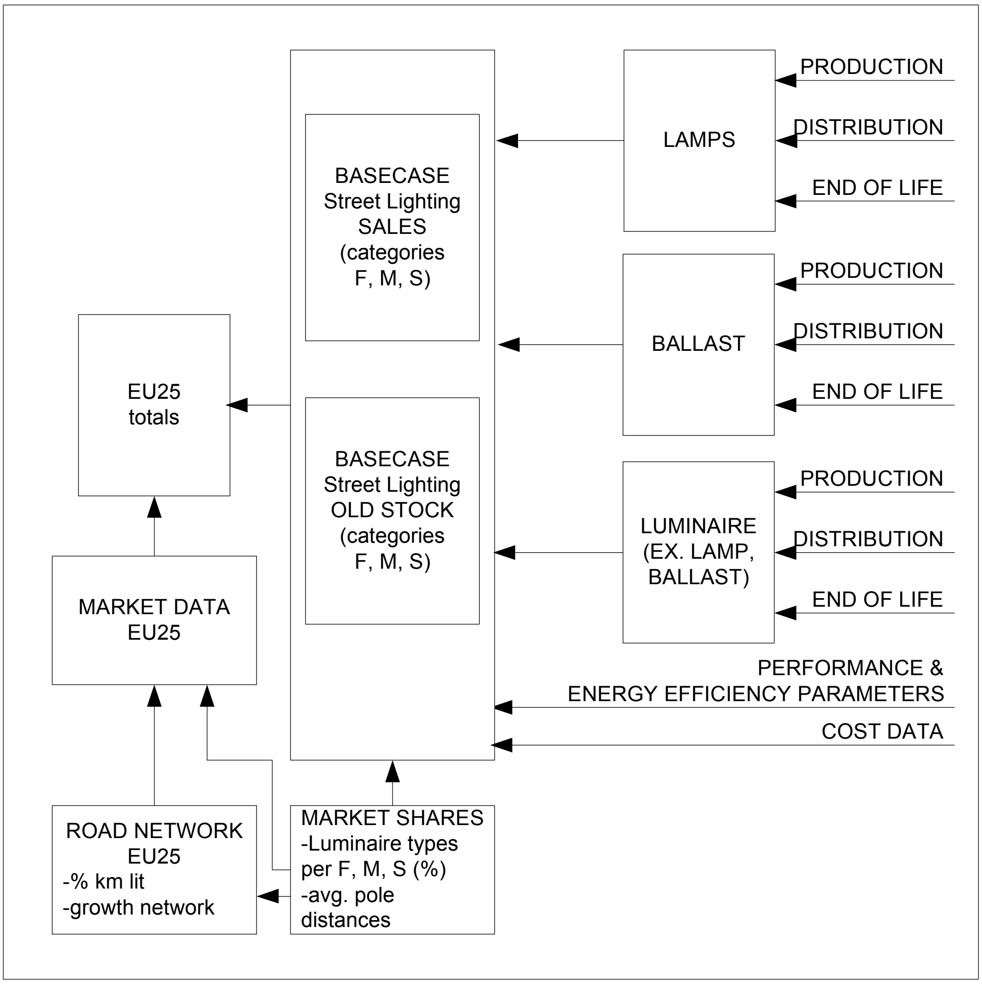


Figure 25; Data flow of base case calculation

In section 5.3 and 5.4, each single BaseCase for categories F, M and S is calculated as a weighted average of different representative luminaire/lamp/ballast-configurations in each respective category.

Note that each single product configuration has different functional lumen outputs (see chapter 1.1.3 for definition of functional unit), therefore a one-on-one comparison or substitution of configurations is not possible. From a total system perspective, also the typical pole height and distance should therefore be determinded in order to result in single product configurations having a similar street lighting performance (lx or cd/m2). For this reason, the MEEuP impact and cost results which are calculated per unit product (can be consulted on www.eup4light.bet) should be correlated to their functional lumen output in order to compare them with each other, i.e. CO2 emissions per unit functional lumen of the BaseCase CFL luminaire in category S compared to CO2 emissions per unit functional lumen of the BaseCase CMH luminaire in the same category.

5.1 BaseCase Lamps and ballasts

5.1.1 Product-specific Inputs

In chapter 4, the product-specific inputs are listed regarding the Bill of Materials (BOM), packaging volume and waste scenario for all these lamps and ballasts.

Unit cost data for lamps and ballasts are retrieved from limited market survey and are shown in section 2.4.1. However, at part-level, no Total Life Cycle Cost is calculated, only at product-level in section 5.3 (LCC) and 5.4 (annual expenditure due to stock).

Category F
In road category F (fast traffic), almost uniquely sodium lamps are used. The literature and expert inquiry has pointed out that typical wattages used for fast traffic motorways are usually 150W, 250W HPS and 131W, 135W and 180W LPS. The only EU-countries with still substantial shares of LPS luminaires in category F, in the installed base, are: Belgium, Holland, Sweden, U.K. and Ireland. The trend is that these are being replaced by HPS (new luminaire sales). For the BaseCase calculation we assume for the existing stock of luminaires 2005 a weighted ratio of 85% HPS and 15% LPS luminaires, with most representative wattages 250W and 131W respectively. For replacement sales, luminaires are replaced with luminaires of the same type. For new project sales we assume no longer LPS sales (thus 100% HPS). These ratios are based on generic market data and expert assumptions since no other detailed reliable market data are available (see chapter 2). The table below gives an overview of the input data for luminaire types, category F.

Note that at installation level, more 131W LPS luminaires are required per km as compared to 250W HPS luminaires to achieve similar minimum luminance levels (between 0,75 and 2 cd/m2 for road category F). For 131W LPS lamps this means a typical luminaire distance of 30-40m, while for 250W HPS lamps this is 45-50m.

As according to the technical analysis on lamps (see section 4.3.1.4), an 131W LPS lamp has an efficiency (ηlamp) of 198 lm/W while a 250W HPS has an average ηlamp of 123 lm/W. In the BaseCase, these lamps are accompanied with electromagnetic ballasts, with efficiencies of 91% for HPS and 87% for LPS.

Table 72: Luminaire types in category F

Luminaire types, CAT F	Stock	Sales, New project	Sales, Replacement	Sales, Total
With Mercury lamp	0%	0%	0%	0%
With Sodium lamp	100%	100% (100% HPS)	100% (85% HPS; 15% LPS)	100% (95,5% HPS; 4,5% LPS)
With Metal Halide lamp	0%	0%	0%	0%
With CFL	0%	0%	0%	0%
Total	100%	100%	100%	100%

Category M

In road category M (mixed traffic), mainly sodium and high pressure mercury lamps are used. Typical wattages used are 250W, 400W HPM and 100W, 150W, 250W HPS.

In the stock of luminaires also 90W, 131W, 135W LPS can be found, but these represent minor shares and are being replaced with HPS lamps/luminaires. The expert inquiry showed that no countries intend to use these lamps anymore in category M and S for new lit streets. There are several reasons for this: when comparing LPS and HPS luminaires, LPS lamps have a higher lamp efficacy but UF is much lower, and LPS lamps are more expensive and have poor color rendition compared to HPS. (Note that in category F, LPS was still considered because the potential is higher in this category. The reason is that color rendition requirements are lower on highways and the UF of LPS-luminaires increases when installing the luminaires in the central reserve of highways.)

HPM lamps are also being replaced but represent still a substantial share in the installed base. 150W HPS and 400W HPM are taken as representative lamp types for category M street lighting. For the BaseCase calculation we assume for the existing stock of luminaires 2005 a weighted ratio of 57% HPS and 43% HPM luminaires. For replacement sales, luminaires are replaced with luminaires of the same type. For new project sales we assume 20% HPM and 80% HPS. These ratios are based on generic market data (see chapter 2) and expert assumptions since no other detailed reliable market data are available. The table below gives an overview of the input data for luminaire types, category M.

Note that at installation level, about the same amount of 400W HPM luminaires are required per km as compared to 150W HPS luminaires to achieve similar minimum illuminance levels (between 10 and 20 lx for road category M). For both 400W HPM and 150W HPS lamps this means a typical luminaire distance of 25-30m.

As according to the technical analysis on lamps (see section 4.3.1.4), a 400W HPM lamp has an efficiency (ηlamp) of 57 lm/W while a 150W HPS has an average ηlamp of 112 lm/W. In the BaseCase, these lamps are accompanied with electromagnetic ballasts, with efficiencies of 95% for HPM and 89% for HPS.

Table 73: Luminaire types in category M

Luminaire types, CAT M	Stock	Sales, New project	Sales, Replacement	Sales, Total
With Mercury lamp	43%	20%	43%	30,5%
With Sodium lamp	57%	80%	57%	69,5%
With Metal Halide lamp	0%	0%	0%	0%
With CFL	0%	0%	0%	0%
Total	100%	100%	100%	100%

Category S

In road category S (slow traffic), mainly sodium and mercury lamps are used and to lesser degree compact fluorescent and metal halide lamps. Typical wattages used are 125W HPM, 50W, 70W HPS, 70W MH and 36W CFL. In the stock of luminaires also 35W, 55W LPS can be found, but these represent minor shares and are being replaced with other lamp types. HPM are also being replaced but represent still a substantial share in the installed base. 125W HPM, 70W HPS, 70W MH and 36W CFL are taken as representative lamp types for category S street lighting. For the BaseCase calculation we assume for the existing stock of luminaires 2005 a weighted ratio of 57% HPS, 32% HPM, 9% CFL and 2% MH. For replacement sales, luminaires are replaced with luminaires of the same type. For new project sales we assume 50% HPS, 30% HPM, 15% CFL and 5% MH. These ratios are based on generic market data (see chapter 2) and expert assumptions since no other detailed reliable market data are available. The table below gives an overview of the input data for luminaire types, category S.

Note that at installation level, different amounts of these lamps are required per km to achieve similar minimum illuminance levels (between 2 and 10 lx for road category S). The following typical pole distances are defined for these luminaires (see section 4.3.1.4): HPM 15m, HPS 30m, MH 20m and CFL 15m.

As according to the technical analysis on lamps (see section 4.3.1.4), a 125W HPM lamp has an efficiency (ηlamp) of 51 lm/W, 70W HPS 88 lm/W, 70W MH 90 lm/W and 36W CFL 80 lm/W. In the BaseCase, these lamps are accompanied with electromagnetic ballasts, with efficiencies of 91% for HPM, 84% for HPS, 84% for MH and 80% for CFL.

Table 74: Luminaire types in category S

Luminaire types, CAT S	Stock	Sales, New project	Sales, Replacement	Sales, Total
With Mercury lamp	32%	30%	32%	31%
With Sodium lamp	57%	50%	57%	53%
With Metal Halide lamp	2%	5%	2%	4%
With CFL	9%	15%	9%	13%
Total	100%	100%	100%	100%

5.1.2 Environmental Impact (per unit lamp, ballast)

The table below gives the environmental impact, by multiplying the inputs with the Unit Indicator values from chapter 5, MEEuP Report.

Note that the use phase impacts are only mentioned informatory in order to compare the impacts of the lamp and ballast (per one unit) with that of the entire product over its life (electricity use over lamp life service (resp. 2,3 or 4 years)). In section 5.3 to 5.4 on BaseCase assessments at product-level, the lamp & ballast replacement over luminaire life are taken into account.

Table 75: Life Cycle Impact per BaseCase lamp, ballast (Category F)

			131W LPS			250W HPS		
	Life Cycle phases -->		TOTAL LAMP (EX USE)	TOTAL BALLAST (EX USE)	USE (12000h)	TOTAL LAMP (EX USE)	TOTAL BALLAST (EX USE	USE (16000h)
	Resources Use and Emissions							
	Other Resources & Waste							
8	Total Energy (GER)	MJ	81	388	20.017	80	370	48.583
9	of which, electricity (in primary MJ)	MJ	13	73	20.017	15	70	48.583
10	Water (process)	ltr	10	40	1.335	3	40	3.239
11	Water (cooling)	ltr	0	30	53.379	9	29	129.555
12	Waste, non-haz./ landfill	g	262	16.141	23.210	297	14.977	56.331
13	Waste, hazardous/ incinerated	g	2	499	461	2	499	1.119
	Emissions (Air)							
14	Greenhouse Gases in GWP100	kg CO2 eq.	6	26	874	6	24	2.120
15	Ozone Depletion, emissions	mg R-11 eq.						
16	Acidification, emissions	g SO2 eq.	20	231	5.154	25	217	12.510
17	Volatile Organic Compounds (VOC)	g	0	1	8	0	1	18
18	Persistent Organic Pollutants (POP)	ng i-Teq	1	94	131	3	88	318
19	Heavy Metals	mg Ni eq.	8	69	343	99	65	834
	PAHs	mg Ni eq.	3	16	39	4	15	96
20	Particulate Matter (PM, dust)	g	7	41	110	4	39	267
	Emissions (Water)							
21	Heavy Metals	mg Hg/20	2	51	129	2	49	313
22	Eutrophication	g PO4	0	1	1	0	1	1
23	Persistent Organic Pollutants (POP)	ng i-Teq						

Table 76: Life Cycle Impact per BaseCase lamp, ballast (Category M)

			150W HPS			400W HPM		
	Life Cycle phases -->		TOTAL LAMP (EX USE)	TOTAL BALLAST (EX USE)	USE (16000h)	TOTAL LAMP (EX USE)	TOTAL BALLAST (EX USE	USE (12000h)
	Resources Use and Emissions							
	Other Resources & Waste							
8	Total Energy (GER)	MJ	74	308	29.805	73	346	55.845
9	of which, electricity (in primary MJ)	MJ	11	60	29.804	9	47	55.845
10	Water (process)	ltr	2	40	1.987	3	1	3.723
11	Water (cooling)	ltr	6	26	79.479	4	18	148.920
12	Waste, non-haz./ landfill	g	244	10.788	34.558	245	16.072	64.751
13	Waste, hazardous/ incinerated	g	2	499	686	4	47	1.287
				0				
	Emissions (Air)			0				
14	Greenhouse Gases in GWP100	kg CO2 eq.	6	20	1.300	6	24	2.437
15	Ozone Depletion, emissions	mg R-11 eq.						
16	Acidification, emissions	g SO2 eq.	22	166	7.674	21	203	14.380
17	Volatile Organic Compounds (VOC)	g	0	1	11	0	1	21
18	Persistent Organic Pollutants (POP)	ng i-Teq	2	65	195	2	105	366
19	Heavy Metals	mg Ni eq.	68	49	511	41	69	958
	PAHs	mg Ni eq.	3	15	58	3	15	110
20	Particulate Matter (PM, dust)	g	4	32	163	4	40	307
	Emissions (Water)							
21	Heavy Metals	mg Hg/20	2	46	192	0	20	360
22	Eutrophication	g PO4	0	1	0	0	0	2
23	Persistent Organic Pollutants (POP)	ng i-Teq	0	0				

Table 77: Life Cycle Impact per BaseCase lamp, ballast (Category S), part 1

			125W HPM			70W HPS		
	Life Cycle phases -->		TOTAL LAMP (EX USE)	TOTAL BALLAST (EX USE)	USE (12000h)	TOTAL LAMP (EX USE)	TOTAL BALLAST (EX USE	USE (16000h)
	Resources Use and Emissions							
	Other Resources & Waste							
8	Total Energy (GER)	MJ	63	235	18.218	64	252	14.067
9	of which, electricity (in primary MJ)	MJ	3	29	18.218	4	52	14.067
10	Water (process)	ltr	1	1	1.214	1	40	937
11	Water (cooling)	ltr	1	12	48.583	2	23	37.511
12	Waste, non-haz./ landfill	g	118	8.624	21.124	124	7.064	16.310
13	Waste, hazardous/ incinerated	g	2	46	419	2	498	324
				0				
	Emissions (Air)			0				
14	Greenhouse Gases in GWP100	kg CO2 eq.	5	17	795	5	17	613
15	Ozone Depletion, emissions	mg R-11 eq.						
16	Acidification, emissions	g SO2 eq.	16	112	4.691	17	120	3.622
17	Volatile Organic Compounds (VOC)	g	0	1	6	0	1	5
18	Persistent Organic Pollutants (POP)	ng i-Teq	1	64	119	1	44	92
19	Heavy Metals	mg Ni eq.	14	40	312	27	34	241
	PAHs	mg Ni eq.	3	14	35	3	14	27
20	Particulate Matter (PM, dust)	g	3	27	100	3	26	77
				0				
	Emissions (Water)			0				
21	Heavy Metals	mg Hg/20	0	13	117	1	42	90
22	Eutrophication	g PO4	0	0	0	0	1	0
23	Persistent Organic Pollutants (POP)	ng i-Teq						

Table 78: Life Cycle Impact per BaseCase lamp, ballast (Category S), part 2

			70W CMH			36W CFL		
	Life Cycle phases -->		TOTAL LAMP (EX USE)	TOTAL BALLAST (EX USE)	USE (8000h)	TOTAL LAMP (EX USE)	TOTAL BALLAST (EX USE)	USE (12000h)
	Resources Use and Emissions							
	Other Resources & Waste							
8	Total Energy (GER)	MJ	63	283	6.877	55	189	7.959
9	of which, electricity (in primary MJ)	MJ	2	58	6.877	2	22	7.958
10	Water (process)	ltr	1	40	458	1	0	530
11	Water (cooling)	ltr	1	27	18.339	0	10	21.221
12	Waste, non-haz./ landfill	g	124	8.351	7.974	79	5.599	9.280
13	Waste, hazardous/ incinerated	g	1	539	158	1	46	183
	Emissions (Air)							
14	Greenhouse Gases in GWP100	kg CO2 eq.	5	19	300	5	14	347
15	Ozone Depletion, emissions	mg R-11 eq.	0			0		
16	Acidification, emissions	g SO2 eq.	16	135	1.770	13	75	2.049
17	Volatile Organic Compounds (VOC)	g	0	1	2	0	0	3
18	Persistent Organic Pollutants (POP)	ng i-Teq	1	55	45	0	47	52
19	Heavy Metals	mg Ni eq.	17	41	118	3	28	136
	PAHs	mg Ni eq.	3	14	13	3	13	15
20	Particulate Matter (PM, dust)	g	3	33	37	1	22	43
	Emissions (Water)							
21	Heavy Metals	mg Hg/20	1	44	44	0	11	51
22	Eutrophication	g PO4	0	1	0	0	0	0
23	Persistent Organic Pollutants (POP)	ng i-Teq						

Discussion of results

The tables above express the environmental results per lamp respectively per ballast, excluding the impacts from electricity consumption. The impact from electricity consumption (over one lamp service life) was mentioned separately in the table. This to give a first indication on the relative importance of material-related impacts versus electricity-related impacts. A consequent total life cycle phases analysis is performed only at the level of the product configuration (lamp/ballast/luminaire) in section 5.3 and 5.4. This section discusses the production-, distribution- and ’end-of-life’-related impacts for the BaseCase lamps with their related electromagnetic ballasts (thus at part-level).

In the table below the results are summarized for the combination of the lamp and the ballast, expressed per lamp lumen output, related to a period of 30 years (total operation period 1 product configuration, thus 1 ballast and multiple lamps required over this period).

Table 79: Life Cycle Impact per BaseCase lamp, ballast, expressed per lamp lumen output over 30 years

LAMP + GEAR, *time period 30 year*		Road category A		Road category B		Road category C			
		131W LPS	250W HPS	150W HPS	400W HPM	125W HPM	70W HPS	70W CMH	36W CFL
PER LUMEN									
Other Resources & Waste									
Total Energy (GER)	MJ	5,79E-02	3,28E-02	5,34E-02	5,49E-02	1,60E-01	1,24E-01	2,03E-01	2,17E-01
of which, electricity (in primary MJ)	MJ	9,95E-03	6,28E-03	8,65E-03	7,17E-03	1,05E-02	1,34E-02	1,49E-02	7,00E-03
Water (process)	ltr	6,69E-03	2,11E-03	3,40E-03	1,49E-03	1,78E-03	7,48E-03	8,70E-03	4,50E-03
Water (cooling)	ltr	1,27E-03	3,17E-03	4,30E-03	2,78E-03	4,10E-03	6,45E-03	7,49E-03	7,16E-05
Waste, non-haz./ landfill	g	7,60E-01	5,64E-01	7,58E-01	8,38E-01	1,58E+00	1,31E+00	1,64E+00	3,10E-01
Waste, hazardous/ incinerated	g	2,00E-02	1,68E-02	3,07E-02	4,14E-03	1,16E-02	8,29E-02	8,84E-02	4,16E-03
Emissions (Air)									
Greenhouse Gases in GWP100	kg CO2 eq.	4,34E-03	2,38E-03	3,97E-03	4,22E-03	1,30E-02	9,57E-03	1,63E-02	1,86E-02
Ozone Depletion, emissions	mg R-11 eq.	0	0	0	0	0	0	0	0
Acidification, emissions	g SO2 eq.	1,94E-02	1,35E-02	2,02E-02	2,01E-02	4,87E-02	4,11E-02	6,14E-02	5,03E-02
Volatile Organic Compounds (VOC)	g	1,25E-04	7,61E-05	1,28E-04	1,34E-04	3,88E-04	3,07E-04	4,86E-04	2,12E-04
Persistent Organic Pollutants (POP)	ng i-Teq	4,38E-03	3,67E-03	5,00E-03	5,50E-03	1,15E-02	8,56E-03	1,12E-02	1,54E-03
Heavy Metals	mg Ni eq.	6,67E-03	2,76E-02	3,51E-02	2,54E-02	3,42E-02	4,00E-02	4,93E-02	1,11E-02
PAHs	mg Ni eq.	2,09E-03	1,49E-03	2,52E-03	2,21E-03	7,53E-03	6,13E-03	1,09E-02	1,19E-02
Particulate Matter (PM, dust)	g	5,50E-03	2,36E-03	3,69E-03	3,96E-03	1,01E-02	8,05E-03	1,26E-02	3,83E-03
Emissions (Water)									
Heavy Metals	mg Hg/20	3,06E-03	2,16E-03	3,43E-03	1,14E-03	2,50E-03	7,63E-03	9,40E-03	1,08E-03
Eutrophication	g PO4	5,69E-05	1,47E-04	1,91E-04	1,23E-04	1,55E-04	2,42E-04	2,93E-04	1,47E-05
Persistent Organic Pollutants (POP)	ng i-Teq	0	0	0	0	0	0	0	0

Comparing the lamp/ballast combinations with each other, it can be concluded that combinations that are used within the same road category have a comparable environmental impact per lm lamp output.

Looking at the contribution of the life cycle stages (excluding the use phase) of the lamps, the distribution phase dominates the impact on total energy consumption, greenhouse gases, acidification, VOC, PAHs and particulate matter (more or less 90%). All life cycle stages considered here are equally important with regard to the impact on waste production, while the production phase contributes most to the heavy metals emissions and the emissions of POP. The dominant contribution of the distribution phase of the lamps is inherent to the VHK model, which assumes a fixed energy consumption for the heating/lighting of retail shops etc., independent of the size of the product. This causes small-sized products to potentially have a relatively high impact during the distribution phase.
With regard to the life cycle stages of the control gear, the production phase dominates by far the environmental impact (more than 80%, for most categories more than 95%). This is due to

the higher weight of the control gear and the use of more contributing materials, which causes the relative impact of the distribution phase of the control gear to be much less than that of the lamps.

Category F

The impacts of the 250W HPS are in general lower than the 131W LPS. This difference is caused by on the one hand the higher lumen output of the HPS and on the other hand by the longer life span of the HPS-lamps. Per lamp the LPS has lower impacts compared to HPS, but these lamps must be replaced more often. The environmental impacts of the ballasts are comparable. The 131W LPS cause less heavy metals to air and the impact on eutrophication, which is due to the significant weight of the coating of the bulb for the 250W HPS lamp.

Category M

For the road category M both lamp/ballast combinations are comparable to each other; for most impacts the differences are insignificant. The HPM option has a significantly lower contribution to the impact categories water, hazardous waste, heavy metal emissions to water and eutrophication. For these categories where the HPM option contributes significantly less, the difference is due to the better lamp lumen output and the fact that HPM lamps don't need an ignitor, which is the most important reason for the contribution to these impacts.

Category S

The 70W MH lamp/ballast combination has a higher environmental impact compared to the other two. This difference does, contrary to the other road categories, not depend on the difference in lamp lumen output, since this factor only differs marginally between the 3. No conclusion can be taken with regard to the other lamp/ballast combinations (HPM and the HPS) because these have, depending on the environmental category, alternately a better or worse contribution. The environmental impact of the individual lamps is comparable. If there is a difference between these combination, this is caused by the lack of an ignitor for the case of HPM, which is required for the other options.

5.2 BaseCase Luminaires (without lamp, ballast)

5.2.1 Product-specific Inputs

As explained earlier (see 4.1.5), data (Bill of Materials) were retrieved from CELMA for 3 typical 'average' luminaires. These were not directly related to a specific type of lamp. The most important parameters that determine the selection of the luminaire, and by consequence the general size/weight of the luminaire, are the type of lamp and ballast, the external conditions in which the luminaire should operate (i.e. weather, dirt, insects…) and the performance criteria imposed by purchasers (i.e. IP rating). There is assumed that these luminaires represent 3 'average' to 'good-practice' BaseCases of the type 'Closed luminaire with medium-' to '-advanced optic reflector' (see section 4.3.1.4) and differ mainly in material composition (glass versus polycarbonate front cover, aluminium versus mix of glassfibre polyester with aluminium housing parts). No detailed market data are available to weigh the exact share of these three BaseCase luminaires or to determine the relevance of other luminaire types (open luminaires, globes with diffuser, other decorative luminaires etc…). Those three cases are mainly taken because they were provided by CELMA as the most representative luminaires for current sales.
It is not useful to calculate the BOM-related impacts for all different available types of luminaire models as described in 4.1.5. First, because of the small contribution of the BOM-related impacts to the total environmental impact compared to the use-phase related impacts (see 5.3 and 5.4). Second, because these luminaires generally consist of more materials and are heavier, e.g. compared to open luminaire types or luminaires without reflector.

For BOM-related impacts in the BaseCase evaluation at product-configuration level (section 5.3 to 5.4), the 'average' of these three luminaires is used. The aim of this section is to demonstrate the difference between the impacts of these three luminaires.

Unit cost data for luminaires are retrieved from limited market survey and is shown in section 2.4.1. These cost data take into account the type and size of lamp that is used in the luminaire. However, at part-level, no Total Life Cycle Cost is calculated, only at product-level in section 5.3 to 5.4.

5.2.2 Environmental Impact

The table below gives the environmental impact, by multiplying the inputs from the previous section with the Unit Indicator values from Chapter 5 of the MEEuP Methodology Report.

Table 80: Aggregated Production, Distribution and End-of-Life Impacts per Luminaire (without lamp, ballast)

			CELMA (see section 4.1.5)			Average
	Type of Luminaire-->		TYPE 1	TYPE 2	TYPE 3	
	Resources Use and Emissions					
	Other Resources & Waste					
8	Total Energy (GER)	MJ	912	1.131	981	1.008
9	of which, electricity (in primary MJ)	MJ	106	57	134	99
10	Water (process)	ltr	79	6	131	72
11	Water (cooling)	ltr	442	20	697	386
12	Waste, non-haz./ landfill	g	8.858	20.952	8.919	12.910
13	Waste, hazardous/ incinerated	g	1.960	1	2.361	1.441
	Emissions (Air)					
14	Greenhouse Gases in GWP100	kg CO2 eq.	57	64	61	61
15	Ozone Depletion, emissions	mg R-11 eq.				
16	Acidification, emissions	g SO2 eq.	279	377	306	320
17	Volatile Organic Compounds (VOC)	g	3	1	3	2
18	Persistent Organic Pollutants (POP)	ng i-Teq	16	44	15	25
19	Heavy Metals	mg Ni eq.	65	69	72	69
	PAHs	mg Ni eq.	169	461	161	264
20	Particulate Matter (PM, dust)	g	286	161	331	259
	Emissions (Water)					
21	Heavy Metals	mg Hg/20	138	175	186	166
22	Eutrophication	g PO4	5	0	8	5
23	Persistent Organic Pollutants (POP)	ng i-Teq				

Discussion of results

The 3 luminaires differ in material composition (luminaire 1 and 3 are partly made of glassfibre reinforced polyester with a polycarbonate front cover, luminaire 2 is entirely made of aluminum with a front cover in glass) and consequently in weight (luminaire 2 has the largest weight). These differences are responsible for the differences in the environmental impacts of the luminaires. The luminaire with the highest proportion of aluminum (type 2) contributes most to the related impact categories : total energy consumption (GER), waste non-hazardous (landfill), greenhouse gasses, acidification, emissions of POP and PAH. Luminaire type 3, which has the highest glass-fiber reinforced polyester content, dominates the impact categories electricity, water, waste hazardous (incinerated), emissions of PM to air and eutrophication.

For most of the impact categories the production phase contributes most (range 60-99%). The contribution to electricity use, water use, non hazardous waste, emissions of VOC and PAH is for more than 90% caused by the production phase, for all luminaires types discussed here. The contribution of the production phase to GER, greenhouse gasses and acidification depends on the weight of the luminaire. The contribution of the production to these impact categories ranges between 55 and 85%, while the remaining impact is more or less equally contributed by the distribution and end of life phase. The contribution of the production phase increases with the weight of the luminaire. In that case, the relative contribution of the distribution phase decreases. This is logical because of the fixed energy consumption that is assumed for lighting/heating in the distribution phase (see MEEuP Methodology Report, Unit Indicator 61). The distribution of the impacts over the different life cycle phases depends on the presence of aluminium respectively glassfibre reinforced polyester for emissions of heavy metals and PM and eutrophication. The contribution of the production phase dominates the emissions of heavy metals and PM for the luminaire with a high aluminum content, while for the other luminaires the EOL phase is the most important. The impact on eutrophication is dominated by the production for the luminaires containing glass fiber reinforced polyester, for the luminaire with a high aluminum content the impact of production and end of life is comparable.

For the 'averagely' composed luminaire, the following table shows the distribution of the impacts over the different life cycle phases (as %). The shares shown in 'Production, Material' and 'Production, Manufacturing' sum up to 100% 'Production, Total'. The same is true for 'End-of-Life, Disposal' and 'End-of-Life, Recycling' that sum up to 100% 'End-of-Life, Total'. 'Production, Total', 'Use', 'Distribution', 'End-of-life, Total' sum up to 100% 'Total'.

Table 81: Distribution of impacts over Life Cycle

	Life Cycle phases -->		PRODUC TION	USE	DISTRI-BUTION	END-O F-LIFE .	TOT-AL
	Other Resources & Waste						
8	Total Energy (GER)	%	74%	16%	1%	10%	100%
9	of which, electricity (in primary MJ)	%	100%	0%	1%	-1%	100%
10	Water (process)	%	100%	0%	1%	-1%	100%
11	Water (cooling)	%	100%	0%	1%	-1%	100%
12	Waste, non-haz./ landfill	%	94%	1%	1%	4%	100%
13	Waste, hazardous/ incinerated	%	1%	0%	0%	99%	100%
	Emissions (Air)						
14	Greenhouse Gases in GWP100	%	66%	21%	1%	13%	100%
16	Acidification, emissions	%	82%	12%	1%	5%	100%
17	Volatile Organic Compounds (VOC)	%	13%	71%	0%	16%	100%
18	Persistent Organic Pollutants (POP)	%	82%	2%	1%	14%	100%
19	Heavy Metals	%	42%	8%	0%	50%	100%
	PAHs	%	97%	2%	1%	0%	100%
20	Particulate Matter (PM, dust)	%	23%	13%	0%	63%	100%
	Emissions (Water)						
21	Heavy Metals	%	93%	0%	1%	6%	100%
22	Eutrophication	%	86%	0%	1%	13%	100%

5.3 BaseCase Sales

The results in the following chapters are given per average BaseCase (unit) product, per category of street lighting.
In order to compare results between categories (F, M, S) it is necessary to take into account the functional unit in lumen (lm) per base case product as indicated.

The result per product unit are calculated as the sum of:

- Impacts/costs of one average luminaire, without lamp or ballast (see par 5.2)
- Lamp consumption over luminaire life, multiplied with intermediate results on lamp impacts/costs, excluding electricity use (see 5.1)
- Ballast consumption over luminaire life, multiplied with intermediate results on ballast impacts/costs (see 5.1)
- Impacts/costs of electricity consumption of the luminaire/lamp/ballast configuration.

5.3.1 Product-specific Inputs

Category F

As mentioned in section 5.1.1, 1 road, sales in category F is approximately 95,5% HPS and 4,5% LPS BaseCase Luminaires; all averages are weighed accordingly.

Both HPS and LPS luminaires are equipped with electromagnetic ballasts that last an entire luminaire life, meaning 30 years.

Taking the technical service life of these lamps into account and the lamp survival factor, LSF (see chapter 4), this results in an annual lamp replacement of 0,27 lamps/yr per HPS luminaires and 0,46 lamps/yr per LPS luminaire. This gives an average of 0,27 lamps/yr per BaseCase luminaire, category F.

The installed power per luminaire is 151W for LPS and 275W for HPS (taking into account lamp power, ballast efficiency and ballast maintenance factor, see chapter 4 for technical parameters). This gives an average of 269W per BaseCase luminaire, category F.

The functional light output for the LPS luminaire is 6270 lm, for the HPS luminaire this is 9859 lm. This gives an average of 9696 lm per BaseCase luminaire, category F.

Category M

Road category B is lit with approximately 69,5% HPS and 30,5% HPM BaseCase Luminaires and also all averages are weighed accordingly.

Both luminaires are equipped with electromagnetic ballasts that last an entire luminaire life, meaning 30 years.

Taking the technical service life of these lamps into account and the lamp survival factor, LSF (see chapter 4) this results in an annual lamp replacement of 0,27 lamps/yr per HPS luminaire and 0,41 lamps/yr per HPM luminaire. This gives an average of 0,31 lamps/yr per BaseCase luminaire, category M.

The installed power per luminaire is 421 W for HPM and 169 W for HPS (taking into account lamp power, ballast efficiency and ballast maintenance factor, see chapter 4 for technical parameters). This gives an average of 246 W per BaseCase luminaire, category M.

The functional light output for the HPS luminaire is 4357 lm, for the HPM luminaire this is 3369 lm. This gives an average of 4055 lm per BaseCase luminaire, category M.

Category S

Road category S is lit with approximately 53% HPS, 31% HPM, 13% CFL and 4% MH BaseCase Luminaires and again all averages are weighed accordingly.

All luminaires are equipped with electromagnetic ballasts that last an entire luminaire life, meaning 30 years.

Taking the technical service life of these lamps into account and the lamp survival factor, LSF (see chapter 4), this results in an annual lamp replacement of 0,41 lamps/yr for HPM, 0,27 lamps/yr for HPS, 0,35 lamps/yr for CFL and 0,53 lamps/yr for MH luminaires. This gives an average of 0,33 lamps/yr per BaseCase luminaire, category S.

The installed power per luminaire is 83 W for HPS, 137 W for HPM, 45 W for CFL and 83 W for CMH (taking into account lamp power, ballast efficiency and ballast maintenance factor, see chapter 4 for technical parameters). This gives an average of 95 W per BaseCase luminaire, category S.

The functional light output for the HPS luminaire is 1327 lm, for the HPM luminaire this is 897 lm, for the CFL this is 319 lm, for the CMH luminaire this is 1000 lm. This gives an average of 1054 lm per BaseCase luminaire, category S.

5.3.2 Environmental Impact

On www.eup4light.net, for all individual luminaire/ballast/lamp configurations the EcoReports can be found. The following tables are the weighted average (based on share in sales) per category F, M, S.

Table 82: Life Cycle Impact, Base Case Sales, Category F (life cycle phases)

Nr	Life cycle Impact per product: Weighted average sales, category F		Author VITO

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Mat.	Manuf	Tot.	BUTION		Disp.	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	kg			**0,1**			0,0	0,0	**0,1**	**0,0**
2	TecPlastics	kg			**1,9**			1,7	0,2	**1,9**	**0,0**
3	Ferro	kg			**2,9**			0,1	2,8	**2,9**	**0,0**
4	Non-ferro	kg			**3,5**			0,2	3,3	**3,5**	**0,0**
5	Coating	kg			**0,0**			0,0	0,0	**0,0**	**0,0**
6	Electronics	kg			**0,1**			0,1	0,1	**0,1**	**0,0**
7	Misc.	kg			**2,0**			0,1	1,9	**2,0**	**0,0**
	Total weight	kg			**10,6**			2,3	8,4	**10,6**	**0,0**
	Other Resources & Waste							debet	Credit		
8	Total Energy (GER)	GJ	1,0	0,2	**1,2**	**0,3**	**356,9**	0,2	0,0	**0,1**	**358,5**
9	of which, electricity (in primary MJ)	GJ	0,2	0,1	**0,3**	**0,0**	**356,9**	0,0	0,0	**0,0**	**357,2**
10	Water (process)	m3	0,1	0,0	**0,1**	**0,0**	**23,8**	0,0	0,0	**0,0**	**23,9**
11	Water (cooling)	m3	0,4	0,1	**0,5**	**0,0**	**951,8**	0,0	0,0	**0,0**	**952,2**
12	Waste, non-haz./ landfill	kg	27,7	0,8	**28,5**	**0,2**	**414,1**	0,7	0,0	**0,6**	**443,4**
13	Waste, hazardous/ incinerated	kg	0,4	0,0	**0,4**	**0,0**	**8,2**	1,8	0,0	**1,8**	**10,5**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	t CO2 eq.	0,1	0,0	**0,1**	**0,0**	**15,6**	0,0	0,0	**0,0**	**15,7**
15	Ozone Depletion, emissions	g R-11 eq.	Negligible								
16	Acidification, emissions	kg SO2 eq.	0,5	0,1	**0,6**	**0,1**	**91,9**	0,0	0,0	**0,0**	**92,5**
17	Volatile Organic Compounds (VOC)	kg	0,0	0,0	**0,0**	**0,0**	**0,1**	0,0	0,0	**0,0**	**0,1**
18	Persistent Organic Pollutants (POP)	µg i-Teq	0,1	0,0	**0,1**	**0,0**	**2,3**	0,0	0,0	**0,0**	**2,5**
19	Heavy Metals	g Ni eq.	0,8	0,0	**0,8**	**0,0**	**6,1**	0,0	0,0	**0,0**	**7,0**
	PAHs	g Ni eq.	0,3	0,0	**0,3**	**0,0**	**0,7**	0,0	0,0	**0,0**	**1,0**
20	Particulate Matter (PM, dust)	kg	0,1	0,0	**0,1**	**0,1**	**2,0**	0,2	0,0	**0,2**	**2,3**
	Emissions (Water)										
21	Heavy Metals	g Hg/20	0,2	0,0	**0,2**	**0,0**	**2,3**	0,0	0,0	**0,0**	**2,5**
22	Eutrophication	kg PO4	0,0	0,0	**0,0**	**0,0**	**0,0**	0,0	0,0	**0,0**	**0,0**
23	Persistent Organic Pollutants (POP)	µg i-Teq	negligible								

Table 83: Life Cycle Impact, Base Case, Category F (per 1000 functional lumen)

	TOTAL (per 1000 functional lm)		WEIGHTED AVERAGE	LPS	HPS
	Other Resources & Waste				
8	Total Energy (GER)	*MJ*	37.024	32.347	**37.166**
9	of which, electricity (in primary MJ)	*MJ*	36.840	**31.997**	**36.987**
10	Water (process)	*ltr*	2.469	**2.169**	**2.478**
11	Water (cooling)	*ltr*	98.209	**85.241**	**98.603**
12	Waste, non-haz./ landfill	*g*	45.789	**42.210**	**45.897**
13	Waste, hazardous/ incinerated	*g*	1.050	**1.049**	**1.050**
	Emissions (Air)				
14	Greenhouse Gases in GWP100	*kg CO2 eq.*	1.621	**1.422**	**1.627**
15	Ozone Depletion, emissions	*mg R-11 eq.*	negligible	**negligible**	**negligible**
16	Acidification, emissions	*g SO2 eq.*	9.556	**8.358**	**9.592**
17	Volatile Organic Compounds (VOC)	*g*	14	**13**	**14**
18	Persistent Organic Pollutants (POP)	*ng i-Teq*	255	**231**	**256**
19	Heavy Metals to Air	*mg Ni eq.*	723	**586**	**727**
	PAHs	*mg Ni eq.*	105	**114**	**104**
20	Particulate Matter (PM, dust)	*g*	237	**240**	**237**
	Emissions (Water)				
21	Heavy Metals to Water	*mg Hg/20*	261	**245**	**262**
22	Eutrophication	*g PO4*	2	**2**	**2**
23	Persistent Organic Pollutants (POP)	*ng i-Teq*	negligible	**negligible**	**negligible**

When comparing the Base Case LPS and HPS luminaires from a total life cycle perspective, impacts per functional lumen output are in the same order of magnitude, with slight apparent advantage for LPS (exept for impacts PAHs and PM).

Table 84: Life Cycle Impact, Base Case, Category F (contribution of production, distribution, end-of-life of lamps, ballast, luminaire and electricity use)

	TOTAL (per 1000 functional lm)	LUMINAIRE	BALLAST	LAMPS	ELECTRICITY
	Other Resources & Waste	%	%	%	%
8	Total Energy (GER)	0%	0%	0%	99%
9	of which, electricity (in primary MJ)	0%	0%	0%	100%
10	Water (process)	0%	0%	0%	99%
11	Water (cooling)	0%	0%	0%	100%
12	Waste, non-haz./ landfill	3%	3%	1%	93%
13	Waste, hazardous/ incinerated	14%	5%	0%	81%
	Emissions (Air)				
14	Greenhouse Gases in GWP100	0%	0%	0%	99%
15	Ozone Depletion, emissions	negligible	negligible	negligible	negligible
16	Acidification, emissions	0%	0%	0%	99%
17	Volatile Organic Compounds (VOC)	2%	1%	1%	96%
18	Persistent Organic Pollutants (POP)	1%	4%	1%	94%
19	Heavy Metals to Air	1%	1%	11%	87%
	PAHs	26%	2%	3%	69%
20	Particulate Matter (PM, dust)	11%	2%	2%	85%
	Emissions (Water)				
21	Heavy Metals to Water	7%	2%	1%	91%
22	Eutrophication	23%	4%	19%	55%
23	Persistent Organic Pollutants (POP)	negligible	negligible	negligible	negligible

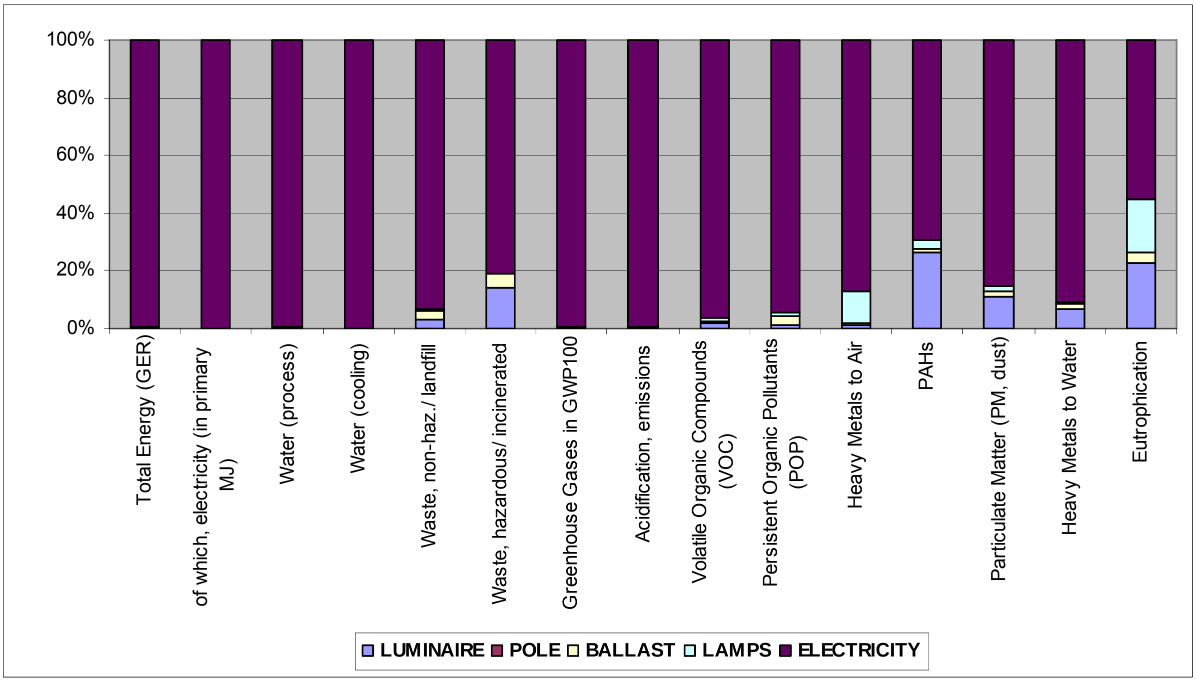


Figure 26: Life Cycle Impact, Base Case, Category F (contribution of production, distribution, end-of-life of lamps, ballast, luminaire and electricity use)

Table 85: Life Cycle Impact, Base Case Sales, Category M (life cycle phases)

Nr	Life cycle Impact per product: Weighted average sales, category M		Author VITO

Nr	Life Cycle phases --> Resources Use and Emissions		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
			Mat.	Manuf	Tot.	BUTION		Disp.	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	kg			**0,1**			0,0	0,0	**0,1**	**0,0**
2	TecPlastics	kg			**1,9**			1,7	0,2	**1,9**	**0,0**
3	Ferro	kg			**2,5**			0,1	2,4	**2,5**	**0,0**
4	Non-ferro	kg			**3,4**			0,2	3,2	**3,4**	**0,0**
5	Coating	kg			**0,0**			0,0	0,0	**0,0**	**0,0**
6	Electronics	kg			**0,1**			0,1	0,1	**0,1**	**0,0**
7	Misc.	kg			**1,5**			0,1	1,4	**1,5**	**0,0**
	Total weight	kg			**9,6**			2,2	7,4	**9,6**	**0,0**
								debet	Credit		
8	Total Energy (GER)	GJ	0,9	0,2	**1,1**	**0,3**	**325,9**	0,2	0,0	**0,1**	**327,4**
9	of which, electricity (in primary MJ)	GJ	0,2	0,1	**0,3**	**0,0**	**325,9**	0,0	0,0	**0,0**	**326,2**
10	Water (process)	m3	0,1	0,0	**0,1**	**0,0**	**21,7**	0,0	0,0	**0,0**	**21,8**
11	Water (cooling)	m3	0,4	0,1	**0,5**	**0,0**	**869,1**	0,0	0,0	**0,0**	**869,5**
12	Waste, non-haz./ landfill	kg	25,0	0,8	**25,8**	**0,2**	**378,1**	0,6	0,0	**0,6**	**404,6**
13	Waste, hazardous/ incinerated	kg	0,3	0,0	**0,3**	**0,0**	**7,5**	1,8	0,0	**1,8**	**9,6**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	t CO2 eq.	0,1	0,0	**0,1**	**0,0**	**14,2**	0,0	0,0	**0,0**	**14,3**
15	Ozone Depletion, emissions	g R-11 eq.	negligible								
16	Acidification, emissions	kg SO2 eq.	0,4	0,0	**0,5**	**0,1**	**83,9**	0,0	0,0	**0,0**	**84,5**
17	Volatile Organic Compounds (VOC)	kg	0,0	0,0	**0,0**	**0,0**	**0,1**	0,0	0,0	**0,0**	**0,1**
18	Persistent Organic Pollutants (POP)	µg i-Teq	0,1	0,0	**0,1**	**0,0**	**2,1**	0,0	0,0	**0,0**	**2,3**
19	Heavy Metals	g Ni eq.	0,5	0,0	**0,6**	**0,0**	**5,6**	0,0	0,0	**0,0**	**6,2**
	PAHs	g Ni eq.	0,3	0,0	**0,3**	**0,0**	**0,6**	0,0	0,0	**0,0**	**0,9**
20	Particulate Matter (PM, dust)	kg	0,1	0,0	**0,1**	**0,1**	**1,8**	0,2	0,0	**0,2**	**2,1**
	Emissions (Water)										
21	Heavy Metals	g Hg/20	0,2	0,0	**0,2**	**0,0**	**2,1**	0,0	0,0	**0,0**	**2,3**
22	Eutrophication	kg PO4	0,0	0,0	**0,0**	**0,0**	**0,0**	0,0	0,0	**0,0**	**0,0**
23	Persistent Organic Pollutants (POP)	µg i-Teq	negligible								

Table 86: Life Cycle Impact, Base Case, Category M (per 1000 functional lumen)

	TOTAL (per 1000 functional lm)		WEIGHTED AVERAGE	HPM	HPS
	Other Resources & Waste				
8	Total Energy (GER)	*MJ*	80.877	166.464	51.750
9	of which, electricity (in primary MJ)	*MJ*	80.433	165.861	51.360
10	Water (process)	*ltr*	5.388	11.084	3.450
11	Water (cooling)	*ltr*	214.438	442.224	136.916
12	Waste, non-haz./ landfill	*g*	99.933	201.630	65.323
13	Waste, hazardous/ incinerated	*g*	2.305	4.284	1.632
	Emissions (Air)				
14	Greenhouse Gases in GWP100	*kg CO2 eq.*	3.542	7.282	2.269
15	Ozone Depletion, emissions	*mg R-11 eq.*	negligible	negligible	negligible
16	Acidification, emissions	*g SO2 eq.*	20.870	42.923	13.365
17	Volatile Organic Compounds (VOC)	*g*	31	64	20
18	Persistent Organic Pollutants (POP)	*ng i-Teq*	556	1.131	361
19	Heavy Metals to Air	*mg Ni eq.*	1.540	3.036	1.031
	PAHs	*mg Ni eq.*	234	419	172
20	Particulate Matter (PM, dust)	*g*	524	1.016	356
	Emissions (Water)				
21	Heavy Metals to Water	*mg Hg/20*	571	1.125	382
22	Eutrophication	*g PO4*	4	7	3
23	Persistent Organic Pollutants (POP)	*ng i-Teq*	negligible	negligible	negligible

When comparing the Base Case HPM and HPS luminaires from a total life cycle perspective, impacts per functional lumen output are substantially higher for HPM luminaires compared to HPS luminaires (a factor 3 for almost all impact categories).

Table 87: Life Cycle Impact, Base Case, Category M (contribution of production, distribution, end-of-life of lamps, ballast, luminaire and electricity use)

	TOTAL	LUMINAIRE	BALLAST	LAMPS	ELECTRICITY
	Other Resources & Waste	%	%	%	%
8	Total Energy (GER)	0%	0%	0%	99%
9	of which, electricity (in primary MJ)	0%	0%	0%	100%
10	Water (process)	0%	0%	0%	99%
11	Water (cooling)	0%	0%	0%	100%
12	Waste, non-haz./ landfill	3%	3%	1%	93%
13	Waste, hazardous/ incinerated	15%	4%	0%	80%
	Emissions (Air)				
14	Greenhouse Gases in GWP100	0%	0%	0%	99%
15	Ozone Depletion, emissions	negligible	negligible	negligible	negligible
16	Acidification, emissions	0%	0%	0%	99%
17	Volatile Organic Compounds (VOC)	2%	1%	1%	96%
18	Persistent Organic Pollutants (POP)	1%	3%	1%	95%
19	Heavy Metals to Air	1%	1%	9%	90%
	PAHs	28%	1%	3%	68%
20	Particulate Matter (PM, dust)	12%	2%	2%	84%
	Emissions (Water)				
21	Heavy Metals to Water	7%	2%	0%	91%
22	Eutrophication	26%	4%	14%	56%
23	Persistent Organic Pollutants (POP)	negligible	negligible	negligible	negligible

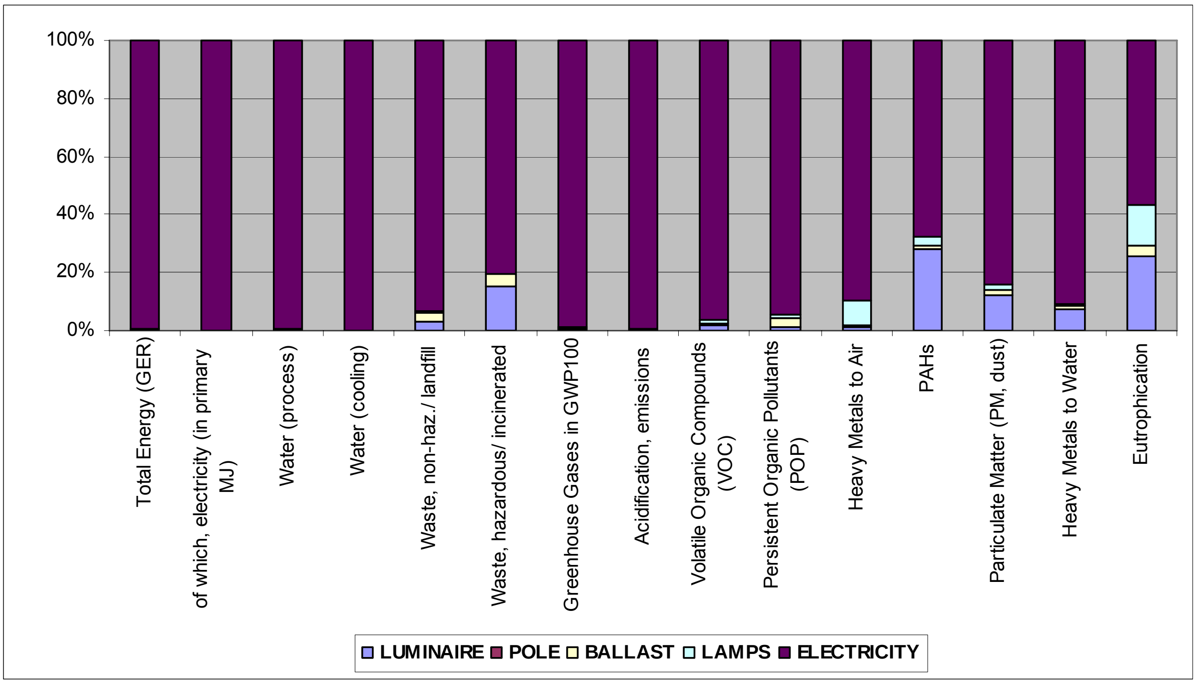


Figure 27: Life Cycle Impact, Base Case, Category M (contribution of production, distribution, end-of-life of lamps, ballast, luminaire and electricity use)

Table 88: Life Cycle Impact, Base Case Sales, Category S (life cycle phases)

Nr	Life cycle Impact per product: Weighted average sales, category S		Author VITO

Nr	Life Cycle phases --> Resources Use and Emissions		PRODUCTION Mat.	Manuf	Tot.	DISTRI-BUTION	USE	END-OF-LIFE* Disp.	Recycl.	Total	TOTAL
	Materials	**unit**									
1	Bulk Plastics	kg			**0,1**			0,0	0,0	**0,1**	**0,0**
2	TecPlastics	kg			**1,9**			1,7	0,2	**1,9**	**0,0**
3	Ferro	kg			**1,7**			0,1	1,6	**1,7**	**0,0**
4	Non-ferro	kg			**3,0**			0,2	2,9	**3,0**	**0,0**
5	Coating	kg			**0,0**			0,0	0,0	**0,0**	**0,0**
6	Electronics	kg			**0,1**			0,0	0,0	**0,1**	**0,0**
7	Misc.	kg			**0,8**			0,0	0,7	**0,8**	**0,0**
	Total weight	kg			**7,6**			2,1	5,5	**7,6**	**0,0**
	Other Resources & Waste								see note!	debet	credit
8	Total Energy (GER)	GJ	0,8	0,2	**1,0**	**0,3**	**126,1**	0,1	0,0	**0,1**	**127,5**
9	of which, electricity (in primary MJ)	GJ	0,1	0,1	**0,2**	**0,0**	**126,1**	0,0	0,0	**0,0**	**126,3**
10	Water (process)	m3	0,1	0,0	**0,1**	**0,0**	**8,4**	0,0	0,0	**0,0**	**8,5**
11	Water (cooling)	m3	0,4	0,0	**0,4**	**0,0**	**336,3**	0,0	0,0	**0,0**	**336,7**
12	Waste, non-haz./ landfill	kg	19,2	0,7	**19,8**	**0,2**	**146,4**	0,5	0,0	**0,4**	**166,8**
13	Waste, hazardous/ incinerated	kg	0,3	0,0	**0,3**	**0,0**	**2,9**	1,8	0,0	**1,8**	**5,0**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	t CO2 eq.	0,0	0,0	**0,1**	**0,0**	**5,5**	0,0	0,0	**0,0**	**5,6**
15	Ozone Depletion, emissions	g R-11 eq.	Negligible								
16	Acidification, emissions	kg SO2 eq.	0,3	0,0	**0,4**	**0,1**	**32,5**	0,0	0,0	**0,0**	**32,9**
17	Volatile Organic Compounds (VOC)	kg	0,0	0,0	**0,0**	**0,0**	**0,0**	0,0	0,0	**0,0**	**0,1**
18	Persistent Organic Pollutants (POP)	µg i-Teq	0,1	0,0	**0,1**	**0,0**	**0,8**	0,0	0,0	**0,0**	**0,9**
19	Heavy Metals	g Ni eq.	0,2	0,0	**0,2**	**0,0**	**2,2**	0,0	0,0	**0,0**	**2,4**
	PAHs	g Ni eq.	0,3	0,0	**0,3**	**0,0**	**0,3**	0,0	0,0	**0,0**	**0,5**
20	Particulate Matter (PM, dust)	kg	0,1	0,0	**0,1**	**0,1**	**0,7**	0,2	0,0	**0,2**	**1,0**
	Emissions (Water)										
21	Heavy Metals	g Hg/20	0,2	0,0	**0,2**	**0,0**	**0,8**	0,0	0,0	**0,0**	**1,0**
22	Eutrophication	kg PO4	0,0	0,0	**0,0**	**0,0**	**0,0**	0,0	0,0	**0,0**	**0,0**
23	Persistent Organic Pollutants (POP)	µg i-Teq	negligible								

Table 89: Life Cycle Impact, Base Case, Category S (per 1000 functional lumen)

	TOTAL (per 1000 functional lm)		WEIGHTED AVERAGE	HPM	HPS	CMH	CFL
	Other Resources & Waste						
8	Total Energy (GER)	*MJ*	110.126	205.400	84.638	2.326	3.867
9	of which, electricity (in primary MJ)	*MJ*	108.548	203.284	83.413	194	383
10	Water (process)	*ltr*	7.323	13.633	5.641	127	228
11	Water (cooling)	*ltr*	289.437	542.066	222.398	445	1.277
12	Waste, non-haz./ landfill	*g*	145.641	260.773	112.114	22.906	56.996
13	Waste, hazardous/ incinerated	*g*	4.194	6.400	3.410	2.026	4.746
	Emissions (Air)						
14	Greenhouse Gases in GWP100	*kg CO2 eq.*	4.849	9.026	3.726	166	242
15	Ozone Depletion, emissions	*mg R-11 eq.*	negligible	negligible	negligible	negligible	negligible
16	Acidification, emissions	*g SO2 eq.*	28.464	53.013	21.884	718	1.273
17	Volatile Organic Compounds (VOC)	*g*	45	82	35	6	9
18	Persistent Organic Pollutants (POP)	*ng i-Teq*	789	1.439	603	94	222
19	Heavy Metals to Air	*mg Ni eq.*	2.124	3.801	1.664	377	296
	PAHs	*mg Ni eq.*	499	745	390	331	870
20	Particulate Matter (PM, dust)	*g*	893	1.481	692	341	880
	Emissions (Water)						
21	Heavy Metals to Water	*mg Hg/20*	886	1.511	696	224	551
22	Eutrophication	*g PO4*	9	13	7	7	15
23	Persistent Organic Pollutants (POP)	*ng i-Teq*	negligible	negligible	negligible	negligible	negligible

When comparing the Base Case HPM, HPS, CMH and CFL luminaires from a total life cycle perspective, impacts per functional lumen output are substantially higher for HPM luminaires compared to HPS luminaires (a factor 2,5 for almost all impact categories). Due to their high functional lumen outputs, CMH and CFL have very low impacts per functional lumen. It is not always possible to replace HPM or HPS luminaires with one of these types due to different contexts in which these particular products are used. But where possible, benefits are enormous.

Table 90: Life Cycle Impact, Base Case, Category S (contribution of production, distribution, end-of-life of lamps, ballast, luminaire and electricity use)

	TOTAL	LUMINAIRE	BALLAST	LAMPS	ELECTRICITY
	Other Resources & Waste	%	%	%	%
8	Total Energy (GER)	1%	0%	0%	98%
9	of which, electricity (in primary MJ)	0%	0%	0%	100%
10	Water (process)	1%	0%	0%	99%
11	Water (cooling)	0%	0%	0%	100%
12	Waste, non-haz./ landfill	8%	5%	1%	86%
13	Waste, hazardous/ incinerated	33%	7%	0%	60%
	Emissions (Air)				
14	Greenhouse Gases in GWP100	1%	0%	1%	98%
15	Ozone Depletion, emissions	negligible	negligible	negligible	negligible
16	Acidification, emissions	1%	0%	0%	98%
17	Volatile Organic Compounds (VOC)	5%	1%	3%	91%
18	Persistent Organic Pollutants (POP)	3%	6%	1%	90%
19	Heavy Metals to Air	3%	2%	8%	88%
	PAHs	50%	2%	5%	43%
20	Particulate Matter (PM, dust)	28%	3%	3%	67%
	Emissions (Water)				
21	Heavy Metals to Water	18%	3%	0%	79%
22	Eutrophication	48%	7%	8%	37%
23	Persistent Organic Pollutants (POP)	negligible	negligible	negligible	negligible

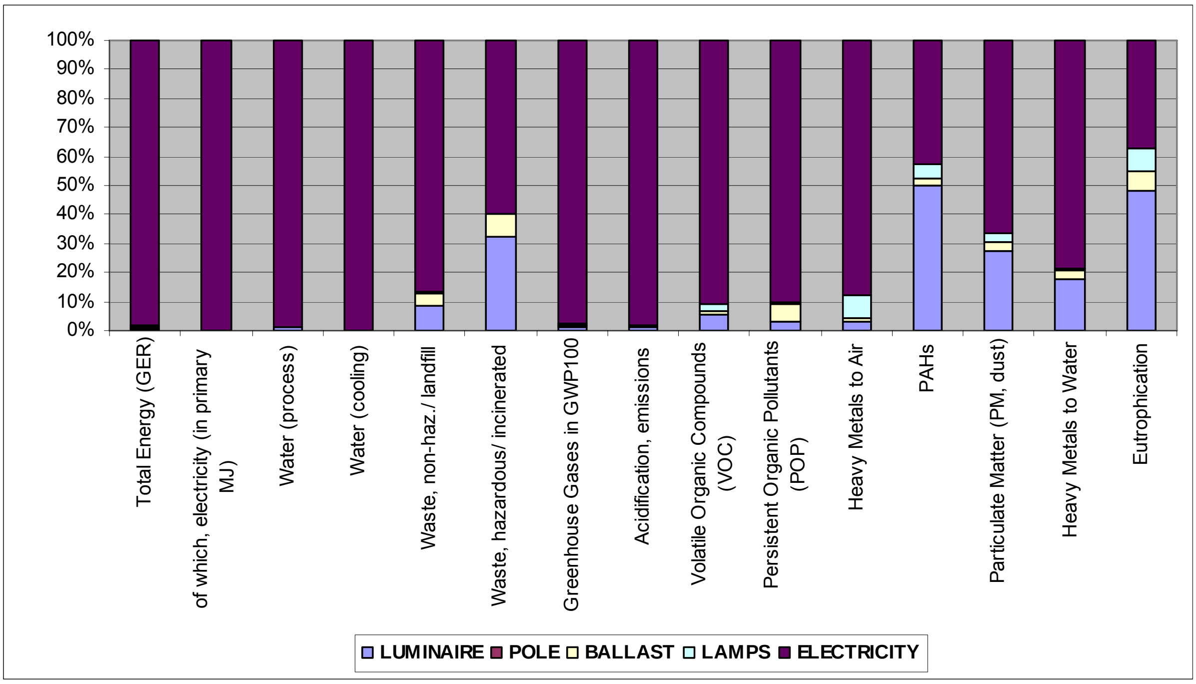


Figure 28: Life Cycle Impact, Base Case, Category S (contribution of production, distribution, end-of-life of lamps, ballast, luminaire and electricity use)

Discussion of results:

For most impact categories, the contribution of the electricity use during the life of the street lighting luminaire configuration is most substantial. This is clearly shown in figures Figure 26 to Figure 28 where the material-related impacts from production, distribution and end-of-life waste treatment of lamps, ballast and luminaire are clearly distinguished from the electricity use. The impacts related to materials become more prominent for lower wattage luminaire configurations, hence explaining why in category S the impacts are more prominent compared to M, and even more in category F. Impact categories dominated by electricity use are GER, water use, non-hazardous waste, GHG, acidification, VOC, POP and HM to air and water. Impact categories where material aspects contribute largely are hazardous waste (where the contribution from the luminaire is almost exclusively from polyester housing in the end-of-life phase), PAH (largely due to aluminium production), PM (due to incineration of the luminaire polyester housing), Eutrophication (contribution from the production of the luminaire polyester housing). The relationship from individual indicators to materials can be found in the MEEUP methodology report (table 29).
Based on these results it can be concluded that the focus should be on energy efficiency in order to reduce environmental impact.

No normalisation factors are available for EU25 impact totals, so no conclusions can be drawn regarding the relative importance of each single impact.

When comparing different luminaires with different lamp types, HPM luminaires are worst case with HPS luminaires having a factor 2,5 to 3 less environmental impacts per functional lumen output. CMH and CFL luminaires generate obviously the least impacts per functional lumen output and where appropriate for application, substitution with these types of luminaires can lead to substantial impact reductions.

5.3.3 BaseCase Life Cycle Costs

The table below gives the Life Cycle Costs for the BaseCase, using the rates and prices given in section 2.4. The actual total consumer expenditure in the EU25 due to the installed base (stock) is presented in 5.4.3. Note that maintenance costs (K) are included in the operating costs for replacing lamps (H). Also the purchase prices of lamps are included in the operating costs for replacing lamps (H).

Table 91: Table . Life Cycle Costs per unit new sales

Item (€) Category	D – Product Price	E – Installation costs	F – Operating cost: electricity	H – Operating cost: lamps	I – Operating costs: ballast	K – Repair and maintenance costs	LCC
F	220	11	2.030	169	n.a.	n.a.	2.430
M	187	11	1.854	152	n.a.	n.a.	2.201
S	166	11	717	114	n.a.	n.a.	1.007
Average*	172	11	1.002	124	n.a.	n.a.	1.307

***weighted average based on market data (2% cat F, 23% cat M, 75% cat S luminaires)**

Each time EU buyers/users make a buying decision, they decide not just on a purchase price of 183 € but on the total Life Cycle Costs (LCC) of the product – including running costs discounted to their net present value-of on average 1307 €. Initial purchase costs representing only 14% of total LCC. Operating costs represent 86% in total, of which electricity costs 77% and lamp replacement (incl. maintenance) costs 9%. Note that compared to the distribution of environmental effects over the life cycle phases, a similar conclusion could be drawn, but there the use phase has an even more substantial share compared to the impacts (of production, distribution, end-of-life) of the luminaire, lamps and ballast.

5.3.4 EU25 Total impacts and expenditure

In chapter 8.1.2.1, total EU25 expenditure is shown in table Table 107: Aggregated results, Business As Usual (BAU) from 1990 up to 2020.

The following tables represent the EU25 total life cycle impacts from product sales in 2005 for average product configurations per category F, M, S. On www.eup4light.net, the EcoReports for all individual product configurations can be found.

Table 92: EU Total Impact of NEW Luminaires, category F, produced in 2005 (over their lifetime)

Nr	EU Impact of New Models sold 2005 over their lifetime: sales, category F		Author VITO

Nr	Life Cycle phases --> Resources Use and Emissions	unit	PRODUCTION Mat.	PRODUCTION Manuf	PRODUCTION Tot.	DISTRI-BUTION	USE	END-OF-LIFE* Disp.	END-OF-LIFE* Recycl.	END-OF-LIFE* Total	TOTAL
	Materials	**unit**									
1	Bulk Plastics	kt			**0,0**			0,0	0,0	**0,0**	**0,0**
2	TecPlastics	kt			**0,1**			0,1	0,0	**0,1**	**0,0**
3	Ferro	kt			**0,1**			0,0	0,1	**0,1**	**0,0**
4	Non-ferro	kt			**0,1**			0,0	0,1	**0,1**	**0,0**
5	Coating	kt			**0,0**			0,0	0,0	**0,0**	**0,0**
6	Electronics	kt			**0,0**			0,0	0,0	**0,0**	**0,0**
7	Misc.	kt			**0,1**			0,0	0,1	**0,1**	**0,0**
	Total weight	kt			**0,4**			0,1	0,3	**0,4**	**0,0**
	Other Resources & Waste								see note!	debet	credit
8	Total Energy (GER)	PJ	0,0	0,0	**0,0**	**0,0**	**13,3**	0,0	0,0	**0,0**	**13,3**
9	of which, electricity (in primary MJ)	PJ	0,0	0,0	**0,0**	**0,0**	**13,3**	0,0	0,0	**0,0**	**13,3**
10	Water (process)	mln. m3	0,0	0,0	**0,0**	**0,0**	**0,9**	0,0	0,0	**0,0**	**0,9**
11	Water (cooling)	mln. m3	0,0	0,0	**0,0**	**0,0**	**35,4**	0,0	0,0	**0,0**	**35,4**
12	Waste, non-haz./ landfill	kt	1,0	0,0	**1,1**	**0,0**	**15,4**	0,0	0,0	**0,0**	**16,5**
13	Waste, hazardous/ incinerated	kt	0,0	0,0	**0,0**	**0,0**	**0,3**	0,1	0,0	**0,1**	**0,4**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	mt CO2 eq.	0,0	0,0	**0,0**	**0,0**	**0,6**	0,0	0,0	**0,0**	**0,6**
15	Ozone Depletion, emissions	t R-11 eq.	Negligible								
16	Acidification, emissions	kt SO2 eq.	0,0	0,0	**0,0**	**0,0**	**3,4**	0,0	0,0	**0,0**	**3,4**
17	Volatile Organic Compounds (VOC)	kt	0,0	0,0	**0,0**	**0,0**	**0,0**	0,0	0,0	**0,0**	**0,0**
18	Persistent Organic Pollutants (POP)	g i-Teq	0,0	0,0	**0,0**	**0,0**	**0,1**	0,0	0,0	**0,0**	**0,1**
19	Heavy Metals	ton Ni eq.	0,0	0,0	**0,0**	**0,0**	**0,2**	0,0	0,0	**0,0**	**0,3**
	PAHs	ton Ni eq.	0,0	0,0	**0,0**	**0,0**	**0,0**	0,0	0,0	**0,0**	**0,0**
20	Particulate Matter (PM, dust)	kt	0,0	0,0	**0,0**	**0,0**	**0,1**	0,0	0,0	**0,0**	**0,1**
	Emissions (Water)										
21	Heavy Metals	ton Hg/20	0,0	0,0	**0,0**	**0,0**	**0,1**	0,0	0,0	**0,0**	**0,1**
22	Eutrophication	kt PO4	0,0	0,0	**0,0**	**0,0**	**0,0**	0,0	0,0	**0,0**	**0,0**
23	Persistent Organic Pollutants (POP)	g i-Teq	negligible								

Table 93: EU Total Impact of NEW Luminaires, category M, produced in 2005 (over their lifetime)

Nr	EU Impact of New Models sold 2005 over their lifetime: sales, category M		Author VITO

Nr	Life Cycle phases --> Resources Use and Emissions		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
			Mat.	Manuf	Tot.	BUTION		Disp.	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	kt			**0,0**			0,0	0,0	**0,0**	**0,0**
2	TecPlastics	kt			**0,9**			0,8	0,1	**0,9**	**0,0**
3	Ferro	kt			**1,3**			0,1	1,2	**1,3**	**0,0**
4	Non-ferro	kt			**1,7**			0,1	1,6	**1,7**	**0,0**
5	Coating	kt			**0,0**			0,0	0,0	**0,0**	**0,0**
6	Electronics	kt			**0,1**			0,0	0,0	**0,1**	**0,0**
7	Misc.	kt			**0,8**			0,0	0,7	**0,8**	**0,0**
	Total weight	kt			**4,7**			1,1	3,6	**4,7**	**0,0**
	Other Resources & Waste								see note!	debet	credit
8	Total Energy (GER)	PJ	0,5	0,1	**0,6**	**0,1**	**160,6**	0,1	0,0	**0,1**	**161,4**
9	of which, electricity (in primary MJ)	PJ	0,1	0,1	**0,1**	**0,0**	**160,6**	0,0	0,0	**0,0**	**160,8**
10	Water (process)	mln. m3	0,1	0,0	**0,1**	**0,0**	**10,7**	0,0	0,0	**0,0**	**10,8**
11	Water (cooling)	mln. m3	0,2	0,0	**0,2**	**0,0**	**428,4**	0,0	0,0	**0,0**	**428,6**
12	Waste, non-haz./ landfill	kt	12,3	0,4	**12,7**	**0,1**	**186,4**	0,3	0,0	**0,3**	**199,4**
13	Waste, hazardous/ incinerated	kt	0,2	0,0	**0,2**	**0,0**	**3,7**	0,9	0,0	**0,9**	**4,8**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	mt CO2 eq.	0,0	0,0	**0,0**	**0,0**	**7,0**	0,0	0,0	**0,0**	**7,1**
15	Ozone Depletion, emissions	t R-11 eq.	Negligible								
16	Acidification, emissions	kt SO2 eq.	0,2	0,0	**0,2**	**0,0**	**41,4**	0,0	0,0	**0,0**	**41,7**
17	Volatile Organic Compounds (VOC)	kt	0,0	0,0	**0,0**	**0,0**	**0,1**	0,0	0,0	**0,0**	**0,1**
18	Persistent Organic Pollutants (POP)	g i-Teq	0,0	0,0	**0,1**	**0,0**	**1,1**	0,0	0,0	**0,0**	**1,1**
19	Heavy Metals	ton Ni eq.	0,3	0,0	**0,3**	**0,0**	**2,8**	0,0	0,0	**0,0**	**3,1**
	PAHs	ton Ni eq.	0,1	0,0	**0,1**	**0,0**	**0,3**	0,0	0,0	**0,0**	**0,5**
20	Particulate Matter (PM, dust)	kt	0,0	0,0	**0,0**	**0,0**	**0,9**	0,1	0,0	**0,1**	**1,1**
	Emissions (Water)										
21	Heavy Metals	ton Hg/20	0,1	0,0	**0,1**	**0,0**	**1,0**	0,0	0,0	**0,0**	**1,1**
22	Eutrophication	kt PO4	0,0	0,0	**0,0**	**0,0**	**0,0**	0,0	0,0	**0,0**	**0,0**
23	Persistent Organic Pollutants (POP)	g i-Teq	negligible								

Table 94: EU Total Impact of NEW Luminaires, category S, produced in 2005 (over their lifetime)

Nr	EU Impact of New Models sold 2005 over their lifetime: sales, category S		Author VITO

Nr	Life Cycle phases --> Resources Use and Emissions		PRODUCTION Mat.	Manuf	Tot.	DISTRI-BUTION	USE	END-OF-LIFE* Disp.	Recycl.	Total	TOTAL
	Materials	**unit**									
1	Bulk Plastics	kt			**0,1**			0,1	0,0	**0,1**	**0,0**
2	TecPlastics	kt			**3,1**			2,8	0,3	**3,1**	**0,0**
3	Ferro	kt			**2,7**			0,1	2,6	**2,7**	**0,0**
4	Non-ferro	kt			**4,9**			0,2	4,6	**4,9**	**0,0**
5	Coating	kt			**0,0**			0,0	0,0	**0,0**	**0,0**
6	Electronics	kt			**0,1**			0,1	0,1	**0,1**	**0,0**
7	Misc.	kt			**1,3**			0,1	1,2	**1,3**	**0,0**
	Total weight	kt			**12,1**			3,3	8,8	**12,1**	**0,0**
	Other Resources & Waste								see note!	debet	credit
8	Total Energy (GER)	PJ	1,3	0,3	**1,6**	**0,5**	**202,5**	0,2	0,1	**0,2**	**204,7**
9	of which, electricity (in primary MJ)	PJ	0,1	0,2	**0,3**	**0,0**	**202,5**	0,0	0,0	**0,0**	**202,7**
10	Water (process)	mln. m3	0,2	0,0	**0,2**	**0,0**	**13,5**	0,0	0,0	**0,0**	**13,7**
11	Water (cooling)	mln. m3	0,6	0,1	**0,7**	**0,0**	**539,9**	0,0	0,0	**0,0**	**540,6**
12	Waste, non-haz./ landfill	kt	30,7	1,1	**31,8**	**0,3**	**235,0**	0,7	0,0	**0,7**	**267,9**
13	Waste, hazardous/ incinerated	kt	0,4	0,0	**0,4**	**0,0**	**4,7**	2,9	0,0	**2,9**	**8,0**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	mt CO2 eq.	0,1	0,0	**0,1**	**0,0**	**8,8**	0,0	0,0	**0,0**	**9,0**
15	Ozone Depletion, emissions	t R-11 eq.	Negligible								
16	Acidification, emissions	kt SO2 eq.	0,5	0,1	**0,6**	**0,1**	**52,1**	0,0	0,0	**0,0**	**52,9**
17	Volatile Organic Compounds (VOC)	kt	0,0	0,0	**0,0**	**0,0**	**0,1**	0,0	0,0	**0,0**	**0,1**
18	Persistent Organic Pollutants (POP)	g i-Teq	0,1	0,0	**0,1**	**0,0**	**1,3**	0,0	0,0	**0,0**	**1,5**
19	Heavy Metals	ton Ni eq.	0,3	0,0	**0,3**	**0,0**	**3,5**	0,1	0,0	**0,1**	**3,9**
	PAHs	ton Ni eq.	0,4	0,0	**0,4**	**0,0**	**0,4**	0,0	0,0	**0,0**	**0,8**
20	Particulate Matter (PM, dust)	kt	0,1	0,0	**0,1**	**0,1**	**1,1**	0,3	0,0	**0,3**	**1,7**
	Emissions (Water)										
21	Heavy Metals	ton Hg/20	0,3	0,0	**0,3**	**0,0**	**1,3**	0,0	0,0	**0,0**	**1,6**
22	Eutrophication	kt PO4	0,0	0,0	**0,0**	**0,0**	**0,0**	0,0	0,0	**0,0**	**0,0**
23	Persistent Organic Pollutants (POP)	g i-Teq	negligible								

Discussion of results

Again, EU25 totals demonstrate the substantial importance of the use phase of the street lighting products. Over the entire life of the products (sales 2005), the gross energy requirement (GER) is 379,4 PJ primary energy equivalents, category F contributing 3,5%, category M 42,5%, category S 53,9%. For all impact categories, category S street lighting products are most important (slow traffic, urban areas). These are luminaires with lower wattages per luminaire compared to M and F luminaires, but due to the high quantity, their contribution is the highest.

Table 95: Aggregated Results

Nr	EU Impact of New Models sold 2005 over their lifetime: sales, aggregated		Author VITO

Nr	Life Cycle phases --> Resources Use and Emissions		PRODUCTION Mat.	Manuf	Tot.	DISTRI-BUTION	USE	END-OF-LIFE* Disp.	Recycl.	Total	TOTAL
	Materials	**unit**									
	Total weight	kt			**17,2**			4,5	12,7	**17,2**	**0,0**
									see note!		
	Other Resources & Waste									debet	credit
8	Total Energy (GER)	PJ	1,8	0,4	**2,2**	**0,6**	**376,4**	0,3	0,1	**0,2**	**379,4**
9	of which, electricity (in primary MJ)	PJ	0,2	0,2	**0,4**	**0,0**	**376,4**	0,0	0,0	**0,0**	**376,8**
10	Water (process)	mln. m3	0,2	0,0	**0,2**	**0,0**	**25,1**	0,0	0,0	**0,0**	**25,3**
11	Water (cooling)	mln. m3	0,8	0,1	**0,9**	**0,0**	**1003,6**	0,0	0,0	**0,0**	**1004,5**
12	Waste, non-haz./ landfill	kt	44,1	1,5	**45,6**	**0,4**	**436,8**	1,1	0,0	**1,0**	**483,8**
13	Waste, hazardous/ incinerated	kt	0,6	0,0	**0,6**	**0,0**	**8,7**	3,9	0,0	**3,8**	**13,1**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	mt CO2 eq.	0,1	0,0	**0,1**	**0,0**	**16,4**	0,0	0,0	**0,0**	**16,6**
16	Acidification, emissions	kt SO2 eq.	0,8	0,1	**0,9**	**0,2**	**96,9**	0,0	0,0	**0,0**	**98,0**
17	Volatile Organic Compounds (VOC)	kt	0,0	0,0	**0,0**	**0,0**	**0,1**	0,0	0,0	**0,0**	**0,2**
18	Persistent Organic Pollutants (POP)	g i-Teq	0,2	0,0	**0,2**	**0,0**	**2,5**	0,0	0,0	**0,0**	**2,7**
19	Heavy Metals	ton Ni eq.	0,6	0,1	**0,6**	**0,0**	**6,5**	0,1	0,0	**0,1**	**7,2**
	PAHs	ton Ni eq.	0,6	0,0	**0,6**	**0,0**	**0,7**	0,0	0,0	**0,0**	**1,3**
20	Particulate Matter (PM, dust)	kt	0,1	0,0	**0,2**	**0,2**	**2,1**	0,4	0,0	**0,4**	**2,8**
	Emissions (Water)										
21	Heavy Metals	ton Hg/20	0,4	0,0	**0,4**	**0,0**	**2,4**	0,0	0,0	**0,0**	**2,9**
22	Eutrophication	kt PO4	0,0	0,0	**0,0**	**0,0**	**0,0**	0,0	0,0	**0,0**	**0,0**

5.4 BaseCase stock

The results in the following chapters are given per average Base Case (unit) product, per category. In order to compare results between categories (F, M, S) it is necessary to take into account the functional unit in lumen (lm) per base case product as indicated.

5.4.1 Product-specific Inputs

The inputs are identical to those of new sales (see section 5.3.1) except for the average composition of the stock, which is given in tables 2 to 4 of section 5.1.1. There are two exceptions: technical input parameters LMF and UF in stock luminaires are considered 97,5% of LMF and UF in new products (sales). This ratio is assumed similar for all single base case luminaire configurations.

This results in the following:

<u>per BaseCase luminaire, category F (stock):</u>
- annual lamp replacement of 0,29 lamps/yr
- installed power of 256 W
- functional light output of 8861 lm

<u>per BaseCase luminaire, category M (stock):</u>
- annual lamp replacement of 0,33 lamps/yr
- installed power of 277 W
- functional light output of 3738 lm

<u>per BaseCase luminaire, category S (stock):</u>
- annual lamp replacement of 0,33 lamps/yr
- installed power of 97 W
- functional light output of 1038 lm

Note that the increase in installed power per luminaire in 'sales' base cases compared to 'stock' base cases (and thus electricity consumption) can be largely explained by the demand for more light output (lm). 'Annual lamp replacement' doesn't change much compared to 'sales'. It decreases slightly as HPM are being replaced with HPS that have a longer service life.

5.4.2 Environmental Impact

Table 96: Life Cycle Impact, Base Case Stock, Category F (life cycle phases)

Nr	Life cycle Impact per product: Weighted average stock, category F		Author VITO

Nr	Life Cycle phases --> Resources Use and Emissions		PRODUCTION			DISTRI-BUTION	USE	END-OF-LIFE*			TOTAL
			Mat.	Manuf	Tot.			Disp.	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	kg			**0,1**			0,0	0,0	**0,1**	**0,0**
2	TecPlastics	kg			**1,9**			1,7	0,2	**1,9**	**0,0**
3	Ferro	kg			**3,0**			0,1	2,8	**3,0**	**0,0**
4	Non-ferro	kg			**3,5**			0,2	3,3	**3,5**	**0,0**
5	Coating	kg			**0,0**			0,0	0,0	**0,0**	**0,0**
6	Electronics	kg			**0,1**			0,1	0,1	**0,1**	**0,0**
7	Misc.	kg			**3,3**			0,2	3,2	**3,3**	**0,0**
	Total weight	kg			**12,0**			2,3	9,6	**12,0**	**0,0**
	Other Resources & Waste									debet	credit
8	Total Energy (GER)	GJ	1,0	0,2	**1,2**	**0,3**	**339,8**	0,2	0,0	**0,1**	**341,4**
9	of which, electricity (in primary MJ)	GJ	0,2	0,1	**0,3**	**0,0**	**339,8**	0,0	0,0	**0,0**	**340,1**
10	Water (process)	m3	0,2	0,0	**0,2**	**0,0**	**22,7**	0,0	0,0	**0,0**	**22,8**
11	Water (cooling)	m3	0,4	0,1	**0,5**	**0,0**	**906,0**	0,0	0,0	**0,0**	**906,5**
12	Waste, non-haz./ landfill	kg	27,9	0,8	**28,7**	**0,2**	**394,2**	0,7	0,0	**0,7**	**423,8**
13	Waste, hazardous/ incinerated	kg	0,4	0,0	**0,4**	**0,0**	**7,8**	1,8	0,0	**1,8**	**10,1**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	t CO2 eq.	0,1	0,0	**0,1**	**0,0**	**14,8**	0,0	0,0	**0,0**	**14,9**
15	Ozone Depletion, emissions	g R-11 eq.	Negligible								
16	Acidification, emissions	kg SO2 eq.	0,5	0,1	**0,6**	**0,1**	**87,5**	0,0	0,0	**0,0**	**88,1**
17	Volatile Organic Compounds (VOC)	kg	0,0	0,0	**0,0**	**0,0**	**0,1**	0,0	0,0	**0,0**	**0,1**
18	Persistent Organic Pollutants (POP)	µg i-Teq	0,1	0,0	**0,1**	**0,0**	**2,2**	0,0	0,0	**0,0**	**2,4**
19	Heavy Metals	g Ni eq.	0,7	0,0	**0,7**	**0,0**	**5,8**	0,0	0,0	**0,0**	**6,6**
	PAHs	g Ni eq.	0,3	0,0	**0,3**	**0,0**	**0,7**	0,0	0,0	**0,0**	**1,0**
20	Particulate Matter (PM, dust)	kg	0,1	0,0	**0,1**	**0,1**	**1,9**	0,2	0,0	**0,2**	**2,2**
	Emissions (Water)										
21	Heavy Metals	g Hg/20	0,2	0,0	**0,2**	**0,0**	**2,2**	0,0	0,0	**0,0**	**2,4**
22	Eutrophication	kg PO4	0,0	0,0	**0,0**	**0,0**	**0,0**	0,0	0,0	**0,0**	**0,0**
23	Persistent Organic Pollutants (POP)	µg i-Teq	negligible								

Table 97: Life Cycle Impact, Base Case, Category F (per 1000 functional lumen)

	TOTAL (per 1000 functional lm)		WEIGHTED AVERAGE (SALES)	WEIGHTED AVERAGE (STOCK)
	Other Resources & Waste			
8	Total Energy (GER)	*MJ*	37.024	38.585
9	of which, electricity (in primary MJ)	*MJ*	36.840	38.379
10	Water (process)	*ltr*	2.469	2.574
11	Water (cooling)	*ltr*	98.209	102.306
12	Waste, non-haz./ landfill	*g*	45.789	47.890
13	Waste, hazardous/ incinerated	*g*	1.050	1.105
	Emissions (Air)			
14	Greenhouse Gases in GWP100	*kg CO2 eq.*	1.621	1.689
15	Ozone Depletion, emissions	*mg R-11 eq.*	negligible	negligible
16	Acidification, emissions	*g SO2 eq.*	9.556	9.960
17	Volatile Organic Compounds (VOC)	*g*	14	15
18	Persistent Organic Pollutants (POP)	*ng i-Teq*	255	267
19	Heavy Metals to Air	*mg Ni eq.*	723	750
	PAHs	*mg Ni eq.*	105	111
20	Particulate Matter (PM, dust)	*g*	237	250
	Emissions (Water)			
21	Heavy Metals to Water	*mg Hg/20*	261	274
22	Eutrophication	*g PO4*	2	2
23	Persistent Organic Pollutants (POP)	*ng i-Teq*	negligible	negligible

Table 98: Life Cycle Impact, Base Case Stock, Category M (life cycle phases)

Nr	Life cycle Impact per product: Weighted average stock, category M		Author VITO

Nr	Life Cycle phases --> Resources Use and Emissions		PRODUCTION			DISTRI-BUTION	USE	END-OF-LIFE*			TOTAL
			Mat.	Manuf	Tot.			Disp.	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	kg			**0,1**			0,0	0,0	**0,1**	**0,0**
2	TecPlastics	kg			**1,9**			1,7	0,2	**1,9**	**0,0**
3	Ferro	kg			**2,7**			0,1	2,6	**2,7**	**0,0**
4	Non-ferro	kg			**3,4**			0,2	3,2	**3,4**	**0,0**
5	Coating	kg			**0,0**			0,0	0,0	**0,0**	**0,0**
6	Electronics	kg			**0,1**			0,1	0,1	**0,1**	**0,0**
7	Misc.	kg			**1,7**			0,1	1,6	**1,7**	**0,0**
	Total weight	kg			**9,9**			2,2	7,7	**9,9**	**0,0**
	Other Resources & Waste									debet	credit
8	Total Energy (GER)	GJ	1,0	0,2	**1,1**	**0,3**	**367,6**	0,2	0,0	**0,1**	**369,1**
9	of which, electricity (in primary MJ)	GJ	0,2	0,1	**0,3**	**0,0**	**367,6**	0,0	0,0	**0,0**	**367,8**
10	Water (process)	m3	0,1	0,0	**0,1**	**0,0**	**24,5**	0,0	0,0	**0,0**	**24,6**
11	Water (cooling)	m3	0,4	0,1	**0,5**	**0,0**	**980,1**	0,0	0,0	**0,0**	**980,6**
12	Waste, non-haz./ landfill	kg	25,8	0,8	**26,5**	**0,2**	**426,4**	0,6	0,0	**0,6**	**453,7**
13	Waste, hazardous/ incinerated	kg	0,3	0,0	**0,3**	**0,0**	**8,5**	1,8	0,0	**1,8**	**10,6**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	t CO2 eq.	0,1	0,0	**0,1**	**0,0**	**16,0**	0,0	0,0	**0,0**	**16,1**
15	Ozone Depletion, emissions	g R-11 eq.	Negligible								
16	Acidification, emissions	kg SO2 eq.	0,5	0,1	**0,5**	**0,1**	**94,6**	0,0	0,0	**0,0**	**95,2**
17	Volatile Organic Compounds (VOC)	kg	0,0	0,0	**0,0**	**0,0**	**0,1**	0,0	0,0	**0,0**	**0,1**
18	Persistent Organic Pollutants (POP)	µg i-Teq	0,1	0,0	**0,1**	**0,0**	**2,4**	0,0	0,0	**0,0**	**2,5**
19	Heavy Metals	g Ni eq.	0,5	0,0	**0,6**	**0,0**	**6,3**	0,0	0,0	**0,0**	**6,9**
	PAHs	g Ni eq.	0,3	0,0	**0,3**	**0,0**	**0,7**	0,0	0,0	**0,0**	**1,0**
20	Particulate Matter (PM, dust)	kg	0,1	0,0	**0,1**	**0,1**	**2,0**	0,2	0,0	**0,2**	**2,4**
	Emissions (Water)										
21	Heavy Metals	g Hg/20	0,2	0,0	**0,2**	**0,0**	**2,4**	0,0	0,0	**0,0**	**2,6**
22	Eutrophication	kg PO4	0,0	0,0	**0,0**	**0,0**	**0,0**	0,0	0,0	**0,0**	**0,0**
23	Persistent Organic Pollutants (POP)	µg i-Teq	negligible								

Table 99: Life Cycle Impact, Base Case, Category M (per 1000 functional lumen)

	TOTAL (per 1000 functional lm)		WEIGHTED AVERAGE (SALES)	WEIGHTED AVERAGE (STOCK)
	Other Resources & Waste			
8	Total Energy (GER)	*MJ*	80.877	98.891
9	of which, electricity (in primary MJ)	*MJ*	80.433	98.398
10	Water (process)	*ltr*	5.388	6.587
11	Water (cooling)	*ltr*	214.438	262.339
12	Waste, non-haz./ landfill	*g*	99.933	121.537
13	Waste, hazardous/ incinerated	*g*	2.305	2.744
	Emissions (Air)			
14	Greenhouse Gases in GWP100	*kg CO2 eq.*	3.542	4.329
15	Ozone Depletion, emissions	*mg R-11 eq.*	negligible	negligible
16	Acidification, emissions	*g SO2 eq.*	20.870	25.513
17	Volatile Organic Compounds (VOC)	*g*	31	38
18	Persistent Organic Pollutants (POP)	*ng i-Teq*	556	678
19	Heavy Metals to Air	*mg Ni eq.*	1.540	1.861
	PAHs	*mg Ni eq.*	234	276
20	Particulate Matter (PM, dust)	*g*	524	630
	Emissions (Water)			
21	Heavy Metals to Water	*mg Hg/20*	571	690
22	Eutrophication	*g PO4*	4	5
23	Persistent Organic Pollutants (POP)	*ng i-Teq*	negligible	negligible

Table 100: Life Cycle Impact, Base Case Stock, Category S (life cycle phases)

Nr	Life cycle Impact per product: Weighted average stock, category S		Author VITO

Nr	Life Cycle phases --> Resources Use and Emissions		PRODUCTION			DISTRI-BUTION	USE	END-OF-LIFE*			TOTAL
			Mat.	Manuf	Tot.			Disp.	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	kg			**0,1**			0,0	0,0	**0,1**	**0,0**
2	TecPlastics	kg			**1,9**			1,7	0,2	**1,9**	**0,0**
3	Ferro	kg			**1,7**			0,1	1,6	**1,7**	**0,0**
4	Non-ferro	kg			**3,1**			0,2	2,9	**3,1**	**0,0**
5	Coating	kg			**0,0**			0,0	0,0	**0,0**	**0,0**
6	Electronics	kg			**0,1**			0,0	0,0	**0,1**	**0,0**
7	Misc.	kg			**0,7**			0,0	0,7	**0,7**	**0,0**
	Total weight	kg			**7,5**			2,1	5,4	**7,5**	**0,0**
	Other Resources & Waste									debet	credit
8	Total Energy (GER)	GJ	0,8	0,2	**1,0**	**0,3**	**128,9**	0,1	0,0	**0,1**	**130,3**
9	of which, electricity (in primary MJ)	GJ	0,1	0,1	**0,2**	**0,0**	**128,9**	0,0	0,0	**0,0**	**129,1**
10	Water (process)	m3	0,1	0,0	**0,1**	**0,0**	**8,6**	0,0	0,0	**0,0**	**8,7**
11	Water (cooling)	m3	0,4	0,0	**0,4**	**0,0**	**343,7**	0,0	0,0	**0,0**	**344,1**
12	Waste, non-haz./ landfill	kg	19,2	0,7	**19,9**	**0,2**	**149,6**	0,5	0,0	**0,4**	**170,1**
13	Waste, hazardous/ incinerated	kg	0,3	0,0	**0,3**	**0,0**	**3,0**	1,8	0,0	**1,8**	**5,0**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	t CO2 eq.	0,0	0,0	**0,1**	**0,0**	**5,6**	0,0	0,0	**0,0**	**5,7**
15	Ozone Depletion, emissions	g R-11 eq.	Negligible								
16	Acidification, emissions	kg SO2 eq.	0,3	0,0	**0,4**	**0,1**	**33,2**	0,0	0,0	**0,0**	**33,7**
17	Volatile Organic Compounds (VOC)	kg	0,0	0,0	**0,0**	**0,0**	**0,0**	0,0	0,0	**0,0**	**0,1**
18	Persistent Organic Pollutants (POP)	µg i-Teq	0,1	0,0	**0,1**	**0,0**	**0,8**	0,0	0,0	**0,0**	**0,9**
19	Heavy Metals	g Ni eq.	0,2	0,0	**0,2**	**0,0**	**2,2**	0,0	0,0	**0,0**	**2,5**
	PAHs	g Ni eq.	0,3	0,0	**0,3**	**0,0**	**0,3**	0,0	0,0	**0,0**	**0,5**
20	Particulate Matter (PM, dust)	kg	0,1	0,0	**0,1**	**0,1**	**0,7**	0,2	0,0	**0,2**	**1,0**
	Emissions (Water)										
21	Heavy Metals	g Hg/20	0,2	0,0	**0,2**	**0,0**	**0,8**	0,0	0,0	**0,0**	**1,0**
22	Eutrophication	kg PO4	0,0	0,0	**0,0**	**0,0**	**0,0**	0,0	0,0	**0,0**	**0,0**
23	Persistent Organic Pollutants (POP)	µg i-Teq	negligible								

Table 101: Life Cycle Impact, Base Case, Category S (per 1000 functional lumen)

	TOTAL (per 1000 functional lm)		WEIGHTED AVERAGE (SALES)	WEIGHTED AVERAGE (STOCK)
	Other Resources & Waste			
8	Total Energy (GER)	*MJ*	110.126	118.596
9	of which, electricity (in primary MJ)	*MJ*	108.548	116.982
10	Water (process)	*ltr*	7.323	7.887
11	Water (cooling)	*ltr*	289.437	311.923
12	Waste, non-haz./ landfill	*g*	145.641	155.789
13	Waste, hazardous/ incinerated	*g*	4.194	4.424
	Emissions (Air)			
14	Greenhouse Gases in GWP100	*kg CO2 eq.*	4.849	5.220
15	Ozone Depletion, emissions	*mg R-11 eq.*	negligible	negligible
16	Acidification, emissions	*g SO2 eq.*	28.464	30.648
17	Volatile Organic Compounds (VOC)	*g*	45	48
18	Persistent Organic Pollutants (POP)	*ng i-Teq*	789	845
19	Heavy Metals to Air	*mg Ni eq.*	2.124	2.279
	PAHs	*mg Ni eq.*	499	520
20	Particulate Matter (PM, dust)	*g*	893	945
	Emissions (Water)			
21	Heavy Metals to Water	*mg Hg/20*	886	944
22	Eutrophication	*g PO4*	9	9
23	Persistent Organic Pollutants (POP)	*ng i-Teq*	negligible	negligible

Discussion of results

The relative distribution of impacts over the life cycle for stock luminaires is similar to that of sales luminaires.

When comparing total impacts per unit of product sales versus stock (Table 102) we notice that in category F, impacts per average product unit are higher for sales compared to stock, while in categories M and S this is the other way around. This can be explained by relatively lower impacts for LPS luminaires compared to HPS luminaires (see table Table 83 and single EcoReports for LPS and HPS on www.eup4light.net) and the assumption that for new sales LPS are being replaced with HPS luminaires. When however considering the functional unit (see tables Table 97, Table 99, Table 101) impacts per functional lumen output of sales luminaires are lower compared to existing stock luminaires. Besides the difference in average weights for luminaire types sales versus stock, this is also related to the assumption that stock luminaires have generally worse LMF and UF (97,5% compared to new products).

Table 102: Impacts sales versus stock (per unit product)

	Life Cycle phases -->	Category F	Category M	Category S
	Resources Use and Emissions			
	Materials	**Production**	**Production**	**Production**
1	Bulk Plastics	100%	100%	102%
2	TecPlastics	100%	100%	100%
3	Ferro	99%	94%	100%
4	Non-ferro	100%	99%	100%
5	Coating	112%	101%	108%
6	Electronics	102%	99%	96%
7	Misc.	61%	89%	105%
	Total weight	89%	96%	100%
	Other Resources & Waste	**Total**	**Total**	**Total**
8	Total Energy (GER)	105%	89%	98%
9	of which, electricity (in primary MJ)	105%	89%	98%
10	Water (process)	105%	89%	98%
11	Water (cooling)	105%	89%	98%
12	Waste, non-haz./ landfill	105%	89%	98%
13	Waste, hazardous/ incinerated	104%	91%	99%
	Emissions (Air)			
14	Greenhouse Gases in GWP100	105%	89%	98%
15	Ozone Depletion, emissions			
16	Acidification, emissions	105%	89%	98%
17	Volatile Organic Compounds (VOC)	105%	89%	98%
18	Persistent Organic Pollutants (POP)	105%	89%	98%
19	Heavy Metals	106%	90%	98%
	PAHs	104%	92%	99%
20	Particulate Matter (PM, dust)	104%	90%	99%
	Emissions (Water)			
21	Heavy Metals	**105%**	**90%**	**98%**
22	Eutrophication	**104%**	**94%**	**99%**
23	Persistent Organic Pollutants (POP)			

5.4.3 EU25 Total expenditure and impacts

In chapter 8.1.2.1, total EU25 environmental impacts and expenditure from the installed base are shown in table Table 107: Aggregated results, Business As Usual (BAU).

6 TECHNICAL ANALYSIS BAT AND BNAT

Scope: This entails a technical analysis and description of the Best Available Technology (BAT) and Best Not yet Available Technology (BNAT) that can be implemented on product or part level. The described BAT is in many cases already available on the market, but is less frequently used because of the purchase price. It partly provides the input for the identification of part of the improvement potential (task 7), i.e. especially the part that relates to the best available technology. In chapter 7 also cost, intellectual property and availability are taken into account for the selection of options. This is not the case in this chapter and many of the presented technologies are intellectual property or linked to individual companies. The input of this chapter is partially the result of an organised visit to the Light and Building trade fare in Frankfurt 2006 (see also chapter 9 stakeholder consultation). Much research is ongoing and information is not always publicly available, therefore this chapter can never claim to be complete but aims to give a general overview. For commercial reasons, brand names are avoided in the text as far as possible.

6.1 Identified BAT

6.1.1 New luminaires with improved luminaire maintenance factor (LMF)

Luminaires with a low LMF will require an overdimensioning because the LMF depreciation factor must be taken into account when installations are calculated according to the EN 13201 standard series.

The technical solutions for an increase in LMF are:

- New luminaire designs with a high degree of ingress protection (IP rating see chapter 1). For example an IP66 class humid and dust ingress protection of the optic compartment with an innovative double gasket, is a guarantee of the long term cleanliness of the optical compartment. The ingress protection is also guaranteed after repetitive opening of the luminaire for lamp or control gear replacement and is designed to withstand the high temperature variations that can occur.
- Recently new luminaires were presented with glass that has been treated with a self-cleaning coating that reduces the build-up of external dirt. UV rays activate the self-cleaning coating to break down and disintegrate dirt. The surface of the glass is hydrophilic which means that the rain spreads over the glass, instead of forming drops, and washes away the residue. There is a patent claim on the technology (US 6599618) filed in 1999 and issued in 2003, therefore the technology is only treated as optional in this study.

Conclusion:
LMF (@ 4 years) = 0,95 can be expected for medium polluted environments.

6.1.2 New luminaires with rapid access to lamp and a separate ballast compartment with rapid access

Figure 29: Luminaire with an optimised thermal design for electronic ballast

Luminaires with difficult and time consuming lamp access can discourage street lighting owners from taking into account appropriate short lamp group replacement time periods.
Luminaires with an integrated electronic ballast can suffer from decreased ballast life time because electronic ballasts are more sensitive to high temperature, mainly caused by the failure of the incorporated electrolytic capacitor. As a rule of thumb the electrolytic capacitors lifetime doubles with every 10°C of operational temperature decrease (consult manufacturers catalogue).

The technical solutions are:

- Design that provides rapid access and replacement with a minimum or no tools required.
- Recently luminaires were presented that have separate thermal isolated electronic ballast compartment with rapid access (Figure 29).

Conclusion:
Average lamp and ballast replacement time (see chapter 2) can be further reduced.
It can be expected that new luminaires can host new electronic ballasts without negative effect on their lifetime.

6.1.3 Luminaires with improved utilization factor (UF) to reduce wasted light

In order to obtain a high utilisation factor UF it is important to direct the light to the intended surface or area (e.g. road). The higher the UF is, the lower the needed energy to operate the lamp.

Figure 30: Luminaires with high utilization factor (left) and luminaire with very poor utilization factor due to the high upward light output (right).

Figure 31: New luminaires with multi-facet reflector (left, middle) that can be used for very complicated area shape illumination

The technical solutions are:

- The upward light (ULOR) from luminaires is mainly wasted light in outdoor street lighting; it has no sense to illuminate the night sky (see Figure 30). The use of luminaires with internal top reflectors or reflective top shielding covers.

- Street lighting luminaires need to redirect the lamp light output as much as possible downward (DLOR) to the street surface or its surroundings in order to be useful. The appropriate use of transparent protector material with reduced diffuse optic properties and high optic transmittance.
- New multi-facet reflector technology for highly asymmetric light distribution. The principle is easy: light is directed to a complex multi-facets reflector on top of the luminaire (Figure 31). Innovation is included in the production and coating of these reflectors. The main advantage of this kind of luminaire is that light can be distributed in various and asymmetric light distributions. The total light output (LOR) is lower than standard street lighting. The upwards light flux (ULOR) is very low which reduces light pollution through sky glow. This high asymmetric light distribution can contribute to high utilisation factors (UF) for particular street lighting situations.
- The use of more compact light sources will allow to design associated high performing reflectors resulting in a higher UF. This can also be deducted when correlating the UF values in chapter 4 to the light sources. Light sources with a high light intensity (e.g. HPS and CMH in tubular clear envelope) have a significantly higher UF compared to lower intensity light sources (LPS, CFL, HPM or HPS with fluorescent balloon envelope). Advanced reflectors adapted to the light sources are designed using computer simulation software.

Conclusion:
Further increase in UF can be expected, probably UF as high as 0,6
In general high intensity light sources (HID) provide higher UF compared to the lower intensity ones (e.g. CFL, LPS). Despite their relative lower intensity, fluorescent lamps are still attractive when optic reflector and refractors are used (for road classes S5 and S6). Wasted light can be avoided when ULOR is limited (e.g. < 5 to 15 %) and DLOR is increased. Please note that DLOR is only a first indication of luminaire efficiency but does not garantee an optimum light distribution or UF.

6.1.4 Luminaires specially designed to reduce sky glow

As pointed out in 4.3.1.3 it is not only important to reduce the upward light output (ULOR) but especially the light emitted between the horizontal and 10 degrees above when the objective is to reduce sky glow. The reduction of near to horizontal light output is also beneficial for reducing glare. In general the objective to reduce ULOR is in line with energy saving and is therefore also in line with the previous section.

A problem did arise with luminaires with ‘curved glass’, ‘deep bowl’ or ‘refractor bowl’ transparent protectors because due to parasitic upward reflections from within the transparent protector, these luminaires still have some very low ULOR and unfortunately in the close to horizontal angles.
A solution to this problem could be found in the application of flat glass transparent protectors (see Figure 32) or ultimately outer screens or caps. Please note that the ideal installation position for this luminaires is horizontal.
These transparent protectors were introduced in the last decades to increase the LMF (see 6.1.1). The ‘curved glass’, ‘deep bowl’ or ‘refractor bowl’ transparent protectors were historically introduced in order to have wide beam luminaires with reduced internal reflection and hence increased efficiency(DLOR) because when simple, flat transparent glass protectors are used,

there is an increased reflection on the inner glass surface, due to the so-called 'Brewster angle effect'. New flat transparent optical protector solutions were introduced to overcome this problem but there is not yet a consensus whether or not these ‘flat glass’ or ‘flat refractor’ designs can compete ultimately in energy efficiency with the ‘curved glass’ or ‘deep bowl’ transparent protectors. Technologies are described hereafter but they are not yet generally proliferated among manufacturers.

The following terminology was introduced by IESNA (the Illuminating Engineering Society of North America) to designate luminaires in relationship to sky glow and light pollution:

- Full Cutoff luminaire: a luminaire that allows zero candela at or above an angle of 90 degrees above nadir and additionally the candela per 1000 lamp lumens does not numerically exceed 100 (10%) at a vertical angle of 80 degrees above nadir.
- Cutoff luminaire: a luminaire light distribution where the candela per 1000 lamp lumens does not numerically exceed 25 (2,5 %) at an angle of 90 degrees above nadir, and 100 (10 %) at a vertical angle of 80 degrees above nadir.
- Semi cutoff luminaire: a luminaire light distribution where the candela per 1000 lamp lumens does not numerically exceed 50 (5%) at an angle of 90 degrees above nadir, and 200 (20%) at a vertical angle of 80 degrees above nadir.
- Non-cutoff luminaire: a luminaire light distribution where there is no candela limitation.

The technical solutions to overcome the problems with increased reflection on flat transparent protectors are:

- The use of compact ‘flat refractors’ (see Figure 32) that breaks the optics into segments (e.g. prismatic elements) similar to ‘fresnel lens’ or ‘micro-optics’ technology. The refractor segments should are at the inner surface in order to avoid pollution by dirt. These designs can be particularly attractive for residential areas with low illuminance requirements (road classes S5 and S6) because it can be applied to low wattage fluorescent lamps (e.g. 36 Watt) and the white light of the fluorescent lamp contributes to an increased scotopic view (see chapter 3) at low illuminance levels. The result of the disc shaped refractor design is also a very low light pollution, low disability and discomfort glare, and optimal protection against obtrusive light.
- The application of antireflective coating technology on the inner surface of flat glass transparent protectors. The technology was disclosed in 1978 (US patent 4173778), the patent is expired.

Figure 32: ‘Curved glass’ protector(left) versus ‘Flat glass’ luminaires (middle) and ‘flat disc refractor’ luminaire (right) with low sky glow contribution.

Conclusion:
When applying 'Cutoff' Luminaires there is a reduction of sky glow in comparison with the base case luminaires in this study. In these 'Cutoff' luminaires the small ULOR is due to parasitic reflections in 'curved glass' or curved synthetic' transparent protectors.
'Full Cutoff' luminaires can offer the best performance in relationship to sky glow and glare but there is no consensus yet[53,54,55] if the ultimate most energy efficient design can be obtained; special techniques are required and are part of current R&D.

6.1.5 Improved HID light sources

Low pressure sodium (LPS) lamps have been in use since 1930 (IEA (2006)). Since 1960 they were improved with an infrared reflecting coating and these lamps are often called SOX lamps. The last important improvement was made in the late 1970's when the efficacy was raised with 15%, the so called SOX-E lamp. No significant progress has been reported in the last decade. The lamp efficacy is mainly high because the orange colour is close to maximum photopic eye sensitivity (see chapter 3) of the human eye (see Table 103).

Table 103: Efficiency for radiant power and Efficiency for visible (scotopic) radiant power for various lamp types (source: (de Groot&van Vliet(1986))

lamp type	Efficiency for radiant power (%)	Efficiency for visible (photopic) radiation(%)	Luminous efficacy (lm/W)
LPS	44	39	200
HPS	56	31	120
HPM	48	17	60

High Pressure Mercury (HPM) is the oldest high pressure HID lamp technology (IEA (2006)) and was introduced in early 1930. The lamp produces, in an inner arc tube, partially visible light and a high amount of UV-radiation besides; the arc tube is enclosed in an outer bulb coated with fluorescent powder that converts most UV into visible light. The inner arc tube is commonly made of fused silica glass. The production technology is widely proliferated. The efficacy of this lamp is low due to a poor efficiency for radiant power and poor colour matching to eye sensitivity (see Table 103). No significant progress has been reported in the last decades.

In the mid 1960s the first commercial Metal Halide (MH) lamp appeared on the market. MH lamps were very similar to HPM lamps but the major difference being that the arc tube contains various metallic halides in addition to mercury and argon(Lighting Handbook (1993)).
They have the advantage to produce white light without the need for a phosphor coated outer envelope and have therefore an improved efficiency.

[53] NEMA: 'White paper on outdoor lighting' (January 2004).
[54] Minutes of Meeting: 'EuP street lighting stakeholder meeting ' (18 December 2006).
[55] International Dark-Sky Association: 'Point of view communicated' (January 2006).

MH lamps can have a quite short lamp life compared to HPS lamps and can suffer from serious lumen depreciation over lamp lifetime. Therefore these types of lamps are not commonly used in street lighting but in sports lighting and floodlighting. Also the lamp colour is not stable over lamp lifetime (more greenish) because metals start to react with the arc wall and diffuse from the arc tube to the outer envelope. New developments for these quartz metal halide lamps are still ongoing (see also below).

The first commercial available High Pressure Sodium (HPS) lamp appeared around 1965 on the market. An important preliminary step in the development of this lamp took place between 1955 and 1957 when translucent, gas-tight polycrystalline alumina (PCA) was discovered; this PCA material is a ceramic material composed of 99.9 % sintered Al_2O_3. This material was required to withstand the highly reactive sodium at high temperature and high pressure. Processing of this ceramic material is far more complicated compared to fused silica glass. The production technology is therefore less proliferated compared to HPM or quartz MH lamps. These lamps have, compared to other HID lamps: a high lamp efficacy (see Table 103), acceptable colour rendition, long lamp life and high lamp lumen maintenance. Therefore they are often used in street lighting.
About 1982 a substantial increase in lumen output was realized by enhancing the xenon-pressure in the arc tube and so the 'plus' or 'super' lamps came on the market. The cheeper standard lamps with lower efficacy stayed on the market. (This explains the lower efficacy for some cases in 4.3.1.4, Table 62, Table 64 and Table 67.) Lamps with longer lifetime (4 years) were introduced from 1996 on.
Other HPS types exist and are often a design compromise between colour rendering, lamp efficacy and long life.
New developments are still ongoing.

In the mid 90s the first Ceramic Metal Halide lamps were commercialised. The use of a PCA ceramic arc tube has greatly improved colour stability because the reaction of metal halides with the arc tube and the diffusion of certain metal halides trough the arc tube could be reduced. Another option to improve the colour stability of classic quartz MH lamps is to use a shroud or a second quartz shelve around the discharge tube. These solutions came on the market recently. The new MH lamps are actually often used for commercial indoor lighting as an energy-efficient replacement for halogen (incandescent) lamps. Since a few years, there also exists a version of this lamp type for outdoor (public) lighting, especially designed to replace an HPS lamp in the same luminaire and working on the same ballast. All CMH lamps still have a reduced lumen maintenance and lamp life compared to HPS lamps. New CMH lamp developments are ongoing.
The production technology for quality HPS and MH lamps is sophisticated and new developments can be expected in the near future. This can also be deducted from published European patents related to HID lamps: 6 in 2006 (until October), 3 in 2005 and 3 in 2004. Please note that these patents did not lead to a manufacturer monopoly probably due to a cross-licensing policy in order to satisfy the requirement for a second source supplier by public bodies.

Figure 33: New developed HID lamp with dedicated dimming electronic ballast

Some of the driving forces for further HPS and MH lamp (Figure 33) developments are:
- optimised lamp-ballast combinations for electronic ballasts;
- new ceramic arc tube designs;
- new quartz tube designs for MH lamps with a double quartz shroud;
- new coating technology;
- new arc material.
- optimised arc tube - luminaire reflector combinations.

Table 104: LLMF for various lamp types with lowest and highest values (source: ELC federation)

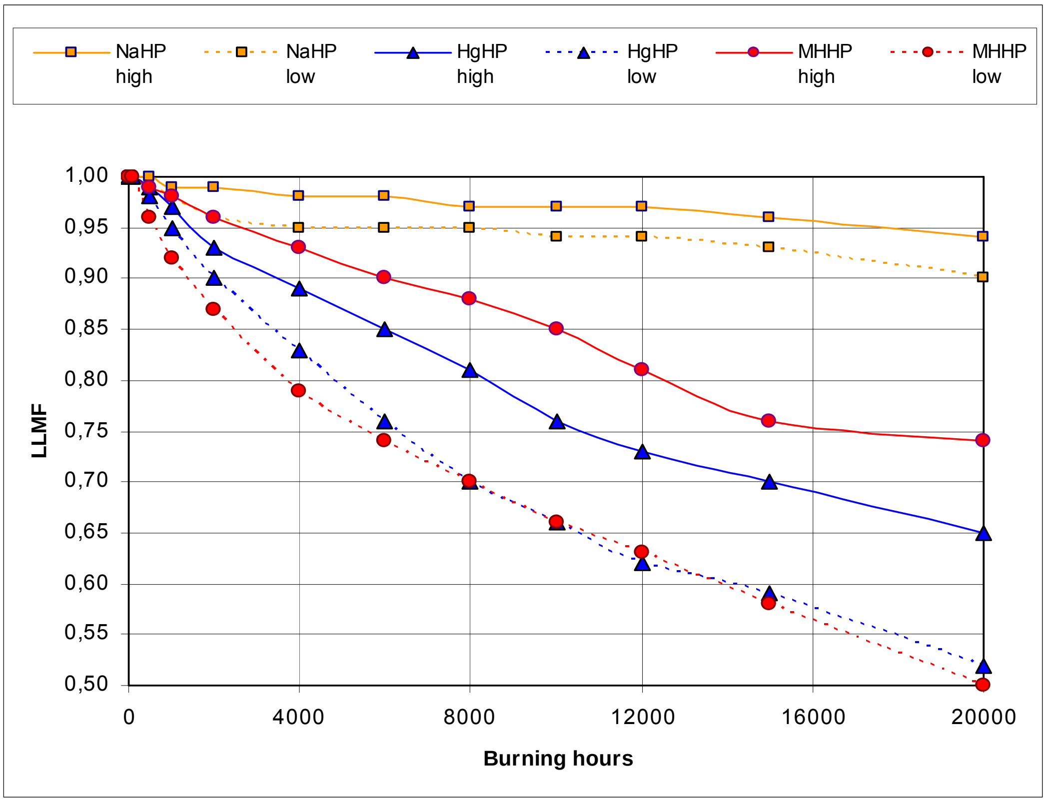
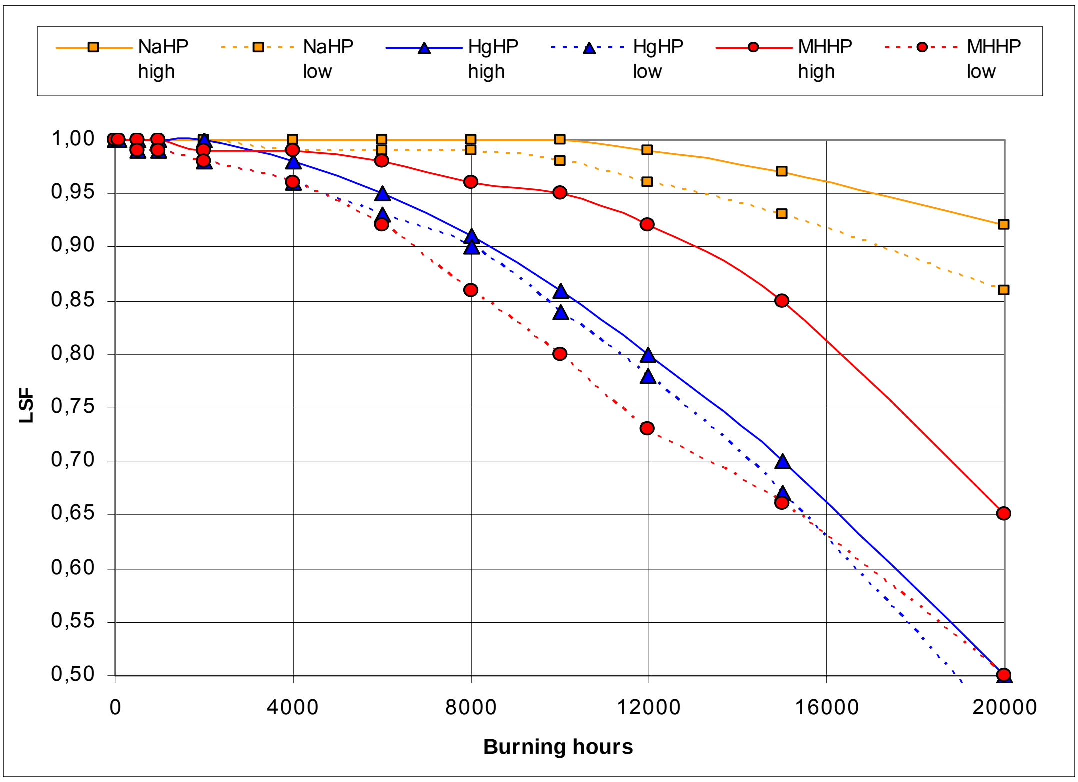


Table 105: LSF for various lamp types with lowest and highest values (source: ELC federation)



Conclusion:

- For HPS and MH there is a large differentiation for products on the market. Anno 2006 ELC supplied the data for lamp survival and lumen maintenance in Table 104 & Table 105.
- Please remark that:
    - the data and curves presented are a visualisation of the ranges covered by the different technologies. The data therefore should not be interpreted as guarantees but rather as industry averages.
    - the variation of the metal halide category is relatively large due to the fact that a large product range is considered.
    - since metal halide technology is still young major improvements are to be expected in the near future.
    - although the LSF and LLMF are important measures it must also be considered that the initial efficacy and CRI are different for the different technologies and therefore play an equally important role when selecting (see also chapter 3).
- The highest values for MHHP lamps are the expected values for the newest developments; they are far better than assumed in chapter 4. Therefore we can use the BAT values in Table 106 for the improvement potential in chapter 7.

Table 106; Prospective t_{group}, LSF and LLMF values for BAT MHHP lamps.

t_{group}	LLMF	LSF
12000 h	0.81	0.92

6.1.6 Improved low pressure discharge lamps (CFL) for outdoor use

Several manufacturers offer long life fluorescent lamps for outdoor use that are also suffering less from light output decrease at lower ambient temperatures.
For achieving long life operation specific cathode shield construction and inside protection layers are used. It is also possible to achieve a considerably higher light output at low temperatures, e.g. by positioning the bridge differently between the two fluorescent tubes or using new 'amalgam' technology.
Conclusion:
This lamp stays attractive in low power outdoor applications.
The LLMF and LSF values are as high as 0.9 at 35000 h, even on a magnetic ballast.

6.1.7 Intelligent electronic dimmable ballast

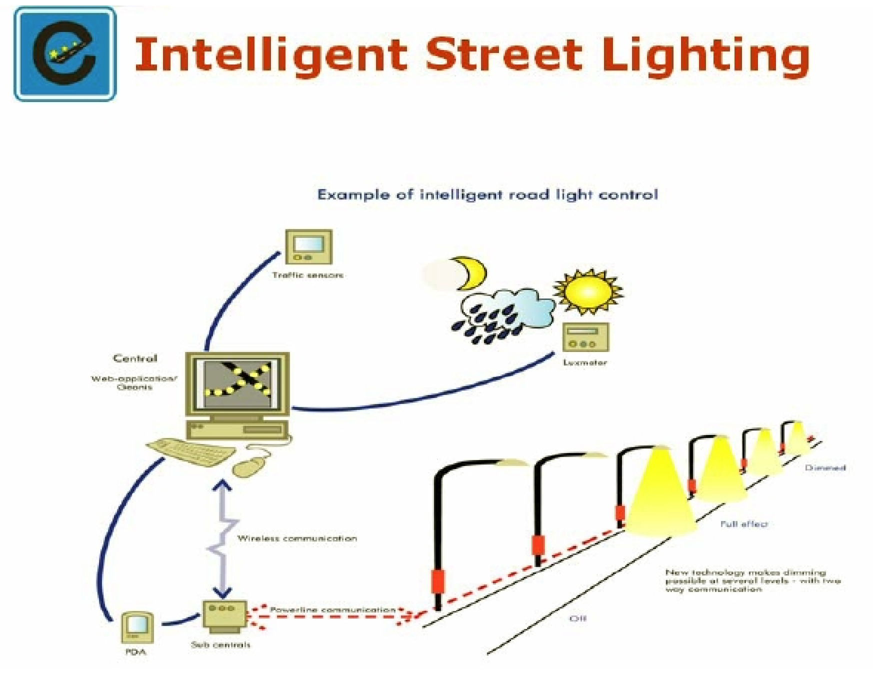


Figure 34: Typical set up for intelligent street lighting (source E-street)

The E-street SAVE project is dedicated to intelligent street lighting and dimming of the lamp (see Figure 34). The core element is dimming of the lamp depending on: traffic density, the weather situation and the real life lighting performance on the street. In addition the system may include energy metering, two-way communication on the existing power supply and an administrative toolkit for utilizing the operational tasks.
These ballasts can provide the energy savings as described in chapter 3.1.3. and 3.1.4.

The energy saving advantages of dimmable electronic ballasts or control gear for HID lamps over electromagnetic ballasts are (Caddet newsletter (2000)):

- Electronic ballasts are often more compact and efficient than ferromagnetic ballasts (up to 10%) for lower wattage lamps(70-150 W);
- Electronic ballasts have a power factor near to 1 and lower harmonical distortion (see also chapter 3.1.4);
- The lamp power is independent of the line and lamp voltage (see also chapter 3.1.3). With a ferromagnetic ballast a ±10% in line voltage variation causes a ±20% lamp power variation. The electronic ballast feature could possibly justify a lower power set point (90%) while maintaining the same minimum light level on the street;
- Some electronic ballasts contain a ballast and lamp status monitoring feature which reduces maintenance cost. The lamp status monitoring includes aged lamp detection;
- Future optimised lamp-ballast combinations can be expected for electronic ballasts that increase LLMF and LSF of lamps, similar to electronic ballasts for fluorescent lamps;
- A hot restrike delay can be incorporated. This can be useful after a voltage dip that has switched off the lamp. A hot lamp can not be restarted with the normal ignition voltage. An ignitor with an electromagnetic ballast keeps generating high voltage pulses trying to reignite the lamp until the lamp is cooled down. These pulses are harmful for the lamp and ballast lifetime. An incorporated hot restrike delay prevents that damage. Please note that alternatively HPS lamps with double burner can be used on electromagnetic and electronic ballasts; this second burner allows a hot restrike.
- The lamp can be dimmed automatically at a high environmental temperature to save the ballast.
- The lamp can also be dimmed automatically at high lamp voltages. At the end of life, the arc voltage of HID lamps increases. This voltage increases also by warming up during operation. A magnetic ballast can not supply this increased voltage and the lamp switches off. Especially for HPS lamps this results in ‘cycling’ (ignition, warming up, switching off, cooling down, ignition, warming up, switching off, etc.). An electronic ballast can dim an aged lamp so that the warming up is limited and the cycling can be avoided.

Nevertheless that dimmable electronic ballasts for HID lamps and street lighting were developed for over a decade, they are actually seldom used in street lighting. The critical points were: the higher price, the lower lifetime reliability due to the intrinsically higher complexity, compatibility with the wide range of available HID lamp types and finally there is an extra cost required for making rugged electronics for the harsh outdoor environment. This technology can be expected to become available in the required quality and price in the near future because the basic technology is available for other harsh outdoor environments such as: railways, aerospace, military, mobile telecom and automotive applications. There is no immediate lamp efficacy increase for HID lamps that are operated with electronic ballasts nowadays. Therefore electronic ballasts as such without dimming or power control capabilities will not be considered as an improvement option for street lighting.

Conclusion:
These ballasts can provide the energy savings as described in chapter 3.1.3. and 3.1.4.

6.1.8 Bi-level dimmable magnetic ballasts

It is also possible to use bi-level magnetic ballasts; dimming can be realized by switching the lamp power between 100 and 50 %.

Conclusion:
These ballasts can provide the energy savings as described in chapter 3.1.3.

6.1.9 High reflectance aluminium material

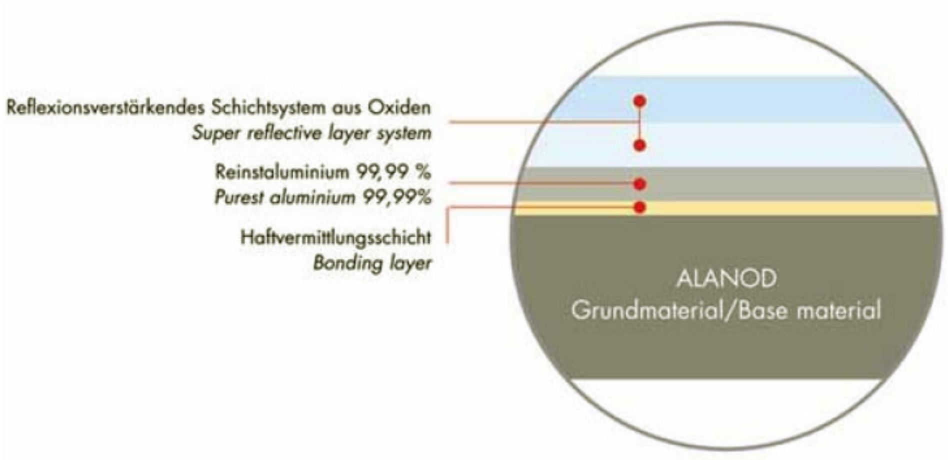


Figure 35: Multi-layer structure of high reflective aluminium

Aluminium reflectance can be increased using advanced multi-layer coating techniques (Figure 35). Normal anodised aluminium for lighting applications has a total reflectivity of up to 87%. To increase or enhance this total reflectivity to another level , several nanometre-thin optical coatings must be applied to the aluminium surface in a vacuum. The principle of multi-layer thin film coatings is widely known in physics but the production of this material for aluminium lighting reflector applications is almost exclusively done by one company. This company sells pre-treated multi-layer aluminium coils with specular and diffuse surfaces and 95% total reflectivity. This highly reflective surface allows the lighting manufacturer to achieve 5 up to 15 % increase in Light Output Ratio (LOR). The process for creating reflectors with this aluminium is also more expensive because careful assembly is required to avoid surface damage (scratches) and therefore important shaping of this material is not possible. (Anodization of ordinary aluminium can be performed after shaping and assembly of the reflector and is less expensive.) In Europe many high performing luminaires are using this material, especially for indoor lighting.

Conclusion:
DLOR can be improved with 5 up to 15 % when applying multi-layer highly reflective aluminium.

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

The EU has premises of leading international companies in the field of lighting with also important R&D related to street lighting within the EU.
In many cases these international companies are technological leaders for developments on medium term (up to 5 years). These companies are internationally active and it is difficult to allocate their activities and achievements exclusively to the EU.
On the longer term (above 5 years), the proliferation of more advanced electronic ballasts and solid state lighting such as LEDs could be allocated to new product technology resulting from Asian developments (actually mainly at electronic parts production level).

Developments from outside the EU:

- In 1990, a sulfur lamp was developed in the USA. This lamp produces a white light, with a continuous spectrum and a colour rendering index Ra ≈ 80; the lamp system efficacy is about 95 lm/W and so thelamp can be compaired with a metal halide lamp. This lamp never reached a commercial application for many reasons:
  - a microwave generator is needed to excite the sulfur to produce light,
  - this generator has to be cooled by ventilators,
  - the lifetime of the microwave generator and cooling is only 15,000h,
  - the only available lamp power is 1000W (system power 1425W) with a lumen output of 135,000 lumens and as a consequence not practicable in street lighting
  - also the dimensions are to high for street lighting.
- A US company introduced the first low power, quarz metal halide street lighting lamps. They focus exclusively on the development of quartz metal halide lamps with improved colour stability.
- Advanced CMH lamps are also developed in Japan but the little information could not be translated.
- Production of HPS lamps with an integrated reflector in Russia for street lighting, eliminating the need for a reflector in the luminaire and therefore the optic cleaning requirements when replacing the lamp.
- Production in China of a low cost mixed light lamp (self ballasted HPM lamp) where the filament is replaced by a built-in halogen lamp. As mentioned earlier, this lamp can operate without ballast. Due to the incorporated halogen lamp, the light output is a little bit higher than for the comparable mixed light lamp. However the lamp efficacy still remains much lower than the other HID lamps: it is only half of the efficacy of a HPM lamp and only a quarter of the efficacy of a good HPS lamp.
- The advanced optic luminaire technology using self cleaning glass(US patent 6599618) (6.1.1) and antireflective coatings(US patent 4173778)(6.1.4) were first disclosed in the US.

6.3 Identified BNAT in applied research

6.3.1 New luminaires for WLED lamps

Figure 36: Street lighting luminaire with LEDs ((picture source: Philips, 2006)

At prototype level several manufacturers are developing WLED lamp luminaries (Figure 36) (see also chapter 6.5.1). LEDs cannot suffer high operational temperatures and are only available in relatively low power (1 to 3 Watt) compared to actual HID lamps (power range starts at 20 Watt). The future application of WLEDs would therefore also influence luminaire design. A typical WLED luminaire would be composed of a series of low wattage WLEDs that are distributed over a wide surface that provides good cooling. When these WLEDs are equipped with individual lenses (e.g. picture above) very excellent utilisation factors (UF, definition see chapter 1) could be obtained for various street lighting applications in a similar way as multi-facet reflectors. A back reflector is not required for LEDs because they have an hemispherical radiation pattern, DLOR is about 80-95 % ('LED Quarterly Insights: white LEDs', IOP, London, 2006). This principle is close to the reflector technology in the previous chapter (6.1.2) but the absence of a reflector with WLEDs will boost efficiency.

Conclusion: This technology is only considered as BNAT because it is related to the availability of WLEDs (see next chapter).

As a case study the following hypothetical values can be introduced in the performance model (estimate for 2015):

ULOR	0%
DLOR	90 %
UF	80 %

6.3.2 Increasing lamp gain factor (LGF) by white light at low illuminance

Research is still going on. It willonly be applicable in road category S.

6.3.3 WLEDs lamps

Figure 37: Typical WLED

White-light emitting diode WLED lamps (Figure 37) are recently becoming available on the market with increasing efficacy (e.g. 20 up to 40 lumen/W) and increasing lifetime as a result of decades of semiconductor research and progress. In street lighting also amber LEDs could be used that offer a higher efficacy (e.g. 40 lumen/W) but a lower colour rendering. Also applications where efficient coloured light is required benefit nowadays from LEDs, e.g. traffic and other signs (applications with a low power density). LEDs also have perfect dimming capabilities far better than HID lamps which could be beneficial for street lighting where dimming is required.

WLEDs that are nowadays on the market are Solid State Lighting (SSL) that rely on semiconductor material. For this SSL technology efficacy and lifetime rapidly decrease with ambient temperature. SSLs are primarily produced as discrete devices; they are mainly available in low wattages (typical 1 to 5 Watt) and the main applications on the market nowadays are small portable devices (e.g. back lighting in cell phones). They are also sold as multiple LED packages for signalisation applications. In comparison to the same lumen output, HID lamps are very compact and are available from 20 Watt and above; HID lamps therefore actually have power levels that are more suited for street lighting.

The SSL dependence on solid state semiconductor material could keep the price relatively high for these sources. LED semi-conductors are crystals comprised of combinations of typically two or tree inorganic elements, such as gallium phosphide (GaP), gallium nitride (GaN), gallium indium nitride (GaInN) or gallium indium phosphide (GaInP). The production of semiconductor crystals can also require high amounts of energy and can increase the price. For this reason photovoltaic panels are sometimes evaluated in energy pay-back times in years (Peeters (2005)). Photovoltaic panels are mainly constructed out of silicon semiconductors. For the LED semiconductor crystals, energy requirements for production are however unknown nowadays, due to the high competition and intellectual property concerns. Also the LEDs make use of rare raw materials (Ga and In) that are used in many other high tech applications (PV panels, monitors, LCD displays with coatings of indium tin oxide) ('Only united are we strong: supply problems await areas other than silicon', Photon International, July 2006). The world annual indium production was estimated(2005) at 455 ton at 650 €/kg with about 6000 ton global reserves only(US Geological Survey, Mineral Commodity Summaries, January 2006). The indium price did rise with a factor 8 from 2002 to 2005. The world annual gallium production was estimated in 2005 at 208 tons at 410 €:kg and the global reserve is more difficult to estimate. Gallium occurs in very small concentrations in ores of other metals and is produced as a byproduct (e.g. bauxite). Based on the world resource of bauxite the reserve exceeds 1

million ton but probably only a small percentage of this metal is economically recoverable (US Geological Survey, Mineral Commodity Summaries, January 2006).
By consequence it can be far too optimistic to rely on a large price drop for SSL technology.

To tackle this material and energy problem OLEDs based on organic material are under development; for some display applications they are already on the market. The actual OLEDs still have a too poor lifetime and efficacy for street lighting application. Actually OLEDs also produce a diffuse light and thus UF advantage as described in the previous section is lost.

<u>Conclusion:</u>
For traffic signs or other signs where coloured lights are required, LEDs are the technology of choice. Compared to HID lamps the price of WLEDs is very high and lumen output still poor. For street lighting, taking into account advantages, disadvantages and possible technological progress, it is still very difficult to predict if and when WLEDs will be applied. WLED technology has therefore been classified as BNAT for street lighting applications, unless the requirements will become much lower with respect to illuminance levels.

As a case study the following hypothetical values can be introduced in the performance model (estimate for 2015):

ηlamp (lm/W)	50
tgroup (y)	15
price (€/Watt)	4

7 IMPROVEMENT POTENTIAL

7.1 Introduction

The importance of assessing the improvement potential is addressed in Article 15 c of the 2005/32/EC Directive. It says that '*the EuP shall present significant potential for improvement in terms of its environmental impact without entailing excessive costs, taking into account in particular the absence of other relevant Community legislation or failure of market forces to address the issue properly and a wide disparity in the environmental performance of EuPs available on the market with equivalent functionality*'. (Source: MEEUP report)
As mentioned this indicates that costs, existing Community legislation and self-regulation as well as the environmental performance and functionality of a wider range of the existing EuP need to be assessed.

What "costs" entail is indicated in Article 15 c, imposing that the implementing measure shall not have a significant negative impact on

a) the functionality of the product for the user;
b) health, safety and the environment;
c) the affordability and life cycle costs to the consumer;
d) industry's competitiveness.
as well as not leading to
e) imposing proprietary technology or;
f) an excessive administrative burden for industry.

The boundary conditions a) and b) are to be defined per product to a large extent in harmonised EN standards to provide an objective basis for assessment conditions. Condition e) is relatively easy to assess from desk-research and discussions with stakeholders. The question of which characteristics of an implementing measure would create 'an excessive administrative burden' can only truly be established *ex-post* if one or more proposals for legislation are known. Which leaves us with two conditions c) and d), which are –in part—linked and which play a key role in the methodology that will be discussed hereafter.

Identifying design options, their monetary consequences in terms of Life Cycle Cost for the consumer, their environmental costs and benefits and pinpointing the solution with the Least Life Cycle Costs (LLCC) and the Best Available Technology (BAT). The assessment of monetary Life Cycle Costs is relevant to indicate whether design solutions might negatively or positively influence the total EU consumer's expenditure over the total product life (purchase, running costs, etc.). The distance between the LLCC and the BAT indicates —in the case a LLCC solution is set as a minimum target— the remaining space for product-differentiation (competition). The BAT indicates a medium-term target that would probably be more subject to promotion measures than restrictive action. The BNAT (subtask 6.5) indicates long-term possibilities and helps to define the exact scope and definition of possible measures.

7.2 Improvement options with cost and impact

Scope: Identification and description of design options for environmental improvement with a quantitative assessment of estimated cost impact and the environmental improvement using the EuP EcoReport.

The base case life cycle cost is calculated using the next formulas:

LCC = PP + PWF * OE,

where,
LCC is Life Cycle Costs,
PP is the Purchase Price (see also chapter 2 and 4),
OE is the Operating Expenses per year,
PWF (Present Worth Factor) is PWF= $\{1 – 1/(1+ r)^N \}/r$,
N is the product life (see also chapter 2 and 3),
r is the discount (interest-inflation) rate (see chapter 2).

In this project a complementary spreadsheet is made available that contains the related resource use (energy, lamps) formulas defined in chapter 4, the LCC calculation together with information of the base case. The input parameters are the defined (chapter 1, 2 and 3) performance and cost parameters. Stakeholders can use this spreadsheet for assessing and verifying individual options.

For each option we also calculate the Functional unit (useful lumen only) together with Energy use per product life per functional unit (kWh/(30y.lm)) and LCC per functional unit (€/lm). These calculated values will serve in chapter 7.3 for the Least Life Cycle Cost and BAT analysis.
The performance and product cost parameters for all options are summarized in one table (see 7.2.3).
The EuP EcoReports for all options are summarized in one table (see 7.2.4).
If the accumulative improvement of options is particular beneficial (e.g. substitution of HPM lamps and lamp dimming) also combined options are included as such in this section.

7.2.1 Design options for energy efficiency

7.2.1.1 Increasing the lamp efficacy (ηlamp)

The first and most obvious improvement is the elimination of lamps with poor efficacy (see chapter 4). From chapter 4 it can be deducted that HPM (High Pressure Mercury) lamps have a significantly lower efficacy compared to other HID lamps and we assume for this option that they are eliminated (Figure 38).
It should be noted that saving energy by simply changing the HID lamp type in an installed (stock) luminaire is not as easy because:

- the ballast can in most cases only operate one lamp power rating, so switching to a more efficient lamp will not save energy but only provide more light.
- in many cases the ballast is not able to operate another lamp type.

Option 1 (stock base):
HPS retrofit lamps exist for High Pressure Mercury and in this option we assume that they are used in existing luminaries, this means that sales of all HPM lamps is excluded. These retrofit lamps consume about 10 % less power and produce about 40 % more light. So retrofitting increases the probability of non compliance of the installation with existing regulations and standards.
This option is of course hypothetical, because it still allows to sell new HPM luminaires for HPS retrofit lamps. Therefore in practice, option 13 should be considered.

Option 13:
In this combination, there is assumed that, in addition to option 1, all sales of HPM luminaires are excluded, as well for new projects as for replacement luminaires.

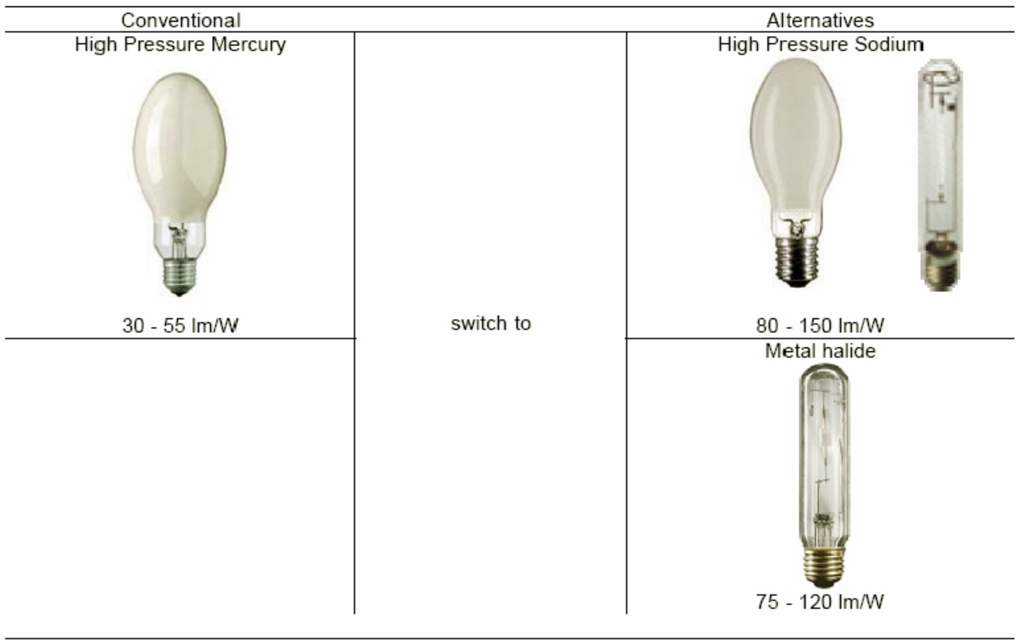


Figure 38: Energy saving by 'switching' lamp types (Source: ELC)

Option 2 :
In this option we assume that all HPS-lamps are types with enhanced lumen output, the super or plus lamps (see chapter 4). This is calculated as well for the stock as for the new sales.

7.2.1.2 Using improved HID light sources

Option 3 (new sales base):
This option assumes that improved MH lamps are used to replace all MH lamps in category S as described in chapter 6.2.1. (We also assumed 110 lm/W efficacy).
The calculated impact on the performance parameters is low due to the actual low market share of MH lamps (see chapter 2) but it can become significant if these lamps become more popular in future.

7.2.1.3 Increasing ballast efficiency (ηballast)

Option 4 (new sales base):
By using more copper, more magnetic material and higher grade silicon steel the efficiency (ηballast) of magnetic ballasts can be increased.
For fluorescent lighting MEPS (Minimum Energy Performance Standards) were therefore already introduced(Directive 2000/55/EC ' on energy efficiency requirements for ballasts for fluorescent lighting'), but for HID lamps MEPS are non-existing and could be introduced.
The potential is only significant in category S.
In this option it is assumed that only the best performing ballasts (see chapter 4) are used in category S.

7.2.1.4 Increasing luminaire maintenance factor (LMF) by IP rating (Ingress Protection)

Option 5 (new sales base):
Luminaires have a minimum LMF and therefore IP rating (dust and moisture protection).
It is assumed that the best options are chosen as described in 4.3.1.4, this is IP65 ingress protection in all categories.

Figure 39; Example of functional luminaire IP21 that was excluded from this improvement option, reason: the open optic has a poor LMF due to dirt.

7.2.1.5 Increasing luminaire maintenance factor (LMF) by self cleaning glass

Option 6 (new sales base):
In this option the best value of the BAT from 6.1.1 is used for all categories (i.e. self cleaning glass for the outer glazing and ingress protection degree IP65).

7.2.1.6 Increasing optic efficiency and lamp efficacy by using only tubular clear lamps

Option 7 (new sales base):
The proposed options are based on the following technical properties:

- That tubular clear (TC) lamps are used that allow improved optics and thus improved UF compared to balloon fluorescent (BF) lamps when appropriate optics are used.
- That TC lamps have higher lamp efficacy (ηlamp) compared to BF lamps.

- This option is only technically possible for HPS and CMH lamps.
- The improvement value is estimated according to chapter 4.3.1.4 by substituting OP, OM and CM luminaires by CH luminaires.

Figure 40: Example of balloon fluorescent (BF) lamps (left) that were excluded in this option and the alternative tubular clear (TC) lamp.

7.2.1.7 Increasing optic efficiency by decreasing upward light flux ULOR

Option 8 (new sales base):
This option allows the substitution of globe and diffuser luminaires (GO and GH) in chapter 4.3.1.4 by decorative luminaires with a reflector (DR) and clear transparent housing in category S.

Figure 41: Example of a luminaire that was excluded from this improvement option, reason: too much upward light, little directed to walking lane and light loss in the opal diffuser.

7.2.1.8 Increasing optic efficiency by increasing UF and DLOR

Option 9 (new sales base):

In this option increased values of UF are adopted that are close to the maximum obtained in the calculated ones in chapter 4 (4.3.1.4). This increased UF can of course only be realized with tubular clear (TC) lamps.

7.2.1.9 Increasing ballast gain factor (BGF) by bi-level dimmable ballasts

Option 10 (new sales base):
In this option we assume that the energy saving potential by light dimming can be realised according to the values as described in chapter 3 (3.1.3) with the technology as described in chapter 6 (6.2.4).
In this option it is also assumed that no HPM (high pressure mercury) lamps are used; dimming technology is unknown for these old lamp types. The HPM luminaires sales are distributed over 2/3 HPS and 1/3 CMH lamps.
In future the use of electronic ballasts and dimming could also contribute to an increase of LSF and LLMF as indicated in chapter 6 (6.2.1) and confirmed by CELMA. These positive effects could not yet be taken into account because of an actual lack of sufficient data.

7.2.1.10 Increasing ballast gain factor (BGF and BMF) by electronically dimmable ballasts

Option 11 (new sales):
In this option we assume that the energy saving potential by light dimming and electronic ballasts can be realised according to the values as described in chapter 3 (3.1.3 and 3.1.4) with the technology as described in chapter 6 (6.2.3).

7.2.2 Design options for product weight reduction

7.2.2.1 Increasing lamp life (LSF)

This is included in option 7.2.1.2

7.2.2.2 Decreasing mercury content in lamps

Option 12 (stock and new sales base):
Only HPS lamps can be obtained without mercury content. All other HID lamps need a minimum of mercury to operate (see BOM in chapter 4).
The mercury free HPS lamps however have a lower lamp efficacy and thus increased energy consumption.
This option assumes that all HPS lamps are substituted by mercury free HPS lamps.

7.2.3 Table with performance and product cost parameters for all improvement options

The performance parameters per option are summarized in the draft spreadsheet 'Hfstk7resultsanalyse.xls' that can be downloaded from the project website.

7.2.4 Table with EuP EcoReports for all improvement options

The EuP EcoReports per option are summarized in the draft spreadsheet 'Hfstk7resultsanalyse.xls' that can be downloaded from the project website.

7.3 Analysis LLCC and BAT

Scope:

- Ranking of the individual design options by LCC (e.g. option 1, option 2, option 3);
- Identifying the Least Life Cycle Cost (LLCC) point and the point with the Best Available Technology (BAT).

Options are ranked according to their energy saving potential (Figure 42). The correlation between energy saving and LCC is striking.
There is an almost linear relationship between LCC and energy saving per functional unit.
This can easily be explained by the dominance of electricity cost in LCC. This is a consequence of the actual product prices compared to the long product life (30 y) and low discount rate (2% = interest - inflation).
Therefore all options, with the exception for mercury free lamps (7.2.2.2) should be considered equally from this point of view.
The options with negative impact on energy efficiency (Figure 42) are related to the use of mercury free HPS lamps (that have lower efficiency).
By consequence the LLCC and BAT point is the sum of all options.

7.3.1 Combined design option for energy efficiency

Option combination 1 (new sales base):
This option calculates the result of banning all mercury high pressure lamps and luminaires in new sales, using only the most efficient tubular clear HPS-lamps and this only in luminaires with an IP-rating of at least IP65.

7.3.2 BAT design option for energy efficiency

Option BAT or combination 2 (new sales base):
This option takes into account that:

- all high pressure mercury lamps and luminaires are banned
- only the most efficient tubular clear HPS- and new MH-lamps are used
- only luminaires with an IP-rating of at least IP65 are allowed,
- all luminaires for installation on a height higher than 5 m have self cleaning glas,
- all luminaires have the highest possible UF rating,
- all ballasts are electronically dimmable.

Detailed information per option and identification information can be found in the draft spreadsheet 'Hfstk7resultsanalyse.xls' that can be downloaded from the project website.

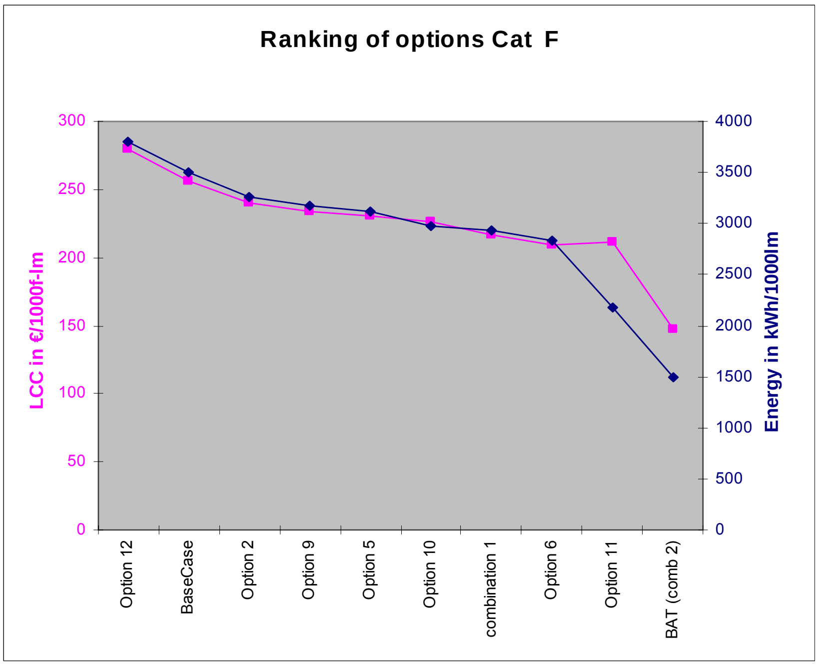


Figure 42: All options ranked according to 'energy saving potential' with LCC information for cat F

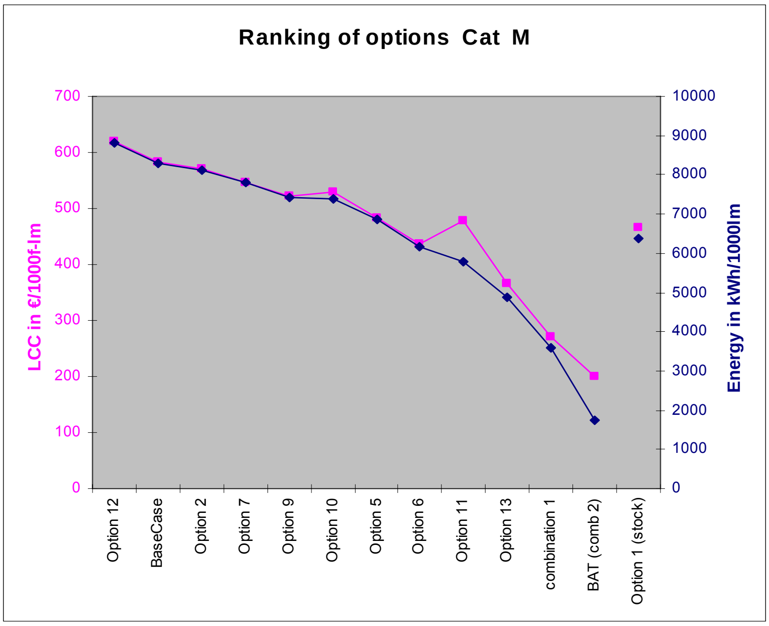


Figure 43: All options ranked according to 'energy saving potential' with LCC information for cat M

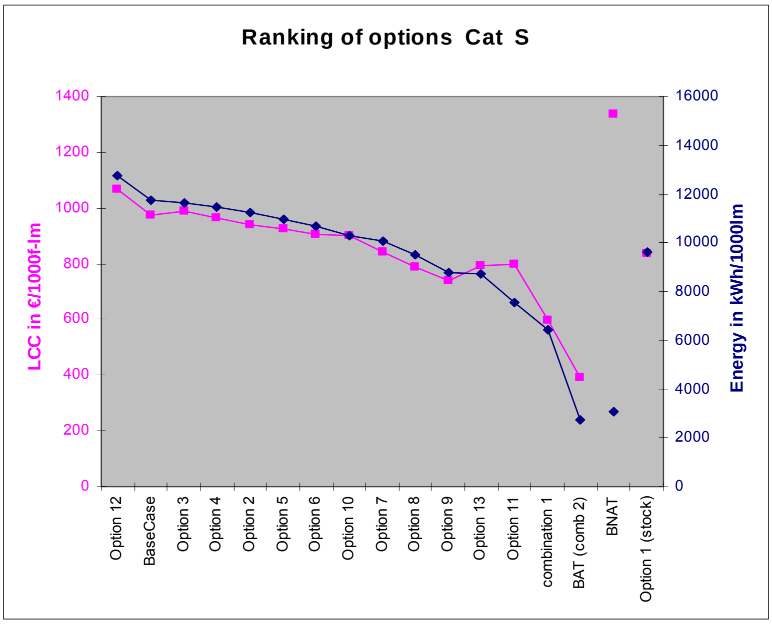


Figure 44: All options ranked according to 'energy saving potential' with LCC information for cat S

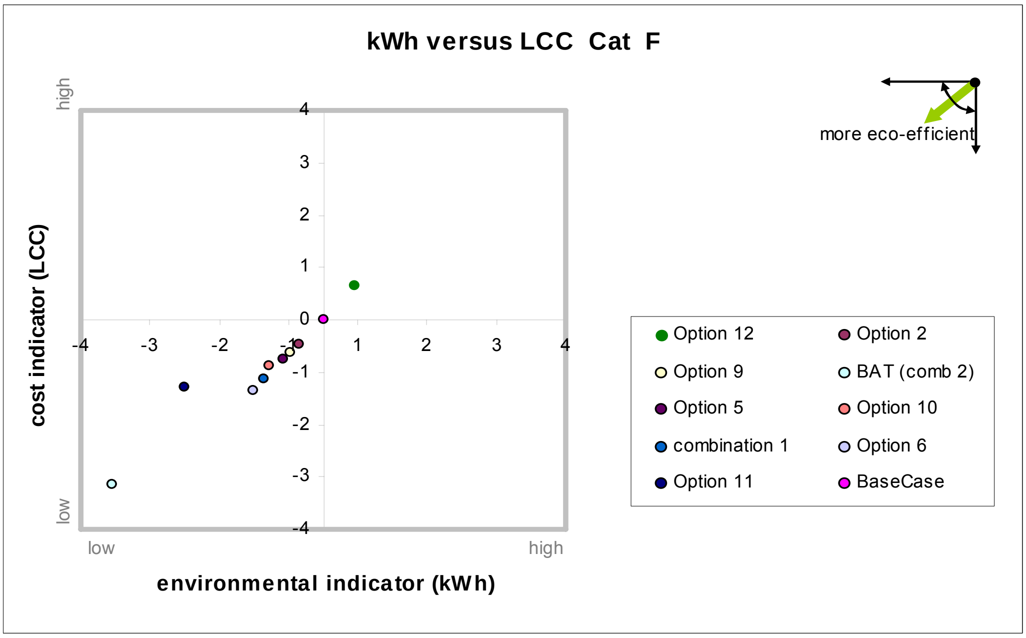


Figure 45: Energy saving versus impact on LCC for all options in cat F

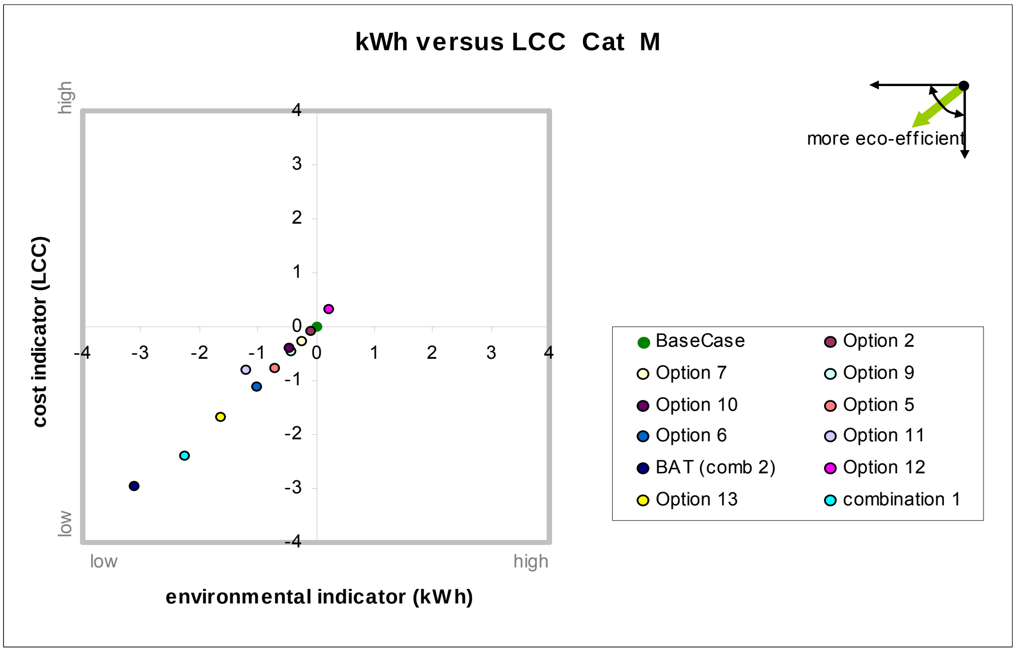


Figure 46: Energy saving versus impact on LCC for all options in cat M

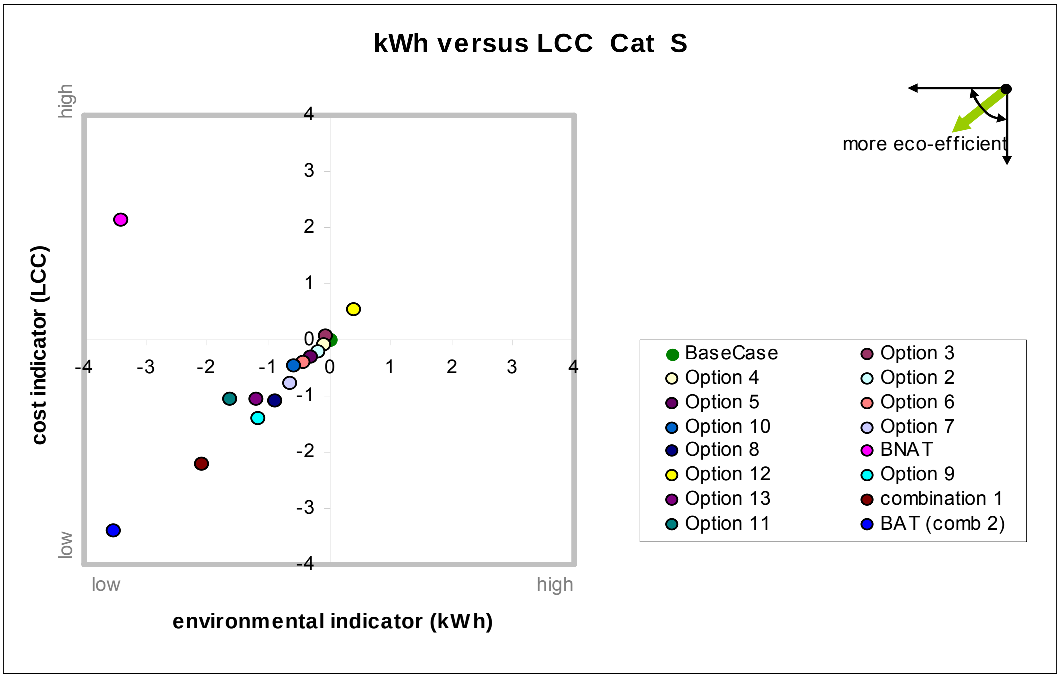


Figure 47: Energy saving versus impact on LCC for all options in cat S

7.4 Long-term targets (BNAT) and system analysis

Scope:

- o Discussion of long-term technical potential on the basis of outcomes of applied and fundamental research, but still in the context of the present product archetype;
- o Discussion of long-term potential on the basis of changes of the total system to which the present archetype product belongs.

7.4.1 Market introduction of BNAT new LED luminaires

LED's and LED-luminaires are described in chapter 6 as BNAT. They could contribute to further improvement.
Prospective values are included in chapter 6 and a corresponding Energy use per product life per functional unit (kWh/(30y.lm)) and LCC per functional unit (€/lm) can be calculated.
When this technology becomes available as BAT performance needs to be revaluated. Also more detailed Bill Of Material data is required to perform an accurate environmental impact assessment .

The estimated values for option BNAT are:

Energy use per product life per functional unit (kWh/(y.lm))	0.10
LCC per functional unit (€/lm)	1.34

This is better then the actual base case but this could also be achieved with other technology with a lower cost. Therefore it is very difficult to evaluate this technology nowadays.

7.4.2 Use of BNAT new HID lamps and dimmable ballasts

As stated in chapter 6 (6.2.1 and 6.2.3) further improvements can be expected and the BAT performance parameters can be expected to increase.

7.4.3 System related improvement potential

The following system-related changes can also contribute to a reduced environmental impact:

- Increased installation skills and appropriate procedures in order to obtain the best fit between luminaires and installation performance (see chapter 3 and 4) .
- Increasing the awareness of the energy consumption of outdoor lighting. In this context it is also important that energy consumption of outdoor lighting is billed according to real consumption and not according to fixed prices per installed luminaire as sometimes done in public lighting.
- Careful examination of the maximum levels of outdoor lighting is required, also in relation to dimming requirements (see chapter 3). Much research has been done to examine the minimum requirements that are included in standards but the ALARA (as low as reasonable acceptable) principle is actually not included in standards. In some cases the opportunity of installing new luminaires can be used to increase lighting and

comfort of outdoor lighting, the final result could be an increase in comfort without energy saving at system level.

8 SCENARIO-, POLICY-, IMPACT- AND SENSITIVITY ANALYSIS

Scope: This chapter summarizes and totals the outcomes of all previous tasks. It looks at suitable policy means to achieve the potential e.g. implementing LLCC as a minimum and BAT as a promotional target, using legislative or voluntary agreements, labeling and promotion. It draws up scenarios 1990 – 2020 quantifying the improvements that can be achieved vs. a Business-as-Usual. It makes an estimate of the impact on consumers and industry as described in Appendix 2 of the Directive, explicitly.
Finally, in a sensitivity analysis of the main parameters, it studies the robustness of the outcome.

8.1 Policy- and scenario analysis

8.1.1 Eco-design requirements

In this chapter specific eco-design requirements are described that can be used as suitable policy means to achieve BAT or LLCC scenario targets.
Please note that Fluorescent lamps and LPS lamps are not considered in this chapter. The reason is that no additional eco-design requirements are recommended versus business as usual. LPS lamps have a very high efficacy and these lamps still can render good service where low light levels and/or low colour rendering are acceptable. Because of the poor colour rendering and high purchase price of lamps and matching luminaires, LPS is likely to disappear from the market by 2020 (see expert inquiry). Fluorescent lamps (FL) or CFL-ni lamp efficacy standards will be considered in the office lighting EuP study as they are mainly used for this applications. Special outdoor FL lamps (see chapter 6) are on the market with improved low temperature performance but the benefits are heavily related to the local climate and improvements are therefore installation related and cannot be part of product related measures. FL lamps are a good choice where a high efficacy, low cost and low lumen output lamp is required. Therefore they are applied where very low light levels are acceptable. Fluorescent lamps have a low market share in number of street lighting points and even much lower in lumen output (see chapter 2), therefore the total EU25 environmental impact is limited.

8.1.1.1 Generic Eco-design requirements on the supply of information

Optimal design and use of street lighting systems needs adequate information on existing products and parts, therefore we propose that the manufacturers provide the following most relevant eco-design parameters and follow the proposals for appropriate means for communication of these parameters.

For luminaires:

- Luminaires within the scope of this study should be marked with a label in order to allow indentification as 'street lighting' luminaires. They could be marked with “F” if they are appropriate for luminance criteria (EN 13201), corresponding with the F+M road lighting categories in this study, and with “S” if they are appropriate for illuminance criteria, corresponding with the S road lighting category in this study. Luminaires that can match luminance as well as illuminance criteria could be marked with “F + S”.

- Luminaire manufacturers shall supply the following data and instructions:
    - Photometric data according to EN 13032 (complete all 10° & CENF =1.0 * CEN file format).
      These data are essential for designing and calculating any street lighting project according to the standard.
    - LMF value up to 4 years, in accordance to CIE 154: 'The maintenance of outdoor lighting systems' (see Figure 48) .
      Because the standard EN 13201 uses 'maintained' values of luminance or illuminance, the LMF at typical cleaning interval periods are needed for this calculation. Cleaning of the luminaire is currently done at lamp replacement and as high pressure sodium lamps (NaHP) have a lifetime of 16000h, therefore specifying LMF at 4 years is necessary.

LMF							
Pollution category	**Exposure time in years**						
	1,0	**1,5**	**2,0**	**2,5**	**3,0**	**3,5**	**4,0**
High							
Medium							
Low							

Figure 48: Typical model for LMF value specification according to CIE 154.

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    - Realistic maintenance instructions to assure that the luminaire maintains, as nearly as possible, its original quality throughout its lifetime.
    - Lamp and ballast replacement instructions to keep maintenance costs low.
    - Disassembly instructions.
    - UF values for standard road conditions (e.g.: ASSIL proposal, Type tender specification Synergrid, this study, any other proposal).
      These UF values could be supplied in tabular form in compliance with the requirements of EN 13201 for the defined road class and for an asphalt road surface type R3008 with q_0=0,08. The table should contain the most energy efficient UF values for different road widths, different pole heights, maximum pole distances, luminaire overhang and inclination.
      This can give a first indication of the suitability of the luminaire for a certain application and the possibility to compare (roughly) luminaires under the same circumstances. Of course, after a first selection, this should be completed by a detailed photometric calculation.
    - Installation instructions for optimizing the Utilization Factor.
    - Additional installation recommendations to minimize light pollution (if not conflicting with UF optimization and safety).

For all HID lamps:

- Lamp efficacy at 100 h, and LLMF at 4000 h, 8000 h, 12000 h and 16000h.
  These data are essential to determine the maintained lighting levels according to standard EN 13201.
- LSF data at 4000 h, 8000 h, 12000 h and 16000 h.
  Combination of LSF, LLMF and LMF data are necessary to optimize the maintenance period in order to achieve the minimum operating costs.

- For lamps with Ra < 80 power balance information (de Groot(1986, p.50)): Efficiency in visible radiant power (Pvis/Plamp (%)) (see chapter 6.2) or the lamp efficacy in scotopic lumens. These values are needed because actual lamp efficacy information is according to photopic lumens (see chapter 3) and photopic vision is often not a representative value for street lighting (see chapter 3).
- Special mark or indication that the lamp is suitable for street (and other) outdoor lighting applications.

For all HID ballasts:

- Ballast efficiency according to BAT levels (see 8.1.1.6) and please note that a new measurement standard is needed (see 8.1.5).
- Special mark or label that the ballast is suitable for outdoor lighting applications.

Proposed timing for this measures:

ASAP with exception for the UF value supply method that needs to be elaborated with industry.

8.1.1.2 Generic eco-design requirement on reducing light pollution

As explained in chapter 4.3.1.3., the environmental impact of light pollution and the design options to reduce it, has not been quantified in the study for the reasons outlined there. Nevertheless, we propose that the option of introducing some kind of generic requirement to address light pollution should be examined for implementing measures.
In this framework, manufacturers would be required to take into account - to the extent possible - considerations on light pollution when designing luminaires. However, any improvements aiming to reduce light pollution must not have a negative effect on the energy efficiency of the luminaires.
At a later stage, when more evidence is gathered on the environmental significance of light pollution and on design options to combat it, mandates could be given to the European Standardisation Organisations for the development of harmonized standards that could be ultimately used for conformity with such a generic eco-design requirement.

8.1.1.3 Specific ecodesign requirement required for option 1&13 from chapter 7: increasing lamp efficacy by using HPS retrofit for HPM in installed luminaires and excluding sales of HPM luminaires

The proposed ecodesign requirement is to set minimum efficacy targets for street lighting lamps or for 'all' lighting applications (see also section 8.2) so that HPM lamps are actually banned and HPS retrofits are used instead of them in installed luminaires.
Even self ballasted (mixed light) HPM lamps could be excluded, because these can be replaced by CFL’s with integrated ballast.
Complementary to this measure, sales of new luminaires for HPM lamps should be prohibited.

An advantage of the immediate implementation of this measure is a considerable economy of energy that will gradually be reached in three years because the normal lifetime of HPM lamps is 3 year.

Some minor disadvantages are the change of the light colour from cold white to warm golden-yellow and the higher amount of generated light.

The table below contains minimum lamp efficacy requirements that cannot be achieved by HPM lamps:

Lamp wattage [W]	Minimal Lamp Efficacy [lm/W]
W≤ 50	55
50 < W ≤ 70	65
70 < W ≤ 125	70
125 < W ≤ 400	75
400 < W ≤ 1000	80
1000 < W ≤ 2000	85
2000 and higher	90

Proposed timing:

ASAP because this measure realizes a quick energy saving without special investments. The immediate ban on the sale of new luminaires for HPM lamps will prevent the installation of this energy inefficient lamps also for replacement luminaires.

8.1.1.4 Specific ecodesign requirements required for option 2&7 from chapter 7: increasing lamp efficacy by using HPS lamps with enhanced lumen output

A separate requirement was made only for HPS lamps that can not be extended to all HID lamps for the reasons that will be mentioned below in 8.1.1.5. This requirement can be implemented by requiring high minimum lamp efficacy (ηlamp) for HPS lamps (lamps with enhanced xenon pressure) and require high quality lamps (LSF & LLMF) compliant to chapter 6, Table 104 and Table 105, based on data supplied by ELC. This measure can be imposed for all HPS lamps, also the ones that are occasionally used indoor..

Lamptype	NaHP-TC	NaHP-BF *
Lamp Wattage W	Average Lamp Efficacy Lm/W	Average Lamp Efficacy Lm/W
W≤ 50	≥ 80	≥ 70
50 < W ≤ 70	≥ 90	≥ 80
70 < W ≤ 100	≥ 100	≥ 95
100 < W ≤ 150	≥ 110	≥ 105
150 < W ≤ 250	≥ 125	≥ 120
250 < W ≤ 400	≥ 135	≥ 130

Burning hours	LLMF
16000h	>0.90

Burning hours	LSF
16000h	>0.90

* As ellipsoid, frosted HPS lamps (NaHP-BF) are less efficient than the tubular clear lamps (NaHP-TC), it is recommended to phase out the sale of these BF lamps in a timespan of 10 years. An immediate ban of these lamps is not recommended because the optics of (installed) luminaires for BF-lamps are mostly not appropriate for TC-lamps; they can cause to much glare.
The efficacy of HPS retrofit lamps does not even reach the efficacy in the table for normal NaHP-BF-lamps, as a consequence a phasing out period of 10 years should also be recommended for those lamps. This phasing out accelerates the replacement of old inefficient luminaires by new efficient ones.

Proposed timing:

ASAP because these values are based on the data announced in the catalogues of several lamp manufacturers for their products that are widely available on the market and also based on the data delivered by ELC.

8.1.1.5 Specific ecodesign requirements required for option 3 from chapter 7: increasing lamp efficacy by using MH lamps with enhanced lumen output and enhanced lumen maintenance

These requirements can be implemented by requiring high minimum lamp efficacy (η_{lamp}) for MH lamps and require high quality lamps (LSF & LLMF) compliant to chapter 6, Table 104 and Table 105, based on data supplied by ELC.
Similar MH lamps are used also in indoor lighting for replacing inefficient halogen lamps. The requirements for these lamps are different from those for street lighting lamps. In street lighting, high lamp efficacy and a long lifetime (LLMF & LSF) have a significant influence on operating costs. Lamp replacement costs are lower for indoor lighting but here a high colour rendering is much more important.
MH lamps are also used in image projectors and car headlights.
There are also blue metal halide lamps for special applications on the market that have de facto a lower efficacy due to the sensitivity of the human eye (explanation see 3.1.1).
These requirements are only applicable for 'street lighting' marked lamps; it is impossible to impose these requirement for all MH lamps or for all HID lamps (including HPS).
Separate lamp type related requirements are inevitable and as a consequence, this study proposes separate values for the different HID lamp-types.
There are also ellipsoid, frosted MH lamps (MHHP-BF) for street lighting. In accordance with the proposal for HPS lamps, it is also recommended to phase out the sale of those lamps for street lighting applications in a timespan of 10 years.

Lamp Wattage W	Lamp efficacy Lm/W
W≤ 50	≥ 80
50 < W ≤ 70	≥ 90
70 < W ≤ 100	≥ 100
100 < W ≤ 150	≥ 110
150 < W ≤ 250	≥ 120
250 < W ≤ 400	≥ 130

Burning hours	LLMF
12000h	>0.80

Burning hours	LSF
12000h	>0.90

Proposed timing:

With some delay, from 2009 on because these values are based on the most recent data supplied by ELC for lamps that are coming on the market.

8.1.1.6 Specific ecodesign requirements required for option 4 from chapter 7: requiring minimum ballast efficiency for HID ballasts

This measure is similar to the existing directive for fluorescent lamp ballasts.
This is especially useful for 50-70-100 Watt HID lamp ballasts.

Lamp power W	Maximum ballast losses W
50	10
70	11
100	14
150	19
250	26
400	35

Proposed timing:

ASAP because these values are based on the best products on the market. The technolgy is very simple and not protected by any patent; therefore they can be produced by any ballast manufacturer.

8.1.1.7 Specific ecodesign requirements required for option 5 from chapter 7: Increasing luminaire maintenance factor (LMF) by IP rating (Ingress Protection)

This measure requires IP65 rating for all luminaires (F+M, S).

Proposed timing:

ASAP because these values are also based on products widely available on the market.

8.1.1.8 Specific ecodesign requirements required for option 6 from chapter 7: Increasing luminaire maintenance factor (LMF) by self-cleaning optical protector

This measures requires self-cleaning glass or self-cleaning synthetics for all F+M category luminaires. This measure cannot be imposed to all luminaires. Therefore it is an optional eco-design improvement that manufacturers can choose for. This improvement option could be part of a list of improvement options from which a manufacturer can choose to implement one. This measure could be used as optional when an other option cannot be fulfilled.

Proposed timing:

It is an optional ecodesign measure because the technology is quite new and not widely available.

8.1.1.9 Specific ecodesign requirements required for option 8 and 9 from chapter 7: 'Increasing optic efficiency by decreasing upward light flux ULOR' and 'Increasing optic efficiency by increasing UF and DLOR'

This measures require a maximum ULOR and minimum DLOR for luminaires.

	ULOR max	**DLOR min**
luminaires cat F+M		
all lamp wattages	5%	75%
luminaires cat S		
150W ≤ lamp	5%	75%
100W ≤ lamp < 150W	10%	75%
50W ≤ lamp < 100W	15%	70%
lamp < 50W	20%	65%

Proposed timing:

ASAP because these values are based on products widely available on the market and it will also contribute to the decrease of light pollution.

8.1.1.10 Specific ecodesign requirements required for option 10 from chapter 7: Increasing ballast gain factor (BGF) by bi-level dimmable ballasts

This measure requires bi-level dimmable ballasts installed in the luminaire. This measure is not useful for luminaires with permanent low light output. Therefore it is an optional eco-design improvement that manufacturers can choose for. This improvement option could be part of a list of improvement options from which a manufacturer can choose to implement one. The measure could be connected to the lamp power (e.g. required for lamps above 100 W). This option could also be realised technically at system level with line voltage lowering devices (see chapter 2.3.1). ELC declares that voltage lowering is not a recommended way for power reduction as it will lead to early extinction and disfunction of HID lamps (see Stakeholder comments in project report). This statement of ELC was also confirmed by laboratory tests at Laborelec.

Proposed timing:

Electronic dimmable ballasts are becoming more and more available on the market. As a consequence, implementing bi-level dimmable ballasts is only a transititional measure and not recommended. Moreover, this measure creates an additional lock-in effect that would hamper the introduction of the outranking (a.o. longer lamp lifetime) electronic dimmable ballasts (see option 11).

8.1.1.11 Specific ecodesign requirements required for option 11 from chapter 7: Increasing ballast gain factor (BGF and BMF) by electronic dimmable ballasts

This measure requires electronic dimmable ballasts installed with lamp power control in the luminaire. This measure is not useful for luminaires with permanent low light output. Therefore it is an optional eco-design improvement that manufacturers can choose for. This improvement option could be part of a list of improvement options from which a manufacturer can choose to implement one. The measure could be connected to the lamp power (e.g. required for lamps above 100 W). Possibly this option can only be implemented later in time because the devices are not yet available in sufficient quantity and low price (e.g. 2010).
This measure could also be implemented gradually related to the road category and lamp power. It is recommended to start the requirement in F+M luminaires due to the benefits of fine tuning to real road reflection characteristics and adaptation to traffic circumstances. For S luminaires the requirement could be imposed for high power luminaires (e.g. 100 Watt and above) only because low power lamps are mainly used when low light levels are installed where further dimming is not useful.
As an interim measure, electronic, non dimmable ballasts could be recommended for reason of their advantages over ferromagnetic ballasts: an electronic ballast incorporates power control during lamp lifetime and stabilizes the voltage supplied to the lamp, independently from line voltage fluctuations. This results in constant power consumption and longer lamp lifetime.

Proposed timing:

Gradual implementation, in order to give time to manufacturers to prepare for this large technological change required for this improvement option.
Realistic timing: 2010 for category F+M & Plamp ≥ 150W, 2015 for lamps ≥ 70 W.

Remark: An electronic non dimmable ballast as interim measure is not recommended because the technological step from non dimmable to dimmable is not considered as a barrier.

8.1.1.12 Specific ecodesign requirements required for option 12 from chapter 7: Mercury free HID lamps

This can be implemented by banning mercury use in HID lamps.

8.1.2 Scenario analysis

This section draws up scenarios 1990-2020 quantifying the improvements that can be achieved versus a Business-as-Usual scenario.

In these scenario analysis, the expected trends 2010-2020 are estimated for the following main parameters:

- Installed base of luminaires
- Annual sales of luminaires
- Annual sales of lamps
- Ey: annual electricity use by the installed base of street lighting
- FU: functional lumen output by the installed base of street lighting
- Life Cycle Cost (LCC) of new products (replacement + new street projects)

In the 'BAT scenario' the combination of individual options (1-9, 11, 13) is assumed because they are complementary and all reduce LCC and increase energy efficiency. In the BAT scenario option 10 (bilevel dimmable ballast) is not implemented because it is a low performance alternative for option 11 (electronic, continuously dimmable ballasts). Option 12 (mercury free HPS lamps) is also not implemented because of the negative impact on LCC due to its lower energy efficiency.
It is important to remark that some individual improvement options (2,3,5-9) would not always result in energy saving but would result in more light on the street due to the 'Lock-in effect' for replacement sales where light points cannot be relocated (see 3.3.1). The combination with option 11 (electronic continuous dimmable ballasts) can overcome this problem by fine tuning the lamp power to the exact required maximum level.

The 'Option 1 scenario' (retrofit HPS lamps) is treated separate in the analysis because implementation is linked to the lamp life time (approx. 3 y) and EU25 impact is relative fast.

Other options (2-13) are linked to the long life time of the luminaire and the total EU25 impact is therefore relative slow. Please note that options (10, 11) (dimming ballasts) could be implemented faster when replacing only the ballast in existing luminaires, However this scenario is not calculated because, due to the high actual cost, it is better to replace the existing luminaire.
.
In the first subchapters these scenarios are given for BAU, BAT and option 1 retrofit HPS lamps. In the last subchapter, the contribution of individual options is given.

As the trend in EU25 total impacts result mainly from changes in electricity use (parameter Ey), a table representing the expected impacts and impact reductions due to BAT and individual options in 2020 is given in the last subchapter.

8.1.2.1 Scenario : Business as Usual (BAU)

The installed base of luminaires and the growth rate is based on the expected growth of road infrastructure and the amount of luminaires currently installed. In section 8.1.3.3 the uncertainty on the base assumptions influencing the results regarding EU25 stock and sales ara discussed in detail.

In the Business as usual scenario, Base Case Stock luminaires are used to calculate the impacts up until 2005. From 2005 on, they are gradually replaced by Base Case Sales luminaires (see chapter 5).

Table 107: Aggregated results, Business As Usual (BAU)

DATA	Unit	EU Total Impact of STOCK of Products in: ((produced, in use, discarded)			
		2005	2010	2015	2020
Annual Sales Luminaires	*Millions*	2,1	2,4	2,5	2,7
Annual Sales Lamps	*Millions*	18,3	19,4	20,6	21,9
Stock Luminaires	*Millions*	56,3	59,7	63,4	67,4
Other Resources & Waste					
Annual Electricity use	*TWh*	35,0	36,4	37,9	39,4
Total Energy (GER)	*PJ*	361,9	374,5	388,0	402,5
of which, electricity (in primary MJ)	*PJ*	358,3	370,5	383,8	398,0
Water (process)	*Mln.m^3*	24,1	24,9	25,8	26,8
Waste, non-haz./ landfill	*Kt*	463,4	482,4	501,0	521,0
Waste, hazardous/ incinerated	*Kt*	12,1	12,8	13,3	14,0
Emissions (Air)					
Greenhouse Gases in GWP100	*Mt CO2 eq.*	15,9	16,4	17,0	17,7
Acidification, emissions	*Kt SO2 eq.*	93,5	96,7	100,2	104,0
Volatile Organic Compounds (VOC)	*Kt*	0,145	0,150	0,156	0,162
Persistent Organic Pollutants (POP)	*g i-Teq*	2,5	2,6	2,7	2,8
Heavy Metals	*T Ni eq.*	6,9	7,2	7,5	7,8
PAHs	*T Ni eq.*	1,3	1,4	1,5	1,6
Particulate Matter (PM, dust)	*Kt*	2,6	2,8	2,9	3,0
Emissions (Water)					
Heavy Metals	*T Hg/20*	2,7	2,8	3,0	3,1
Eutrophication	*Kt PO4*	11,0	11,4	11,8	12,3
Annual Expenditure, total	*M Euros*	3.506	3.671	3.835	4.012
Purchase, luminaires	*M Euros*	388	427	454	484
Operating expense, lamp replacement	*M Euros*	208	220	233	247
Operating expense, ballast replacement	*M Euros*	-	-	-	-
Operating expense, electricity use	*M Euros*	2.805	2.913	3.029	3.156
Operating expense, installation & maintenance	*M Euros*	105	111	118	125

Table 108: Installed base of street lighting luminaires, per category (mio. units)

		1990	1995	2000	2005	2010	2015	2020
Fast	INSTALLED BASE LUMINAIRES (mio.)	0,6	0,6	0,7	0,8	0,9	1,0	1,1
Mixed		14,2	14,6	14,9	15,2	15,6	15,9	16,3
Slow		34,0	36,4	38,2	40,3	43,3	46,5	50,0
TOTAL		**48,8**	**51,6**	**53,8**	**56,3**	**59,7**	**63,4**	**67,4**

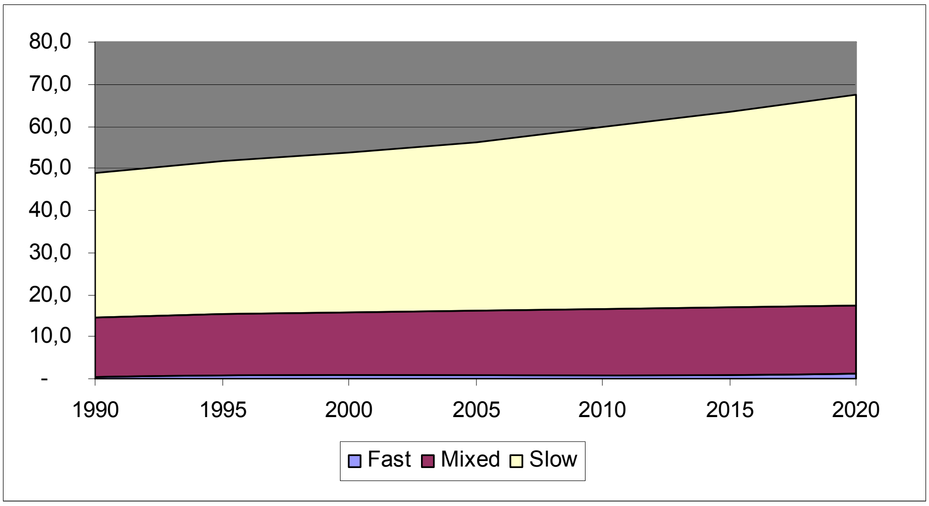

Figure 49: Installed base of street lighting luminaires, per category (mio. units)

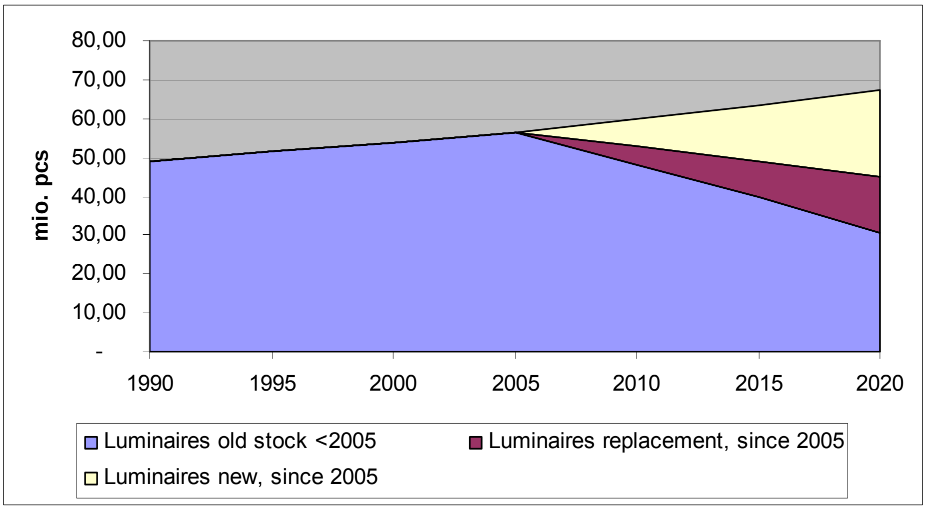

Figure 50: New luminaires replacing old stock since 2005 (mio. units)

Table 109: Annual luminaire sales, per category (mio. units)

		1990	1995	2000	2005	2010	2015	2020
Fast	ANNUAL LUMINAIRE SALES (mio.)	0,0	0,0	0,0	0,0	0,0	0,1	0,1
Mixed		0,4	0,5	0,5	0,5	0,5	0,5	0,5
Slow		1,5	1,5	1,4	1,6	1,8	1,9	2,1
TOTAL		**2,0**	**2,0**	**1,9**	**2,1**	**2,4**	**2,5**	**2,7**

Table 110: Annual expenditure luminaire purchases, per category (mio. €)

		1990	1995	2000	2005	2010	2015	2020
Fast	ANNUAL LUMINAIRE SALES (mio. €)	4	6	6	9	10	12	13
Mixed		85	98	91	96	99	102	105
Slow		271	261	249	283	318	341	365
TOTAL		**360**	**365**	**346**	**388**	**427**	**454**	**484**

Table 111: Annual lamp sales, per category (mio. units)

		1990	1995	2000	2005	2010	2015	2020
Fast	ANNUAL LAMP SALES (mio.)	0,2	0,2	0,2	0,2	0,2	0,3	0,3
Mixed		4,7	4,8	4,9	5,0	5,1	5,1	5,2
Slow		11,1	11,8	12,4	13,1	14,1	15,2	16,4
TOTAL		**15,9**	**16,8**	**17,5**	**18,3**	**19,4**	**20,6**	**21,9**

Table 112: Annual expenditure lamp purchases, per category (mio. €)

		1990	1995	2000	2005	2010	2015	2020
Fast	ANNUAL LAMP SALES (mio.)	4	5	5	6	6	7	8
Mixed		71	73	75	76	78	80	82
Slow		106	114	119	126	136	147	158
TOTAL		**182**	**191**	**199**	**208**	**220**	**233**	**247**

Compared to 2005, the total EU25 installed base of streetlighting will increase with 20% (in number of luminaires) from 56 mio. in 2005 to approximately 67 mio. in 2020. Lamp sales for street lighting applications are expected to surpass 20 mio. units annually, annual luminaire sales more than 2,5 mio. units.

The share of category street lighting ‘Fast’ is by far less relevant compared to ‘Mixed’ and ‘Slow’ (1% F, 27% M, 72% S). This is shown in figure 45. The sensitivity analysis (see 8.1.3.3) also shows that even when the assumed share of road network lit substantially increases (now 13% assumed for F) and more EUROSTAT ‘State’ and ‘Provincial’ road-km are allocated to category F, it’s total share remains less relevant compared to categories M and S.

From 2005 on, new luminaires will replace old stock luminaires and in 2020, they will constitute about 50% of the total installed base. This is the consequence of the long luminaire life (assuming average luminaire life of 30 yrs). This is shown in Figure 50. Note that for measures to be introduced in 2010, new luminaires will cumulate only to about 33% in 2020. From this, it can be concluded that, by only introducing measures focussed on new luminaires (sales), only part of the saving potential can be realised by 2020 and full potential of the measures should be expected on the longer run. For short-term savings it is thus also worthwhile to consider measures focussing on the existing old stock of street lighting. This includes measures regarding lamp type substitution in existing luminaires and even accelerated replacement of old luminaires.

From chapter 5 it could be concluded that for most impact categories, electricity use in the total product life cycle is determinant. Because this scenario is the reference for the scenarios introducing measures from 2010 on, in Figure 52 the share of annual electricity use from new luminaires versus the old stock of luminaires can be seen. Note that for new products introduced since 2010, the electricity use cumulates in 2020 to 33% of the total stock electricity use.

Table 113: Annual electricity use of installed base (unit: GWh)

		1990	1995	2000	2005	2010	2015	2020
Fast	Ey (GWh)	618	656	727	811	941	1.093	1.268
Mixed		16.511	17.013	17.387	17.752	17.833	17.908	17.984
Slow		13.925	14.884	15.646	16.495	17.633	18.868	20.193
TOTAL		**31.054**	**32.553**	**33.760**	**35.058**	**36.407**	**37.869**	**39.444**

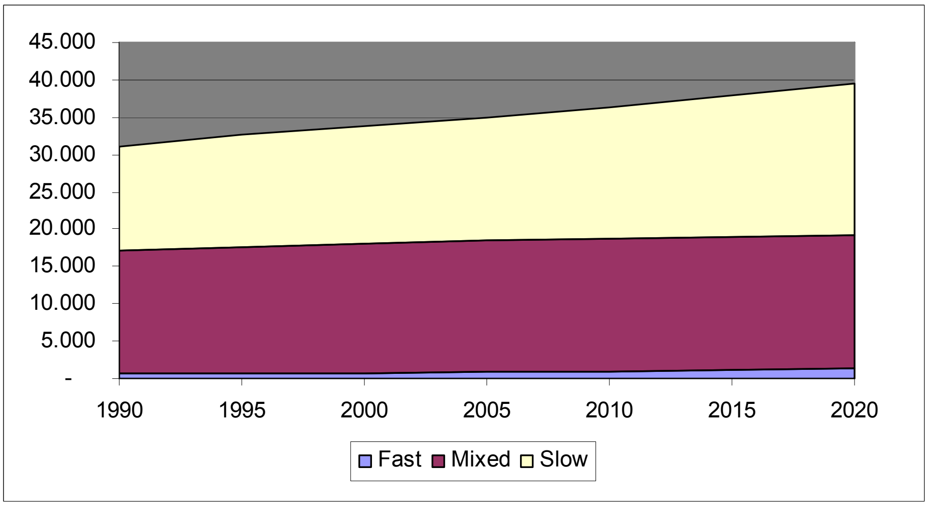

Figure 51: Annual electricity use of installed base (unit: GWh)

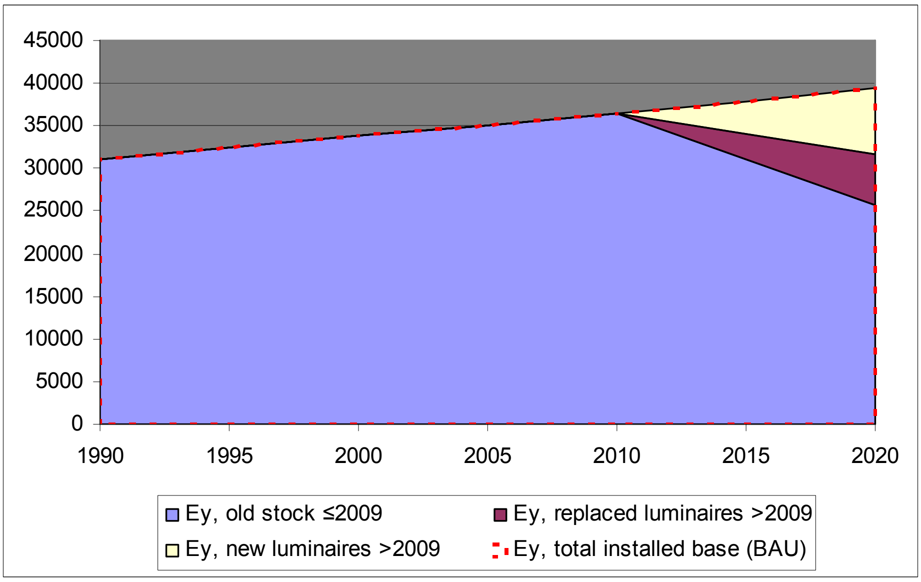

Figure 52: Annual electricity use of old stock versus new luminaires since 2010

In BAU, the annual electricity use will increase from 35 in 2005 to 39-40 TWh in 2020 which is an increase of 13%. Note that the difference in general street lighting growth of 20% (2005-2020) compared to 13% growth in electricity use is declared by the fact that the BaseCase new luminaires (sales) consume less energy than BaseCase old stock (≤2005) luminaires. Also note that, category M and F are almost equally important with regard to total

EU25 electricity consumption, although in number of luminaires, category S is almost three times bigger.

Table 114: Functional light output FU, installed base

		1990	1995	2000	2005	2010	2015	2020
Fast	FU (functional lumen) (mio.)	5.337	5.665	6.281	7.007	8.117	9.401	10.886
Mixed		55.641	57.331	58.590	59.821	61.536	63.257	65.024
Slow		37.175	39.737	41.772	44.039	46.947	50.108	53.496
TOTAL		**98.153**	**102.733**	**106.643**	**110.866**	**116.600**	**122.765**	**129.405**

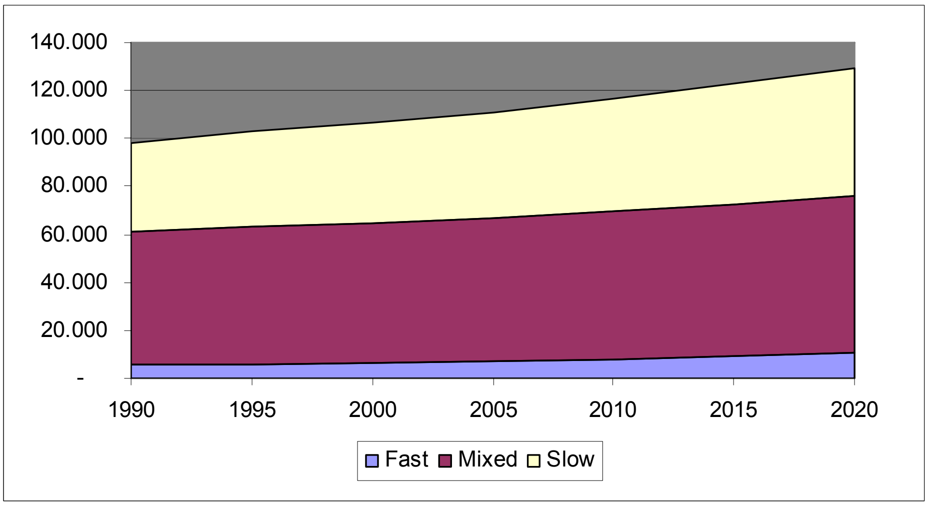

Figure 53: Functional light output FU, installed base (mio. functional lm)

Compared to 2005, the functional lumen output willl have increased by 17%. Note that even when category M (and to lesser extent F) is less relevant compared to S in number of units, it does generate relatively more light output (F 6%, M 54% and S 40%). In BAU, the increase in total EU25 light lumen output is proportional to growth in number of luminaires. It is important to note that a street lighting performance of 1,5 cd/m2 is assumed for an average base case street lighting in category fast, 1 cd/m2 in category mixed and 7,5 lx in category slow. No increase or decrease of this lighting performance is assumed (thus constant over time).

In this BAU scenario, also the mercury content in the installed base is calculated in Table 115.

Table 115: Total mercury content, installed base

		1990	1995	2000	2005	2010	2015	2020
Fast	total lamp mercury,	2	2	2	3	3	4	4
Mixed	INSTALLED BASE	208	214	219	224	221	218	216
Slow	(kg)	174	186	196	206	220	235	251
TOTAL		**384**	**403**	**417**	**433**	**444**	**457**	**471**

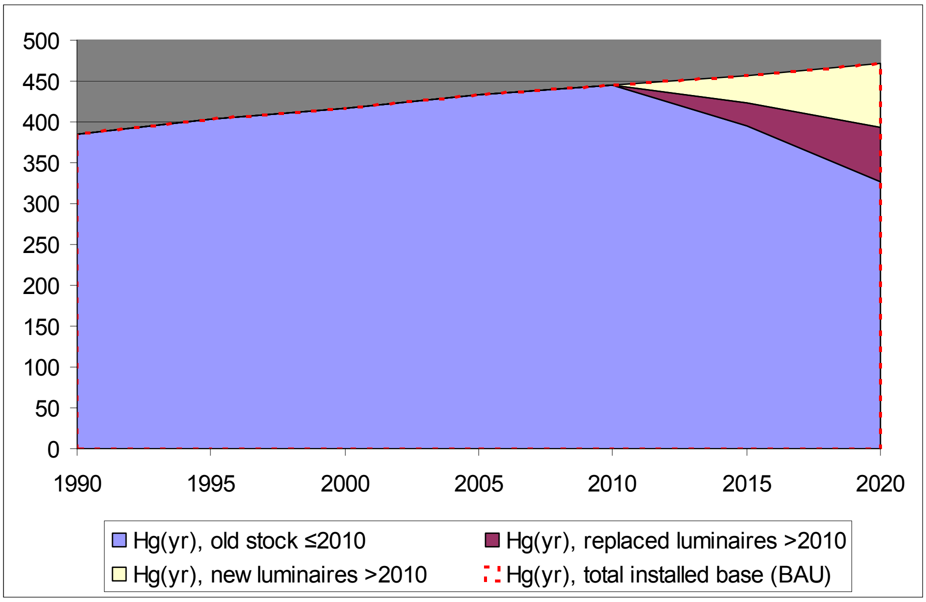

Figure 54: Total mercury content, installed base (in kg)

For the impact assessment in this study, there is supposed that 10% of that installed mercury is fugitive and dumped. The MEEUP report proposes 20% if no further data are available. Taking into consideration that recycling of all gas discharge lamp under the WEEE directive is already started, we assume 10% as current situation. It's probable that this % will still decrease to 5% or less, wenn all countries have implemented the directive.
The fugitive and dumped mercury can thus be estimated between 95 and 23 kg per year.

8.1.2.2 Scenario 2020 analysis: implementing 'Option 1 & 13', substitution of HPM with HPS lamps

In this scenario, HPM lamps in the entire installed base are replaced with retrofit HPS lamps and, for new luminaire sales, HPM luminaires are restricted and replaced with HPS luminaires. This measure is implemented from 2010 on. This means that, for the old luminaires stock (≤2010); all lamps are replaced within the timeframe 2010-2015 and for new luminaires; it takes 30 years (assumed average luminaire lifetime) before all luminaires of the old stock (≤<2010) are replaced. Since no HPM luminaires are assumed in the base case for category Fast, savings result only in categories mixed and slow.

Table 116: Aggregated results, Scenario 1

DATA	Unit	EU Total Impact of STOCK of Products in: ((produced, in use, discarded)			
		2005	2010	2015	2020
Annual Sales Luminaires	*Millions*	2,1	2,4	2,4	2,6
Annual Sales Lamps	*Millions*	18,3	19,4	20,2	20,9
Stock Luminaires	*Millions*	56,3	59,7	63,4	67,4
Other Resources & Waste					
Annual Electricity use	*TWh*	35,0	36,4	35,0	35,4
Total Energy (GER)	*PJ*	361,9	374,5	357,5	359,4
of which, electricity (in primary MJ)	*PJ*	358,3	370,5	353,7	355,3
Water (process)	*Mln.m^3*	24,1	24,9	23,8	23,9
Waste, non-haz./ landfill	*Kt*	463,4	482,4	461,7	466,8
Waste, hazardous/ incinerated	*Kt*	12,1	12,8	12,8	13,1
Emissions (Air)					
Greenhouse Gases in GWP100	*Mt CO2 eq.*	15,9	16,4	15,7	15,8
Acidification, emissions	*Kt SO2 eq.*	93,5	96,7	92,4	92,9
Volatile Organic Compounds (VOC)	*Kt*	0,145	0,150	0,144	0,145
Persistent Organic Pollutants (POP)	*g i-Teq*	2,5	2,6	2,5	2,5
Heavy Metals	*T Ni eq.*	6,9	7,2	7,0	7,0
PAHs	*T Ni eq.*	1,3	1,4	1,4	1,5
Particulate Matter (PM, dust)	*Kt*	2,6	2,8	2,7	2,7
Emissions (Water)					
Heavy Metals	*T Hg/20*	2,7	2,8	2,8	2,8
Eutrophication	*Kt PO4*	11,0	11,4	10,9	10,9
Annual Expenditure, total	*M Euros*	3506	3671	3669	3735
Purchase, luminaires	*M Euros*	388	427	440	469
Operating expense, lamp replacement	*M Euros*	208	220	314	318
Operating expense, ballast replacement	*M Euros*	-	-	-	-
Operating expense, electricity use	*M Euros*	2.805	2.913	2.800	2.830
Operating expense, installation & maintenance	*M Euros*	105	111	114	117

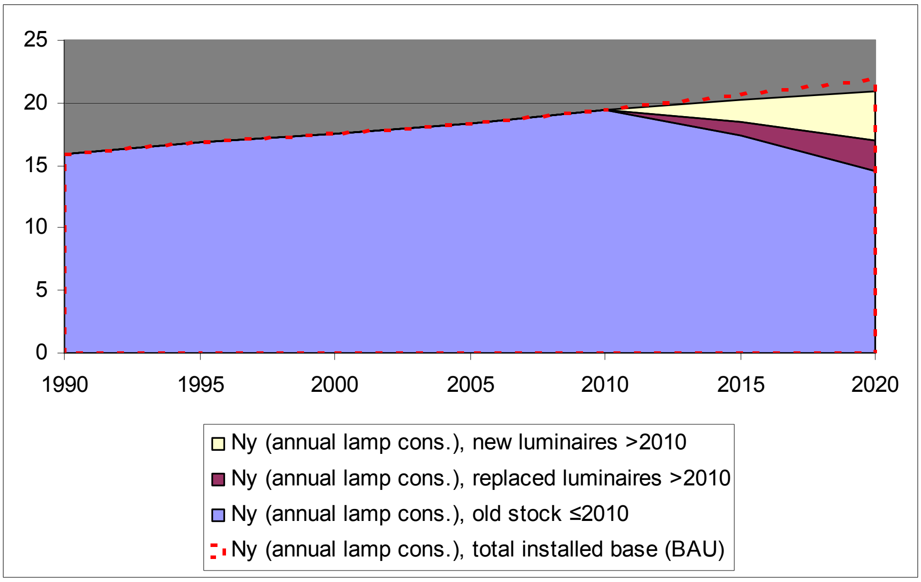

Figure 55: Annual lamp sales (mio. units)

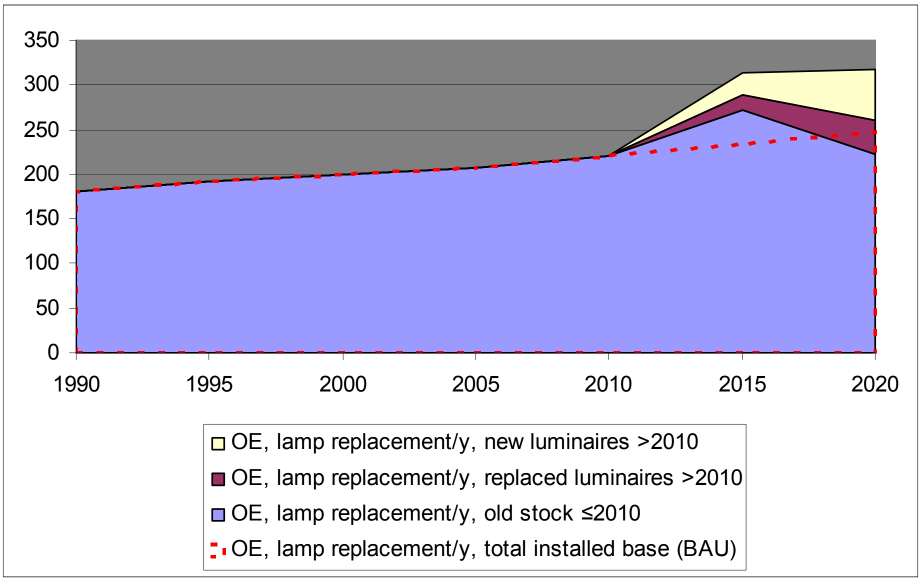

Figure 56: Annual expenditure, lamps (mio. Euros)

Sales of luminaires and lamps in terms of units decreases slightly (5%). This has several reasons. While HPS retrofit lamps are assumed to have the same lifetime as HPM lamps (3 yrs), HPS lamps for new luminaires have a longer lifetime (4 yrs). Also, pole distance for HPS luminaires in new street projects is wider compared to HPM luminaires to achieve similar lighting levels, thus less street lighting poles and luminaires are required per km lit street. On the other hand, the expenditure from lamps will increase substantially as shown in the figure above. This is because HPM lamps are sold relatively cheap compared to retrofit HPS and HPS lamps. In 2020, expenditure on lamps will be 30% higher compared to BAU, or approx. 70 mio.

€ increase. The increase between 2010-2015 is explained by the fact that in this period all HPM lamps in existing luminaires will be replaced with HPS retrofit lamps.

Table 117: Annual electricity use of installed base (unit: GWh)

		1990	1995	2000	2005	2010	2015	2020	2020 %saving
Fast	**Ey (GWh)**	618	656	727	811	941	1.093	1.268	0%
Mixed		16.511	17.013	17.387	17.752	17.833	16.203	15.635	13%
Slow		13.925	14.884	15.646	16.495	17.633	17.708	18.474	9%
TOTAL		**31.054**	**32.553**	**33.760**	**35.058**	**36.407**	**35.004**	**35.377**	**10%**

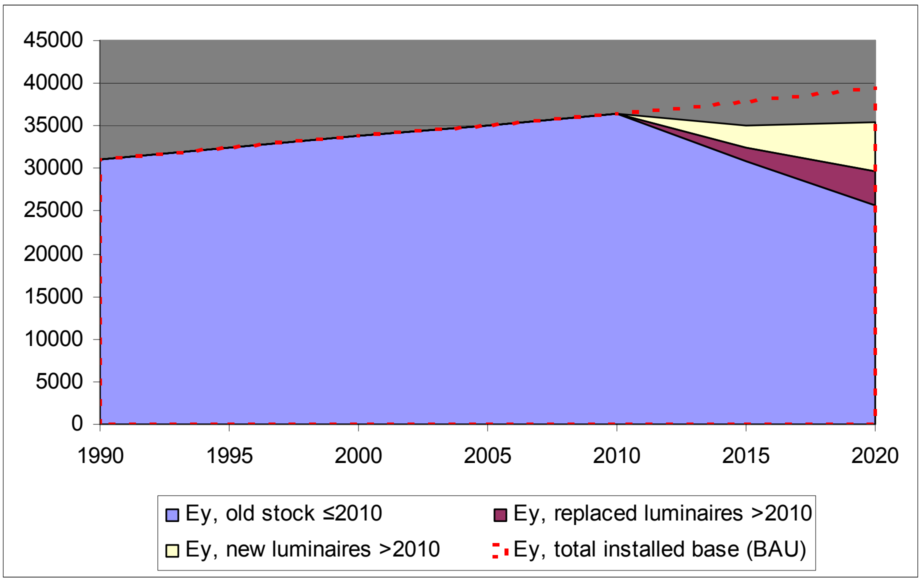

Figure 57: Annual electricity use by installed base (unit: GWh)

The saving in electricity expenses in 2020 is 10% compared to BAU, approx. 325 mio. € decrease. The annual purchase expenditure for new luminaires remains relatively the same compared to BAU. Notice, that in the short run, already a substantial energy saving can be achieved only by replacing HPM lamps in the existing stock.

Table 118: Functional lm output of installed base (unit:mio. lm)

		1990	1995	2000	2005	2010	2015	2020	2020 %increase
Fast	**FU (mio. lm)**	5.337	5.665	6.281	7.007	8.117	9.401	10.886	0%
Mixed		55.641	57.331	58.590	59.821	61.536	75.881	75.912	17%
Slow		37.175	39.737	41.772	44.039	46.947	56.584	60.027	12%
TOTAL		**98.153**	**102.733**	**106.643**	**110.866**	**116.600**	**141.866**	**146.824**	**13%**

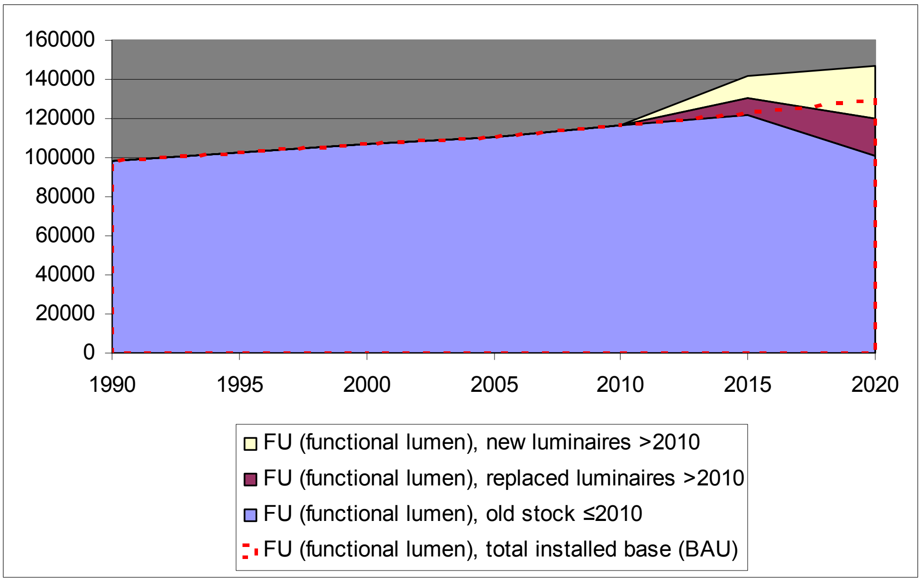

Figure 58: Functional light lumen output (unit: mio. lm)

While in this scenario, the total energy use decreases, the functional lumen output of the installed base in 2020 increases with about 13%, compared to BAU. With the need to deal with the lock-in effect of existing street lighting luminaires and with current street lighting performance requirements, generally demanding more light output compared to currently existing installations, applying retrofit HPS lamps in existing HPM luminaires is an energy- and cost-saving measure that can be implemented in the short term. For replacement sales, where pole distances are not changed (thus lock-in effect), replacing end-of-life HPM luminaires with new HPS luminaires also increases the functional lumen output. Where the same lighting level as before should be attained, a lower wattage HPS (i.e. 50W) luminaire could be installed. In this scenario, the first is calculated thus additional energy saving can be achieved doing so.

In this scenario, also the mercury content in the installed base will significantly decrease as calculated in Table 119.

Table 119: Total mercury content, installed base scenario 1 & 13.

		1990	1995	2000	2005	2010	2015	2020
Fast	total lamp mercury,	**2**	**2**	**2**	**3**	**3**	**4**	**4**
Mixed	INSTALLED BASE	**208**	**214**	**219**	**224**	**221**	**97**	**96**
Slow	(kg)	**174**	**186**	**196**	**206**	**220**	**207**	**215**
TOTAL		**384**	**403**	**417**	**433**	**444**	**308**	**316**

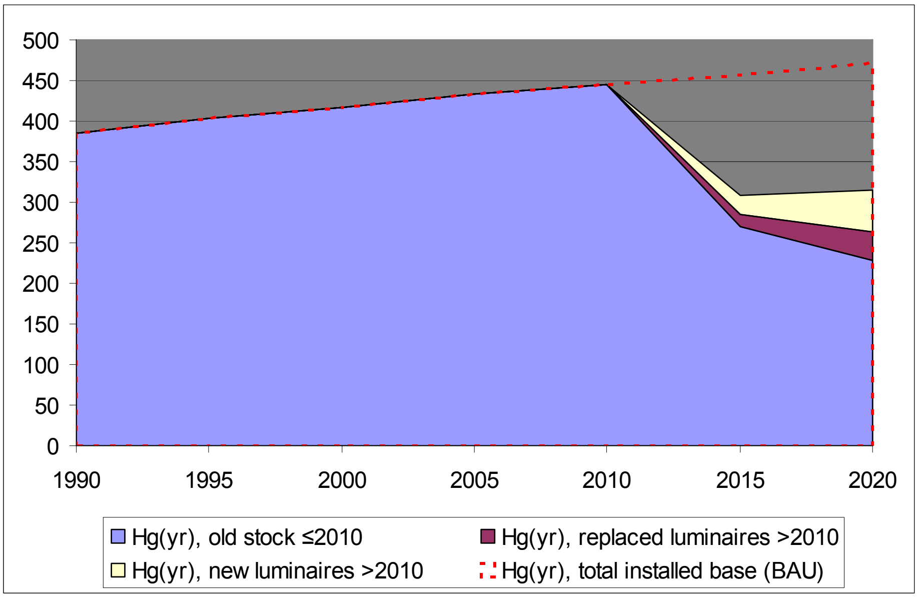

Figure 59: Total mercury content, installed base (in kg)

As a consequence, the fugitive and dumped mercury will also decrease and can be estimated between 60 and 15 kg per year (to compare with 95 to 23 kg for the BAU scenario).

8.1.2.3 Scenario 2020 analysis : implementing Best Available Technology (BAT)

In this scenario, the following measures are implemented in the existing installed base:

- HPM lamps are replaced with retrofit HPS lamps (option 1) and;
- HPS lamps are replaced with HPS lamps, type 'super' (option 2).

For new luminaire sales, all following options are implemented;

- HPM luminaires are restricted and replaced with HPS luminaires (option 13);
- all HPS luminaires have high lm/W efficiency lamps, type 'super'(option 2);
- CMH is of new type (option 3)
- all luminaires are IP65 (option 5),
- HPS and CMH luminaires have glass protector (option 6),
- HPS and CMH with high UF (option 9),
- HPS, CMH and CFL have electronic dimmable ballasts (option 11).

This measure is implemented from 2010 on. This means that, for the old luminaires stock (≤2010); all lamps are replaced within the timeframe 2010-2015 and for new luminaires; it takes 30 years (assumed average luminaire lifetime) before all luminaires of the old stock (≤<2010) are replaced. Thus in 2020, 33% of old luminaires are replaced with newer luminaires since year of implementation.

Table 120: Aggregated results, Scenario BAT

DATA	**Unit**	**EU Total Impact of STOCK of Products in: ((produced, in use, discarded)**			
		2005	**2010**	**2015**	**2020**
Annual Sales Luminaires	*Millions*	2,1	2,4	2,6	2,7
Annual Sales Lamps	*Millions*	18,3	19,4	20,2	20,8
Stock Luminaires	*Millions*	56,3	59,7	63,4	67,4
Other Resources & Waste					
Annual Electricity use	*TWh*	35,0	36,4	33,2	31,1
Total Energy (GER)	*PJ*	361,9	374,5	341,8	322,1
of which, electricity (in primary MJ)	*PJ*	358,3	370,5	337,2	317,3
Water (process)	*Mln.m^3*	24,1	24,9	22,7	21,4
Waste, non-haz./ landfill	*Kt*	463,4	482,4	435,2	414,9
Waste, hazardous/ incinerated	*Kt*	12,1	12,8	12,5	12,4
Emissions (Air)					
Greenhouse Gases in GWP100	*Mt CO2 eq.*	15,9	16,4	15,0	14,2
Acidification, emissions	*Kt SO2 eq.*	93,5	96,7	88,2	83,2
Volatile Organic Compounds (VOC)	*Kt*	0,145	0,150	0,142	0,135
Persistent Organic Pollutants (POP)	*g i-Teq*	2,5	2,6	2,4	2,3
Heavy Metals	*T Ni eq.*	6,9	7,2	6,7	6,5
PAHs	*T Ni eq.*	1,3	1,4	1,6	1,6
Particulate Matter (PM, dust)	*Kt*	2,6	2,8	2,7	2,7
Emissions (Water)					
Heavy Metals	*T Hg/20*	2,7	2,8	2,7	2,6
Eutrophication	*Kt PO4*	11,0	11,4	10,4	9,8
Annual Expenditure, total	*M Euros*	3506	3671	3792	3743
Purchase, luminaires	*M Euros*	388	427	653	693
Operating expense, lamp replacement	*M Euros*	208	220	322	328
Operating expense, ballast replacement	*M Euros*	-	-	51	118
Operating expense, electricity use	*M Euros*	2.805	2.913	2.652	2.487
Operating expense, installation & maintenance	*M Euros*	105	111	114	117

Table 121: Annual electricity use of installed base (unit: GWh)

		1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Fast	**Ey (GWh)**	618	656	727	811	941	1.005	1.055
Mixed		16.511	17.013	17.387	17.752	17.833	15.586	14.228
Slow		13.925	14.884	15.646	16.495	17.633	16.565	15.809
TOTAL		**31.054**	**32.553**	**33.760**	**35.058**	**36.407**	**33.156**	**31.092**

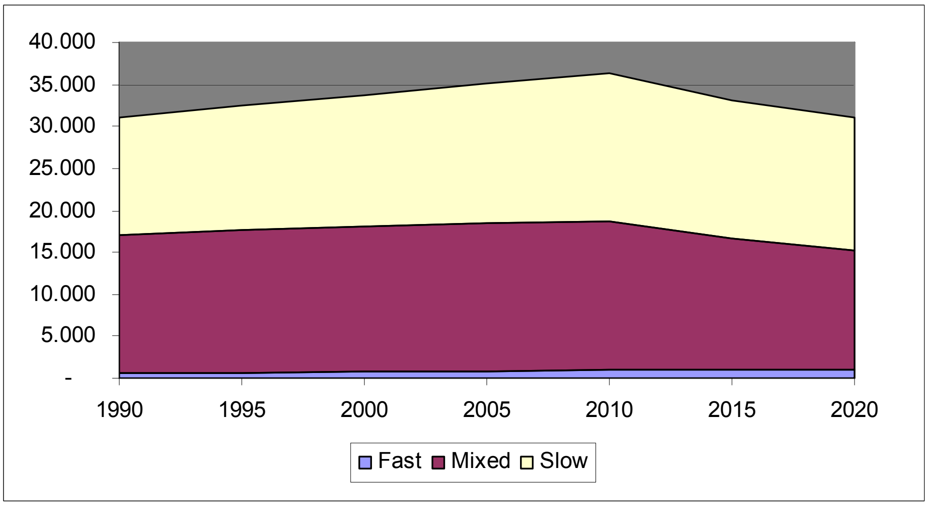

Figure 60: Annual electricity use of installed base (unit: GWh)

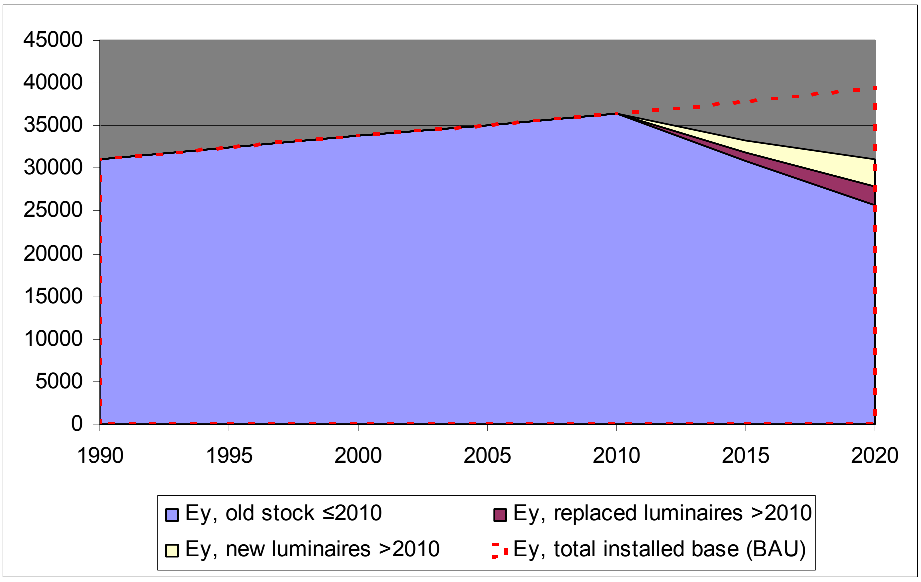

Figure 61: Annual electricity use of installed base (unit: GWh)

In BAT, the annual electricity use will decrease from 35 TWh in 2005 to 31 TWh in 2020 which is a decrease of 21%. Knowing that in 2020 only 33% of the installed base is naturally replaced with BAT luminaires, further savings can be expected (note: absolute decoupling) until the entire old stock is replaced.

The functional lumen output is identical to that of scenario 1 (increase of 13% in 2020) and is due to the increase in light output caused by lamp replacement in the existing stock of luminaires (having non-dimmable ballasts). In all new luminaires, all additional light output (more than required) is dimmed by means of the electronic ballast.

Annual expenditure for luminaire and lamp purchases increases substantially compared to BAU. This is shown in the following tables.

Table 122: Annual sales luminaires (mio. Units):

		1990	1995	2000	2005	2010	2015	2020	%decrease 2020
Fast	LUMINAIRE SALES	0,0	0,0	0,0	0,0	0,0	0,1	0,1	0%
Mixed	(mio. Luminaires per yr)	0,4	0,5	0,5	0,5	0,5	0,5	0,5	2%
Slow		1,5	1,5	1,4	1,6	1,8	1,8	2,0	5%
TOTAL		**2,0**	**2,0**	**1,9**	**2,1**	**2,4**	**2,4**	**2,6**	**4%**

Table 123: Annual expenditure luminaires (mio. Euros):

		1990	1995	2000	2005	2010	2015	2020	%increase 2020
Fast	PP, Purchase Price, SALES (annual)	4	6	6	9	10	19	21	60%
Mixed	(mio.)	85	98	91	96	99	154	158	51%
Slow		271	261	249	283	318	441	472	29%
TOTAL		**360**	**365**	**346**	**388**	**427**	**614**	**652**	**35%**

From the model simulation it can be concluded that luminaire sales decreases slightly after 2010 for both categories mixed and slow. This is because HPM luminaires are replaced with HPS luminaires that lit larger areas of road (wider pole distance assumed). However, sector turnover will increase more than proportional to sales in numbers because of the higher average purchase prices for these luminaires.

Table 124: Annual sales lamps (mio. Units):

		1990	1995	2000	2005	2010	2015	2020	%decrease 2020
Fast	LUMINAIRE SALES	0,2	0,2	0,2	0,2	0,2	0,3	0,3	0%
Mixed	(mio. Luminaires per yr)	4,7	4,8	4,9	5,0	5,1	5,0	5,0	4%
Slow		11,1	11,8	12,4	13,1	14,1	14,8	15,5	6%
TOTAL		**15,9**	**16,8**	**17,5**	**18,3**	**19,4**	**20,2**	**20,8**	**5%**

Table 125: Annual expenditure lamps (mio. Euros):

		1990	1995	2000	2005	2010	2015	2020	%increase 2020
Fast	PP, Purchase Price, SALES (annual)	4	5	5	6	6	7	8	6%
Mixed	(mio.)	71	73	75	76	78	107	104	28%
Slow		106	114	119	126	136	207	216	36%
TOTAL		**182**	**191**	**199**	**208**	**220**	**322**	**328**	**33%**

As for luminaires, the same is true for lamp sales; although a slight decrease in sales amount, the expected increase in expenditure for lamps is more than proportional.

Table 126: LCC of luminaire sales in year:

		1990	1995	2000	2005	2010	2015	2020	%saving 2020
Fast	LCC (mio. €)	42	59	65	90	106	101	117	17%
Mixed		965	1.099	1.029	1.085	1.120	746	765	36%
Slow		1.548	1.493	1.424	1.618	1.818	1.483	1.590	28%
TOTAL		**2.555**	**2.652**	**2.518**	**2.793**	**3.044**	**2.329**	**2.472**	**30%**

As shown in the table above; (total EU25) LCC of BAU luminaires sold in 2010 are substantially higher then those of BAT introduced after 2010. In 2020, total EU25 LCC BAT is 30% lower compared to LCC BAU. A substantial increase in purchase price for lamps and luminaires is thus outweighed by savings in the use phase.

This scenario has the same influence on installed mercury and thus also on fugitive and dumped mercury as the scenario 1 & 13 above.

8.1.2.4 Scenario 2020 analysis : implementing Best Available Technology (BAT) with accelerated replacement of the installed base

The actual long product life (30 years) has for consequence that there is still a stock of energy inefficient equipment in service. Therefore accelerated replacement can be considered in order to save energy by promotional measures, voluntary agreements with local authorities or even by enforcing the replacement on poor performing installed equipment. In the following scenario, BAT is implemented from 2010 on and with total stock replacement in 15 yrs.

High initial investment cost and long pay back period could make it difficult to get local authorities to replace existing installation unless a careful examination is done of the existing installation and financial means that are available.

Table 127: Aggregated results, Scenario BAT accelerated

DATA	Unit	EU Total Impact of STOCK of Products in: ((produced, in use, discarded)			
		2005	2010	2015	2020
Annual Sales Luminaires	*Millions*	2,1	2,4	4,2	4,5
Annual Sales Lamps	*Millions*	18,3	19,4	19,9	20,1
Stock Luminaires	*Millions*	56,3	59,7	63,5	67,5
Other Resources & Waste					
Annual Electricity use	*TWh*	35,0	36,4	31,4	27,0
Total Energy (GER)	*PJ*	361,9	374,5	325,2	282,5
of which, electricity (in primary MJ)	*PJ*	358,3	370,5	319,4	276,3
Water (process)	*Mln.m^3*	24,1	24,9	21,6	18,8
Waste, non-haz./ landfill	*Kt*	463,4	482,4	434,0	388,0
Waste, hazardous/ incinerated	*Kt*	12,1	12,8	14,4	13,9
Emissions (Air)					
Greenhouse Gases in GWP100	*Mt CO2 eq.*	15,9	16,4	14,3	12,5
Acidification, emissions	*Kt SO2 eq.*	93,5	96,7	84,1	73,1
Volatile Organic Compounds (VOC)	*Kt*	0,145	0,150	0,138	0,123
Persistent Organic Pollutants (POP)	*g i-Teq*	2,5	2,6	2,3	2,0
Heavy Metals	*T Ni eq.*	6,9	7,2	6,4	5,7
PAHs	*T Ni eq.*	1,3	1,4	1,9	1,9
Particulate Matter (PM, dust)	*Kt*	2,6	2,8	3,0	2,9
Emissions (Water)					
Heavy Metals	*T Hg/20*	2,7	2,8	2,8	2,6
Eutrophication	*Kt PO4*	11,0	11,4	9,8	8,5
Annual Expenditure, total	*M Euros*	3506	3671	3988	3814
Purchase, luminaires	*M Euros*	388	427	1066	1133
Operating expense, lamp replacement	*M Euros*	208	220	298	295
Operating expense, ballast replacement	*M Euros*	-	-	-	-
Operating expense, electricity use	*M Euros*	2.805	2.913	2512	2157
Operating expense, installation & maintenance	*M Euros*	105	111	112	111

Table 128: Annual electricity use of installed base, per category (unit: GWh)

		1990	1995	2000	2005	2010	2015	2020
Fast	**Ey (GWh)**	618	656	727	811	943	959	948
Mixed		16.511	17.013	17.387	17.752	17.646	14.791	12.513
Slow		13.925	14.884	15.646	16.495	17.614	15.655	13.507
TOTAL		**31.054**	**32.553**	**33.760**	**35.058**	**36.203**	**31.405**	**26.968**

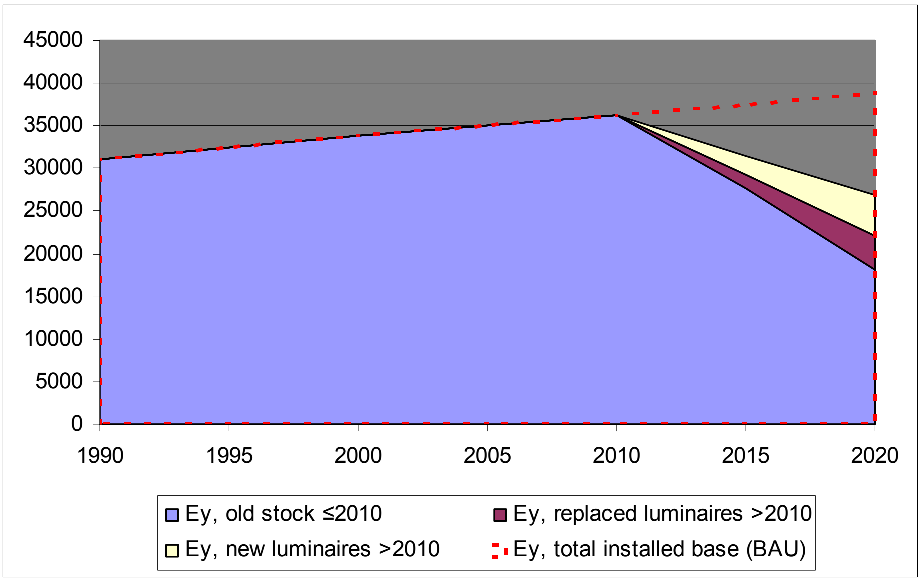

Figure 62: Annual electricity use of installed base (unit: GWh)

In case of accelerated replacement of all existing BAU luminaires within 15 years with BAT luminaires, total energy saving that can be achieved in 2020 is 31%.

The impact on industry of accelerated replacement is increase in production from 2010 on and fall back in 2025 when all old luminaires have been replaced. From 2010 on production capacity has to increase with about 63% to cope with increased demand for BAT luminaires.

8.1.2.5 BAU and BAT scenario analysis : relative contribution of individual improvement options

The individual contribution of the improvement options to the BAT and BAU scenario is proportional to the values obtained in chapter 7 (see fig. 45-47). These values are available in a spreadsheet that is separately published.

8.1.3 Sensitivity Analysis

The main purpose of this chapter is to verify the robustness of the outcome with regard to the main parameters in this study.

8.1.3.1 Main parameters related to the energy efficiency of a street lighting base case luminaire (Ey/FU)

This is determined by the uncertainty regarding product performance input parameters in the model. So far, non-weighted average input parameters for the product performance are used (see chapters 4 and 5).

8.1.3.2 Main parameters related to the LCC

The following parameters have on influence on LCC:

1. Uncertainty regarding Expected Luminaire Life
2. Uncertainty regarding interest rate
3. Uncertainty regarding electricity rate

For reasons of simplicity we apply the sensitivity analysis on BAU and BAT only. The following demonstrates the effects of uncertainty on LCC for category Slow Traffic.

Weighted average output parameters		**BAU**	**BAT**	**BAU (life=20)**	**BAT (life=20)**	**BAU (interest = 6%)**	**BAT (interest = 6%)**	**BAU (0,1€/kWh)**	**BAT (0,1€/kWh)**
Ny (annual lamp cons.)	n°/yr	0,33	0,29	0,33	0,29	0,33	0,29	0,33	0,29
FU (functional lumen)	lm_f	1078	2053	1078	2053	1078	2053	1078	2053
P	W	96	72	96	72	96	72	96	72
Ey	kWh/y	406	179	406	179	406	179	406	179
Ey/FU	kWh/(y.lm)	0,42	0,11	0,42	0,11	0,42	0,11	0,42	0,11
PP, Purchase Price	€	176,37	242,98	176,37	242,98	176,37	242,98	176,37	242,98
OE, lamp replacement/y	€/y	3,14	4,79	3,14	4,79	3,14	4,79	3,14	4,79
OE, ballast replacement	€/y	0	3,58	0	3,58	0	3,58	0	3,58
OE, electricity	€/y	32,45	14,32	32,45	14,32	32,45	14,32	40,56	17,9
OE, labour/y	€/y	1,86	1,54	1,86	1,54	1,86	1,54	1,86	1,54
LCC	€	1014,88	785,9	788,56	639,36	823,77	662,16	1196,55	866,1
U		no data	no data	no data	no data	no data	no data	no data	no data
max. lost upw. Flux	Lm	no data	no data	no data	no data	no data	no data	no data	no data
total lamp mercury	Mg	151,73	100,9	101,16	67,27	151,73	100,9	151,73	100,9

Average luminaire life from 30 to 20 yrs: causes a logical increase of material related impacts and luminaire cost of goods and installation. PP (Purchase Price) is 17% of LCC in BAU and 30% in BAT when assuming an average luminaire life of 30yrs. With a reduced average luminaire life to 20 yrs by, this becomes respectively 22% and 38%. The extra PP cost of 66€ per luminaire is paid back in both cases (229€ and 150€ LCC saving respectively. In both cases ROI (return on investment) is much longer than 3 or 6 yrs which are the common timeframes to justify an increase of purchase price. This could be a set back for street lighting purchasers (when no ecodesign requirement is set).

Interest rate from 4% to 6%: (discount rate changes from 2% to 4%, PWF from 22,4 to 17,3 yrs): again, does not affect results in the sense that increase in PP (66€) is paid back by LCC saving (162€). Even in case of increase in interest rate combined with shorter average luminaire life (20 yrs) this is paid back (difference in LCC is then 112,75 €). In this case, the luminaire should be at least 13 yrs before savings in OE (operational expense) are paid back by increase in PP.

Electricity price from 0,08 €/kWh to 0,1 €/kWh: LCC saving obviously becomes more substantial and ROI period reduces to about 8 yrs assuming interest rate of 4%. In case of 6% interest rate, ROI becomes 9 yrs. At a electricity price of 0,12 to 0,14 €/kWh ROI is around 6 yrs (combined with 4% and 6 % interest rate respectively).

In the following graphs, the impact of uncertainty on results for individual options is shown. Uncertainty in electricity cost (€/kWh) will not affect the individual ranking of options; all results then change proportionally in the same direction. Of main influence on the individual ranking is from uncertainty in purchase price of luminaires. On average, purchase price (PP) is 10% to 20% of total LCC. When assuming a maximum uncertainty of 50% in the PP used in the model, this means a maximum of 10% uncertainty in results on total LCC. In the graphs below, this is represented by the vertical bars centered on each option. Annual electricity use is much influenced by the input parameters (efficacy lamps, ballast, LLMF, etc…). A maximum uncertainty of 15% is represented by the horizontal bars centered on each option.

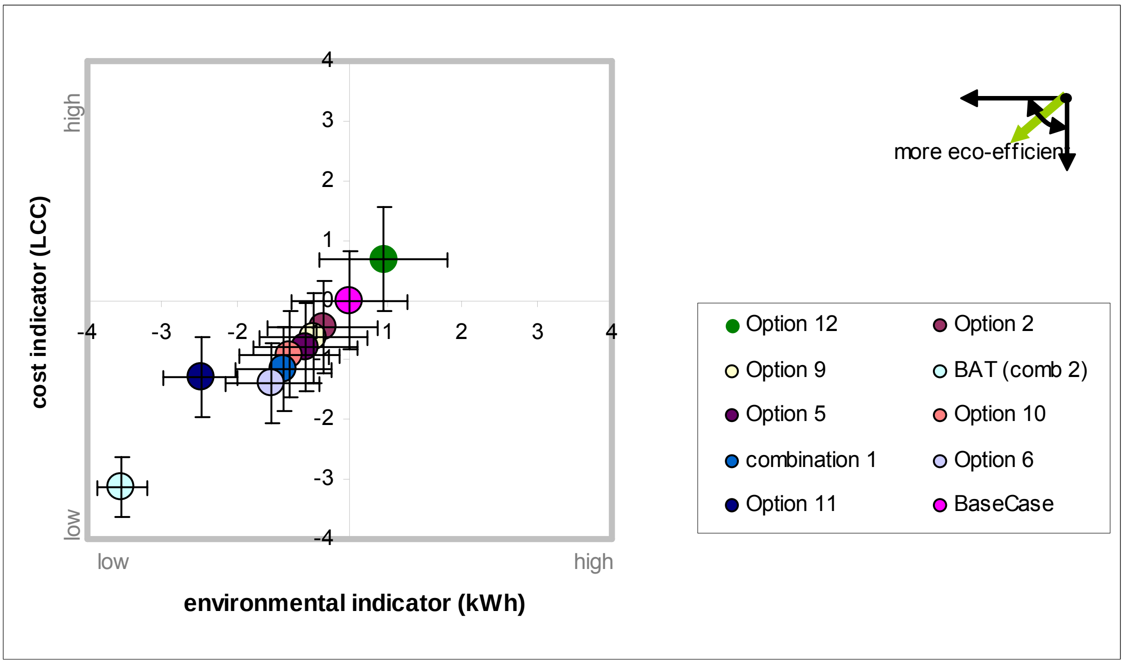

Figure 63: Uncertainty, category Fast

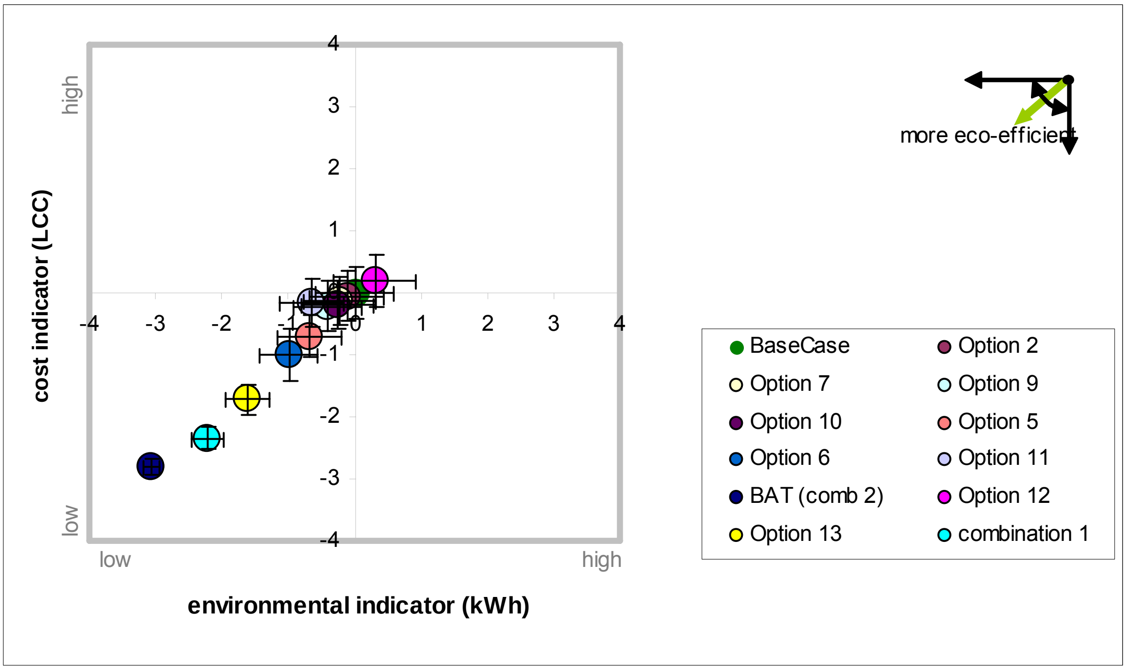

Figure 64: Uncertainty, category Mixed

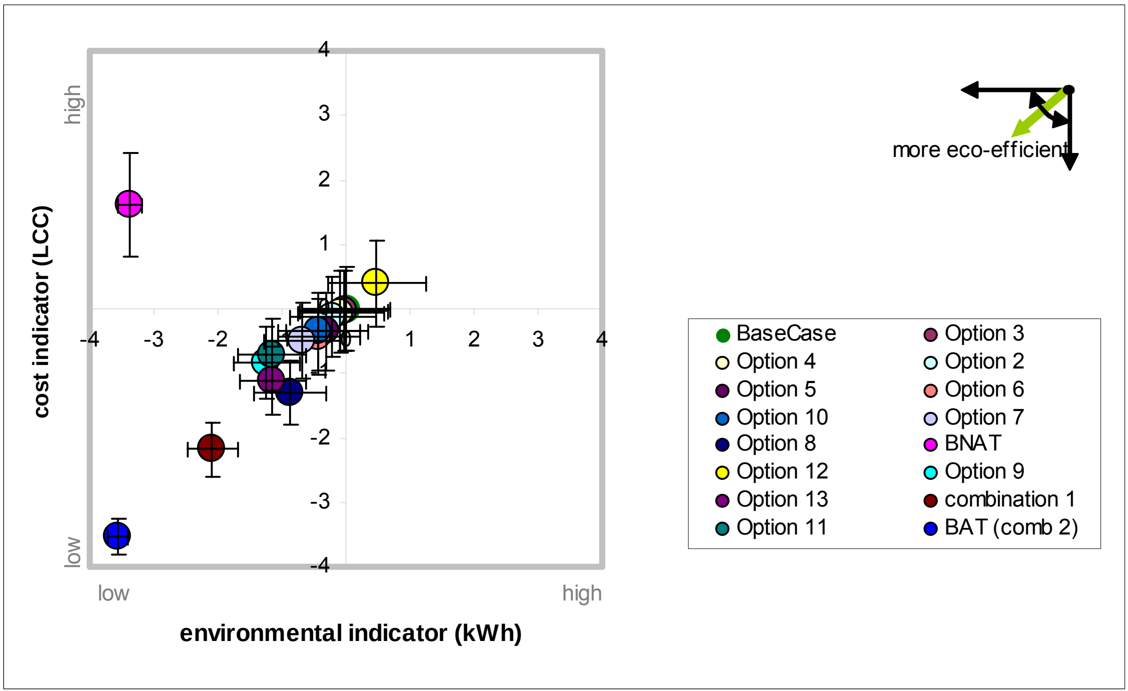

Figure 65: Uncertainty, category Slow

When accounting with this magnitude of uncertainty almost none of the individual options can be favoured comparing one to another, and contribute to the total saving in the same order of magnitude having non-substantial differences. In some cases option 11 (electronically dimmable ballasts) and option 13 (HPM replacement with HPS and CMH) and of course simultaneous implementation of different options clearly demonstrate substantial savings compared to BAU.

8.1.3.3 Accuracy of the estimated EU25-total energy consumption

It is important to note that there is an uncertainty on the estimated EU25-total energy consumption and the related scenarios. The main origin is the lack of data about installed stock, the related long service time of the stock products and the wide variety in new products performance and future consumer needs.

The following main uncertainties can be identified that have an impact on the calculated E25 energy consumption:

1. Uncertainty regarding assumed wattage per luminaire for the base cases.
2. Uncertainty regarding base case parameters (see chapter 5)
3. Uncertainty regarding % road lit in category slow traffic versus mixed traffic
4. Uncertainty regarding number of luminaires in the installed base (current assumption 56 mio.)
5. Uncertainty regarding % road infrastructure growth
6. Uncertainty regarding burning hours
7. Uncertainty regarding expected luminaire life and pole life that affect the ratio of luminaire replacement sales versus new street project sales

Uncertainty regarding assumed wattage per luminaire for the base cases:

The following tables demonstrate the known and the assumed wattage per luminaire values as used in the model.

Table 129: Available data, expert enquiry installed base luminaires and installed lamp power

Country	Luminaires	Installed Power MW	Watt/luminaire W
Belgium	2.005.250	249	124
France	8.570.000	1.250	146
Germany	9.130.000	1.000	110
Ireland	400.820	43	108
Netherlands	2.660.000	161	61
Poland	2.500.000	600	240
Sweden	2.500.000	250	100
United Kingdom	8.117.000	619	76
Total / Average	**35.883.070**	**4.173**	**116**

Table 130: Installed base luminaires and installed lamp power (base case scenario)

		1990	1995	2000	2005	2010	2015	2020
Fast	**Luminaires** (mio.)	0,57	0,61	0,67	0,75	0,87	1,00	1,16
Mixed		14,05	14,58	14,89	15,21	15,63	16,02	16,42
Slow		34,03	36,38	38,24	40,32	43,18	46,32	49,69
TOTAL		**48,66**	**51,57**	**53,81**	**56,28**	**59,67**	**63,34**	**67,27**
Fast	**Installed (lamp) Power MW**	133	141	157	175	202	234	270
Mixed		3.607	3.743	3.823	3.905	4.011	4.081	4.151
Slow		2.875	3.074	3.231	3.406	3.648	3.908	4.186
TOTAL		**6.616**	**6.958**	**7.211**	**7.486**	**7.862**	**8.222**	**8.607**
TOTAL/ AVERAGE	**Watt/luminaire W**	**136**	**135**	**134**	**133**	**132**	**130**	**128**

Comparing the base case data used in the model and the available data from the expert enquiry, it must be concluded that there is an uncertainty of at least 15% on the assumption regarding the total EU25 installed power (and thus annual electricity usage). It should be noted that available data are mainly from western EU countries and data are missing from most other eastern EU countries, with the exception of Poland. As can be seen, Poland has a much higher average wattage per luminaire compared to the other countries in the table and thus real EU25 average wattage per luminaire is likely to be higher than the above 116 W per luminaire and thus closer to the values used in the model

Uncertainty regarding % road lit in category slow traffic versus mixed traffic:

Please not that the implementation of the new standard EN 13201 (2004) series can have a similar impact. This is possible due to the lack of data about existing installations and their compliance with the new standard, the impact of the implementation of this standard could hardly be forecasted from the enquiry data. The few answers on our inquiry showed that the new EN 13201-1(2004) guideline minimum lighting levels are lower then the previous national applied recommendations (Sweden, Netherlands, Belgium). Because the model categories have higher lighting value requirements from category slow to fast the impact is similar with a shift in % lit roads in a defined catergory.

It is likely that in the model, that road category ‘Fast Traffic’ is underestimated because (EUROSTAT) ‘State roads’ and ‘Provincial roads’, are now both and 100% summed under category ‘Mixed Traffic’ but should be partly lit according to ‘Fast Traffic’ lighting performance standards. Per 1% road category Mixed to category Fast: total EU25 electricity use decreases with 0,3%. Thus when 10% of State and Provincial roads are lighted as Fast Traffic roads, total EU25 electricity use decreases with 3%.

It could also be likely that the amount of communal roads lighted as Mixed Traffic is underestimated. Currently, only 5% of communal roads are allocated to category Mixed Traffic. Per 1% extra communal road to Mixed road, total EU25 electricity use increases with 0,42%.

Uncertainty regarding % road infrastructure growth

Please note that the implementation of the new standard EN 13201 (2004) series can have a similar impact. Due to the lack of data about existing installations and their compliance with the new standard, the impact of the implementation of this standard could hardly be forecasted. Some installations probably do not comply with the new standard by reason of bad uniformity. Compliance could require installing more poles and thus can result in an increase in 'new lit streets' in model terminology.

In category slow traffic, for 2005, 40 million base case luminaires were estimated and is hence the largest category in terms of n° luminaires, installed power, associated costs and impacts. Under the base assumption that this category of road is lighted at on average 7,5 lx would mean that approximately 22,5 %km of total road category S is lit (or 720.000 km lit street) with this amount of base case luminaires.

The growth rate of street lighting stock is derived from the assumed growth rate of road infrastructure (% km) for this street category. Forecasting can be based on the assumption that annual growth rate since 1995 will continue after 2005 (approximately 1 %) but can also be based on the assumption that road infrastructure growth will follow the expected increase in transport activity (approximately 1,7 % annually). An in between value of 1,4% increase annually has been taken for the scenario analysis. At the same time, there are no indications to assume a relative growth of km lit street (km lit street / km total street remains 22,5%).

In 2020, the amount of installed luminaires for this street category (slow traffic) is then between 47 mio. and 52,5 mio. depending on the underlying assumption for street lighting growth. Related annual lamp sales will than vary from 15 to 17 mio. units. In Table 131 and Table 132 the values are given for the amount of installed luminaires and related annual lamp use.

Based on annual growth rate before 2005 (1%), expected luminaire life and installed base; luminaire replacement sales can be calculated. For category slow, in 2005, this amounts up to about 75% to 80% of total new luminaire sales. The so-called ‘lock-in effect’ can thus not be underestimated in this category.

Table 131: Forecast of installed base of luminaires and lamp use, Business as Usual (units: million)

	n°	**€**	**n°**	**€**	**n°**	**€**	**n°**	**€**	**n°**	**€**	**n°**	**€**
Luminaires (mio.)	**HPM**		**HPS**		**CMH**		**CFL**		**n.a.**		**TOTAL**	
1990	*10,9*	*1.666,3*	*19,4*	*3.394,8*	*0,7*	*130,7*	*3,1*	*459,4*	*0,0*	*0,0*	***34,0***	***5.651***
1995	*11,6*	*1.781,1*	*20,7*	*3.628,8*	*0,7*	*139,7*	*3,3*	*491,1*	*0,0*	*0,0*	***36,4***	***6.041***
2000	*12,2*	*1.872,3*	*21,8*	*3.814,6*	*0,8*	*146,8*	*3,4*	*516,3*	*0,0*	*0,0*	***38,2***	***6.350***
2005	*12,9*	*1.973,9*	*23,0*	*4.021,6*	*0,81*	*154,8*	*3,6*	*544,3*	*0,0*	*0,0*	***40,3***	***6.695***
2010	*13,8*	*2.110,0*	*24,5*	*4.291,1*	*0,9*	*172,9*	*4,0*	*599,6*	*0,0*	*0,0*	43,2	7.173
2015	*14,8*	*2.257,5*	*26,2*	*4.582,9*	*1,0*	*192,9*	*4,4*	*660,6*	*0,0*	*0,0*	46,4	7.694
2020	*15,8*	*2.415,4*	*28,0*	*4.894,5*	*1,1*	*214,9*	*4,8*	*727,3*	*0,0*	*0,0*	49,7	8.252
Lamps (mio./yr)	**HPM**		**HPS**		**CMH**		**CFL**		**n.a.**		**TOTAL**	
1990	*4,5*	*17,1*	*5,1*	*77,1*	*0,4*	*7,9*	*1,1*	*4,2*	*0,0*	*0,0*	*11,1*	*106*
1995	*4,8*	*18,3*	*5,5*	*82,4*	*0,4*	*8,4*	*1,1*	*4,5*	*0,0*	*0,0*	*11,8*	*114*
2000	*5,1*	*19,2*	*5,8*	*86,6*	*0,4*	*8,8*	*1,2*	*4,8*	*0,0*	*0,0*	*12,4*	*119*
2005	*5,3*	*20,3*	*6,1*	*91,3*	*0,4*	*9,3*	*1,3*	*5,0*	*0,0*	*0,0*	*13,1*	*126*
2010	*5,7*	*21,7*	*6,5*	*97,5*	*0,5*	*10,4*	*1,4*	*5,5*	*0,0*	*0,0*	14,1	135
2015	*6,1*	*23,2*	*6,9*	*104,1*	*0,5*	*11,6*	*1,5*	*6,1*	*0,0*	*0,0*	15,1	145
2020	*6,5*	*24,8*	*7,4*	*111,2*	*0,6*	*12,9*	*1,7*	*6,7*	*0,0*	*0,0*	16,2	156

Table 132: Sensitivity analysis on growth forecast, Business as Usual

	trend 1995-2005		**transport activity**		**in between**	
	n°	**€**	**n°**	**€**	**n°**	**€**
Luminaires (mio.)	TOTAL		TOTAL		TOTAL	
1990	34,0	5.651	34,0	5.651	34,0	5.651
1995	36,4	6.041	36,4	6.041	36,4	6.041
2000	38,2	6.350	38,2	6.350	38,2	6.350
2005	40,3	6.686	40,4	6.702	40,3	6.695
2010	42,4	7.033	44,0	7.298	43,2	7.173
2015	44,6	7.396	48,0	7.964	46,4	7.694
2020	46,9	7.777	52,4	8.690	49,7	8.252
Lamps (mio./yr)	TOTAL		TOTAL		TOTAL	
1990	11,1	106	11,1	106	11,1	106
1995	11,8	114	11,8	114	11,8	114
2000	12,4	119	12,4	119	12,4	119
2005	13,1	126	13,1	126	13,1	126
2010	13,8	132	14,3	137	14,1	135
2015	14,5	139	15,6	150	15,1	145
2020	15,3	147	17,1	164	16,2	156

Uncertainty regarding burning hours:
The annual operating expenses electricity and lamp replacement have a linear relation with burning hours. Similar with regard to their share in the total life cycle costs and total life cycle impacts.

Uncertainty regarding expected luminaire life and pole life that affect the ratio of luminaire replacement sales versus new project sales:

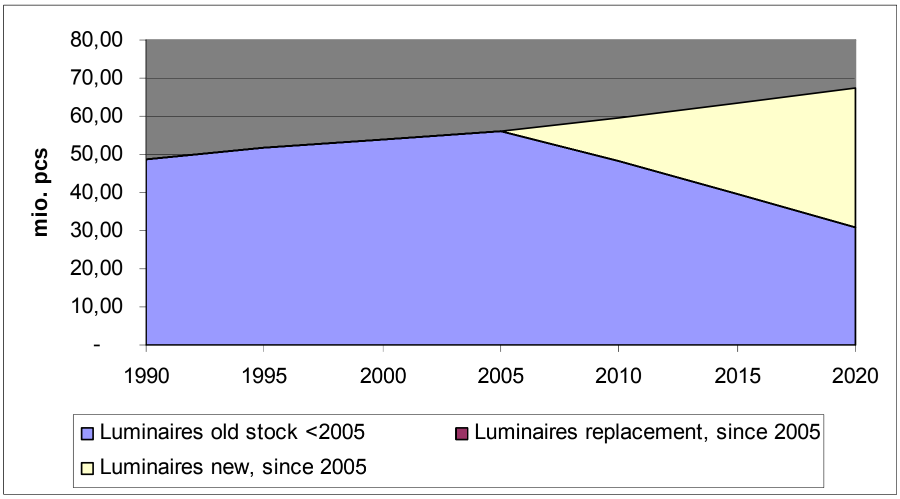

Figure 66: Scenario, luminaire life = pole life (no lock-in, no replacement sales)

Table 133: Aggregated results, Business As Usual (BAU)

DATA	Unit	EU Total Impact of STOCK of Products in: ((produced, in use, discarded)			
		Life (Pole/Luminaire)=2		Life (Pole/Luminaire)=1	
		2005	2020	2005	2020
Annual Sales Luminaires	*Millions*	2,1	2,7	2,1	2,7
Annual Sales Lamps	*Millions*	18,3	21,9	18,3	21,9
Stock Luminaires	*Millions*	56,3	67,4	56,3	67,5
Other Resources & Waste					
Annual Electricity use	*TWh*	35,0	39,4	35,0	38,4
Total Energy (GER)	*PJ*	361,9	402,5	361,9	388,8
of which, electricity (in primary MJ)	*PJ*	358,3	398,0	358,3	384,3
Water (process)	*Mln.m^3*	24,1	26,8	24,1	25,9
Waste, non-haz./ landfill	*Kt*	463,4	521,0	463,0	504,6
Waste, hazardous/ incinerated	*Kt*	12,1	14,0	12,1	13,7
Emissions (Air)					
Greenhouse Gases in GWP100	*Mt CO2 eq.*	15,9	17,7	15,9	17,1
Acidification, emissions	*Kt SO2 eq.*	93,5	104,0	93,5	100,4
Volatile Organic Compounds (VOC)	*Kt*	0,145	0,162	0,145	0,157
Persistent Organic Pollutants (POP)	*g i-Teq*	2,5	2,8	2,5	2,8
Heavy Metals	*T Ni eq.*	6,9	7,8	6,9	7,6
PAHs	*T Ni eq.*	1,3	1,6	1,3	1,6
Particulate Matter (PM, dust)	*Kt*	2,6	3,0	2,6	3,0
Emissions (Water)					
Heavy Metals	*T Hg/20*	2,7	3,1	2,7	3,0
Eutrophication	*Kt PO4*	11,0	12,3	11,0	11,8
Annual Expenditure, total	*M Euros*	3.506	4.012	3503	3923
Purchase, luminaires	*M Euros*	388	484	385	480
Operating expense, lamp replacement	*M Euros*	208	247	208	248
Operating expense, ballast replacement	*M Euros*	-	-	-	-
Operating expense, electricity use	*M Euros*	2.805	3.156	2.805	3.070
Operating expense, installation & maintenance	*M Euros*	105	125	105	125

The annual expenditures in the figure above excludes the cost of the additional poles required. In a scenario to avoid lock-in effect and renew also pole (distances) when new luminaires are installed, this additional cost should be taken into account.

8.1.3.4 The impact contribution of the street lighting pole

The impact contribution including the street lighting pole is included hereafter. This is done to illustrate the importance of the lock-in effect that was taken into account in this study (see also chapter 3.3.1) and also to indicate how much it could contribute to environmental impact and cost if new poles should be installed (see Table 134).

Table 134: Aggregated results, Business As Usual (BAU)

DATA	Unit	EU Total Impact of STOCK of Products in: (produced, in use, discarded)					
		Life Pole / Life Luminaire = 2 (system excludes cost & impacts pole) *(=BAU model)*		Life Pole / Life Luminaire = 2 (system includes cost & impacts pole)		Life Pole / Life Luminaire = 1 (system includes cost & impacts pole)	
		2005	2020	2005	2020	2005	2020
Annual Sales Luminaires	*Millions*	2,1	2,7	2,1	2,7	2,1	2,7
Annual Sales Lamps	*Millions*	18,3	21,9	18,3	21,9	18,3	21,9
Stock Luminaires	*Millions*	56,3	67,4	56,3	67,4	56,3	67,5
Other Resources & Waste							
Annual Electricity use	*TWh*	35,0	39,4	35,0	39,4	35,0	38,4
Total Energy (GER)	*PJ*	361,9	402,5	366,8	408,6	371,4	400,5
of which, electricity (in primary MJ)	*PJ*	358,3	398,0	359,4	399,4	360,4	386,8
Water (process)	*Mln.m^3*	24,1	26,8	24,1	26,8	24,1	25,9
Waste, non-haz./ landfill	*Kt*	463,4	521,0	632,0	730,4	790,0	911,0
Waste, hazardous/ incinerated	*Kt*	12,1	14,0	12,1	14,0	12,1	13,7
Emissions (Air)							
Greenhouse Gases in GWP100	*Mt CO2 eq.*	15,9	17,7	16,2	18,1	16,6	18,0
Acidification, emissions	*Kt SO2 eq.*	93,5	104,0	94,6	105,4	95,6	103,0
Volatile Organic Compounds (VOC)	*Kt*	0,145	0,162	0,159	0,180	0,172	0,191
Persistent Organic Pollutants (POP)	*g i-Teq*	2,5	2,8	5,0	5,9	7,3	8,7
Heavy Metals	*T Ni eq.*	6,9	7,8	7,5	8,5	8,0	8,8
PAHs	*T Ni eq.*	1,3	1,6	1,4	1,6	1,4	1,6
Particulate Matter (PM, dust)	*Kt*	2,6	3,0	3,4	3,9	4,0	4,7
Emissions (Water)							
Heavy Metals	*T Hg/20*	2,7	3,1	3,1	3,5	3,4	3,9
Eutrophication	*Kt PO4*	11,0	12,3	11,0	12,2	11,0	11,8
Annual Expenditure, total	*M Euros*	3.506	4.012	3842	4430	4176	4761
Purchase, luminaires (poles)	*M Euros*	388	484	724	902	1058	1318
Operating expense, lamp replacement	*M Euros*	208	247	208	247	208	248
Operating expense, ballast replacement	*M Euros*	-	-	-	-	-	-
Operating expense, electricity use	*M Euros*	2.805	3.156	2.805	3.156	2.805	3.070
Operating expense, installation & maintenance	*M Euros*	105	125	105	125	105	125

When comparing product analysis excluding the pole versus including the pole, the contribution of the following environmental impacts caused by the pole are not te be neglected; non-hazardous waste (+40%), VOC (+10%), POP (+100%), Heavy Metals (+10~15%) and PM, dust (+30%).

With regard to costs, the operating expenses remain unchanged, but the purchase price increases with pole purchase price (330€ in category F, 200€ in M and 155€ in S) and old pole removal and new pole installation costs (approx. 4 to 5 hrs labour per pole). As can be shown in the table above, this increases PP with approx. 85%. Taking all aspects of LCC into account, total annual expenditure increases with about 10%.

In a scenario where there is no luminaire replacement, but poles are always renewed and pole distances adjusted to optimum system configuration (thus only new project sales), the situation ‘Life Pole / Life Luminaire = 2’ and ‘Life Pole / Life Luminaire = 1’ should be compared, taking into account pole removal and installation costs. A situation of no replacement sales, thus no lock-in is beneficial for annual electricity use and the main electricity-related environmental impacts (decrease with approx. 2 to 3%). This situation is however not beneficial towards the environmental impacts non-hazardous waste (+25%), VOC (+5%), POP (+45%), HM (+5 to 10%) and PM, dust (+20%). The explanation for this is straightforward, namely the impacts of the additional poles that are required compared to a scenario where poles are always reused for one more luminaire generation. The additional requirement for poles is also reflected in the increase in annual purchase expenditure (+45%). In 2020, the total annual expenditure, despite the decrease in operating expense on electricity use, is 7% more compared to the BAU scenario where poles last 2 luminaire generations. It can thus be concluded that reinstalling and relocating lighting poles is not a recommended improvement option and therefore confirms that the lock-in effect will remain a factor to be taken into account and should be evaluated at installation level.

In the following Table 135, the relative environmental impact of including a pole in the product system is demonstrated. In this example for category 'Slow', the impacts from half a steel pole are contributed, assuming that one pole will serve two luminaire lives and/or more luminaires can be attached to one pole.

Table 135: MEEUP results for one category 'Slow' product unit, including pole in product system

			TOTAL	Electricity	Luminaire	Lamps	Ballast	½ pole
	Other Resources & Waste			%	%	%	%	%
8	Total Energy (GER)	MJ	132.201	97%	1%	0%	0%	2%
9	of which, electricity (in primary MJ)	MJ	128.502	99%	0%	0%	0%	0%
10	Water (process)	Ltr	8.627	99%	1%	0%	0%	0%
11	Water (cooling)	Ltr	341.336	100%	0%	0%	0%	0%
12	Waste, non-haz./ landfill	G	259.290	57%	5%	0%	3%	35%
13	Waste, hazardous/ incinerated	G	4.739	62%	30%	0%	7%	0%
	Emissions (Air)							
14	Greenhouse Gases in GWP100	Kg CO2 eq.	5.895	95%	1%	1%	0%	3%
15	Ozone Depletion, emissions	mg R-11 eq.	negligible	-	-	-	-	-
16	Acidification, emissions	g SO2 eq.	34.061	97%	1%	0%	0%	2%
17	Volatile Organic Compounds (VOC)	g	60	80%	4%	2%	1%	13%
18	Persistent Organic Pollutants (POP)	ng i-Teq	2.240	37%	1%	0%	2%	59%
19	Heavy Metals	mg Ni eq.	2.758	79%	2%	7%	1%	10%
	PAHs	mg Ni eq.	556	45%	48%	5%	2%	1%
20	Particulate Matter (PM, dust)	G	1.393	50%	19%	2%	2%	27%
	Emissions (Water)							
21	Heavy Metals	mg Hg/20	1.210	68%	14%	0%	2%	16%
22	Eutrophication	g PO4	3.938	100%	0%	0%	0%	0%
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible	-	-	-	-	-

From the table of results it can be concluded that:

- from the perspective of energy-related impacts; the production, distribution, recycling and disposal of the luminaire, lamps, ballast and pole contribute only marginally;
- for the other non-energy-related impacts, the pole contributes to some extent and mainly with regard to waste, the emission of VOC's, POP's, PM, and heavy metals to air and water due to the production of steel and it's disposal and recycling processes.

In terms of product design; the pole weight, the pole material selection, the number of luminaires attached per pole, production waste (e.g. avoiding metal scrap) and product recycling are determinant to reduce these impacts.

8.1.3.5 Summary on sensivity analysis

- When taking into account the uncertainties, almost none of the individual options can be favoured comparing one to another with an exception for option 11 (electronically dimmable ballasts) and option 1+13 (HPM replacement with HPS and CMH).
- It can be concluded that reinstalling and relocating lighting poles is not a recommended improvement option and therefore confirms the lock-in effect.
- The uncertainties can have an impact on 'estimated EU25 energy consumption' because they rely on the underlying assumptions of this study, however they do not influence the 'energy consumption in real life.

8.1.4 Suggested additional requirements for the appropriate putting into service

Recommendation 1:

It is recommended to complement the following existing standards:

Standard series EN 13201:

- The standard gives only minimum requirements but no maximum light levels (see 7.4.3); the majority of lighting designers apply these values as standard values but introducing also maximum values could in some cases reduce energy consumption and light nuisance.
- The standard offers no clear solution for dimming applications as it determines traffic density on a daily base. It would be better to determine it on hourly base so that it is clear when and to what level the lighting can be dimmed safely.

CIE 154 technical guide:

- As the HPS (NaHP-TC) lamps are now commonly replaced after 4 years service, Luminaire Maintenance Factor LMF should also be given for 4 years of service.
- Discrimination on LMF for outer glazing made of synthetic material (e.g. PMM or PC) versus glass should be taken into account.

Recommendation 2:

It is important that EU25 member states undertake action to create accurate inventories of public street lighting.

An important general remark about energy management and energy saving is the need for real and actual data. The fact that Ireland, the UK and Belgium have these detailed data, proves that this ecodesign requirement is not utopian and can create a market transformation toward energy efficient public lighting. It is therefore recommended that EU25 member states undertake action to create these inventories.

Recommendation 3:

It is also recommended that complementary installation requirements are introduced by the member states for the defined product category in order to close the back door ways for installing other luminaires not intended for street lighting use or causing energy spill by not following the appropriate installation guidelines from the manufacturer.

The suggestion is that for each installation a project evaluation sheet is completed and it should be verified that the LPD (lighting power density) is within the scope (minimum value) and compare it with the best bench mark values (BAT). Therefore the spreadsheet that is published together with this study can be used.

It is also recommended that these project sheets are regularly collected by member states in order to verify how far the measures are effective and to update the BAT value. Analysing and publishing these data can also create a valuable data source for new street lighting project developers and stimulate energy efficiency.

Similar bench mark values for street lighting already exist (NSVV (2004)'Kengetallen'), in this publication in dutch bench mark values are listed per EN 13201 road class in kW/km.

Suggested minimum and bench mark values are included in table below:

	LPD_l $(W/(m^2.Cd/m^2))$ minimum	LPD_l $(W/(m^2.Cd/m^2))$ BAT	LPD_i $((W/m^2.lx))$ minimum	LPD_i $((W/m^2.lx))$ BAT
ME classes (R3008, q_0=0,08)	0,5	0,25.	NA	NA
CE and other classes	NA	NA	0,06	0,03

Recommendation 4:

It is very important that the product definition of chapter 1 is strictly implemented and applied without creating backdoor ways for the putting into service of other non- compliant luminaires in street lighting. This especially requires that whenever one of the luminaire functions is within the product definition of chapter 1 it is within the scope of the suggested eco-design requirements.

This means for example that a luminaire intended for street and monument lighting may not be an argument for escaping from the implementation of eco-design requirements for street lighting. This will have no further negative impact on industry and users because functional problems that might arise can be more appropriately solved by installing two luminaires without compromising the street lighting and monument lighting function.

Recommendation 5:

The following system related changes can also contribute to a reduced environmental impact (see 7.4.3):

- Increased installation skills and procedures in order to obtain the best fit between luminaires and installation performance (see chapter 3 and 4) .
- Increasing the awareness of the energy consumption of outdoor lighting. It this context it is also important that energy consumption of outdoor lighting is billed according to real consumption and not according to fixed prices per installed luminaire, as sometimes done in public lighting.
- Careful examination of the maximum levels of outdoor lighting is required, also in relation to dimming requirements (see chapter 3). Much research has been done to

examine the minimum requirements that are included in standards but the ALARA (as low as reasonable acceptable) principle is actually not included in standards. In some cases the opportunity for installing new luminaires can be used to increase lighting and comfort of outdoor lighting, the final result could be an increase in comfort without energy saving at system level.

8.1.5 Required new measurement standards

There is a need to draw up a standard for measuring the energy efficiency of ballasts for HID lamps. CELMA mentioned that this will be done in future.

8.1.6 Suggested additional research

Tunnel lighting was excluded from the study for reasons mentioned in chapter 1, but it is recommended to carry out further research outside the scope of this directive. It should focus at installation level and the maximum use of daylight and creating a systematic approach at EU25 level.

It is also recommended that further research is done on the ecological impact of street lighting and the reduction of sky glow for astronomic observation.

It is also recommended to carry out further research on monument and architectural outdoor lighting:

- taking into account the 'colour' of the light source and the environment. A blue light source will be useless to lit a green tree. Therefore installation requirements are particular useful for these applications.
- taking into account that only the target area needs to be lit.
- light pollution should be taken into account and is also very related to installation requirements.
- the annual product sales is probably low (<200000 units/y) and products are very diverse.

The focus for this monument.and architectural lighting application should be therefore on installation requirements.

8.2 Impact analysis industry and consumers

This chapter includes a supplementary qualitative impact analysis on industry and consumers, for the quantified impact (e.g. annual product sales volumes) please look at 8.1.2.

8.2.1 Potential application of the ecodesign requirements outside the defined product category

All of these ecodesign requirements can also apply to other outdoor applications that are not 'public' 'street' lighting, especially on non public outdoor car parks and outdoor working places. Many of those ecodesign requirements can even be applied in private outdoor lighting and amenity outdoor lighting. Analysing those impacts is not part of this study, which deals only with street lighting products which should therefore be identified as such through product information provided by the manufacturers. The annual lamp sales estimated in this study for street lighting is 18 million units and these sales should be compared to reported sales of 38 million units sodium vapour lamps (HPS, LPS) and 24 million units mercury vapour discharge lamps (MH, HPM) in Europroms statistics (see chapter 2).

8.2.2 Warnings for avoiding negative impact on consumers outside the defined product category

A total ban of standard HPM (HgHP-BF) lamps from the market could be absorbed by using retrofit HPS lamps that have better efficacy or by using MH lamps that have better efficacy and better colour rendering. These MH lamps can also replace HPM lamps that actually are still used in indoor and outdoor workplaces, sports halls etc. Also a ban of the self ballasted HPM lamps, the so called ‘mixed light’ lamps, used in indoor luminaires where no ballast can be placed, could be absorbed by using compact fluorescent lamps with integrated ballast and E27/E40 socket (available with lumen output up to 23000lm).
It is also possible that the HPM lamps are actually used for specific applications where an amount of UV radiation is necessary. Albeit no such applications are found in literature, this could have a negative impact on that consumers. Stakeholders should confirm this option.

8.2.3 Warnings and additional measures for avoiding potential negative impact on industry and consumers from products in the defined product category

As most proposed measures are applications of existing technologies, a great negative impact on industry cannot be expected because the production of HPM lamps will be replaced by the other lamp types by the same manufacturer.
The enforcement of continuous dimmable ballasts with lamp power control for HID lamps in street lighting is actually only possible with electronic ballasts. This measure might affect some SMEs that produce magnetic control gear.

Some companies might experience/suffer severe competition if electronic control gear technology takes over the old ferromagnetic control gear technology because other production lines and technological competences are needed. The switch of ferromagnetic to electronic control gear will also affect the copper and silicon steel industry because lower volumes of this material are needed in this technology.

Imposing extra standards related to eco-design and energy performance might create additional administration and costs for industry. It should be noted that international standards as defined in chapter 1 (e.g. CIE and IEC standards) and that are related to eco-design are not free available and are copyright protected. These standards are sold electronically for about typically 1 euro per page and refer in many cases to many other standards. The trade in copies of these standards provides the main source of income to CIE and IEC. These standards are very technical and sometimes difficult to understand. The authorities could undertake further actions to make this information free and easy available.

8.2.4 Return on investment barrier for authorities or municipalities

Remark on the return on investment for the implementation of improvement option 1 'retrofit HPS lamps':
The pay back is short and does not impose any barrier to authorities or municipalities (lower than product life of 3 years).

Remark on the return on investment for the implementation of improvement options 2-10:
When new luminaires need to be purchased and installed, the simple pay-back period easily surpasses 10 years (see 8.1.3.2). Albeit there is a pay-back, this period is often too long to spur local authorities to replace existing installations unless a careful examination is done and financial means are available for investment. When taking into account inflation and interest rates, the low return on investment can create a financial barrier to owners of public lighting for these improvement options. Especially when also other investments with higher return have to be done, the ROI can create a barrier for accelerated replacement.
However, when it comes to new installations or non-accelerated replacement, the additional cost for the BAT versus BAU is relative low (30 % of the purchase price) and therefore the return on investment for this extra price is justified, the pay back period for the extra cost is 3-4 years. Therefore it is justified to implement the BAT eco-design requirements for new products (parts) brought on the market, as it would not impose significant financial barriers for authorities or municipalities.

Remark on the return on investment for implementation of improvement option 11 and 12 'dimming ballasts':
Please note that there is an ongoing SAVE study (E-Street (see chapter 6)) related to this technology. This technology can be implemented in existing luminaires, therefore the cost can be acceptable.
The technology is relative new and the product prices were found not representative nowadays to take conclusions so far but the potential savings are high and implementation of these improvement options needs to be considered for the medium term (2010&2015).

8.2.5 Overall impact and conclusion when implementing the BAT scenario

When taking into account the previous recommendations and the analysis results the overall impact on the EU25 industry can be very positive by increasing the sales volumes without negative impact on the public lighting installation performance and the lighting quality of existing installations could even improve at the same time. Taking a typical design cycle of 2 years into account in order to create additional time for companies to adopt their product portfolios accordingly the implementation could start from 2010 on. The authorities responsible for the purchase of public lighting will need to pay higher product prices but that can be earned back by the reduction in electricity cost.

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10 ABBREVIATIONS and ACRONYMS

Abbreviation / Acronym	Full text	Defined in
BAT	Best Available Technology	MEEuP
BAU	Business-As-Usual	MEEuP
BGF	Ballast Gain Factor	3.1.3
BMF	Ballast Maintenance Factor	3.1.4
BNAT	Best Not yet Available Technology	MEEuP
BOM	Bill Of Materials	MEEuP
BS xxxxx	Prefix for a British Standard	
Cat F	Road lighting category for Fast traffic, used in this study	1.1.2
Cat M	Road lighting category for Mixed traffic, used in this study	1.1.2
Cat S	Road lighting category for Slow traffic, used in this study	1.1.2
cd	candela (unit for light intensity)	
cd / m²	candela per square meter (unit for luminance)	
CELMA	Federation of National Manufacturers Associations for Luminaires and Electrotechnical Components for Luminaires in the European Union	
CEN	Comité Européen de Normalisation European Committee for Standardization	
TC 169/226 JWG	Technical Commission 169/229 Joint Working Group (Lighting) in CEN	
CEN/TR	CEN Technical Report (no standard)	
CENELEC	Comité Européen de Normalisation Electrotechnique European Committee for Electrotechnical Standardization	
CFL	Compact Fluorescent Lamp	1.1.4.1
CFL-i	Compact Fluorescent Lamp with integrated ballast	1.1.4.1
CFL-ni	Compact Fluorescent Lamp non integrated ballast	1.1.4.1
CIE	Commission Internationale de l'Eclairage International Commission on Illumination	
CMH	Ceramic Metal Halide	1.1.4.1
CRI	Colour Rendering Index (see also Ra)	

DG TREN	Directorat General for Transport and Energy	
DLOR	Downward Light Output Ratio	1.1.4.3
E	Illuminance [lx]	
E_{avg}	Average illuminance [lx]	
EC	European Commission	
EEI	Energy Efficiency Index	
ELC	European Lamp Companies Federation	
EMC	ElectroMagnetic Compatibility	1.3.1.3
E_{min}	minimum illuminance	
EN xxxxx	Prefix for a European Standard	
EOL	End Of Life	MEEuP
ERF	European Road Federation	
EU25	The European Union of the 25 member countries	
EuP	Energy using Product	
E_y	Energy consumption per year (per luminaire)	4.3.2
E_{yreal}	Real energy consumption per year (per luminaire)	4.3.2
FL	Fluorescent Lamp	1.1.4.1
FU	Functional Unit	1.1.3
GER	Gross Energy Requirements	MEEuP
HgHP-BF	High Pressure Mercury vapour lamp, ovoid, fluorescent	1.1.4.1
HgLP-TF	Low Pressure Mercury Vapour lamp, Tubular, Fluorescent (normal fluorescent lamp)	1.1.4.1
HgLP-TF comp	Low Pressure Mercury Vapour lamp, Tubular, Fluorescent, compact (compact fluorescent lamp)	1.1.4.1
HID	High Intensity Discharge	1.1.4.1
HPM	High Pressure Mercury	1.1.4.1
HPS	High Pressure Sodium	1.1.4.1
IEA	International Energy Agency	
IEC	International Electrotechnical Committee	
IEE	Intelligent Energy for Europe	

IESNA	Illuminating Engineering Society of North America	
ILCOS	International Lamp COding System	1.1.4.1
IP (rating)	Ingress Protection	1.2.2
IRF	International (World) Road Federation	
ISO	International Standards Organisation	
L	Luminance [cd/m^2]	
LCA	Life Cycle Assessment	MEEuP
LCC	Life-Cycle Cost	MEEuP
LED	Light Emitting Diode	
LGF	Lamp Gain Factor	3.1.1
LLCC	Least Life-Cycle Cost	MEEuP
LLMF	Lamp Lumen Maintenance Factor	1.1.4.1
LMF	Luminaire Maintenance Factor	1.1.4.3
LOR	Light Output Ratio	1.1.4.3
LPD	Lighting Power Density	4.4
LPD_i	Lighting Power Density for illuminance criteria	4.4
LPD_l	Lighting Power Density for luminance criteria	4.4
LPS	Low Pressure Sodium	1.1.4.1
LSF	Lamp Survival Factor	1.1.4.1
LVD	Low Voltage Directive	1.3.1.3
lx	lux (unit for illumination)	
MEEUP	Methodology study for Ecodesign of Energy-using Products	
MEPS	Minimum Energy Performance Standard	
MH	Metal Halide	1.1.4.1
MHHP-TC	High Pressure Metal Halide lamp, Tubular, Clear	1.1.4.1
NA	Not Applicable	
NaHP-BF	High Pressure Sodium lamp, ovoid, frosted	1.1.4.1
NaHP-BF retr	High Pressure Sodium lamp, ovoid, frosted, retrofit for HgHP-BF lamp	1.1.4.1
NaHP-TC	High Pressure Sodium lamp, tubular, clear	1.1.4.1
NaLP-TC	Low Pressure Sodium lamp, tubular, clear	1.1.4.1

OLED	Organic Light Emitting Diode	
PAH	Polycyclic Aromatic Hydrocarbons	MEEuP
P_{lamp}	Lamp power [W]	1.1.4.1
PM	Particulate Matter	MEEuP
POP	Persistant Organic Pollutants	MEEuP
P_{real}	Real power consumption of a luminaire	4.3.2
QMH	Quarz Metal Halide	1.1.4.1
Q_O	Average luminance coefficient	3.3.5
Ra	Colour rendering index (see also CRI)	
RoHS	Restriction of the use of certain Hazardous Substances	1.3.1.1
ROI	Return On Investment	
SHR	Space to Height Ratio	3.3.7
SME	Small and Medium-sized Enterprises	
SSL	Solid State Lighting (LED)	
t_{group}	time period for group replacement (of lamps)	2.2.2
TI	Threshold Increment	
U	Utilance (of an installation)	1.1.4.3
UF	Utilization Factor	1.1.4.3
U_l	Longitudinal uniformity	
ULOR	Upward Light Output Ratio	1.1.4.3
U_O	Overall uniformity	
VHK	Van Holsteijn en Kemna BV	
VOC	Volatile Organic Compounds	MEEuP
WEEE	Waste of Electrical and Electronic Equipment	1.3.1.1
WLED	White Light LED	
$\eta_{ballast}$	Ballast efficiency	1.1.4.2
η_{lamp}	Luminous efficacy of a lamp [lm/W]	1.1.4.1
Φ	(luminous) Flux [lm]	1.1.4.1

ANNEX A: PRODCOM CATEGORIES OF LIGHTING PARTS APPLICABLE IN STREET LIGHTING

Table 136: Lamp types applicable in street lighting

PRODUCT GROUP	PRODCOM	DESCRIPTION
lamp type	31501510	Fluorescent hot cathode discharge lamps, with double ended cap (excluding ultraviolet lamps)
lamp type	31501530	Fluorescent hot cathode discharge lamps (excluding ultraviolet lamps, with double ended cap)
lamp type	31501553	Mercury vapour discharge lamps (excluding ultraviolet lamps, dual lamps)
lamp type	31501556	Sodium vapour discharge lamps other than ultraviolet lamps
lamp type	31501559	Discharge lamps (excluding fluorescent hot cathode lamps, dual lamps, mercury or sodium vapour lamps, ultraviolet lamps)

Table 137contains the Prodcom ballast categories. For the further analysis in this report we will use a more refined product segmentation that is compliant with CELMA.

Table 137: Ballasts and ballast parts

PRODUCT GROUP	PRODCOM	DESCRIPTION
lamp parts	31105013	Inductors for discharge lamps or tubes
lamp parts	31105015	Ballasts for discharge lamps or tubes (excluding inductors)
lamp parts	31504250	Parts (excluding of glass or plastics) of lamps and lighting fittings, etc.
lamp parts	31504257	Other parts (excl. glass or plastics) of lamps and lighting fittings, etc.

Luminaire data can also be found in Prodcom statistics (see Table 138). They are incomplete (see market study) and this limited segmentation is not further used.

Table 138: Luminaires for different street lighting categories

PRODUCT GROUP	PRODCOM	DESCRIPTION
Street lighting	31503441	Road lighting : decorative kind for pedestrian areas : for incandescent lamps
Street lighting	31503442	Road lighting : decorative kind for pedestrian areas : for fluorescent lamps
Street lighting	31503443	Road lighting : decorative kind for pedestrian areas : for other lamps
Street lighting	31503444	Other road lighting : for incandescent lamps
Street lighting	31503445	Other road lighting : for fluorescent lamps
Street lighting	31503446	Other road lighting : for high pressure sodium lamps
Street lighting	31503447	Other road lighting : for low pressure sodium lamps
Street lighting	31503448	Other road lighting : for other lamps

ANNEX B: EUROPROMS RESULTS FOR LAMP TYPES APPLICABLE IN STREET LIGHTING

Remark regarding the availability of data

According to the Eurostat data shop Handbook (part 6.4.2. Europroms-Prodcom data, version 29/08/2003) there are two reasons why expected data might not be found in Europroms:

- The data is confidential. This is indicated by (1) in the following tables.
  If only a small number of enterprises produce a product in the reporting country, there is a risk that information regarding an individual enterprise might be revealed. If the enterprise does not agree to this the reporting country declares the production figures confidential. They are transmitted to Eurostat but not published. However if several countries declare their production for a heading to be confidential, an EU total can be published because the data for an individual country cannot be inferred.
- The data is missing. This is indicated as ‘-’ in the following tables.
  There are a number of reasons why data might be missing: the reporting country does not survey the heading; the reporting country has reason to doubt the accuracy of the data and suppresses it; or the reporting country uses the wrong volume unit or the wrong production type, which means that the data is not comparable with other countries and is suppressed by Eurostat.
  If data is missing for one or more Member States the corresponding EU total cannot be calculated and is also marked as missing.

Table 139: Fluorescent hot cathode discharge lamps, with double ended cap (excluding ultraviolet lamps): Europroms results

		Production		Imports		Exports		Apparent consumption	
Year	Region	Volume (Unit)	Value (Euro)	Volume (Unit)	Value (Euro)	Volume (Unit)	Value (Euro)	Volume (Unit)	Value (Euro)
1995	EU-15	-	-	35.499.391	33.613.480	84.309.412	64.049.380	-	-
2000	EU-15	-	392.905.940	58.594.285	49.459.660	65.388.744	74.478.450	-	367.887.150
2001	EU-15	417.402.169 (2)	456.910.317	63.627.007	57.261.540	77.804.599	71.625.520	403.224.577	442.546.337
2002	EU-15	384.928.874 (2)	430.431.029	57.526.654	51.399.280	88.768.820	72.442.220	353.686.708	409.388.089
2003	EU-15	-1	-1	77.570.470	65.283.680	178.684.941	72.359.410	-	-
2003	EU-25	447.475.713 (2)	440.158.829 (2)	116.254.466	83.489.024	296.927.308	124.933.837	266.802.871	398.714.016
2004	EU-15	-1	-1	87.508.252	61.858.890	207.383.653	117.288.650	-	-
2004	EU-25	443.176.926	433.341.545	119.260.965	75.769.736	252.438.197	137.006.112	309.999.694	372.105.169

Table 140: Fluorescent hot cathode discharge lamps (excluding ultraviolet lamps, with double ended cap): Europroms results

		Production		Imports		Exports		Apparent consumption (calculated)	
Year	Region	Volume (Unit)	Value (Euro)	Volume (Unit)	Value (Euro)	Volume (Unit)	Value (Euro)	Volume (Unit)	Value (Euro)
1995	EU-15	-	-	62.323.576	99.696.890	25.556.790	72.634.460	-	-
2000	EU-15	-	231.075.692	219.537.412	248.364.380	38.704.621	73.368.010	-	406.072.062
2001	EU-15	90.387.134 (2)	241.696.472	176.773.359	244.993.840	38.002.872	61.090.760	229.157.621	425.599.552
2002	EU-15	91.283.564 (2)	238.391.908	193.172.037	237.399.460	39.204.326	59.676.730	245.251.275	416.114.638
2003	EU-15	-1	-1	204.509.443	239.160.840	55.158.828	104.458.840	-	-
2003	EU-25	98.710.007	269.028.401	245.452.416	270.925.972	79.282.263	149.058.218	264.880.160	390.896.155
2004	EU-15	-1	-1	198.971.818	286.211.330	66.283.486	125.406.810	-	-
2004	EU-25	101.143.024	266.291.528	251.652.273	323.730.412	76.434.650	141.599.010	276.360.647	448.422.930

Table 141: Mercury vapour discharge lamps (excluding ultraviolet lamps, dual lamps): Europroms results

Year	Region	Production			Imports			Exports			Apparent consumption (calculated)		
		Volume	Value	Price per item (calculated)	Volume	Value	Price per item (calculated)	Volume	Value	Price per item (calculated)	Volume	Value	Price per item (calculated)
		(Unit)	(Euro)	(Euro per item)	(Unit)	(Euro)	(Euro per item)	(Unit)	(Euro)	(Euro per item)	(Unit)	(Euro)	(Euro per item)
1995	EU-15	-	-	-	3.239.777	17.213.030	5,3	2.548.842	14.370.850	5,6	-	-	-
2000	EU-15	-	156.265.163	-	3.532.577	13.470.110	3,8	3.753.979	17.578.790	4,7	-	152.156.483	-
2001	EU-15	24.610.460 (2)	-1	-	3.463.189	14.382.130	4,2	2.189.100	12.081.550	5,5	25.884.549	-	-
2002	EU-15	24.524.478 (2)	-1	-	5.111.913	16.150.700	3,2	1.772.481	6.723.960	3,8	27.863.910	-	-
2003	EU-15	-1	-1	-	2.121.113	9.175.850	4,3	2.201.183	6.731.510	3,1	-	-	-
2003	EU-25	23.877.022	205.743.373	8,6	4.541.230	13.518.530	3	5.966.285	15.347.971	2,6	22.451.967	203.913.932	9,1
2004	EU-15	-1	-1	-	4.013.813	15.664.340	3,9	5.011.019	13.292.490	2,8	-	-	-
2004	EU-25	28.779.086	-1	-	6.867.781	19.257.845	2,8	5.648.619	14.575.522	2,6	29.998.248	-	-

Table 142: Sodium vapour discharge lamps other than ultraviolet lamps: Europroms results

Year	Region	Production			Imports			Exports			Apparent consumption (calculated)		
		Volume	Value	Price per item (calculated)	Volume	Value	Price per item (calculated)	Volume	Value	Price per item (calculated)	Volume	Value	Price per item (calculated)
		(Unit)	(Euro)	(Euro per item)	(Unit)	(Euro)	(Euro per item)	(Unit)	(Euro)	(Euro per item)	(Unit)	(Euro)	(Euro per item)
1995	EU-15	-	-	-	-	-	-	-	-	-	-	-	-
2000	EU-15	-	-	-	3.426.102	21.319.590	6,2	3.026.469	25.232.300	8,3	-	-	-
2001	EU-15	-1	-1	-	4.040.737	22.785.390	5,6	3.116.633	20.634.430	6,6	-	-	-
2002	EU-15	-1	-1	-	4.687.430	23.383.390	5	2.512.846	18.700.170	7,4	-	-	-
2003	EU-15	-1	-1	-	4.607.891	21.167.500	4,6	2.099.262	12.855.610	6,1	-	-	-
2003	EU-25	37.788.062	171.237.258	4,5	5.439.706	24.768.288	4,6	6.150.386	31.253.028	5,1	37.077.382	164.752.518	4,4
2004	EU-15	-1	-1	-	4.981.511	21.886.190	4,4	5.639.405	34.509.210	6,1	-	-	-
2004	EU-25	39.478.967	176.938.811	4,5	5.628.983	24.318.606	4,3	6.180.682	36.718.159	5,9	38.927.268	164.539.258	4,2

Table 143: Discharge lamps (excluding fluorescent hot cathode lamps, dual lamps, mercury or sodium vapour lamps, ultraviolet lamps): Europroms results

Year	Region	Production			Imports			Exports			Apparent consumption (calculated)		
		Volume	Value	Price per item (calculated)	Volume	Value	Price per item (calculated)	Volume	Value	Price per item (calculated)	Volume	Value	Price per item (calculated)
		(Unit)	(Euro)	(Euro per item)	(Unit)	(Euro)	(Euro per item)	(Unit)	(Euro)	(Euro per item)	(Unit)	(Euro)	(Euro per item)
1995	EU-15	-	-	-	106.594.346	44.429.380	0,4	18.489.297	63.782.400	3,4	-	-	-
2000	EU-15	-	199.492.019	-	97.798.065	70.847.770	0,7	21.392.847	107.706.560	5	-	162.633.229	-
2001	EU-15	-1	232.546.280	-	166.091.543	80.106.860	0,5	26.600.462	142.180.190	5,3	-	170.472.950	-
2002	EU-15	88.939.641 (2)	207.318.967	2,3	157.044.844	88.888.400	0,6	42.646.203	160.883.560	3,8	203.338.282	135.323.807	0,7
2003	EU-15	7.425.493 (2)	-1	-	184.419.282	85.115.230	0,5	34.769.465	94.467.670	2,7	157.075.310	-	-
2003	EU-25	-1	228.476.393	-	239.320.646	97.689.011	0,4	53.039.238	119.307.168	2,2	-	206.858.236	-
2004	EU-15	7.727.002 (2)	-1	-	179.830.052	101.013.690	0,6	36.599.451	205.842.910	5,6	150.957.603	-	-
2004	EU-25	-1	347.390.025 (2)	-	210.327.046	108.263.558	0,5	40.561.353	214.277.843	5,3	-	241.375.740	-

(1) Data for this item is confidential and has been suppressed

(2) Data for this item is estimated and has been suppressed

ANNEX C: OVERVIEW OF PRODUCTION, TRADE AND CONSUMPTION DATA FOR LAMP TYPES APPLICABLE IN STREET LIGHTING

Table 144: Overview of 'Mercury vapour discharge lamps (excluding ultraviolet lamps, dual lamps)' production, trade and consumption data: 2001-2004 (Source: Europroms)

		2001	**2002**	**2003**	**2003**	**2004**	**2004**
VALUE (1000 Euro)	Remark	EU-15	EU-15	EU-15	EU-25	EU-15	EU-25
EU Manufacturer sales	This corresponds to Europroms "Production"	(1)	(1)	(1)	205.743	(1)	(1)
Total (extra EU-25) Imports		14.382	16.151	9.176	13.519	15.664	19.258
Total (extra EU-25) Exports		12.082	6.724	6.732	15.348	13.292	14.576
Net Balance	= Total Imports – Total Exports	2.300	9.427	2.444	-1.829	2.372	4.682
EU Net supply	This corresponds to Europroms 'Apparent consumption' = EU Manufacturer sales + Imports - Exports	-	-	-	203.914	-	-
Export as % of EU Manufacturer sales	Export as % of production						
EU Manufacturer sales		(1)	(1)	(1)	100	(1)	(1)
Total (extra EU-25) Exports	Sales on a foreign market	-	-	-	7,4	-	-
EU Sales	Sales on the EU-25 market	-	-	-	92,6	-	-
Import as % of EU Net supply	Import as % of Apparent consumption						
EU Net supply		-	-	-	100	-	-
Total (extra EU-25) Imports		-	-	-	6,6	-	-
EU production		-	-	-	93,4	-	-

Table 145: Overview of 'Sodium vapour discharge lamps other than ultraviolet lamps' production, trade and consumption data: 2001-2004 (Source: Europroms)

		2001	**2002**	**2003**	**2003**	**2004**	**2004**
VALUE (1000 Euro)	Remark	EU-15	EU-15	EU-15	EU-25	EU-15	EU-25
EU Manufacturer sales	This corresponds to Europroms	(1)	(1)	(1)	171.237	(1)	176.939
Total (extra EU-25) Imports		22.785	23.383	21.167	24.768	21.886	24.318
Total (extra EU-25) Exports		20.634	18.700	12.856	31.253	34.509	36.718
Net Balance	= Total Imports – Total Exports	2.151	4.683	8.311	-6.485	-12.623	-12.400
EU Net supply	This corresponds to Europroms 'Apparent consumption' = EU Manufacturer sales + Imports - Exports	-	-	-	164.752	-	164.539
Export as % of EU Manufacturer	Export as % of production						
EU Manufacturer sales		(1)	(1)	(1)	100	(1)	100
Total (extra EU-25) Exports	Sales on a foreign market	-	-	-	18,3	-	20,8
EU Sales	Sales on the EU-25 market	-		-	81,7	-	79,2
Import as % of EU Net supply	Import as % of Apparent consumption						
EU Net supply		-	-	-	100	-	100
Total (extra EU-25) Imports		-	-	-	15,0	-	14,8
EU production		-	-	-	85,0	-	85,2

ANNEX D: EUROPROMS RESULTS FOR BALLASTS AND BALLAST PARTS APPLICABLE IN STREET LIGHTING

Table 146: Inductors for discharge lamps or tubes: Europroms results

Year	Region	Production			**Imports**			Exports			Apparent consumption (calculated)		
		Volume	Value	Price per item (calculated)	Volume	Value	Price per item (calculated)	Volume	Value	Price per item (calculated)	Volume	Value	Price per item (calculated)
		(Unit)	(Euro)	(Euro per item)	(Unit)	(Euro)	(Euro per item)	(Unit)	(Euro)	(Euro per item)	(Unit)	(Euro)	(Euro per item)
1995	EU-15	-	-	-	18.329.283	6.376.630	0,3	40.369.012	82.063.690	2,0	-	-	-
2000	EU-15	-	-	-	50.092.153	32.781.200	0,7	105.666.500	43.175.779	0,4	-	-	-
2001	EU-15	228.827.672 (2)	446.473.007	2,0	24.765.054	35.158.430	1,4	54.726.648	143.705.680	2,6	198.866.078	337.925.757	1,7
2002	EU-15	232.313.434 (2)	432.665.383	1,9	16.026.270	41.599.010	2,6	59.894.676	112.040.380	1,9	188.445.028	362.224.013	1,9
2003	EU-15	(1)	(1)	-	19.242.992	49.845.890	2,6	53.890.048	124.656.660	2,3	-	-	-
2003	EU-25	498.360.548	379.028.141	0,8	136.068.039	70.062.622	0,5	68.408.689	136.498.580	2,0	566.019.898	312.592.183	0,6
2004	EU-15	(1)	(1)	-	62.718.631	59.870.960	1,0	60.386.997	147.863.600	2,5	-	-	-
2004	EU-25	591.918.052	342.501.771	0,6	126.957.810	69.681.800	0,5	69.039.908	154.293.914	2,2	649.835.954	257.889.657	0,4

Table 147: Ballasts for discharge lamps or tubes (excluding inductors): Europroms results

Year	Region	Production			Imports			Exports			Apparent consumption (calculated)		
		Volume	Value	Price per item (calculated)	Volume	Value	Price per item (calculated)	Volume	Value	Price per item (calculated)	Volume	Value	Price per item (calculated)
		(Unit)	(Euro)	(Euro per item)	(Unit)	(Euro)	(Euro per item)	(Unit)	(Euro)	(Euro per item)	(Unit)	(Euro)	(Euro per item)
1995	EU-15	-	-	-	37.576.736	27.561.130	0,7	12.858.904	39.174.160	3,0	-	-	-
2000	EU-15	-	-	-	23.320.605	137.019.270	5,9	33.421.768	162.134.120	4,9	-	-	-
2001	EU-15	110.223.186 (2)	306.612.259	2,8	26.437.324	162.667.850	6,2	29.929.947	154.265.580	5,2	106.730.563	315.014.529	3,0
2002	EU-15	134.301.811 (2)	294.796.269	2,2	35.382.099	188.806.210	5,3	43.998.579	189.165.390	4,3	125.685.331	294.437.089	2,3
2003	EU-15	(1)	282.808.303	-	43.491.975	216.005.030	5,0	34.170.160	211.295.500	6,2	-	287.517.833	-
2003	EU-25	65.935.720 (2)	291.642.194	4,4	72.978.439	240.527.041	3,3	35.462.997	214.313.341	6,0	103.451.162	317.855.894	3,1
2004	EU-15	56.209.323 (2)	362.281.767	6,4	60.393.776	233.184.990	3,9	35.590.166	226.867.170	6,4	81.012.933	368.599.587	4,5
2004	EU-25	63.336.031 (2)	370.751.342	5,9	85.730.636	246.020.727	2,9	36.632.814	228.751.216	6,2	112.433.853	388.020.853	3,5

Table 148: Parts (excluding of glass or plastics) of lamps and lighting fittings: Europroms results

		Production		**Imports**		**Exports**		**Apparent consumption (calculated)**	
Year	R	Volume (Unit)	Value (Euro)	Volume (Unit)	Value (Euro)	Volume (Unit)	Value (Euro)	Volume (Unit)	Value (Euro)
Parts (excluding of glass or plastics) of lamps and lighting fittings (31.50.42.50)									
1995	E	-	-	-	63902340	-	118770150	-	-
2000	E	-	-	-	141900650	-	194329780	-	-
2001	E	(3)	(1)	-	150621040	-	211979820	-	-
2002	E	(3)	(1)	-	147422590	-	190934000	-	-
2003	E	(3)	(1)	-	137636070	-	176674790	-	-
2003	E	(3)	(1)	-	151018779	-	188043194	-	-
2004	E	(3)	(1)	-	172718790	-	195546440	-	-
2004	E	(3)	(1)	-	178210098	-	201306111	-	-
Tracks for electric lighting and parts thereof (31.50.42.53)									
1995	E	-	-	-	-	-	-	-	-
2000	E	-	-	-	-	-	-	-	-
2001	E	-	-	-	-	-	-	-	-
2002	E	-	-	-	-	-	-	-	-
2003	E	-	-	-	-	-	-	-	-
2003	E	-	-	-	-	-	-	-	-
2004	E	-	-	-	-	-	-	-	-
2004	E	-	-	-	-	-	-	-	-
Lamps-shades in paper cardboard (31.50.42.55)									
1995	E	-	-	-	-	-	-	-	-
2000	E	-	-	-	-	-	-	-	-
2001	E	-	-	-	-	-	-	-	-
2002	E	-	-	-	-	-	-	-	-
2003	E	-	-	-	-	-	-	-	-
2003	E	-	-	-	-	-	-	-	-
2004	E	-	-	-	-	-	-	-	-
2004	E	-	-	-	-	-	-	-	-
Other parts (excl. glass or plastics) of lamps and lighting fittings, .. (31.50.42.57)									
1995	E	-	-	-	-	-	-	-	-
2000	E	-	-	-	-	-	-	-	-
2001	E	-	-	-	-	-	-	-	-
2002	E	-	-	-	-	-	-	-	-
2003	E	-	-	-	-	-	-	-	-
2003	E	-	-	-	-	-	-	-	-
2004	E	-	-	-	-	-	-	-	-
2004	E	-	-	-	-	-	-	-	-

(1) Data for this item is confidential and has been suppressed (3) Not applicable-data is not collected for this item

ANNEX E: OVERVIEW OF PRODUCTION, TRADE AND CONSUMPTION DATA FOR BALLASTS AND BALLAST PARTS APPLICABLE IN STREET LIGHTING

Table 149: Overview of 'Inductors for discharge lamps or tubes-ferromagnetic ballasts' production, trade and consumption data, 2001-2004 (Source: Europroms)

		2001	**2002**	**2003**		**2004**	
VALUE (1000 Euro)	Remark	EU-15	EU-15	EU-15	EU-25	EU-15	EU-25
EU Manufacturer sales	This corresponds to	446.473	432.665	(1)	379.028	(1)	342.502
Total (extra EU-25) Imports		35.158	41.599	49.846	70.063	59.871	69.682
Total (extra EU-25) Exports		143.706	112.040	124.657	136.499	147.864	154.294
Net Balance	= Total Imports – Total	-108.548	-70.441	-74.811	-66.436	-87.993	-84.612
EU Net supply	This corresponds to Europroms 'Apparent consumption' = EU Manufacturer sales +	337.926	362.224	-	312.592	-	257.890
Export as % of EU Manufacturer sales	Export as % of production						
EU Manufacturer sales		100	100	(1)	100	(1)	100
Total (extra EU-25) Exports	Sales on a foreign market	32,2	25,9	-	36,0	-	45,0
EU Sales	Sales on the EU-25 market	67,8	74,1	-	64,0	-	55,0
Import as % of EU Net supply	Import as % of Apparent						
EU Net supply		100	100	-	100	-	100
Total (extra EU-25) Imports		10,4	11,5	-	22,4	-	27,0
EU production		89,6	88,5	-	77,6	-	73,0

Table 150: Overview of 'Ballasts for discharge lamps or tubes (excluding inductors)-electronic ballasts' production, trade and consumption data, 2001-2004 (Source: Europroms)

		2001	**2002**	**2003**		**2004**	
VALUE (1000 Euro)	Remark	EU-15	EU-15	EU-15	EU-25	EU-15	EU-25
EU Manufacturer sales	This corresponds to Europroms "Production"	306.612	294.796	282.808	291.642	362.282	370.751
Total (extra EU-25) Imports		162.668	188.806	216.005	240.527	233.185	246.021
Total (extra EU-25) Exports		154.266	189.165	211.295	214.313	226.867	228.751
Net Balance	= Total Imports – Total Exports	8.402	-359	4.710	26.214	6.318	17.270
EU Net supply	This corresponds to Europroms 'Apparent consumption' = EU Manufacturer sales + Imports – Exports	315.014	294.437	287.518	317.856	368.600	388.021
Export as % of EU Manufacturer sales	Export as % of production						
EU Manufacturer sales		100	100	100	100	100	100
Total (extra EU-25) Exports	Sales on a foreign market	50,3	64,2	74,7	73,5	62,6	61,7
EU Sales	Sales on the EU-25 market	49,7	35,8	25,3	26,5	37,4	38,3
Import as % of EU Net supply	Import as % of Apparent consumption						
EU Net supply		100	100	100	100	100	100
Total (extra EU-25) Imports		51,6	64,1	75,1	75,7	63,3	63,4
EU production		48,4	35,9	24,9	24,3	36,7	36,6

ANNEX F: EUROPROMS RESULTS FOR LUMINAIRES IN STREET LIGHTING CATEGORIES

Table 151: Luminaires In Street Lighting Categories: Europroms Results

		Production		Imports		Exports		Apparent consumption (calculated)	
Year	Region	Volume (Unit)	Value (Euro)	Volume (Unit)	Value (Euro)	Volume (Unit)	Value (Euro)	Volume (Unit)	Value (Euro)
Road lighting - decorative kind for pedestrian areas - for incandescent lamps									
1995	EU-15	-	-	-	-	-	-	-	-
2000	EU-15	-	-	-	-	-	-	-	-
2004	EU-15	-	-	-	-	-	-	-	-
2004	EU-25	-	-	-	-	-	-	-	-
Road lighting - decorative kind for pedestrian areas - for fluorescent lamps									
1995	EU-15	-	-	-	-	-	-	-	-
2000	EU-15	-	-	-	-	-	-	-	-
2004	EU-15	-	-	-	-	-	-	-	-
2004	EU-25	-	-	-	-	-	-	-	-
Road lighting - decorative kind for pedestrian areas - for other lamps									
1995	EU-15	-	-	-	-	-	-	-	-
2000	EU-15	-	-	-	-	-	-	-	-
2004	EU-15	-	-	-	-	-	-	-	-
2004	EU-25	-	-	-	-	-	-	-	-
Other road lighting - for incandescent lamps									
1995	EU-15	-	-	-	-	-	-	-	-
2000	EU-15	-	-	-	-	-	-	-	-
2004	EU-15	-	-	-	-	-	-	-	-
2004	EU-25	-	-	-	-	-	-	-	-
Other road lighting - for fluorescent lamps									
1995	EU-15	-	-	-	-	-	-	-	-
2000	EU-15	-	-	-	-	-	-	-	-
2004	EU-15	-	-	-	-	-	-	-	-
2004	EU-25	-	-	-	-	-	-	-	-
Other road lighting - for high pressure sodium lamps									
1995	EU-15	-	-	-	-	-	-	-	-
2000	EU-15	-	-	-	-	-	-	-	-
2004	EU-15	-	-	-	-	-	-	-	-
2004	EU-25	-	-	-	-	-	-	-	-
Other road lighting - for low pressure sodium lamps									
1995	EU-15	-	-	-	-	-	-	-	-
2000	EU-15	-	-	-	-	-	-	-	-
2004	EU-15	-	-	-	-	-	-	-	-
2004	EU-25	-	-	-	-	-	-	-	-
Other road lighting - for other lamps									
1995	EU-15	-	-	-	-	-	-	-	-
2000	EU-15	-	-	-	-	-	-	-	-
2004	EU-15	-	-	-	-	-	-	-	-
2004	EU-25	-	-	-	-	-	-	-	-

ANNEX G: OVERVIEW OF LAMP AND BALLAST PRODUCTION, TRADE AND CONSUMPTION IN EU-25 IN 2003

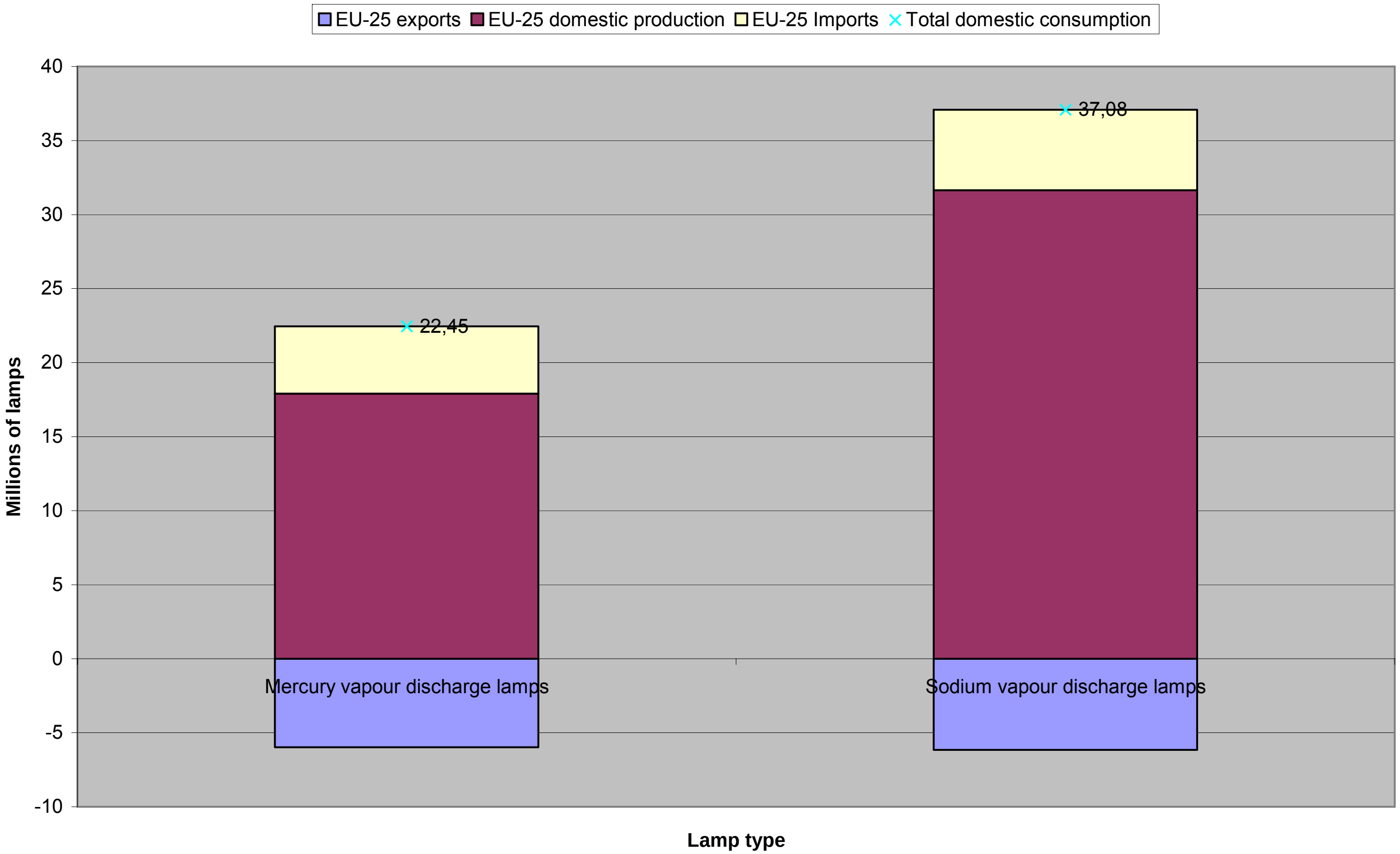

Figure 67: Lamp production, trade and consumption volume in EU-25, 2003

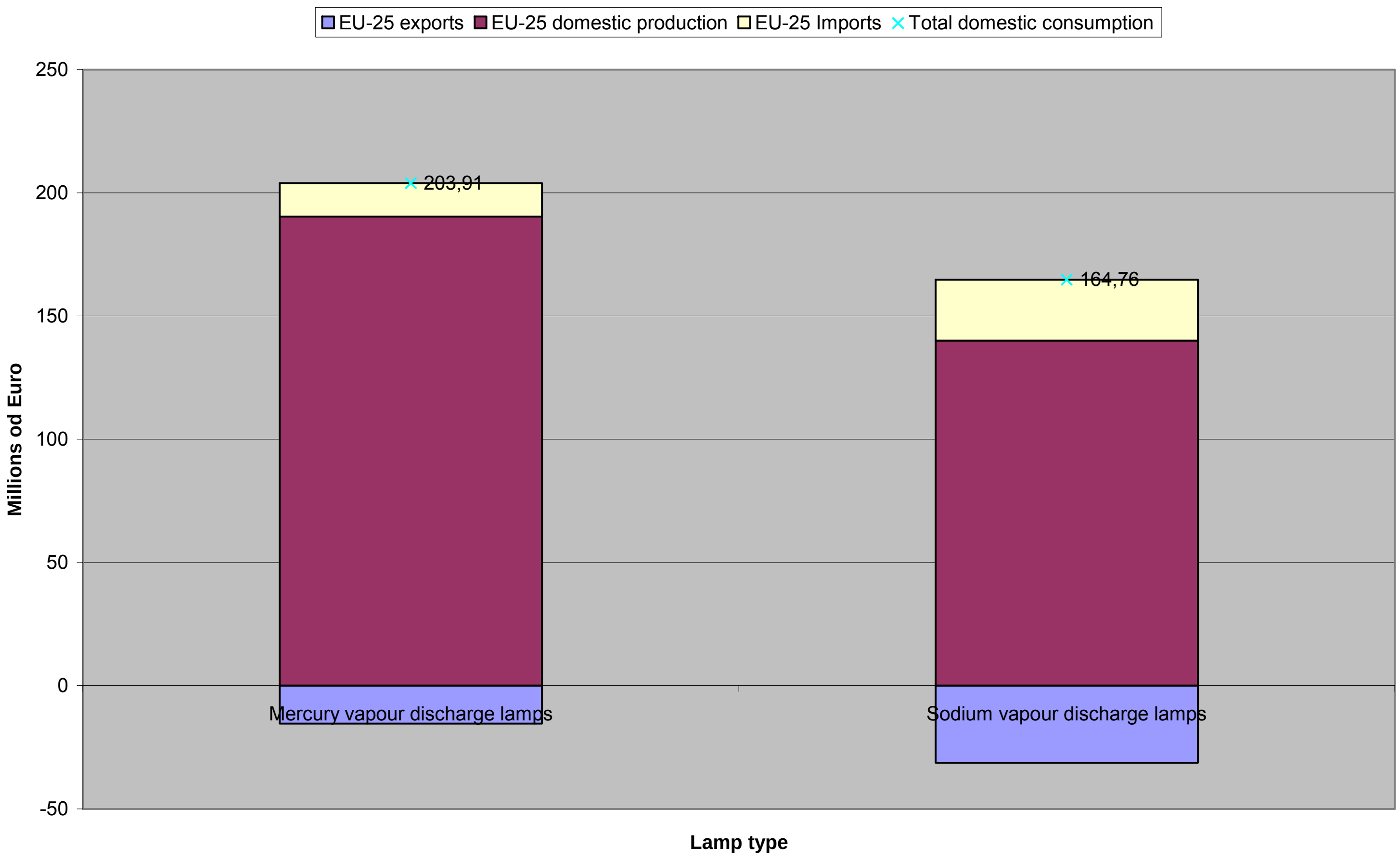

Figure 68: Value of lamp production, trade and consumption in EU-25, 2003

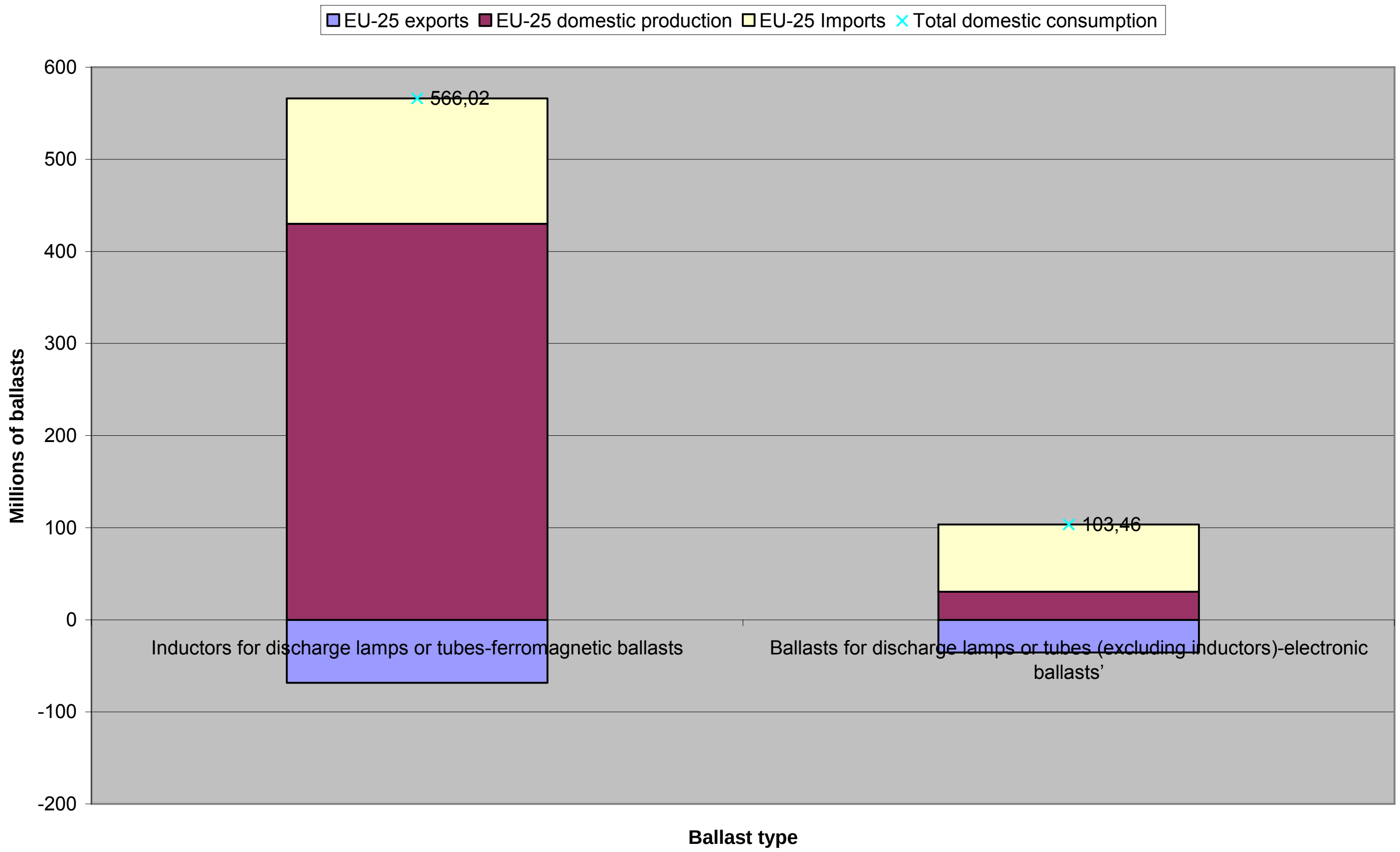

Figure 69: Value of lamp production, trade and consumption in EU-25, 2003

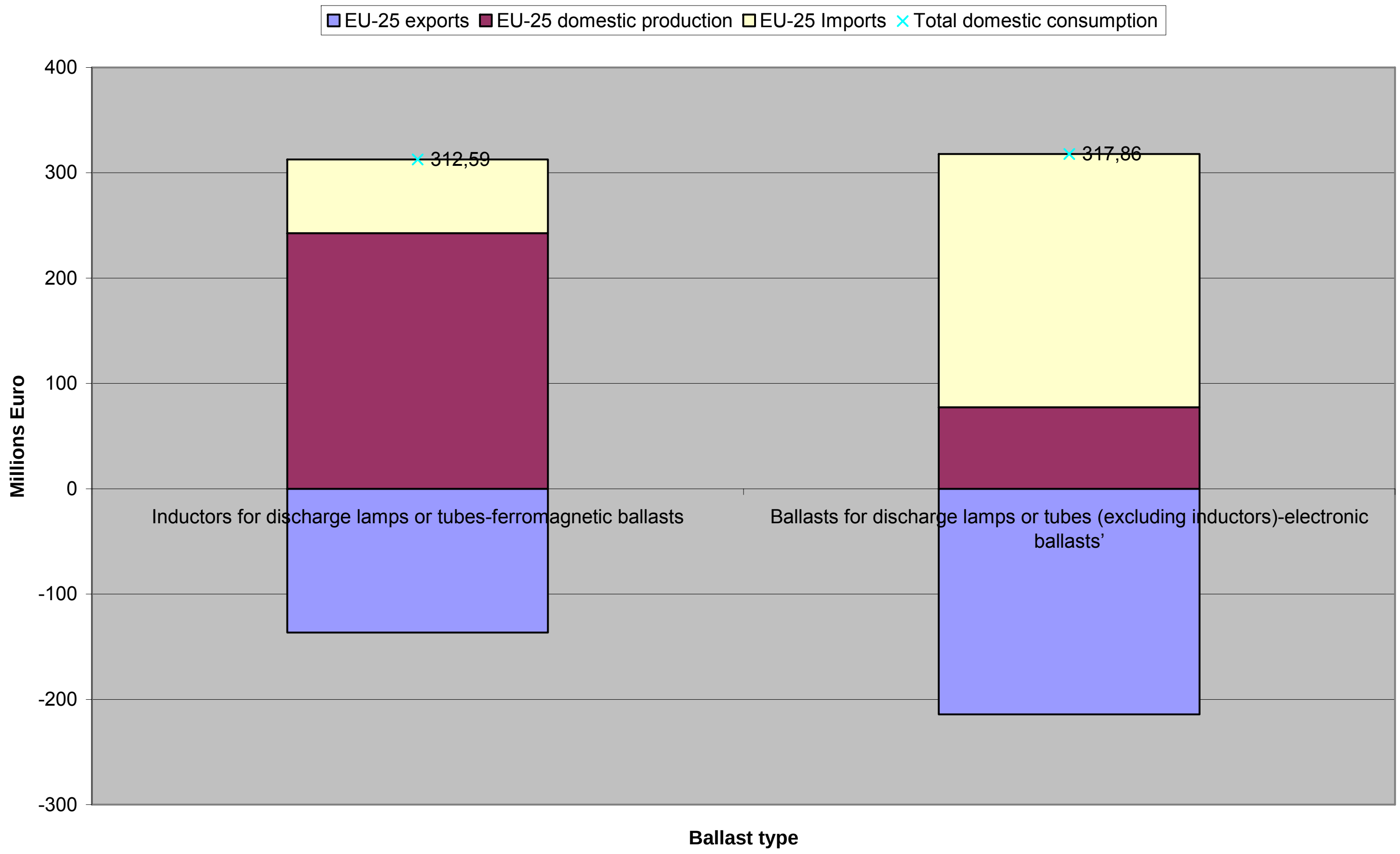

Figure 70: Value of ballast production, trade and consumption in EU-25, 2003

ANNEX H: EXPERT-INQUIRY

Preparatory study for Eco-design Requirements of Street lighting as subcontractor of the European Commission.

GENERAL INQUIRY

http://www.eup4light.net

	VITO Boeretang 200 B – 2400 Mol BELGIUM	**Contacts:** **ir. Veronique VAN HOOF** + 32 14 33 58 53 mailto:veronique.vanhoof@vito.be **ir. Lieven VANHOOYDONCK** + 32 478 65 24 24 lieven.vanhooydonck@kreios.be

Introduction

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

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

The creation of a coherent framework for environmental product policy avoids the adoption of uncoordinated measures that could lead to an overall negative result; for example eliminating a toxic substance from a product, such as mercury from lamps, might lead to increased energy consumption, which on balance would have a negative impact on the environment. A Community framework also ensures that no divergent national or regional measures that could hinder the free movement of products and reduce the competitiveness of businesses are taken. It is not the intention to switch off or decrease the quality of street lighting.

This enquiry is part of the preparatory study an has for purpose to acquire data for a realistic EU25 environmental and economic impact model for street lighting. The objective is to base this study on available and realistic data.

We kindly ask for your contribution by completing this questionnaire and assumed that you or your organization can help us to get the right information. If we made a wrong assumption, we urgently request you to send us the correct contact details of people or another organizations that could give us this kind of information..

You can follow the progress of our study on the project website:

http://www.eup4light.net

May we friendly ask you to register as stakeholder so that you will be able to participate in the study.

VITO was also charged to make a similar study for Office Lighting.

You can already register for Office Lighting on the same, above-mentioned website.

As the European Commission expects a first interim report by mid-August, we urge you to return the completed questionnaire <u>before 30 June 2006</u> to:
VITO, Veronique Van Hoof, Boeretang 200, 2400 Mol, BELGIUM.
Veronique.vanhoof@vito.be

Thank you in advance for your cooperation!

RESPONDENT IDENTIFICATION

Contact details of person who completed the questionnaire:
Organisation:
Mr/Mrs.:
Address:

Tel:
Email:

Is this data for a country (y/n):
Country for which data are specified:

Is this data for a country (y/n):
Area for which data are specified:
Number of habitants for this area:

Enquiry Methodology

As the objective of the study is also to provide a basis for possible implementing measures in the future, we need data about:

- present existing situations (installed base)
- the evolution from past till now
- expectations for the future
- normal practice etc.

For the PRESENT **situation (data of year 2005)** we ask the **most recent realistic** data (between 2003 and 2005; please circle the year (2003/2004/2005) to which the supplied data apply).

For the PAST situation and evolution we ask data for the years **1990, 1995** and **2000**.
If you do not have the required information for that specific year, please provide us the information for a year as close as possible to the indicated year. We always provide an empty box in the tables to indicate the year on which the data apply (please cross out the standard year).

For the FUTURE situation, we ask your estimation for two time periods (i.e. 2010-2012 and 2020-2025; your based on the possibility that more roads will be lit) and that there could be a demand for higher lighting levels for safety’s sake.

Road types

In our study, we distinguish 3 categories of roads for the simulation model:

- **Cat F**: Fast traffic, only for road motor vehicles with only luminance requirements, (according to EN 13201-1&2: classes ME4a up to ME1 + older roads with similar requirements not yet in line with the new EN 13201 system) with speed limit up to more than 80 or 90km/h. We assume that these roads are classified in EUROSTAT as:
  - Motorways[56]
  - E-roads[57]

- **Cat M**: Mixed traffic, with both luminance and illuminance requirements, (according to EN 13201-1&2: classes ME6 up to ME2 & classes CE6 up to CE2+ older roads with similar requirements not yet in line with the new EN 13201 system) with speed limit 50km/h < maximum ≤ 80 or 90km/h. We assume that these roads can be found under the EUROSTAT definitions as:
  - State roads
  - Provincial Roads
  - Communal roads (partly).

- **Cat S**: Slow traffic only, (according to EN 13201-1&2: classes S6 up to S1+ older roads with similar requirements not yet in line with the new EN 13201 system) with speed limit ≤ 50km/h , i.e. commercial and residential roads, cycle tracks and pedestrian roads. We assume that these roads are classified in EUROSTAT as:
  - Communal Roads (partly).

[57] The international "E" network consists of a system of reference roads as laid down in the European Agreement on Main International Arteries, Geneva, 15 November 1975 and its amendments

1. Our assumptions concerning the road categorization are summarized in the following table.
   If you do not agree with these assumptions for your country, please correct them in this table.

eurostat type road	cat f		cat m		cat s	
	default	adapted	default	adapted	default	adapted
motorways	100%		0%		0%	
e-ways	100%		0%		0%	
state roads	0%		100%		0%	
provincial roads	0%		100%		0%	
communal roads	0%		5%		95%	

2. We have EUROSTAT data of the road length (per type of road) for EU-25 countries.
   Could you please check those data and correct where necessary?

type eurostat	motorways	e-roads	state roads	provincial roads	communal roads
country:					
km eurostat					
km adapted					

If you have additional information, please provide it in the space below.

General street lighting data – Installed base

3. Do you have data or statistics at your disposal about the present installed power and energy consumption for street lighting and the installed number of lighting points in your country?
   (Most recent, realistic data between 2003 and 2005; please circle the year to which the supplied data apply.)

Installed power in MW	2003 / 2004 / 2005
Installed power in MW	
Energy consumption in GWh	
Number of lighting points	
Average kWh price for street lighting (euro)	
Average labour cost for lamp replacement, all included	

If you have other interesting documents about general data in public lighting, we invite you to send them to us. You can send these documents in the format you have and in your own language. (We prefer: English, German, French, Spanish or Dutch)

4. What is the **total** energy consumption ***in GWh*** for public lighting in your country at present, past and future per road category?

energy consumption	past			present	future	
in gwh	default: adapted:	default: adapted:	default: adapted:	2003/2004/2005	2010 - 2012	2020-2025
cat f (fast)						
cat m (mixed)						
cat s (slow)						
total						

5. What is the **total** installed power ***in MW*** for public lighting in your country at present, past and future per road category?

installed power	past			present	future	
in mw	default: adapted:	default: adapted:	default: adapted:	2003/2004/2005	2010 - 2012	2020-2025
cat f (fast)						
cat m (mixed)						
cat s (slow)						
total						

Installed Lamp types

Type of lamps in the tables in annex 1 are indicated by following abbreviations:
***- discharge gas: Na** for sodium, **Hg** for mercury, **MH** for metal halide*
*- **internal pressure**: **HP** for high pressure, **LP** for low pressure*
*- outer **bulb form** of the lamp: **B** for ellipsoid or balloon form, **T** for tubular*
*- outer **bulb treatment**: **F** for fluorescent or frosted, **C** for clear*
*e.g. a clear tubular high pressure sodium lamp is indicated as type: **NaHP-TC***
*a high pressure mercury lamp is indicated as type: **HgHP-BF***
*a tubular fluorescent lamp is indicated as type: **HgLP-TF***

6. Can you give us an estimation about the most customary lamp (type and wattage) per road category, for the present, the past and the future?

most typical lamp	past						present		future			
	default:		default:		default:		2003		2010 - 2012		2020-2025	
	adapted:		adapted:		adapted:		2004					
type and wattage	type	watt	type	watt	type	watt	type	watt	type	watt	type	watt
cat f												
cat m												
cat s												

7. Do you have data or statistics at your disposal about the installed lamps in street lighting in your country at present, the past (data of 1990, 1995, 2000) and an estimate about the future evolution (periods 2010-2012 and 2020-2025)?
If possible please complete Table 152 in Annex Inquiry I

8. (if you do not have detailed information per wattage, please indicate and fill in the total per lamp type and, if possible, the average wattage).

If you have other interesting data available, we invite you to send them to us in the format you have and in your own language.
(We prefer English, German, French, Spanish or Dutch)

Installed Luminaires

9. Can you give us an average percentage of the luminaire **replacement** (installed luminaires) per year in your country? Can you give us an average percentage of the yearly **increase** of the installed luminaires for **new installations** in your country? Can you give us an estimate of the average required **life expectancy** of a luminaire in your country?

   average replacement per year in % of installed
   average increase per year in % of installed
   average life expectancy of a luminaire (in years)

10. Do you have data or statistics at your disposal about the installed luminaires in street lighting in your country at present? The evolution of those installed luminaires? (Data of 1990, 1995, 2000)? Prospects for the installed street lighting luminaries for the period 2010-2012 and 2020-2025?

Please complete Table 153 and

Table 154 in Annex Inquiry II.

If you have other interesting data available, we invite you to send them to us in the format you have and in your own language.
(We prefer English, German, French, Spanish or Dutch.)

Standardization of public lighting

11. Are the European standards EN 13201-2, -3 and -4 applied in your country for ***new*** installations?

yes no

12. Is the technical note EN 13201-1 applied in your country?

yes no

13. Are there other standards applied in your country, different from these European standards?

yes no

If yes, which ones?

14. What percentage of the existing lighting installations does already comply with the European standards EN 13201?

comply	yes	no
cat f (fast)		
cat m (mixed)		
cat s (slow)		

If you have additional information about standardization in public lighting, please provide it in the space below.

Roads lit and control

15. What percentage of the road length is lit in your country at past, present and future (estimate) please fill in the table below?

percentage lit	past			present	future	
	default:	default:	default:	2003	2010 - 2012	2020-2025
	adapted:	adapted:	adapted:	2004		
cat f (fast)						
cat m (mixed)						
cat s (slow)						

16. What is the ***customary maintained*** lighting level per above defined road category Fnd what is ***minimum*** and the ***maximum maintained*** lighting level per above defined road category, please fill in the table below?

maintained lighting level	past									present			future					
	default:			default:			default:			2003			2010 - 2012			2020-2025		
	adapted:			adapted:			adapted:			2004								
	cust	min	max	cust	min	max	cust	min	max	cust	min	max	cust	min	max	cust	min	max
cat f fast (cd/m²)																		
cat m mixed (cd/m²)																		
cat m mixed (lx)																		
cat s slow (lx)																		

17. What is the ratio between lighting points that are connected to a separate street lighting network and those directly connected to the residential network?

connection of	street lighting	directly connected to
cat f (fast)		
cat m (mixed)		
cat s (slow)		

18. What is the number of lighting points operating all night and what is average operating time per year (in hours) for installations with interim switch off?

	Lighting points operating entire night (%)	**Average operating hours/year for lamps with interim switch off**
Cat F (fast)		
Cat M (mixed)		
Cat S (slow)		

Road infrastructure

19. Can you give us an estimation about the number of lighting points or luminaires per road category in your country, for the present, the past and the future?

number of lighting points	past			present	future	
	default:	default:	default:	2003	2010 - 2012	2020-2025
	adapted:	adapted:	adapted:	2004		
cat f (fast)						
cat m (mixed)						
cat s (slow)						

20. Can you give us an estimation about the average **distance** between and the average **height** of the lighting points per road category, for the present, the past and the future?

For Cat F there are different possibilities for lighting:

a. Lighting poles can be placed in the central reservation with two luminaires per pole or can be placed on both sides of the road and opposite, with one luminaire per pole. We ask the distance between poles.

b. Lighting poles can be placed in the central reservation with four luminaires, two on both sides of the pole. We ask the distance between poles.

c. Luminaires can be hung up on cables between poles in the central reservation (catenary suspension). We ask the distance between lighting points.

*For Cat M **and Cat S** we assume that lighting points are placed on poles or on house fronts on one side of the road or alternating on both sides. They also can be hung up on cables crossing the road. We ask the distance between lighting points, measured on the centre of the road. If the lighting points are placed on both sides and opposite, we ask you to divide the measured distance in two.*

average distance and height of lighting points		past						present		future			
		default: adapted:		default: adapted:		default: adapted:		2003 2004		2010 - 2012		2020-2025	
(m)		dist	height	dist	height	dist	height	dist	height	dist	height	dist	height
cat f (fast)	a												
	b												
	c												
cat m (mixed)													
cat s (slow)													

21. Can you give us the standard width of a traffic lane per road, the average number of traffic lanes per direction and the percentage of high reflective road per road category (please complete table below)?

	Standard (average) width of a traffic lane (m)	**Average number of traffic lanes per direction**	**Percentage high reflective road (typical for concrete)**
Cat F (fast)			
Cat M (mixed)			
Cat S (slow)			

Street lighting: Maintenance

22. Is the outer glazing of a closed luminaire cleaned at lamp replacement and if possible fill in also the table below?

yes	no

type luminaire	ip65/66	ip5x/4x	
cleaning of the glazing	outside	inside	outside
only at lamp replacement (y/n)			
at lamp replacement and between (y/n)			
alternative cleaning interval in years			
no cleaning at all			

Annex inquiry I: Lamp types

Table 152: Installed lamp types

lamp type	wattage	past			present	future	
	default yr	1990	1995	2000	2003	2010 - 2012	2020-2025
	adapted yr				2004		
nahp-tc (high pressure sodium, tubular, clear)	50						
	70						
	100						
	150						
	250						
	400						
	total						
	avg. watt						
nahp-bf (high pressure sodium, ovoid, frosted)	50						
	70						
	100						
	150						
	250						
	400						
	total						
	avg. watt						
nahp (tc + bf)	total						
	avg. watt						

	Wattage	PAST			PRESENT	FUTURE	
Lamp type	Default yr	1990	1995	2000	2003	2010 - 2012	2020-2025
	Adapted yr				2004		
NaLP-TC (Low pressure sodium, tubular, clear)	18						
	26						
	35						
	36						
	55						
	66						
	90						
	91						
	131						
	135						
	180						
	Total						
	Avg. Watt						
HgHP-BF (High pressure mercury, ovoid, fluorescent)	50						
	80						
	125						
	250						
	400						
	Total						
	Avg. Watt						

lamp type	wattage	past			present	future	
	default yr	1990	1995	2000	2003 2004	2010 - 2012	2020-2025
	adapted yr						
hglp-tf - normal double ended linear fluorescent lamps t12/t8 - u- and o-shaped lamps t12/t8	18						
	20						
	22						
	30						
	32						
	36						
	40						
	58						
	65						
	total						
	avg. watt						
hglp-tf compact non integrated ballast (compact fluorescent lamp without integrated ballast)	18						
	24						
	26						
	32						
	36						
	40						
	42						
	55						
	total						
	avg. watt						
hglp-tf compact with integrated ballast (compact fluorescent lamp with integrated ballast)	≥20						
	<20						
	total						
	avg. watt						

lamp type	wattage	past			present	future	
	default yr	1990	1995	2000	2003 2004	2010 - 2012	2020-2025
	adapted yr						
hglp induction lamp	55						
	85						
	165						
	total						
	avg. watt t						
mhhp-tc ceramic (high pressure metal halide lamp, tubular clear with ceramic burner)	35						
	70						
	100						
	150						
	250						
	400						
	total						
	avg. watt						
mhhp-bf ceramic (high pressure metal halide lamp, ovoid frosted with ceramic burner)	70						
	100						
	150						
	250						
	400						
	total						
	avg. watt						
mhhp ceramic (tc + bf)	total						
	avg. watt						

lamp type	wattage	past			present	future	
	default yr	1990	1995	2000	2003-2004-2005	2010 - 2012	2020-2025
	adapted yr						
mhhp-tc quartz (high pressure metal halide lamp, tubular clear with quartz burner)	70						
	100						
	150						
	250						
	400						
	total						
	avg. watt						
mhhp-bf quartz (high pressure metal halide lamp, ovoid frosted with quartz burner)	70						
	150						
	250						
	400						
	total						
	avg. watt						
mhhp quartz (tc + bf)	total						
	avg. watt						

Annex Inquiry II: Luminaires

Table 153: Installed luminaires

luminaire type	open (ip2x, ip3x)		ip4x		ip5x		ip65		ip66		
	reflector		reflector		reflector		reflector		reflector		
	no	yes	no	yes	no	yes	no	yes	no	yes	
	%	%	%	%	%	%	%	%	%	%	%
default 1990											100%
adapted:......											
default: 1995											100%
adapted:											
default: 2000											100%
adapted:......											
2003											100%
2010-2012											100%
2020-2025											100%

Table 154: Estimated age of installed luminaires

luminaire type		open ip2x / ip3x		closed ip4x		closed ip5x		closed ip65		closed ip66	
		reflector		reflector		reflector		reflector		reflector	
		no	yes	no	yes	no	yes	no	yes	no	yes
		%	%	%	%	%	%	%	%	%	%
estimated age in 2003 2004 2005	age>30y										
	30y>age≥20y										
	20y>age≥15y										
	15y>age≥10y										
	10y>age≥5y										
	5y>age										
		100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

ANNEX I: RESPONSE TO "EXPERT-INQUIRY"

Table 155: Overview of contacts and responses of the "Expert-inquiry" (Status on 15/10/2006)

Member State	Contact	Organisation	Response
Austria	Ilse Neyder, Nikolaus Thiemann	LTG	no data available, refer to BMWA
	Mr. Resch	BMWA	no data available, refer to BMVIT
		BMVIT, Projektkoordinator für Infrastrukturvorhaben (PKI)	no data available, refer to other contacts
Belgium	Lieven Vanhooydonck	BIV	data
Czech Republic	J. Kotek	CIE	no response
Denmark	Kenneth Munck	CIE	no data available
	Thomas Christoffersen	City of Copenhagen	data for Copenhagen only
Germany	Helmut Range, Hans-Georg Schmidt	LiTG	refer to other contacts
	Hans-Hubert Meseberg, Dirk Heuseroth	Bundesanstalt für Straßenwesen	no response
	Sabine Piller	Consultant Bremerhaven	data for Bremerhaven only
	Jörg Kupferschlaeger, Torsten Hünermund, Robert Class	Philips-AEG	no response
Estonia	*no contact found*		
Greece	Giorgos Paissidis	CIE	general data about lamp types, lifetime. No market data
Spain	Alfredo Berges	CIE	data promised
France	Bernard Duval, Christian Remande	AFE	data available
	Dominique Fourtune	ADEME	general data
Ireland	Geraldine Cusack, Valerie Norton	Meath Energy Management Agency	refer to Electricity Supply Board
	Michael Perse	Electricity Supply Board	data
Italy		Associazione Italiana di Illuminazione (Aidiluce)	no response
Cyprus	*no contact found*		
Latvia	Dagnija Blumberga, Claudio Rochas	Right light	no data available
Lithuania	*no contact found*		
Luxembourg (G-D)	*no contact found*		

Member State	Contact	Organisation	Response
Hungary	Janos Schanda	CIE	no response
Malta	*no contact found*		
Netherlands	Bob Hamel	State road administration	data available (Class A roads)
	Dyana Loehr, Onno Jobse	SenterNovem	data available (general)
Poland	J. Grzonkowski	CIE	data estimations
	R. Zwierchanowski	E-street	data estimations
Portugal	Maria Antonio Pinhero-Torres	Schréder Portugal	no data available
Slovenia	Matej B. Kobav	CIE	no response
Slovakia	Alfonz Smola	Lux Europe	no response
Finland	Heikki Härkönen	CIE	other contacts
	Pentti Hautala	CIE	
	Kari Lehtonen	Finnish Road Administration	
	Ulla Suomi	Motiva Oy	
Sweden	Magnus Frantzell	CIE	data
United Kingdom	Hilary Graves	Market Transformation Program (MTP)	data
Organisations			
Eurocities	Valerie Knowles	Eurocities	no response
Energie-cités	Gérard Magnin	Energie-cités	negative response
AIE-elec (contractors)	Evelyne Schellekens	AIE-elec (contractors)	no response
CCRE-CEMR	Pirita Lindholm	CCRE-CEMR	no response

ANNEX J: EU-25 LAMP SALES

Table 156: EU-25 lamp sales, 1999-2004 (Source: rescaled based on population from original ELC sales data for the Western European market)

	Quantity (000's)					
Lamp Type	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
LINEAR & SPECIAL PRODUCT FLUORESCENT LAMPS						
(a) T12	24.179	25.808	19.619	17.486	15.672	14.164
(b) T8 Halo phosphor	116.392	126.321	126.041	127.290	135.310	149.982
(c) T8 tri-phosphor					79.499	88.312
(d) T5 new (14 - 80w)	75.146	80.660	83.050	85.038	9.598	12.133
(e) All others (including T5 old types 4 - 13w and Special)	26.679	28.514	30.654	29.923	31.196	33.048
Total Linear and special product fluorescent lamps	**242.397**	**261.303**	**259.365**	**259.736**	**271.274**	**297.639**
COMPACT FLUORESCENT LAMPS						
(a) Retrofit	32.258	35.369	39.205	41.226	43.500	52.238
(b) Non-Retrofit	40.355	45.750	47.366	48.612	51.131	56.049
Total Compact fluorescent lamps	**72.613**	**81.119**	**86.571**	**89.838**	**94.631**	**108.286**
TUNGSTEN HALOGEN LAMPS						
(a) Single Ended, Mirrored (Low voltage)	42.638	47.587	46.814	48.018	50.222	53.107
(b) Linear (High voltage)	17.404	20.024	19.320	19.435	21.141	22.361
(c) Mains Halogen (Substitute for GLS and Reflector)	10.714	17.073	18.284	16.192	19.785	27.112
(d) LV Halogen Capsule				27.866	32.937	35.319
(e) HV Halogen Capsule				5.521	3.686	5.151
Total Tungsten halogen lamps	**70.756**	**84.684**	**84.417**	**117.031**	**127.772**	**143.051**
INCANDESCENT LAMPS						
(a) Reflector	110.052	126.601	129.744	135.008	137.746	123.208
(b) GLS (Including clear/pearl, candles, coloured & dec.)	925.118	977.008	966.826	956.600	978.737	1.102.092
Total Incandescent lamps	**1.035.170**	**1.103.609**	**1.096.570**	**1.091.608**	**1.116.483**	**1.225.299**
HIGH INTENSITY DISCHARGE LAMPS						
(a) All Mercury Lamps (including mixed)	8.711	9.333	8.501	8.542	8.151	7.938
(b) All Sodium lamps	8.801	9.151	10.265	10.206	10.457	10.982
(c) All Metal Halide lamps	5.649	6.935	7.531	8.011	8.958	10.714
Total High Intensity Discharge lamps	**23.161**	**25.418**	**26.297**	**26.759**	**27.566**	**29.633**

TOTAL	**1.444.097**	**1.556.133**	**1.553.220**	**1.584.971**	**1.637.726**	**1.803.909**

ANNEX K: APPARENT CONSUMPTION VERSUS ACTUAL CONSUMPTION OF DIFFERENT TYPES OF LAMPS APPLICABLE IN STREET LIGHTING

Table 157: Apparent consumption of "Fluorescent hot cathode discharge lamps, with double ended cap (excluding ultraviolet lamps)" versus EU-25 sales and Actual consumption of "Linear and special product fluorescent lamps"

Year	Region	Apparent consumption	EU-25 ELC sales	Difference Apparent consumption versus EU-25 sales	% change	Extra- EU Import (Eurostat-Europroms)	Actual consumption (EU-25 sales + extra-EU Import)	Difference Apparent consumption versus actual consumption	% change
Source:		**Eurostat-Europroms**	**ELC**			**Eurostat-Europroms**	**ELC combined with Eurostat-Europroms**		
		Quantity (000's)				**Quantity (000's)**			
2000	EU-15	-	261.303	-	-	58.594	319.897	-	-
2001	EU-15	403.225	259.365	143.860	55,5	63.627	322.992	80.233	24,8
2002	EU-15	353.687	259.736	93.951	36,2	57.527	317.263	36.424	11,5
2003	EU-25	266.803	271.274	-4.471	-1,6	116.254	387.528	-120.725	-31,2
2004	EU-25	310.000	297.639	12.361	4,2	433.342	730.981	-420.981	-57,6

Table 158: Apparent consumption of “Fluorescent hot cathode discharge lamps (excluding ultraviolet lamps, with double ended cap)” versus EU-25 sales and Actual consumption of “Compact fluorescent lamps”

Year	Region	Apparent consumption	EU-25 sales	Difference Apparent consumption versus EU-25 sales	% change	Extra- EU Import	Actual consumption (EU-25 sales + extra-EU Import)	Difference Apparent consumption versus actual consumption	% change
Source		**Eurostat-Europroms**	**ELC**			**Eurostat-Europroms**	**ELC combined with Eurostat-Europroms**		
		Quantity (000’s)				**Quantity (000’s)**			
2000	EU-15	-	81.119	-	-	219.537	300.656	-	-
2001	EU-15	229.158	86.571	142.587	164,7	176.773	263.344	-34.186	-13,0
2002	EU-15	245.251	89.838	155.413	173,0	193.172	283.010	-37.759	-13,3
2003	EU-25	264.880	94.631	170.249	179,9	245.452	340.083	-75.203	-22,1
2004	EU-25	276.361	108.286	168.075	155,2	251.652	359.938	-83.577	-23,2

Table 159: Apparent consumption of “Mercury vapour discharge lamps (excluding ultraviolet lamps, dual lamps)” versus EU-25 sales and Actual consumption of “All Mercury Lamps (including mixed) + All Metal Halide lamps”

	Region	Apparent consumption	EU-25 sales	Difference Apparent consumption versus EU-25 sales	% change	Extra-EU Import	Actual consumption (EU-25 sales + extra-EU Import)	Difference Apparent consumption versus actual consumption	% change
Source		**Eurostat-Europroms**	**ELC**			**Eurostat-Europroms**	**ELC combined with Eurostat-Europroms**		
		Quantity (000’s)				**Quantity (000’s)**			
2000	EU-15	-	16.268	-	-	3.533	19.801	-	-
2001	EU-15	25.885	16.032	9.853	61,5	3.463	19.495	6.390	32,8
2002	EU-15	27.864	16.553	11.311	68,3	5.112	21.665	6.199	28,6
2003	EU-25	22.452	17.109	5.343	31,2	4.541	21.650	802	3,7
2004	EU-25	29.998	18.652	11.346	60,8	6.868	25.520	4.478	17,5

Table 160: Apparent consumption of "Sodium vapour discharge lamps other than ultraviolet lamps)" versus EU-25 sales and Actual consumption of "All Sodium lamps (low and high pressure)"

	Region	Apparent consumption	EU-25 sales	Difference Apparent consumption versus EU-25 sales	% change	Extra- EU Import	Actual consumption (EU-25 sales + extra-EU Import)	Difference Apparent consumption versus actual consumption	% change
Source		**Eurostat-Europroms**	**ELC**			**Eurostat-Europroms**	**ELC combined with Eurostat-Europroms**		
		Quantity (000's)				**Quantity (000's)**			
2000	EU-15	-	9.151	-	-	3.426	12.577	-	-
2001	EU-15	-	10.265	-	-	4.041	14.306	-	-
2002	EU-15	-	10.206	-	-	4.687	14.893	-	-
2003	EU-25	37.077	10.457	26.620	254,6	5.440	15.897	21.180	133,2
2004	EU-25	38.927	10.982	27.945	254,5	5.629	16.611	22.316	134,3

ANNEX L: CELMA MARKET ESTIMATIONS

Table 161: CELMA estimations of the European street lighting luminaries market

	CELMA (market data and estimations)						
2005	**Luminaires TOTAL**	**% EU25**	**Luminaires HPM**	**% HPM**	**Capita ('000)**	**Luminaires /capita**	
Austria	1.000.000	1,9%	300.000	30%	8.207	0,12	
Belgium	1.750.000	3,3%	350.000	20%	10.446	0,17	
Czech republic	300.000	0,6%	120.000	40%	10.221	0,03	
Denmark	400.000	0,7%	160.000	40%	5.411	0,07	
Finland	400.000	0,7%	160.000	40%	5.237	0,08	
France	8.000.000	15,0%	2.000.000	25%	60.561	0,13	
Germany	10.000.000	18,7%	3.000.000	30%	82.501	0,12	
Greece	900.000	1,7%	450.000	50%	11.076	0,08	
Hungary	600.000	1,1%	200.000	33%	10.098	0,06	
Italy	9.000.000	16,8%	5.760.000	64%	58.462	0,15	
Netherlands	3.500.000	6,6%	400.000	11%	16.306	0,21	
Poland	2.000.000	3,7%	800.000	40%	38.174	0,05	
Portugal	1.100.000	2,1%	330.000	30%	10.529	0,10	
Sweden	500.000	0,9%	200.000	40%	9.011	0,06	
Spain	4.700.000	8,8%	1.175.000	25%	43.038	0,11	
Slovakia	200.000	0,4%	80.000	40%	5.385	0,04	
UK	8.000.000	15,0%	2.400.000	30%	60.035	0,13	
Latvia	85.000	0,2%	34.000	40%	2.306	0,04	as lum/cap Slovakia
Lithuania	125.000	0,2%	50.000	40%	3.425	0,04	as lum/cap Slovakia
Estonia	50.000	0,1%	20.000	40%	1.347	0,04	as lum/cap Slovakia
Malta	45.000	0,1%	15.000	33%	403	0,11	as lum/cap Spain
Cyprus	88.000	0,2%	42.000	48%	775	0,11	as lum/cap Spain
Luxembourg	61.000	0,1%	15.000	25%	455	0,13	as lum/cap France
Ireland	552.000	1,0%	185.000	34%	4.109	0,13	as lum/cap UK
Slovenia	74.000	0,1%	30.000	41%	1.998	0,04	as lum/cap Slovakia
Total EU25	**53.430.000**	**100%**	**18.276.000**	**34%**	**459.514**	**0,12**	

ANNEX M: INSTALLED BASE OF STREET LIGHTING IN EU-25

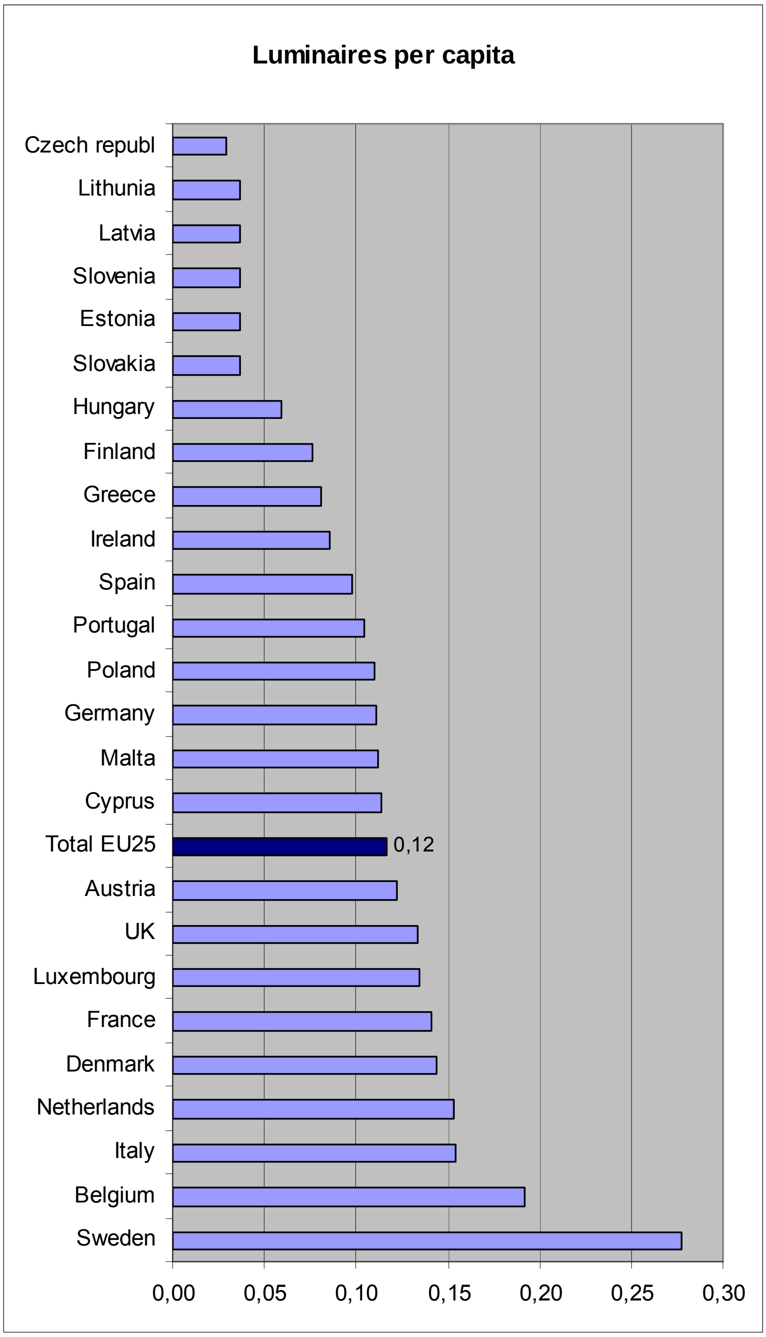

Figure 71: Number of installed luminaires per capita (Source : data from literature and expert inquiry completed with CELMA market data estimations for missing Member States

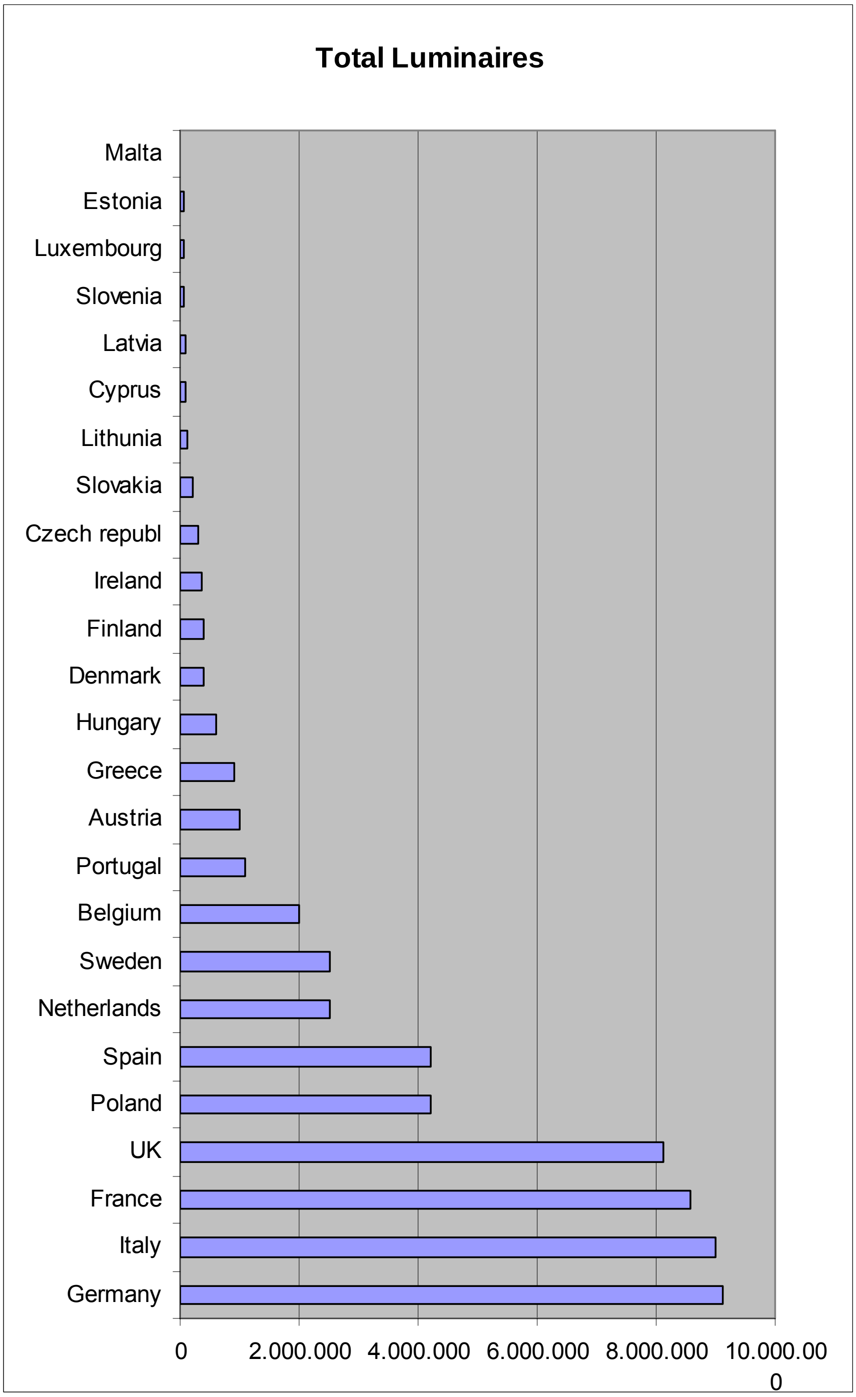

Figure 72: Total number of installed luminaires in EU-25 per Member State (Source: Calculation based on a combination of data from literature and expert inquiry and CELMA market estimations

ANNEX N: EUROPEAN ROAD NETWORK: 1990-2005

Table 162: Length of European motorways: 1990-2005 (Source: Eurostat, ECE UN ABTS, ERF)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Belgium	1.666	1.650	1.658	1.665	1.666	1.666	1.674	1.679	1.682	1.691	1.702	1.727	1.729	1.729	*1.734*	*1.740*
Czech Republic	357	362	366	390	392	414	423	486	499	499	499	517	518	518	*534*	*552*
Denmark	601	653	696	747	796	796	832	855	873	892	953	971	1.010	*1.055*	*1.102*	*1.151*
Germany[48]	10.854	10.955	11.013	11.080	11.143	11.190	11.246	11.309	11.427	11.515	11.712	11.786	12.037	*12.141*	*12.247*	*12.353*
Estonia	41	50	60	62	64	65	65	68	74	87	93	93	98	*106*	*114*	*123*
Greece	190	225	280	*340*	*413*	*501*	*609*	*739*	*898*	*1.090*	*1.324*	*1.608*	*1.952*	*2.371*	*2.879*	*3.496*
Spain	4.693	5.235	6.486	6.577	6.497	6.962	7.295	7.750	8.269	8.893	9.049	9.571	9.739	*10.367*	*11.035*	*11.746*
France	6.824	7.080	7.408	7.614	7.956	8.275	8.596	8.864	9.303	9.626	9.766	10.068	10.223	10.379	*10.735*	*11.103*
Ireland	26	32	32	53	72	70	80	94	103	103	103	125	125	176	*203*	*234*
Italy	6.193	6.301	6.289	6.401	6.375	6.435	6.465	6.469	6.478	6.478	*6.511*	*6.543*	*6.576*	*6.610*	*6.643*	*6.676*
Cyprus	0	0	0	154	159	168	168	194	204	216	240	257	268	268	*282*	*297*
Latvia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	*0*	*0*
Lithuania	421	376	382	394	394	394	404	410	417	417	417	417	417	417	*417*	*417*
Luxembourg	78	78	95	100	121	*129*	*138*	*148*	115	115	114	115	*123*	*131*	*140*	*150*
Hungary	267	269	269	269	293	335	365	382	448	448	448	448	533	542	*575*	*611*
Malta	*1.423*	*1.491*	*1.562*	*1.636*	*1.714*	*1.796*	*1.881*	1.971	1.971	2.154	2.262	*2.370*	*2.483*	*2.601*	*2.725*	*2.855*
Netherlands	2.092	*2.109*	2.134	*2.157*	*2.182*	2.208	*2.309*	2.336	2.225	2.291	2.289	*2.316*	*2.344*	*2.371*	*2.400*	*2.428*
Austria	1.445	1.450	1.554	1.557	1.559	1.596	1.607	1.613	1.613	1.634	1.633	1.645	1.645	1.670	*1.688*	*1.707*
Poland	257	239	257	231	245	246	258	264	268	317	358	398	405	405	*422*	*439*
Portugal	316	474	520	579	587	687	710	797	1.252	1.441	1.482	1.659	1.835	*2.145*	*2.507*	*2.931*
Slovenia	228	246	254	268	277	293	310	330	369	399	427	435	457	477	*506*	*536*
Slovakia	192	198	198	198	198	198	215	219	292	295	296	296	302	313	*326*	*340*
Finland	225	249	318	337	388	394	431	444	473	512	549	591	603	653	*710*	*772*
Sweden	939	968	1.005	1.061	1.125	1.262	1.350	1.423	1.439	1.484	1.499	1.507	1.544	1.591	*1.659*	*1.730*
United Kingdom	3.181	3.211	3.246	3.252	3.286	3.307	3.344	3.412	3.554	3.582	3.600	3.609	3.609	3.609	*3.647*	*3.686*
TOTAL	**42.509**	**43.901**	**46.082**	**47.122**	**47.902**	**49.387**	**50.774**	**52.255**	**54.246**	**56.179**	**57.326**	**59.072**	**60.574**	**62.644**	**65.231**	**68.072**
TrendEU25[49]	1	1,03	1,08	1,11	1,13	1,16	1,19	1,23	1,28	1,32	1,35	1,39	1,42	1,47	1,53	1,6

48 (including ex-GDR from 1991)

49 (index1990)

Table 163: Length of European state roads: 1990-2005 (Source: Eurostat, ECE UN ABTS, ERF)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Belgium	13.115	12.818	12.718	12.718	12.634	12.583	12.600	12.509	12.542	12.542	12.550	12.600	12.610	12.531	12.487	12.444
Czech Republic	55.535	55.530	55.530	55.568	55.530	55.086	55.088	54.908	54.895	54.933	54.909	54.910	54.904	54.929	54.883	54.837
Denmark	3.968	3.908	3.841	3.815	3.764	3.764	3.751	3.780	758	749	718	689	662	608	558	513
Germany[50]	42.554	42.123	42.169	41.995	41.770	41.700	41.487	41.419	41.386	41.321	41.282	41.228	41.246	41.139	41.032	40.926
Estonia	14.781	14.766	14.737	14.709	14.691	14.922	15.303	16.369	16.356	16.343	16.340	16.341	16.442	16.592	16.743	16.895
Greece	9.126	9.181	9.181	9.158	9.158	9.166	9.174	9.182	9.190	9.198	9.206	9.215	9.223	9.231	9.239	9.247
Spain	20.701	20.741	18.302	15.862	17.186	17.294	17.266	17.169	17.132	17.195	17.123	17.074	16.952	16.700	16.452	16.207
France	28.274	28.360	28.243	28.212	28.090	28.097	26.881	26.856	26.584	26.298	26.126	26.050	26.154	26.127	25.971	25.815
Ireland	5.253	5.255	4.432	4.411	4.392	5.260	5.270	5.350	5.329	5.326	5.326	5.310	5.327	5.255	5.268	5.281
Italy	44.740	45.076	44.888	44.757	45.237	45.130	46.043	45.819	42.977	43.319	43.175	43.031	42.888	42.746	42.604	42.462
Cyprus	4.573	4.635	4.697	4.761	4.825	4.855	4.952	5.058	4.959	5.052	5.098	5.261	5.368	5.440	5.514	5.588
Latvia	20.600	8.272	7.018	20.538	20.446	20.411	20.332	20.332	20.329	20.318	20.323	20.320	20.279	20.309	22.129	24.113
Lithuania	20.904	20.522	20.727	20.717	20.725	20.727	20.717	20.711	20.747	20.854	20.896	20.899	20.918	20.916	20.917	20.919
Luxembourg	947	947	964	969	990	952	915	880	837	837	837	837	837	837	837	837
Hungary	29.392	29.625	29.681	29.694	29.738	29.653	29.357	29.415	29.464	29.492	29.533	29.548	30.139	30.536	30.627	30.717
Malta	157	157	157	157	157	157	157	157	157	264	277	344	428	533	663	824
Netherlands	1.956	1.907	1.858	1.571	1.329	998	992	986	814	893	894	874	855	836	818	800
Austria	10.433	10.471	10.209	10.248	10.207	10.243	10.269	10.267	10.276	10.260	10.280	10.265	10.250	10.236	10.221	10.206
Poland	45.280	45.342	45.359	45.595	45.612	45.431	45.417	45.384	45.409	17.803	17.706	18.116	18.166	18.253	17.439	16.661
Portugal	9.198	9.169	9.108	9.069	9.091	9.055	9.032	8.983	10.156	14.099	13.883	10.351	10.564	10.781	11.002	11.227
Slovenia	4.752	4.748	4.749	4.749	4.752	4.752	4.765	4.796	5.797	5.855	5.845	5.897	5.892	5.864	5.968	6.073
Slovakia	3.061	3.069	3.077	3.076	3.077	3.074	3.073	3.219	3.223	3.220	3.222	3.220	3.224	3.335	3.357	3.380
Finland	77.080	77.283	77.409	77.499	77.644	77.722	77.782	77.796	77.894	77.900	77.993	78.059	78.137	78.197	78.284	78.370
Sweden	13.166	13.609	13.605	13.526	13.512	14.645	14.647	14.663	14.651	14.651	14.692	15.079	15.349	15.341	15.527	15.714
United Kingdom	14.886	14.569	12.442	12.203	12.111	12.108	12.403	12.314	12.908	12.924	12.927	12.595	11.864	9.466	9.165	8.874
TOTAL	**494.432**	**482.083**	**475.101**	**485.577**	**486.668**	**487.785**	**487.673**	**488.322**	**484.771**	**461.647**	**461.161**	**458.114**	**458.679**	**456.736**	**457.702**	**458.930**
TrendEU25[51]	1	0,98	0,96	0,98	0,98	0,99	0,99	0,99	0,98	0,93	0,93	0,93	0,93	0,92	0,93	0,93

50 (including ex-GDR from 1991)

51 (index1990)

Table 164: Length of European provincial roads: 1990-2005 (Source: Eurostat, ECE UN ABTS, ERF)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Belgium	1.360	1.354	1.353	1.353	1.331	1.326	1.326	1.326	1.326	1.349	1.349	1.349	1.349	1.349	1.349	1.349
Czech Republic													34.100			
Denmark	7.037	7.102	7.056	7.017	7.053	7.050	7.043	9.941	9.949	9.955	9.986	9.988	9.952	10.295	10.650	11.017
Germany[52]	173.053	173.204	173.623	174.125	175.691	175.970	178.343	178.346	177.852	177.899	177.780	177.834	178.298	178.744	179.191	179.639
Estonia	12.973	13.325	14.223	29.071	29.071	28.833	28.800	27.754	33.050	34.006	34.977	35.603	36.441	37.429	38.444	39.487
Greece	31.235	31.228	31.228	29.107	29.107	28.611	28.124	27.645	27.174	26.711	26.256	25.808	25.369	24.937	24.512	24.094
Spain	71.063	71.502	70.397	70.626	71.547	71.377	70.905	71.095	69.373	69.521	69.259	69.167	67.969	67.721	67.474	67.227
France	352.000	353.000	354.000	354.000	365.607	360.000	358.900	358.380	358.580	359.090	359.055	359.231	359.597	359.644	360.257	360.870
Ireland	10.566	10.566	10.726	10.726	10.726	10.600	10.700	11.690	11.690	11.628	11.628	11.628	11.690	11.607	11.695	11.783
Italy	111.304	110.475	112.875	113.353	113.349	114.442	113.924	113.790	115.125	115.222	115.670	116.120	116.571	117.024	117.479	117.936
Cyprus	2.399	2.412	2.425	2.438	2.451	2.456	2.448	2.493	2.502	2.520	2.532	2.538	2.553	2.571	2.585	2.599
Latvia	12.231	12.312	13.534	39.640	30.000	30.804	31.274	31.619	32.365	32.481	33.042	33.109	32.873	31.787	31.997	32.208
Lithuania	27.409	23.617	27.255	30.893	34.778	36.666	40.238	43.240	45.987	46.828	48.451	49.475	55.813	57.560	61.296	65.275
Luxembourg	1.828	1.828	1.828	1.828	1.828	1.849	1.870	1.891	1.911	1.911	1.891	1.891	1.884	1.878	1.871	1.865
Hungary														53.749		
Malta	1.167	1.167	1.167	1.167	1.167	1.167	1.167	1.167	1.167	1.252	1.343	1.422	1.439	1.456	1.474	1.491
Netherlands	7.082	7.065	7.047	7.001	6.956	6.910	7.051	7.192	7.269	7.347	7.425	7.504	7.585	7.666	7.747	7.830
Austria	23.474	19.713	19.757	23.472	23.472	23.472	23.472	23.472	23.472	23.065	23.086	23.532	23.986	24.450	24.922	25.403
Poland	128.854	128.705	128.673	110.098	110.387	128.624	128.684	128.548	128.544	156.258	156.669	156.005	156.784	157.044	159.969	162.948
Portugal	4.885	4.875	4.865	4.855	4.845	4.835	4.825	4.815	4.805	4.528	4.499	4.500	4.500	4.491	4.481	4.472
Slovenia	9.572	9.750	9.791	9.786	9.781	9.791	9.781	9.804	13.533	13.874	13.905	13.904	13.901	13.995	14.090	14.186
Slovakia	3.856	3.849	3.847	3.844	3.845	3.878	3.921	3.771	3.773	3.826	3.826	3.828	3.829	3.729	3.719	3.710
Finland													28.400			
Sweden	83.753	83.182	83.252	83.233	83.257	83.263	83.368	83.421	83.442	83.442	83.357	83.094	82.892	82.915	82.851	82.787
United Kingdom	35.149	35.629	37.705	35.715	35.791	38.216	38.071	38.048	35.894	36.052	36.084	36.457	37.198	38.462	38.752	39.044
TOTAL	**1.112.251**	**1.105.860**	**1.116.627**	**1.143.348**	**1.152.040**	**1.170.140**	**1.174.234**	**1.179.448**	**1.188.782**	**1.218.764**	**1.222.070**	**1.223.988**	**1.294.973**	**1.290.502**	**1.246.805**	**1.257.220**
TrendEU25[53]	1	0,99	1	1,03	1,04	1,05	1,06	1,06	1,07	1,1	1,1	1,1	1,16	1,16	1,12	1,13

52 (including ex-GDR from 1991)

53 (index1990)

Table 165: Length of European communal roads: 1990-2005 (Source: Eurostat, ECE UN ABTS, ERF)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Belgium	124.100	125.000	125.900	125.900	126.800	127.600	128.200	129.400	130.300	130.900	131.520	132.540	133.330	134.130	134.935	135.744
Czech Republic	66.049	66.933	67.829	68.737	69.270	66.449	70.520	72.300	72.300	72.300	72.300	72.300	72.300	72.300	72.300	72.300
Denmark	59.168	59.259	59.447	59.532	59.642	59.711	59.710	59.861	59.882	59.995	60.018	60.240	60.328	60.426	60.524	60.622
Germany[54]	327.000	370.000	413.000	467.309	528.759	598.290	676.965	765.984	866.710	980.681	1.109.639	1.255.555	1.420.659	1.607.473	1.818.853	2.058.030
Estonia													39.500			
Greece													75.600			
Spain	64.479	64.660	64.802	65.972	66.966	66.984	66.634	66.781	68.499	68.160	68.126	67.987	69.479	69.916	70.357	70.800
France	421.000	500.000	526.000	526.000	562.960	563.000	574.780	579.410	585.900	589.910	594.149	601.733	598.380	601.851	619.313	637.282
Ireland	76.444	76.474	76.314	76.314	76.314	76.500	76.600	78.610	78.610	78.675	78.675	78.675	78.610	78.773	78.957	79.141
Italy	141.666	141.666	650.201	651.591	668.765	660.566	663.503	668.669	672.476	676.305	680.155	684.028	687.922	691.839	695.778	699.739
Cyprus	2.236	2.283	2.330	2.379	2.428	2.839	3.015	3.103	3.155	3.221	3.271	3.352	3.404	3.481	3.553	3.627
Latvia	38.941	38.941	39.640	4.515	4.546	4.990	5.074	5.039	5.124	5.162	5.201	7.210	7.320	7.338	7.403	7.469
Lithuania	4.557	4.618	4.630	4.689	4.677	4.726	4.853	4.882	5.308	5.551	5.753	5.783	5.911	6.043	6.177	6.314
Luxembourg	2.316	2.316	2.316	2.316	2.316	2.316	2.316	2.316	2.316	2.316	2.316	2.316	2.316	2.316	2.316	2.316
Hungary	4.499	4.397	4.372	4.378	4.383	4.384	4.384	4.384	16.308	60.666	225.677	839.512	3.122.955	75.930	75.652	75.375
Malta	647	647	647	647	647	647	647	647	647	1.890	1.985	647	647	647	647	647
Netherlands	93.460	94.119	94.778	97.620	100.547	103.304	104.492	105.680	106.895	108.125	109.368	110.626	111.898	113.185	114.486	115.803
Austria	71.000	71.000	71.000	71.000	71.000	71.000	71.000	71.000	71.000	71.053	71.059	71.089	71.118	71.148	71.177	71.207
Poland	188.725	191.061	192.711	194.203	196.311	198.178	200.631	202.852	206.825	197.351	198.350	203.505	197.389	201.992	203.090	204.194
Portugal	50.976	53.651	56.467	58.321	62.528	65.810	69.264	72.899	76.725	80.752	84.990	89.451	94.145	99.087	104.287	109.761
Slovenia	25.000	24.083	23.200	22.349	21.529	20.740	19.979	19.246	17.665	18.132	18.226	18.338	18.271	32.059	34.706	37.571
Slovakia	10.828	10.804	10.758	10.747	10.769	10.718	10.658	10.418	10.427	10.393	10.394	10.391	10.396	10.396	10.364	10.331
Finland	13.824	14.518	16.472	22.000	22.000	22.000	22.000	24.000	24.000	24.000	24.000	25.000	25.000	25.000	26.256	27.575
Sweden	35.700	38.100	37.100	37.100	37.100	38.325	38.500	38.800	38.500	39.523	39.775	40.000	40.000	40.000	40.361	40.725
United Kingdom	328.899	330.796	333.135	313.156	313.897	337.475	33.911	340.556	360.918	361.651	362.360	363.104	363.918	364.689	365.448	366.208
TOTAL	**2.151.514**	**2.285.327**	**2.873.049**	**2.886.775**	**3.014.155**	**3.106.552**	**2.907.635**	**3.326.838**	**3.480.491**	**3.646.712**	**3.957.307**	**4.743.381**	**7.310.796**	**4.370.018**	**4.616.939**	**4.892.780**
TrendEU25[55]	1	1,06	1,34	1,34	1,4	1,44	1,35	1,55	1,62	1,69	1,84	2,2	3,4	2,03	2,15	2,27

54 (including ex-GDR from 1991)

55 (index1990)

Table 166: Input data regarding road infrastructure for the scenario model (II)

		1990	1995	2000	2005	2010	2015	2020	2025
KM ROAD	**F**	181.367	193.074	213.598	239.211	260.247	283.133	308.032	335.120
	M	1.714.258	1.813.252	1.881.097	1.960.790	2.040.486	2.123.422	2.209.729	2.299.544
	S	2.043.938	2.951.224	3.759.442	4.648.141	5.081.807	5.555.934	6.074.296	6.641.021
	TOT	**3.939.564**	**4.957.550**	**5.854.137**	**6.848.142**	**7.382.540**	**7.962.489**	**8.592.057**	**9.275.684**
INDEX '90	**F**	100%	106%	118%	132%	143%	156%	170%	185%
	M	100%	106%	110%	114%	119%	124%	129%	134%
	S	100%	144%	184%	227%	249%	272%	297%	325%
	TOT	**100%**	**126%**	**149%**	**174%**	**187%**	**202%**	**218%**	**235%**
%ANNUAL GROWTH	**F**	#	2,24%	0,97%	2,93%	1,70%	1,70%	1,70%	1,70%
	M	#	1,33%	0,99%	1,31%	0,80%	0,80%	0,80%	0,80%
	S	#	3,07%	8,52%	5,97%	1,80%	1,80%	1,80%	1,80%
	TOT	**#**	**2,39%**	**5,70%**	**4,49%**	**1,52%**	**1,53%**	**1,54%**	**1,55%**
%LIT ROAD	**F**	5,00%	5,71%	6,43%	7,14%	7,86%	8,57%	9,29%	10,00%
	M	15,00%	16,43%	17,86%	19,29%	20,71%	22,14%	23,57%	25,00%
	S	20,00%	22,14%	24,29%	26,43%	28,57%	30,71%	32,86%	35,00%
KM LIT	**F**	9.068	11.033	13.731	17.086	20.448	24.269	28.603	33.512
	M	257.139	297.891	335.910	378.152	422.672	470.186	520.865	574.886
	S	408.788	653.485	913.007	1.228.437	1.451.945	1.706.465	1.995.840	2.324.357
	TOT	**674.995**	**962.410**	**1.262.649**	**1.623.676**	**1.895.065**	**2.200.920**	**2.545.308**	**2.932.755**

Table 167: Input data regarding road infrastructure for the scenario model (II)

						% growth					% growth
		1990	**1995**	**2000**	**2005**	**(95'-'05)**	**2010**	**2015**	**2020**	**2025**	**'05-'25**
KM ROAD	**F**	181.367	193.074	213.598	239.211	2,17%	266.262	296.373	329.889	367.194	2,95
(x2 for A)	**M**	1.745.440	1.809.743	1.842.744	1.884.321	0,40%	1.922.755	1.961.972	2.001.990	2.042.824	0,53
	S	2.636.392	2.884.543	3.030.736	3.195.235	1,03%	3.362.913	3.539.390	3.725.129	3.920.614	1,4
	TOTAL	**4.563.199**	**4.887.360**	**5.087.077**	**5.318.766**	**0,85%**	**5.551.930**	**5.797.735**	**6.057.007**	**6.330.633**	**1,2**
%LIT ROAD	**F**	10,00%	10,70%	11,40%	12,10%		12,90%	13,60%	14,30%	15,00%	
	M	15,00%	15,40%	15,70%	16,10%		16,40%	16,80%	17,10%	17,50%	
	S	30,00%	31,40%	32,90%	34,30%		35,70%	37,10%	38,60%	40,00%	
KM LIT	**F**	18.137	20.686	24.411	29.047	3,45%	34.234	40.222	47.127	55.079	4,04
	M	261.816	277.925	289.574	302.837	0,86%	315.881	329.331	343.198	357.494	0,95
	S	790.918	906.571	995.813	1.095.509	1,91%	1.201.040	1.314.631	1.436.835	1.568.246	2,18
	TOTAL	**1.070.870**	**1.205.182**	**1.309.798**	**1.427.393**	**1,71%**	**1.551.155**	**1.684.184**	**1.827.161**	**1.980.819**	**1,99**
km road per capita	**TOTAL**	**0,01**	**0,011**	**0,011**	**0,012**		**0,012**	**0,013**	**0,014**	**0,014**	
km lit per capita	**TOTAL**	**0,002**	**0,003**	**0,003**	**0,003**		**0,003**	**0,004**	**0,004**	**0,005**	

ANNEX O: EU ROAD INFRASTRUCTURE PROJECTIONS - BASELINE SCENARIO AND UNDERLYING ASSUMPTIONS

Source: EC DG TREN, EU Energy and Transport trends to 2030 (January 2003)

The Baseline scenario is a projection of energy supply and demand in the European Union for the short, medium and long term (up to 2030). It was developed with the use of the PRIMES[58] model.

The definition of the Baseline scenario is important because it constitutes the basis for further policy analysis in addition to its function as a projection on the basis of current trends and policies. For this purpose, this scenario is conceived as the most likely development of the energy system in the future in the context of current knowledge, policy objectives and means.

The Baseline scenario includes existing trends and the effects of policies in place and of those in the process of being implemented by the end of 2001, whereas tax rates reflect the situation of July 2002 in the EU Member States. For analytical reasons the Baseline scenario excludes all additional policies and measures that aim at further reductions of CO_2 emissions to comply with the Kyoto emission commitments.

For an extensive description of the Baseline scenario and its main underlying assumptions we refer to the final report of the EC DG TREN study "EU Energy and Transport trends to 2030" (January 2003). In the following we confine ourselves to the demographic and economic outlook, which are of relevance in view of this report.

The European Council in Copenhagen in December 2002 concluded the accession negotiations with ten candidate countries for their EU membership from 2004 (Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia and Slovenia); called for brevity reasons Acceding countries (or by the acronym ACC).

Demographic outlook

EU-25 population is projected to remain rather stable, peaking in 2020 at some 462 million but declining thereafter to reach 458 million by 2030 (see Table 168). The population of ACC is projected by 2030 to decline by some 5,6 million people or 7,5% of the population in 2000. Population in ACC accounts by 2030 for 15% of EU-25 population compared to 16,5% in 2000.

[58] PRIMES is a partial equilibrium model for the European Union energy system developed by, and maintained at, the National Technical University of Athens, E3M-Laboratory led by Prof. Capros. The most recent version of the model used in the EC DG TREN Trends to 2030-study covers all EU Member States, uses Eurostat as the main data source and is updated with 2000 being the base year. PRIMES is the result of collaborative research under a series of projects supported by the Joule programme of the Directorate General for Research of the European Commission.

Table 168: Population trends in EU-25, 1990-2030 (Source: Eurostat. Global Urban Observatory and Statistics Unit of UN-HABITAT. PRIMES. ACE

	Million inhabitants					Annual growth rate				
	1990	2000	2010	2020	2030	90/00	00/10	okt/20	20/30	**00/30**
EU-15	366,01	378,69	387,83	390,45	389,02	0,34	0,24	0,07	-0,04	**0,09**
ACC	75,12	74,73	73,4	71,76	69,14	-0,05	-0,18	-0,24	-0,36	**-0,26**
EU-25	**441,13**	**453,41**	**461,23**	**462,11**	**458,16**	**0,28**	**0,17**	**0,02**	**-0,09**	**0,03**

Macroeconomic outlook

The economic outlook of EU-25 is dominated by the evolution of the EU-15 economy. This is because the contribution of accession countries, despite their much faster growth over the projection period (+3,5% pa in 2000-2030 compared to +2,3% pa in EU-15), remains rather limited in terms of overall EU-25 GDP (see table above). By 2030 ACC GDP reaches 6,1% of EU-25 economic activity compared to 4,4% in 2000[59] and, consequently, overall economic growth of EU-25 (+2,4% pa) follows closely that of the EU-15.

Table 169: Evolution of GDP in EU-25, 1990 to 2030 (Source: Eurostat. Economic and Financial Affairs DG. PRIMES. ACE

	000 MEuro'oo					Annual growth rate				
	1990	2000	2010	2020	2030	90/00	00/10	okt/20	20/30	**00/30**
EU-15	6982	8545	10859	13641	16920	2,04	2,43	2,31	2,18	**2,3**
ACC	333	394	574	821	1100	1,7	3,82	3,64	2,97	**3,48**
EU-25	**7315**	**8939**	**11433**	**14462**	**18020**	**2,03**	**2,49**	**2,38**	**2,22**	**2,36**

The slowdown in economic growth for ACC between 1990 and 2000 (+1,7% pa compared to +2,0% pa for the EU-15) largely reflects the major reforms of political and economic structures that Central and Eastern European countries (CEEC) have experienced since the early 1990s. These included: industrial restructuring and privatization; establishment of viable legal structures and regulatory systems; reform of capital markets and trade policies, etc.; which in turn induced a deep recession between 1990 and 1993 in all countries except Poland.

The GDP projections for EU-25 Member States are based on Economic and Financial Affairs DG Forecasts of April 2002 for the short term (2001-2003); and on macroeconomic forecasts from WEFA[60], adjusted to reflect recent developments, for the horizon to 2030. Furthermore the results of the GEM-E3[61] model were used for current EU-15 Member States but the model is not yet available for the acceding countries.

[59] The validity of GDP estimates based on market exchange rates for Central and Eastern European countries is under debate as they generally underestimate the level of GDP. If GDP expressed in purchasing power standards is used, the contribution of ACC economies in EU-25 GDP would reach 8,1% of EU-25 economic activity in 2000.

[60] WEFA (now integrated into DRI-WEFA) is an economic consultancy company which, in the context of the Long Run Energy Modelling framework contract, was subcontracted by NTUA to deliver a consistent macro-economic and sectoral forecast over the horizon to 2020 for the EU Member States and, at a more aggregate level, for candidate countries and EU neighbouring countries (Norway and Switzerland). This projection was delivered in March 2001 and has been used as a benchmark in the context of the EC DG TREN – EU Energy and Transport Trends to 2030 study.

[61] The GEM-E3 model has been constructed under the co-ordination of NTUA within collaborative projects supported by Research DG involving CES-KULeuven and ZEW.

Economic growth is not uniformly distributed across countries, but the convergence of Member States' economies (including ACC) is assumed to continue over the projection period. Furthermore, the integration of ACC into the European Union is assumed to generate accelerated growth for their economies.

However, the convergence of ACC economies towards EU-15 levels remain far from complete even by 2030 (see table underneath). Despite much faster growth of per capita income projected in ACC then in EU-15 (+3,7% pa in 2000-2030 compared to +2,2% pa), per capita GDP in ACC (expressed in purchasing power standards) amounts to 69,3% of the corresponding EU-15 figure in 2030 (compared, however, to only 44,5% in 2000).

Table 170: Per capita GDP in EU-25 (Source: Eurostat. Economic and Financial Affairs DG. PRIMES. ACE)

	MEuro'oo					**Annual growth rate**				
	1990	2000	2010	2020	2030	90/00	00/10	okt/20	20/30	**00/30**
EU-15	19076	22565	28000	34937	43494	1,69	2,18	2,24	2,21	**2,21**
ACC	8663	10048	14912	21787	30144	1,49	4,03	3,86	3,3	**3,73**
EU-25	**17303**	**20502**	**25917**	**32898**	**41479**	**1,71**	**2,37**	**2,41**	**2,34**	**2,38**

ANNEX P: STAKEHOLDERS' LIST

CompanyName	First name	Last name	Participant on 18/12/06 meeting	Country	Type company	Inter or national	Interest lamp	Interest luminaire	Interest control gear	Interest streetl	Interest officel
N. Copernicus Observatory and Planetarium in Brno and Int. Dark Sky Assoc., Czech Section	Jan	Hollan	yes	Czech Republic		national	lamp	luminaire	control gear	street lighting	office lighting
	Tachibana	Hirokazu		Japan	Large company	national	lamp			street lighting	office lighting
ABB	Gianluca	Donato		Italy	Large company		lamp	luminaire	control gear	street lighting	office lighting
AIDI	Paolo	Soardo	yes	Italy		national	lamp	luminaire	control gear	street lighting	office lighting
AIE	Evelyne	Schellekens		Belgium	SME	international			control gear	street lighting	office lighting
Arcelor	Sigrid	Jacobs		Belgium	Large company	international		luminaire		street lighting	office lighting
ARTEMIDE MEGALIT	Bernard	Chevalier		France	Large company		lamp	luminaire	control gear		office lighting
ASSIL / ANIE	Fabio	Pagano		Italy		national	lamp	luminaire	control gear	street lighting	office lighting
Austrian Association of Electricity Companies (VEÖ)	Karl	Pitel		Austria		national	lamp	luminaire	control gear	street lighting	office lighting
Austrian Standards Institute	Monika	Hartl		Austria		national	lamp	luminaire		street lighting	office lighting
AustrianEnergyAgency	Thomas	Barth		Austria		national	lamp	luminaire		street lighting	office lighting
BEGHELLI SPA	Fabio	Pedrazzi		Italy	Large company			luminaire			office lighting
BIO Intelligence Service S.A.S.	Shailendra	Mudgal		France							
Boockmann GmbH	Kai	Boockmann		Germany	SME	international			control gear		
BRE Environment	Hilary	Graves		United Kingdom	Large company		lamp	luminaire	control gear	street lighting	office lighting
CELMA	Stéphanie	Mittelham		Belgium		international		luminaire	control gear	street lighting	office lighting
Centre Design Est-France	Edith	Nanty	yes	France	SME	national	lamp	luminaire	control gear	street lighting	office lighting
CieloBuio	Fabio	Falchi		Italy		national	lamp	luminaire		street lighting	
Danish Energy Authority	Peter	Nielsen		Denmark		national					
Danish Environmental Protection Agency	Janus	Lorentz-		Denmark							

		Petersen									
Danish Illuminating Engineering Society	Kenneth	Munck		Denmark	SME	national	lamp	luminaire	control gear	street lighting	office lighting
DISANO ILLUMINAZIONE SPA	Lorenzo	Franchi		Italy	Large company	international		luminaire		street lighting	office lighting
DKI Deutsches Kupferinstitut Berufsverband	Stefan	Fassbinder		Germany		national			control gear	street lighting	office lighting
Eamonn Bates Europe	Feodora	von Franz		Belgium	SME		lamp	luminaire	control gear	street lighting	office lighting
Eden Energy	Hugues	Dailliez		France		national	lamp	luminaire	control gear	street lighting	office lighting
ELC Federation	Gerald	Strickland		Belgium		international	lamp			street lighting	office lighting
Electricity of France	Odile	Le Cann		France	Large company	national	lamp	luminaire	control gear	street lighting	office lighting
ENDS Europe	Sonja	van Renssen		Belgium	Large company	international				street lighting	office lighting
Energy piano	Casper	Kofod		Denmark	SME	national	lamp	luminaire	control gear	street lighting	office lighting
Environment and Development Foundation	Albert	Chen		Taiwan	SME	national	lamp	luminaire	control gear	street lighting	office lighting
Especialidades Luminotecnicas S.A.	Marco Antonio	Lahoz Pfeiffer		Spain	Large company				control gear	street lighting	office lighting
Essexnexans	Leonard	Danel		France	Large company				control gear	street lighting	office lighting
ETAP NV	Luc	Truyen		Belgium	SME		lamp	luminaire	control gear		office lighting
ETAP NV	Ronny	Verbeeck		Belgium	Large company	national	lamp	luminaire	control gear	street lighting	office lighting
EuP network Germany	Dirk	Jepsen		Germany						street lighting	office lighting
Eurofer	Clare	Broadbent		Belgium		international					
European Commission	Andras	Toth		Belgium		international	lamp	luminaire	control gear	street lighting	office lighting
European Copper Institute	Hans	De Keulenaer	yes	Belgium		international				street lighting	office lighting
European Copper Institute	Sergio	Ferreira		Belgium		international	lamp	luminaire		street lighting	office lighting
European Lamp Companies Federation	Jarita	Christie		Belgium		international	lamp				
Eutema Technology Management GmbH	Erich	Prem		Austria	SME		lamp	luminaire	control gear	street lighting	office lighting
Federale Raad voor Duurzame Ontwikkelling	Stefanie	Hugelier	yes	Belgium		national	lamp	luminaire	control gear	street lighting	office lighting
Finnish Environment Institute	Ari	Nissinen		Finland		national				street lighting	office lighting
Foresite Systems	Rupert	Foxall		United Kingdom	SME	international	lamp	luminaire	control gear	street lighting	office lighting

FOTISTIKI SA	Pakis	Sotiropoulos		Greece	SME					street lighting	office lighting
Foundation of taiwan Industry service	Lin	Yei	yes	Taiwan	Large company	national					
Fraunhofer IZM	Karsten	Schischke		Germany		national	lamp	luminaire	control gear	street lighting	office lighting
Future Electronics	Mauro	Ceresa		Italy	Large company	international	lamp	luminaire	control gear	street lighting	office lighting
German Energy Agency	Tobias	Marsen		Germany		national	lamp	luminaire	control gear	street lighting	office lighting
Groen Licht Vlaanderen	Catherine	Lootens		Belgium	SME	national	lamp	luminaire	control gear	street lighting	office lighting
Helvar	Max	Björkgren		Finland	Large company	international			control gear	street lighting	office lighting
Helvar	Leena	Tähkämö		Finland	SME	international	lamp	luminaire		street lighting	office lighting
Idman Oy	Riikka	Lahdenperä		Finland	SME		lamp	luminaire	control gear	street lighting	office lighting
Illuminating Engineering Society of Finland	Heikki	Härkönen		Finland		national	lamp	luminaire	control gear	street lighting	office lighting
IMQ SpA	Paolo	Gianoglio		Italy	Large company		lamp	luminaire	control gear	street lighting	office lighting
INDAL	Federico	Arias		Spain	Large company	international	lamp	luminaire	control gear	street lighting	office lighting
Industria b.v.	Nic	van Koningsbruggen		Netherlands	Large company		lamp	luminaire	control gear	street lighting	
Industrias Ventura S.L.	Rafael	del Aguila Alvarez		Spain	SME			luminaire	control gear		
Industry Technology Research Insittute	Nick, Tzu-Yar	Liu		Taiwan		national	lamp				office lighting
Industry Technology Research Insittute	George, Shin-Ru	Tang		Taiwan		national	lamp				office lighting
Infineon Technologies	Werner	Ludorf		Germany	Large company		lamp	luminaire	control gear	street lighting	office lighting
Infineon Technologies AG	Manfred	Schlenk		Germany	Large company	international	lamp	luminaire	control gear	street lighting	office lighting
International CFL Harmonisation Initiative	Stuart	Jeffcott		United Kingdom							
International Dark-Sky Association Europe	Friedel	Pas		Belgium		international				street lighting	
IREM SpA	Marco	Ugo	yes	Italy	SME					street lighting	
ISGR	Hisao	Nakashima		Japan	SME	national				street lighting	office lighting
KERP	Andreas	Schiffleitner		Austria	SME	international	lamp	luminaire	control gear	street lighting	office lighting
KREIOS	Lieven	VANHOOYDONCK		Belgium	SME		lamp	luminaire	control gear	street lighting	office lighting

LABORELEC	Marc	Vanden Bosch		Belgium		international	lamp	luminaire		street lighting	office lighting
LG Electronics	Hee Il	Park		KOREA	Large company	international				street lighting	
Light Consult International	Axel	Stockmar		Germany			lamp	luminaire	control gear	street lighting	office lighting
lisheng	Jeff	Zhu	yes	China	SME	international	lamp			street lighting	office lighting
Lund University	Carl	Dalhammar		Sweden		national	lamp	luminaire	control gear	street lighting	office lighting
Lysteknisk Selskab		Velk		Denmark		national	lamp	luminaire	control gear	street lighting	office lighting
MA 39-VFA	Nikolaus	Thiemann		Austria	Large company	national	lamp	luminaire		street lighting	office lighting
Ministry of Economy, Labour and Entrepreneurship	Hrvoje	Medarac		Croatia		national	lamp	luminaire	control gear	street lighting	office lighting
MUSEUM AM SCHÖLERBERG	Andreas	Hänel		Germany							
NEMA	Craig	Updyke	yes	United States	Large company	national	lamp	luminaire	control gear	street lighting	office lighting
Neonlite	Tony	Yu		China	Large company	international	lamp	luminaire	control gear	street lighting	office lighting
Neonlite Electronic & Lighting (HK) Ltd	Debbie	Tam		China	SME	national	lamp	luminaire	control gear	street lighting	office lighting
Odyssey Energy Limited	Roger	Loveless		New Zealand	SME					street lighting	
Öko-Institut e.V.	Dietlinde	Quack		Germany		national	lamp				office lighting
OSRAM Italy	Jürgen	Diano		Italy	Large company	international	lamp	luminaire	control gear	street lighting	office lighting
Osram S.p.A.	Pietro	Tedesco		Italy	Large company	international	lamp	luminaire	control gear	street lighting	office lighting
Palmstep Electronics Ltd	Jan	Christlieb		Mauritius	Large company	international	lamp	luminaire	control gear		office lighting
Panasonic MEI	Gareth	Rice		Japan	Large company	international	lamp	luminaire		street lighting	office lighting
Philips	Bert	Kenis		Belgium	Large company	international	lamp	luminaire	control gear	street lighting	
Philips AG Lighting	Job	Daams		Switzerland	Large company		lamp	luminaire	control gear	street lighting	office lighting
Philips Lighting	Eddy	CEELEN	yes	Netherlands	Large company	international	lamp	luminaire	control gear	street lighting	office lighting
Philips Lighting	Frank	Altena	yes	Netherlands	Large company		lamp	luminaire	control gear	street lighting	office lighting
Philips Lighting	Robert	Class		Germany	Large company	international		luminaire		street lighting	office lighting
Philips Lighting	Gil	Soto Tolosa		Netherlands	Large company	international	lamp	luminaire	control gear	street lighting	

Philips Lighting BV	Marcel	Jacobs	yes	Netherlands	Large company	international	lamp	luminaire	control gear	street lighting	office lighting
Philips Lighting Turnhout	Dirk	Smeyers		Belgium	Large company	international	lamp	luminaire	control gear	street lighting	
Planning & Architecture	Thomas	Christoffersen		Denmark	Large company	international	lamp	luminaire	control gear	street lighting	office lighting
PlesTech	Graham	Adams		United Kingdom	SME	international	lamp				
PlesTech Ltd	Graham	Adams		United Kingdom	SME	international	lamp	luminaire	control gear	street lighting	office lighting
Rijkswaterstaat	Bob	Hamel		Netherlands		national		luminaire	control gear	street lighting	
R-Tech	Marc	Gillet		Belgium	Large company		lamp	luminaire	control gear	street lighting	
Schréder Uitrusting	Rob	Verbeelen	yes	Belgium	SME			luminaire			
SenterNovem	Ruud	van Wordragen		Netherlands		national				street lighting	
Siteco	Oliver	Scopes		United Kingdom	Large company		lamp	luminaire	control gear	street lighting	
Siteco Beleuchtungstechnik GmbH	Kai Hendrik	Sabla		Germany	SME	international					office lighting
Siteco Beleuchtungstechnik GmbH	Bernhard	Schroll		Germany	SME	international		luminaire		street lighting	office lighting
SLI	Christian	Brehm		Germany	Large company	international	lamp	luminaire	control gear	street lighting	office lighting
SLI Sylvania	Rudy	Geens		Belgium	Large company	international	lamp	luminaire	control gear	street lighting	Office lighting
SLI Sylvania	Wannong	Eckhardt		Germany	Large company	international	lamp	luminaire	control gear	street lighting	Office lighting
STU FEI Bratislava	Dionyz	Gasparovsky		Slovakia		national				street lighting	Office lighting
Sylvania	Nicole	Loysch		Belgium	Large company	international	lamp				
Syndicat Eclairage	Jacques	VILLAT	yes	France	SME	national	lamp	luminaire	control gear	street lighting	Office lighting
Technical University Iasi	Dorin	LUCACHE		Romania	SME	international	lamp	luminaire		street lighting	Office lighting
Technology Industries of Finland	Carina	Wiik		Finland		national		luminaire	control gear	street lighting	Office lighting
The Centre	Jacek	Truszczynski		Belgium	SME		lamp	luminaire	control gear	street lighting	Office lighting
The Danish Electricity Saving Trust	Poul Erik	Pedersen		Denmark							
The Lighting Association	Keven	Kearney		United Kingdom		national	lamp	luminaire	control gear	street lighting	Office lighting
Thorn Lighting Ltd	Lou	Bedocs	yes	United Kingdom	Large company	international	lamp	luminaire	control gear	street lighting	Office lighting
Thorn Lighting Ltd	Peter	Thorns		United	Large		lamp	luminaire	control	street	Office

				Kingdom	company				gear	lighting	lighting
TridonicAtco GmbH & Co KG	Roy	Vageskar		Austria	Large company	international			control gear		
Troyes University of Technology	Fabrice	Mathieux		France		national	lamp	luminaire	control gear	street lighting	Office lighting
Tungsram-Schréder Zrt	Péter	Schwarcz		Hungary	SME	international		luminaire		street lighting	
TUV	Gary	Hu		China		international	lamp	luminaire			Office lighting
TUV Rheinland	Adams	Liu		China	Large company	international	lamp	luminaire	control gear	street lighting	Office lighting
TWI Ltd	David	Calder		United Kingdom		international	lamp	luminaire	control gear	street lighting	Office lighting
UK Market Transformation Programme	Hilary	Graves		United Kingdom		national	lamp	luminaire	control gear	street lighting	Office lighting
University of technilogy of troyes	Alexandre	Diepdalle		France		national	lamp	luminaire		street lighting	
VITO	Paul	Van Tichelen		Belgium							
VITO	Theo	Daems		Belgium							
VITO	Veronique	Van Hoof		Belgium		national				street lighting	Office lighting
VITO	Dries	Maes		Belgium	Large company	international					
VITO	Bart	Jansen		Belgium		national	lamp	luminaire	control gear	street lighting	Office lighting
WTCB - CSTC	Arnaud	Deneyer	yes	Belgium	SME	national	lamp	luminaire	control gear		Office lighting
Zumtobel Lighting	Peter	Dehoff		Austria	Large company		lamp	luminaire	control gear		Office lighting
ZVEI	Ralf	Wershoven		Germany		national		luminaire		street lighting	Office lighting