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Preparatory Studies for Eco-design Requirements of EuPs

Lot 19: Domestic lighting - Part 2
Directional lamps and household luminaires
Interim Task Report
Task 8: SCENARIO- POLICY- IMPACT- and SENSITIVITY ANALYSIS

Study for European Commission DGTREN unit D3, contact: Andras Toth

Contractor:

Project performed in cooperation with:

Contact VITO: Paul Van Tichelen, info@eup4light.net

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Project team

VITO:
Paul Van Tichelen
An Vercalsteren
Bio Intelligence Service:
Shailendra Mudgal
Benoît Tinetti
Alexander Thornton
Energy Piano:
Casper Kofod
Kreios:
Lieven Vanhooydonck

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0 PREFACE

VITO and its partners are performing the preparatory study for the new upcoming eco-design directive for Energy Using Products (EuP) related to domestic lighting, on behalf of the European Commission (more info http://ec.europa.eu/enterprise/eco_design/index_en.htm).

The environmental impacts of Energy-using Products such as domestic lighting take various forms, including: energy consumption and the related negative contribution to climate change, consumption of materials and natural resources, waste generation and release of hazardous substances. Eco-design, which means the integration of environmental considerations at the design phase, is arguably the best way to improve the environmental performance of products.

The creation of a coherent framework for environmental product policy avoids the adoption of uncoordinated measures that could lead to an overall negative result; for example eliminating a toxic substance from a product, such as mercury from lamps, might lead to increased energy consumption, which could in total have a negative impact on the environment. A Community framework also ensures that divergent national or regional measures, which could hinder the free movement of products and reduce the competitiveness of businesses, are not taken. It is not the intention to decrease the quality of domestic lighting.

You can follow the progress of our study and find general information related to lot 19 on the project website when you register as stakeholder: http://www.eup4light.net
Please, also consult the website for timing and organisation of the tasks.

Important remark:
It must be clearly stated that this part 2 of the study relies on the draft regulation resulting from part 1 of the study on non-directional light sources. Specific items on non directional lamps that were discussed in part 1 will not be repeated in this part 2. Items that are related to all light sources can be repeated, only to improve the readability.

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8 SCENARIO- POLICY- IMPACT- AND SENSITIVITY ANALYSIS

Important remark: This preliminary chapter 8 discusses part 2 of the study concerning directional light sources and household luminaires.

Scope: This chapter summarizes and totals the outcomes of all previous tasks. It looks at suitable policy means to achieve the improvement potential e.g. implementing LLCC as a minimum and BAT as a promotional target, using legislative or voluntary agreements, labelling and promotion. It draws up scenarios 2007 – 2020 quantifying the improvements that can be achieved vs. Business-as-Usual. It makes an estimate of the impact on consumers and industry as explicitly described in Annex 2 of the Directive.
Finally, in a sensitivity analysis of the main parameters the robustness of the outcomes is studied.

It has to be kept in mind that the conclusions represent solely the point of view of the consortium and they do not reflect the opinion of the European Commission in any way. Unlike chapters 1-7, which will serve as the baseline data for the future work (impact assessment, further discussions in the EuP Consultation Forum, and development of implementing measures, if any) conducted by the European Commission, the chapter 8 simply serves as a summary of policy implications as seen by the consortium. Further, some elements of this chapter may be analysed again in a greater depth during the impact assessment.

8.1 Policy- and scenario analysis

8.1.1 Eco-design requirements

In this chapter generic and specific product related eco-design requirements are described that can be used as suitable policy means to achieve BAT or LLCC scenario targets.
Please note that there was also a part 1 in this study concerning non directional light sources and there are also finalised preparatory studies on 'street' (lot 9) and 'office' (lot 8) lighting that include mainly topics related to HID lamps and fluorescent lamps with non integrated ballasts.
For these products the EC already adopted regulations: Commission Regulation (EC) No 244/2009 with regard to ecodesign requirements for non-directional household lamps and No 245/2009 with regard to ecodesign requirements for for fluorescent lamps without integrated ballast, for high intensity discharge lamps, and for ballasts and luminaires able to operate such lamps.
As domestic lighting products represent the baseline in terms of energy efficiency and performance, the measures that are suggested in this study (lot 19) are recommended for any

lamp type or light source regardless of technology. Other ecodesign implementing measures are or will be formulating higher requirements on particular technologies that are used in other sectors than domestic lighting.
Because even the domestic lighting products examined in this study can be used in many other general lighting applications, the proposed measures hereafter obviously have a wider scope. Therefore, it is important to assess the potential negative impact beyond the domestic lighting sector (see 8.2).

8.1.1.1 Scope of proposed Eco-design requirements

For this study the impact is calculated in relationship to all installed lamps that were within the defined scope in chapter 1.
However, when the final legislation has to be developed the definition of the scope should be done more carefully.
Negative impact should be avoided for particular lamps or luminaires for other applications compared to this study. For more information on impact consult section 8.2. Please note that complementary to this study the EC will organise a consultation forum prior to voting on any regulation and will conduct a more detailed impact analysis, see links on the project website for further information on this process. Apart from impact it is needed to create a synergy with other legislation, in particular already adopted EC regulation (244/2009, 245/2009) within the Eco-design Directive 2005/32/EC and the labelling Directive 98/11/EC,

Some recommendations on the scope of potential regulation are:

- In many cases it is impossible to distinguish, at the 'placing on the market' stage, lamps and luminaires that are intended for 'domestic' lighting from other indoor lighting applications as in restaurants, hotels, etc. It is therefore recommended to define a broader scope for lamps and luminaires within the specific eco-design requirements;
- For luminaires with built-in LEDs or LED modules it is not recommended to impose minimum efficacy requirements, this would create a high development cost for the many SMEs developing these luminaires and hamper market introduction of this promising new technology. Moreover, this LED technology changes frequently in performance and would require many remeasurements. However it is recommended that the luminaire construction files contain the documentation of the LED manufacturer that proofs that the LED component or LED module satisfies the efficacy requirements. This exception needs to be evaluated again after a period of 4 years when the technology is expected to be more mature. The above proposed exemptions for LED lighting products should only be applicable for products that do not make any claim on equivalence to lighting products within the scope, to avoid false claims on performance;
- It will be needed to define a clear borderline between luminaires intended for application in the tertiary sector and those used in general domestic lighting applications. Lamps, luminaires and ballasts for office lighting can also be used in certain domestic applications but they were already discussed in the dedicated preparatory study on office lighting (lot 8), and thus will not be considered again. Street and office lighting products have other needs for the provision of information, see preparatory study on lot 8 and lot 9. In order to distinguish these products, it is recommended to exclude certain light sources, e.g. by light source (above 2000 lumen)

or by lamp type (HID and LFL lamps). It is also proposed to distinguish luminaires for ‘Functional illumination in the tertiary sector’(lot 8&9) and those for general lighting (lot 19);

- The definition of scope for the lamps should be similar to EC regulation 244/2009 on household lamps but for and DLS (Directional Light Sources), in particular lamps that don’t satisfy the 'White light source' criterion (see Commission Regulation (EC) No 244/2009);
- Lamps with less than 120 lumen in a solid angle of π sr if they do not make any claims to lamps within the scope;
- A ‘domestic luminaire’ can be defined as any luminaire that can host the lamps within the scope of this study.

8.1.1.2 Generic Eco-design requirements on the supply of information for lamps (even when sold integrated into the luminaire or in the same package as the luminaire)

Optimal use of domestic lighting starts with adequate information on existing products. Therefore, it is proposed that the manufacturers provide information on the following 'most relevant' eco-design parameters and follow the proposals for the appropriate means for communicating these parameters to the consumer. The provision of information on these 'most relevant' parameters should satisfy article 15.4 (f) to reduce unnecessary administrative burden and allow verifying compliance with proposed specific implementing measures.

Information available to the end-users at the moment of purchase and on free access websites for any white light source (Annex 11.1.1) within the scope of this study:

For directional lamps (even when sold in or in the same package as the luminaire):

a) When the nominal lamp power is displayed outside the energy label in accordance with Directive 98/11/EC, the nominal luminous flux (see requirements below) of the lamp shall also be separately displayed in a font at least twice as large as the nominal lamp power display outside the label.
b) For halogen lamps or LED retrofit lamps the nominal luminous flux in a 90° cone of the lamp shall also be displayed separately in a font at least twice as large as the nominal lamp power display outside the label (the nominal luminous flux shall never be higher than the rated luminous flux);
c) For CFLi-DLS lamps claimed to be retrofit lamps to halogen lamps, the nominal luminous flux in a 90° cone of the lamp shall also be displayed separately in a font at least twice as large as the nominal lamp power display outside the label (the nominal luminous flux shall never be higher than the rated luminous flux);
d) For CFLi-DLS lamps that make no claim to retrofit halogen lamps, the nominal luminous flux in a solid angle of π sr or a 120° cone of the lamp shall also be displayed separately in a font at least twice as large as the nominal lamp power display outside the label and the the nominal luminous flux in a 90° cone *(the nominal luminous flux shall never be higher than the rated luminous flux)*;
e) Nominal life time of the lamp in hours and for LED retrofit lamps both L70F50 and L85F10 as defined in Chapter 1 Section 1.1.3.1 *(not higher than the rated life time)*;
f) Number of switching cycles before premature lamp failure;

g) Colour temperature (also expressed as a value in K);
h) Colour rendering (also expressed as a value R_a). Only $R_a = 100$ can be shown as excellent or perfect, only $R_a \geq 90$ can be shown as very good or improved, and $R_a < 80$ must be shown as poor;
i) Warm-up time up to 80% of the full light output *(may be indicated as "instant full light" if less than 1 second)*;
j) A warning if the lamp cannot be dimmed or can be dimmed only on specific dimmers;
k) If designed for optimal use in non-standard conditions (such as ambient temperature $T_a \neq$ 25 °C), information on those conditions;
l) Lamp dimensions in millimetres (length and diameter);
m) Beam angle;
n) Optional (not obligatory): If equivalence with a standard GLS- or halogen reflector lamp is claimed, a uniform method shall be used that is agreed with the sector federation (needs to be elaborated in consultation with the sector).

The term "energy saving reflector lamp":
This can only be provided if the lamp meets the equivalent Tier 3 (2016) lamp efficacy requirements.

Information to be made publicly available on free-access websites:

The information shall also be expressed as values.
a) The information specified above in points a-n;
b) Rated wattage (0.1 W precision);
c) Rated luminous flux in 90°, 120°(or solid angle π sr) and 180° cone;
d) Rated lamp life time (from Stage 2 if lifetime > 2000 h);
e) Lamp power factor;
f) Lumen maintenance factor at the end of the nominal life
g) Starting time (seconds);

If the lamp contains mercury:
i) Lamp mercury content as X,X mg;
j) Instructions on how to clean up the lamp debris in case of accidental lamp breakage.

Proposed timing for this measure:

As soon as possible.
Please note that the introduction of an energy label is also recommended (see section 8.1.4.1).

8.1.1.3 Generic Eco-design requirements on the supply of information for domestic luminaires sold for general lighting

The user should be informed with the product purchase about application related issues that have an important influence on energy consumption; they are:
- Warn consumers to avoid the use of spotlights for general illumination;
- Provide information on luminaire cleaning when diffusers, reflectors and/or dimmers are applied;

- Avoid continuous dimming with halogen lamps and change if possible to lower lamp power. This avoids lamp blackening with permanent efficacy decrease, moreover dimming also reduces efficacy;
- Do not put further shades on the products to reduce the light emission (it is possible to use those, if any, provided by the manufacturer and already evaluated;
- Warn users that indirect lighting is only beneficial with bright walls/ceiling;
- Warn users that indirect lighting needs an appropriated distance from the ceiling/walls, not too far but also not too close;
- Inform users about the light distribution for spot lights, e.g. beam angle;
- Warn the users for outdoor luminaires that have a high upward light flux (ULOR). This might create a high spilling of light and moreover it creates light pollution;

It is recommende to agree on a uniform method with the sector federation.

8.1.1.4 Specific eco-design requirements for reducing losses in the electrical distribution grid due to a poor power factor

See part 1, however for reasons explained in chapter 3 it is proposed to excempt LED modules or lamps below 6 Watt.

8.1.1.5 Specific ecodesign requirement for increasing lamp efficacy

The proposed ecodesign requirement are intended to set minimum efficacy level (ηlamp) for all lamps as a horizontal entry requirement for all lamps to the EU market, independent of technology and application as far as possible.

For evaluation of the efficacy, it is proposed to use a similar approach as Commission Regulation (EC) No 244/2009 that uses a formula imposing a maximum rated system power Pmax [W] for a given rated luminous flux (Φ) [lm]:

$$‘P_{max\ system} = Y * (0{,}88\sqrt{\Phi}+0{,}049\Phi)’$$

wherein Y is a constant depending on the label (see Table 8.18).
This formula is related to the lamp labelling directive[1] but that directive is currently not applied neither to reflector lamps nor to (safety) extra low voltage (ELV/SELV) lamps, see section 8.1.4.1.
For reflector lamps, it is proposed to use the rated functional lumen in a cone of 90° ($\Phi_{90°}$) (see chapter 1).
For CFLi-DLS lamps, HIDi-R or LED modules or luminaires that make no claim to retrofit halogen lamps the nominal luminous flux in a solid angle of π sr or 120° cone can be used($\Phi_{120°}$) for some applications a.o when used as a downlighter.

In a reflector lamp, there is always lumen loss due to the reflector; a typical LOR for a good reflector lamp, compared to a non reflector lamp can be considered as 0.8. To make a good evaluation for the labelling of a reflector lamp with the same formula as a non-reflector lamp, the rated luminous flux in the 90° cone shall be corrected by multiplying it by 1.25; this

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

correction also reflects the opinion of representative stakeholders. Hence the formula of regulation 244 (2009) for reflector lamps should be corrected to:

$$\mathbf{P_{max\ system} = Y * (0{,}88\sqrt{\Phi_R}+0{,}049\Phi_R)}$$

wherein

$$\mathbf{\Phi_R = \Phi_{90^\circ}\ x\ 1{,}25\ or\ \ \Phi_R = \Phi_{120^\circ}\ x\ 1{,}25}$$

In order to reduce negative impact on manufacturers and distributors (see section 8.2) it is recommended to apply a tiered approach that is included in the section with the scenarios (see 8.1.2). This will enable them to reorganise.

To reduce mercury by unneeded application of CFLi-DLS or HIDi-R lamps it was assumed in scenarios (section 8.1.2) to require a minimum label B+ lamp efficacy equivalent (see section 8.1.1.5).

The reason and the proposed corrections factors on the minima are displayed in Table 8.1. Please note that these correction factors are cumulative.

Table 8.1: Proposed correction factors for the minimum criteria on label values

Correction factors	
Scope of the correction	**Maximum rated power (W)**
CFLi lamp with colour rendering index ≥ 90	P_{max} / 0.85
CFLi lamp with colour rendering index ≥ 90 and Tc >=5000K	P_{max} / 0.75
(Safe) Extra Low Voltage (ELV/SELV) lamps requiring external power supply for mains connections excluding light emitting diode.	P_{max} / 1.06
Light emitting diode requiring external power supply	P_{max} / 1.1

Some lamp caps are nowadays frequently used in general illumination but have no energy efficient alternative with an efficacy level equivalent to label B or A (see section 8.1.4.1). It is connected to the so-called luminaire lock-in effect (see 8.1.1.7). Phasing out these lamps would repeal retrofit lamps from the market for existing luminaires. Therefore in certain scenarios it is proposed to phase out these luminaires first and to introduce special luminaire requirements (see 8.1.1.7) for the time being (see section 8.1.2). It is also possible to announce this phase out and allow people to stock sufficient retrofit lamps for existing luminaires (see 8.1.4.2). The concerned lamp types are:

Lamp type	**Lamp cap**	**Lamp power [W]**	**Minimum label**
Halogen mains voltage (HL-MV-R)	GU10	< 55	D

Please note that for CFLi-DLS or HIDi-R lamps the minimum label can be set to B+ while for other DLS lamps it is only B (see section 8.1.4.1).

8.1.1.6 Specific ecodesign requirements for minimum lamp performance

These should be similar to Commission Regulation (EC) No 244/2009 for part 1 and completed for DLS&NDLS retrofit LED lamps (see Table 8.2).

Different sources describe quality requirements of importance for the consumer when buying LED lamps, modules and luminaires:

- ENERGY STAR;
- LBNL reports;
- IEC/PAS 62612 Ed.1 "Performance requirements for Self-ballasted LED lamps" giving a complete survey of relevant parameters;
- CIE 127:2007 standard addressing individual LEDs.

From a consumer perspective, the most important LED quality factors referred are:

1. Lumens rated output best for the LED luminaire or the LED lamp (data for the LED chip is irrelevant). Requirements to the manufactures could be measurement of total luminous flux e.g. by use of goniometer in order to characterize the light-distribution pattern;
2. Requirements to minimum lamp efficacy in lumens/W;
3. Lifetime in hours for the LED luminaire or lamp (not for the LED chip alone);
4. Lamp efficacy as a function of time. A high-quality LED can maintain high lighting levels for tens of thousands of hours, while the output of low quality products declines more rapidly. Long-term measurements require 12+ months so it is important to find a short-term approach for measuring;
5. Requirement to how fast the light should come on instantly when turned on;
6. Colour: CCT (Correlated Colour Temperature) and CRI (Colour Rendering Index);
7. Glare: Measurement of the intensity of light from the source itself. This is important given the small size of LED lights and their corresponding brightness, which can cause discomfort glare as well as injury if users look directly into the light. A very recent test reports glare varied by a factor 1.4 and that it was above the acceptable threshold in most cases. Anyhow, glare will not be greater than with "traditional" DLS. Limiting glare (UGR) values are specified for many commercial applications;
8. Information about if the lamp is available with dimming, automatic daylight shut-off and/or motion sensors (especially important for outdoor models);
9. Requirement to stroboscope effect and flicker. Power supplies using pulse-width modulation makes the LED blink/flicker with a certain frequency (typically between 100 and 150 Hz). The flicker frequency is not directly visible but may lead to: a) Stroboscopic effects on rotating objects (making it look like it is not moving or like it rotates at another speed or direction). b) “Cascades” of bright points in the visual field when moving the visual direction rapidly ie. when turning the head;
10. Minimum warranty in years.

LED lamp requirement are needed in order to avoid poor market introduction due to bad consumer experience, similar to CFLi see also chapter 3. As a first step it is recommended to introduce minimum requirements (Table 8.2 and Table 8.3) for retrofit LED lamps both for NDLS&DLS. Therefore it is necessary to complete also the Commission Regulation (EC) No 244/2009 for NDLS. The minimum requirements should include the most important of the ten

factors mentioned above while other or more strong requirements could be the subject of a new European quality label.

Table 8.2: Staged performance requirements for retrofit LED lamps (DLS&NDLS)

Performance parameter	**Tier 1**	**Tier 2**	**Tier 3**	**Benchmark**
Minimum rated lamp lifetime for $L_{70}F_{50}$	≥10000 h	≥10000 h	≥10000 h	≥30000 h
Number of switching cycles (IEC 62612 Ed1)	>5000 (30 sec on/off)	>10000 (30 sec on/off)	>20000 (30 sec on/off)	>100000 (30 sec on/off)
Premature failure rate for $L_{85}F_{05}$	≥100h	≥100h	≥200h	≥200h

For any LED lamp that explicitely refer to being a 'halogen or GLS retrofit lamp' additional colour rendering (CRI) and colour temperature requirements are recommended (see Table 8.3).

Table 8.3: Extra requirements for LED lamps claiming equivalence to halogen or GLS lamp

Performance parameter	**Tier 1**	**Tier 2**	**Tier 3**	**Benchmark**
Minimum CRI	80	80	80	90
Maximum CCT	3200	3200	3200	2700-2900

For HIDi-R lamps, similar requirements can be recommended as in the tertiary lighting sector for Metal-Halide lamps (see Table 8.4).

Table 8.4: Staged requirements for HIDi-R lamps (retrofit GLS-R-HW and HL-MV-R-HW)

Performance parameter	**Tier 1**	**Tier 2**	**Tier 3**	**Benchmark**
Minimum rated lamp lifetime (LSF>0.5)	≥8000 h	≥10000 h	≥12000 h	≥16000 h
Minimum lamp lumen maintenance (LLMF)	>0.6	>0.7	>0.8	>0.85
Minimum CRI	≥80	>80	>85	≥90

8.1.1.7 Specific ecodesign requirements for household luminaires

Requirements for any general illumination luminaire that is unable to host a lamp equivalent to at least label B

It is recommended to prohibit that these lamps are placed together with the luminaires on the market (coupled sales).

Requirements for any luminaire with socket R7s or Rx7s:

The sales of all luminaires with holders R7s or FA4 without an incorporated presence detector and that are not at least IP 44 should be prohibited, see also section 8.1.1.6.
Also all luminaires with Rx7s can only be brought on the market if they have a build-in ballast.
Timing: ASAP

Requirements for any luminaire with socket G9/GU9:

It is proposed to prohibit the sales of these luminares, because there is no expected efficient retrofit (the lamp is too small for LED retrofit lamps).
Timing: ASAP

Proposed requirements for all household luminaires :

If the luminaire does not incorporate dimming or intelligent controls, it shall not consume any power when the operated lamps do not emit any light in normal operating conditions.

Unless the luminaire has IP44 or stronger protection, the incorporated halogen converter efficiency shall be at least 85 %.

8.1.1.8 Generic ecodesign requirements for luminaires

It is recommended that for any general illumination luminaire a simplified design rule check is performed by the luminaire designer and included in the technical construction file of the luminaire. This part of the technical construction file should be available for all users of the luminaire and market surveillance.

The follow items should be checked and in case of not choosing the most efficient solution the deviation should be motivated in the technical construction file (for details consult chapter 6):

- Luminaire should be designed to host the most efficient lamps, therefore:
  - Design luminaires that create a positive lock-in effect into efficient lighting by using CFLni lamps or ultra-efficient LED modules;
  - Use coloured LEDs to create coloured light instead of filters;
  - Design luminaires with appropriate and efficient control electronics:
  - Design luminaires that incorporate or are compatible with dimmers;
  - Design Luminaires with incorporated motion sensors where appropriate;
  - Design outdoor luminaires with incorporated day/night sensors;
  - Eliminate standby losses when power supplies are incorporated in luminaires;
  - Use electronic gears instead of magnetic (conventional) low voltage halogen;
- Options to increase the optical efficiency of luminaires:
  - Use material with increased light transmittance for visible parts that are transparent / translucent;
  - Use materials with increased reflectance for invisible parts that are not transparent/translucid;

- Alternatively luminaires can be designed with a high LOR or LER (for LED luminaires);

It is also recommended to agree with the sector federation on an uniform reporting method.

Proposed timing:
As soon as possible

8.1.2 Scenario analysis

Different policy scenarios 2007-2020 are drawn up to illustrate quantitatively the improvements that can be achieved through the replacement of the base-cases with lamps with higher energy efficiency at EU level by 2020 versus a business-as-usual scenario (reference scenario).

The five scenarios listed below have been analysed in order to provide an assessment of various alternative policy options as close as possible within the limits of the model of this study:

- Business-as-Usual (BAU)
- Best Available Technology with lock in (slow)
- Best Available Technology with lock in (fast)
- Best Available Technology without lock in
- Best Not Yet Available Technology

These scenarios are presented and analysed in the following sections. For each of them, results are presented for each year between 2007 and 2020 per lamp technology (i.e. GLS-R, HL-MV-R-HW, HL-MV-R-LW, HL-LV-R, HID-R,and LEDi-R in the last scenario) in terms of stock, sales, electricity consumption (during the use phase), CO_2 emissions[2] (during the use phase), and mercury emissions (due to electricity generation during the use phase and emissions at end-of-life for HID-R and CFLi-R).

Finally, a comparison of scenarios is presented in section 8.1.2.7 as a variation of environmental impacts in reference with the BAU scenario both for the specific year 2020, and for the cumulated total between 2010 (i.e. entry into force of the implementing measure) and 2020.

<u>General remarks</u>:

- **The first Tier for an implementing measure is in 2010 as this was the earliest possible date. In reality, however, a time shift will occur depending on the real timing of implementation measures.**
- **Scenarios are calculated not for the domestic sector only but for all sectors; they are based on the lamp technology and not the end application.**

[2] The emissions factor used is 0.43kg/kWh according to the MEEuP methodology.

- **The scenarios analysis is based on outcomes of chapters 1 to 7, and one has to keep in mind than they are average results based on assumptions (e.g. annual burning hours, wattage, and lamp efficacy).**
- **The model used is a simplification of reality based on 'discrete' base-cases as defined in chapter 5 and connected discrete improvement options as defined in chapter 7. This discrete base-case model approach is reflected in abrupt changes in calculated energy consumption and lamp sales. In reality, this would be smoother due to spreading in lamp wattages, operational hours, new products, and proactive user behaviour (storing phase out lamps, green procurement, promotional campaigns, choice of retrofit options, etc.). These items will be discussed qualitatively in the next sections.**
- **For the scenario without lock in effect, a base-case is replaced with a lamp that also requires luminaire replacement, e.g. the base-case GLS-R E27 with a HL-LV-R GU5.3. Environmental impacts due to the luminaire replacement are not assessed and thus not taken into account in the scenario analysis. Differences in luminaires is considered in the sensitivity analysis.**
- **In some scenarios, a base-case is replaced with a lamp, identified as an improvement option for reducing life cycle cost and environmental impacts, whereas the light quality is not exactly similar, e.g. a GLS-R replaced with a LEDi-R. Therefore, the scenario analysis is done in a quantitative way as the qualitative assessment was already done in previous chapters.**
- **In the tables presenting the scenarios (except for the BAU), minimum requirements (i.e. minimum energy class) are set for each tier. In order to analyse these scenarios, a specific lamp technology is used as replacement lamp, e.g. HL-MV-R-LW xenon replacing the base-case GLS-R in the first tier (2010-2013) for the scenario 'BAT with lock in effect (slow)'. This assumption, based on improvement options identified in chapter 7, does not mean that this technology (HL-MV-R-LW xenon) is the only possible way to meet the requirement.**
- **The tables should be interpreted from the point of view of the defined base-cases and improvement options. For this reason, it was not required to discuss upper or lower lamp lumen limits for future legislation in this section.**
- **Sometimes reference is made to 'labels', this reference is in line to the recommendation for extending the household lamp label to DLS lamps as proposed in section 8.1.4.1. Please note that this label might change in future.**

8.1.2.1 Assumptions used for the scenario analysis

Several assumptions had to be made in order to define scenarios and to assess economic and environmental impacts:

- As the scenario analysis concerned all sectors, annual burning hours used for each base-case are those defined in section 2.2.6: 484 h for GLS-R, 555 h for HL-MV-R-HW, 555 h for HL-MV-R-LW, and 695 h for HL-LV-R. These values were based on a weighted average of sales and annual burning hours for both the "domestic sector" and "other sectors". Please note also that the same annual burning hours were used for the improvement options (see chapter 7) as for the base-case, e.g. even if we replace a

GLS-R with an LEDi-R as an improvement option, the original annual burning hours were used.

- When a lamp with a specific technology is removed from the market, for the year 'n' ('n' being any year after the removal from the market), the stock of this lamp was calculated with the following formula, assuming that the lamp lifetime is X.YZ years:

  *Stock (n) = Stock (n-1) - 0.YZ*Sales (n-1-X) - (1-0.YZ)*Sales (n-X)*

  When the result of this calculation is null or negative, it means that this lamp is no longer operating in the EU-27.

- Mercury emissions to air due to electricity consumption were calculated using the emission factor of 0.016 mg Hg/kWh, as in chapters 5 and 7.

- For HID-R, we assumed that only 20% of lamps are recycled for all years and that the mercury content is 2.5 mg in the base-case.

- Mercury emissions occurring at the end-of-life (EoL) for HID-R sold during the year 'n' were integrated in the calculation of mercury emissions for the year 'n' and not for the year 'n+HID-R lifetime', in order to facilitate the model. This assumption may have an influence when looking at mercury emissions for a specific year, but has a negligible impact when looking at total, cumulative mercury emissions from 2010 to 2020. Therefore, the formula for HID-R is:

  *Mercury emissions (n) = 0.016*Electricity consumption (n) + 80%*2.5*Sales (n),*

  where mercury emissions is in kg, electricity consumption in GWh and sales in million units.
- Sales and stock data (and therefore environmental impacts) are similar for all scenarios (including the BAU) for the years 2007 - 2009, as the entry into force of any legislation is assumed to be in 2010.

8.1.2.2 Calculation principle used for the lamp scenario analysis

The general principle of the environmental analysis for 4 scenarios (excluding the BAU) is that the total annual lumen needed for each base-case (obtained in the BAU scenario) has to be kept constant and is the key parameter in estimating changes in sales when switching from a base-case to its improvement option(s). For a specific year 'n' the annual lumen needed for a base-case A is calculated in the BAU as follow:

$$\text{Annual lumen needed}_A\ (n) = \text{Stock}_A\ (n) \times \text{Annual Burning hours}_A \times \text{Lumen output}_A$$

Therefore, when analysing one of the 4 scenarios, for the year 'n', for the base-case A with its improvement options (i.e. replacement lamps) A_1, A_2, A_3, the following formula was used:

$$\text{Annual lumen needed}_A\ (n) = \text{Annual lumen provided}_A\ (n) + \text{Annual lumen provided}_{A1}\ (n) + \text{Annual lumen provided}_{A2}\ (n) + \text{Annual lumen provided}_{A3}\ (n)$$

And the 'Annual lumen provided$_{Ai}$' for the lamp Ai is computed with the following formula:

$$\text{Annual lumen provided}_{Ai}\ (n) = \text{Stock}_{Ai}\ (n) \times \text{Annual Burning hours}_{Ai} \times \text{Lumen output}_{Ai}$$

Until the base-case A is removed from the market, and therefore not replaced with an improvement option, the following equality has to be verified:

$$\text{Annual lumen needed}_A\ (n) = \text{Annual lumen provided}_A\ (n)$$

When the base-case is replaced with an improvement option (e.g. GLS-R with HL-MV-R-LW xenon) in the year ‘n’, the total amount of annual lumen provided by the GLS-R decreases gradually from the year ‘n’ onwards, until the stock of this specific lamp reaches zero. At the same time, the amount of annual lumen provided by the improvement option HL-MV-R-LW xenon is rising year by year in order to compensate decrease GLS-R sales and to keep the ‘Annual lumen needed$_{GLS-R}$’ constant.

In some scenarios, the replacement of the base-cases GLS-R and HL-MV-R-HW, may lead to an excess lumen output compared to the annual lumen needs of these base-cases in the BAU. This has two main causes: on one hand, this is due to the constant reduction of the ‘Annual lumen needed’ for these base-cases from 2010 to 2020 because the stocks of these lamps is reducing naturally, and on the other hand, the higher lifetime of the replacement lamps, mainly with the HID-R. In this case, the ‘lumen surplus’ is compensated by adjusting the sales of the corresponding base-case(s). For instance, when the base-case HL-MV-R-HW is replaced with a HID-R, which some years after the replacement provides more annual lumen than needed by the HL-MV-R-HW according to the BAU, e.g. difference of 100 billion lumen, the number of new HID-R used as replacement lamp for the base-case HID-R is adjusted so as to provide 100 billion lumen less that needed for this base-case in BAU. Therefore, the total annual lumen needed for all base-cases remains constant.

8.1.2.3 Scenario "BAU" part 2 lamps

The first step required in order to build scenarios is to define the Business-as-Usual scenario that will serve as reference for the base-cases.

First, the number of DLS lamps per household (i.e. in the domestic sector) per lamp type for the year 2011 and 2020 was estimated as specified in chapter 2, section 2.2.3. Moreover, data in 2006 is already known and provided in chapter 2.

Data presented in Table 8.5 shows that the total number of lamps in the domestic sector was assumed to constantly increase (+54% in 2020 compared to 2007). Please note that CFLi-R, LEDi-R, and HIDi-R were not included due to lack of sales data and negligible DLS market share. A scenario based on a hypothetical expansion of the LED market is shown in section 8.1.2.6.

Table 8.5: Forecasts of number of DLS lamps per household in the domestic sector (BAU)

	GLS-R	HL-MV-R-HW	HL-MV-R-LW	HL-LV-R	TOTAL
	Nb/hh	Nb/hh	Nb/hh	Nb/hh	Nb/hh
2007	1.33	0.43	0.49	2.34	4.59
2008	1.22	0.57	0.68	2.41	4.88
2009	1.11	0.70	0.88	2.47	5.17
2010	1.01	0.83	1.09	2.54	5.46
2011	0.90	0.94	1.31	2.60	5.75
2012	0.89	0.95	1.41	2.65	5.90
2013	0.88	0.97	1.50	2.69	6.04
2014	0.87	0.98	1.60	2.74	6.19
2015	0.86	0.98	1.71	2.78	6.33
2016	0.85	0.99	1.81	2.83	6.48
2017	0.84	0.99	1.92	2.87	6.63
2018	0.84	0.98	2.04	2.92	6.77
2019	0.83	0.98	2.15	2.96	6.92
2020	0.82	0.97	2.27	3.01	7.07

Based on these lamp stocks per household, the stock and the sales per lamp type were calculated for the years from 2007 to 2020 for the domestic sector. In chapter 2, sales and stock data were also computed for 2007 for all sectors (i.e. domestic sector + other sectors). For the total stock and sales from 2007 to 2020, it was assumed that the share of the domestic sector remains constant in order to calculate data for all sectors. These estimates are presented in Table 8.6 and are similar to those presented in chapter 2 (see Table 2.16 in section 2.2.6), and detailed results are presented in Annexe 8-1.

Several observations can be made from this table:

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- As expected, even without any legislation, the market share and the stock of incandescent lamps (GLS-R) decrease in line with the chapter 2 assumptions. Between 2010 and 2020 the stock and sales of GLS-R are assumed to be reduced by 18% (i.e. about 41 million units) and 8% (i.e. about 8 million units) respectively.
- According to the assumptions made in chapter 2, it is expected that the share of HL-MV-R-LW lamps in the HL-MV-R market increases (from 53% in 2007 to 70% in 2020), while that of HL-MV-R-HW decreases (from 47% in 2007 to 30% in 2020). This is based on projections of recent sales trends.

Sales and stock data are presented in Figure 8.1 to Figure 8.4 both in % and in units. As explained for Table 8.5, CFLi-R's, HID-R's and LEDi-R's were not included as they currently make up a negligible amount of overall DLS.

Table 8.6: Market data for the BAU scenario (for all sectors)

	GLS-R		HL-MV-R-HW		HL-MV-R-LW		HL-LV-R	
	Stock	**Sales**	**Stock**	**Sales**	**Stock**	**Sales**	**Stock**	**Sales**
2007	291 591 919	126 096 260	107 306 006	67 257 000	121 004 645	75 843 000	584 873 780	153 000 000
2008	268 863 050	115 731 193	136 773 513	75 207 279	162 562 458	91 406 649	599 377 647	155 109 283
2009	246 134 181	105 366 127	164 383 435	83 157 558	205 977 856	106 970 297	613 881 514	157 218 566
2010	223 405 311	95 001 060	190 135 771	91 107 837	251 250 840	122 533 946	628 385 381	159 327 849
2011	200 676 442	84 635 993	214 030 522	99 058 116	298 381 410	138 097 595	642 889 248	161 437 132
2012	198 644 874	84 924 172	217 465 872	95 023 187	319 997 310	145 576 591	654 094 289	163 600 532
2013	196 613 306	85 212 350	220 246 035	90 988 257	342 268 397	153 055 588	665 299 330	165 763 931
2014	194 581 739	85 500 529	222 371 012	86 953 328	365 194 670	160 534 585	676 504 372	167 927 331
2015	192 550 171	85 788 707	223 840 802	82 918 398	388 776 130	168 013 582	687 709 413	170 090 730
2016	190 518 603	86 076 886	224 655 406	78 883 469	413 012 776	175 492 578	698 914 455	172 254 129
2017	188 487 035	86 365 064	224 814 823	74 848 539	437 904 609	182 971 575	710 119 496	174 417 529
2018	186 455 467	86 653 243	224 319 053	70 813 610	463 451 629	190 450 572	721 324 537	176 580 928
2019	184 423 900	86 941 421	223 168 097	66 778 680	489 653 835	197 929 569	732 529 579	178 744 328
2020	182 392 332	87 229 600	221 361 955	62 743 751	516 511 227	205 408 565	743 734 620	180 907 727

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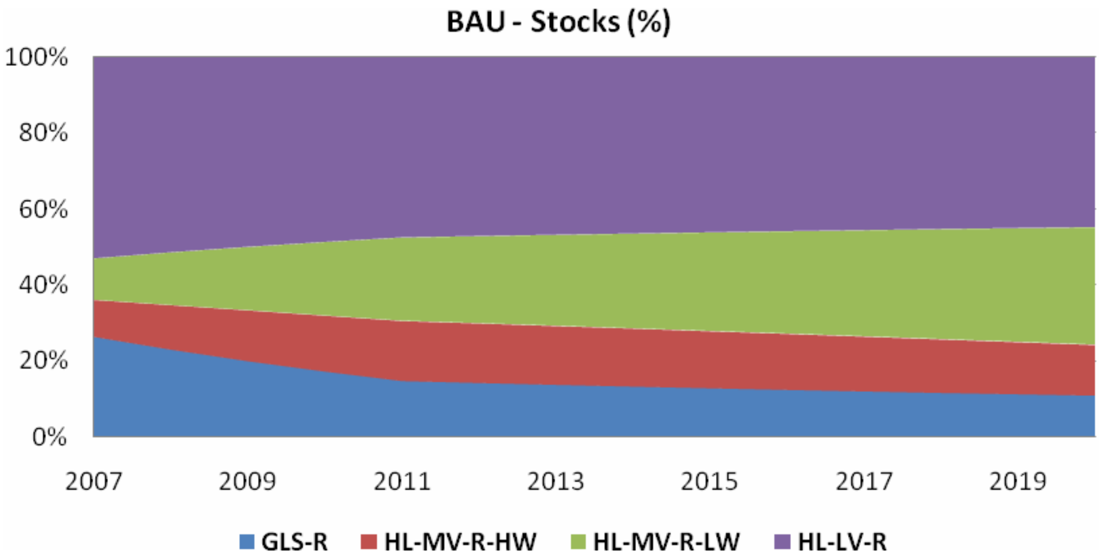

Figure 8.1: BAU – Evolution of lamps stocks (in %)

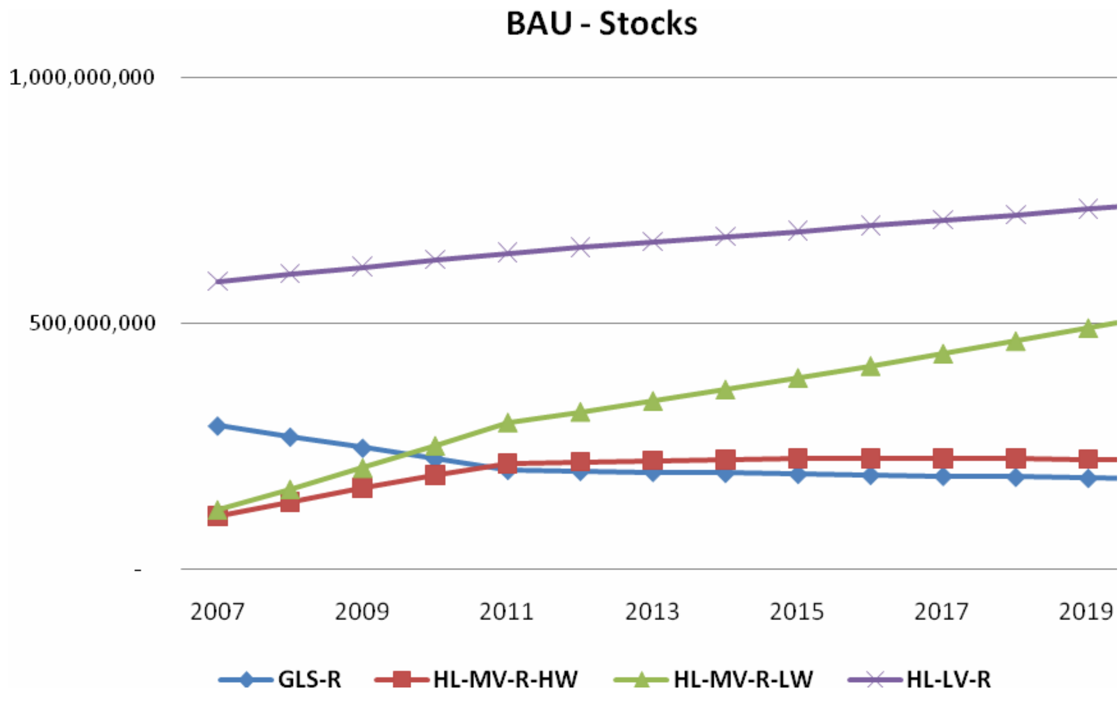

Figure 8.2: BAU – Evolution of lamps stocks (in units)

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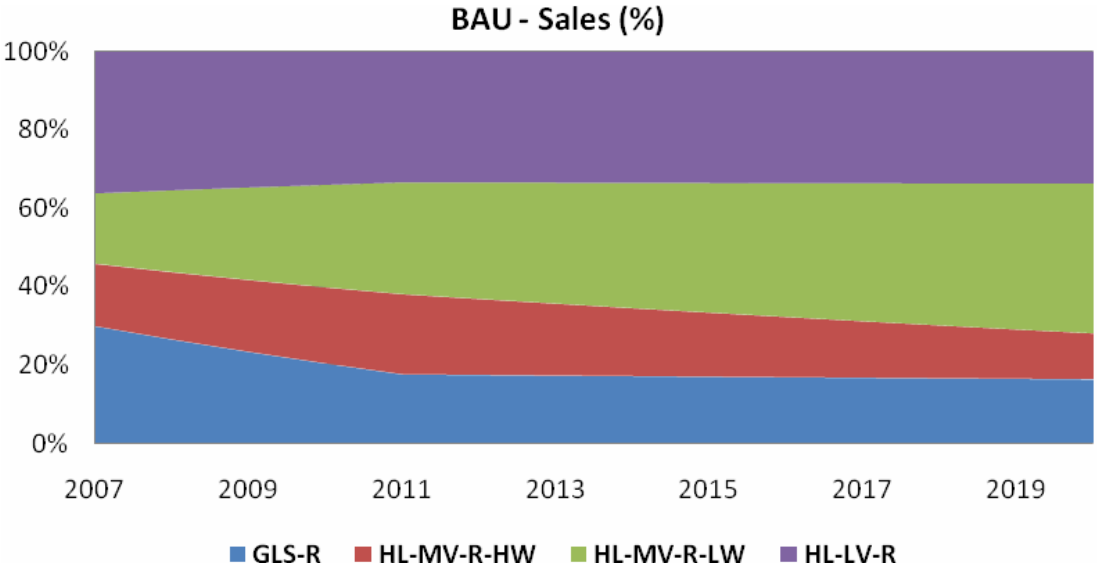

Figure 8.3: BAU – Evolution of lamps sales (in %)

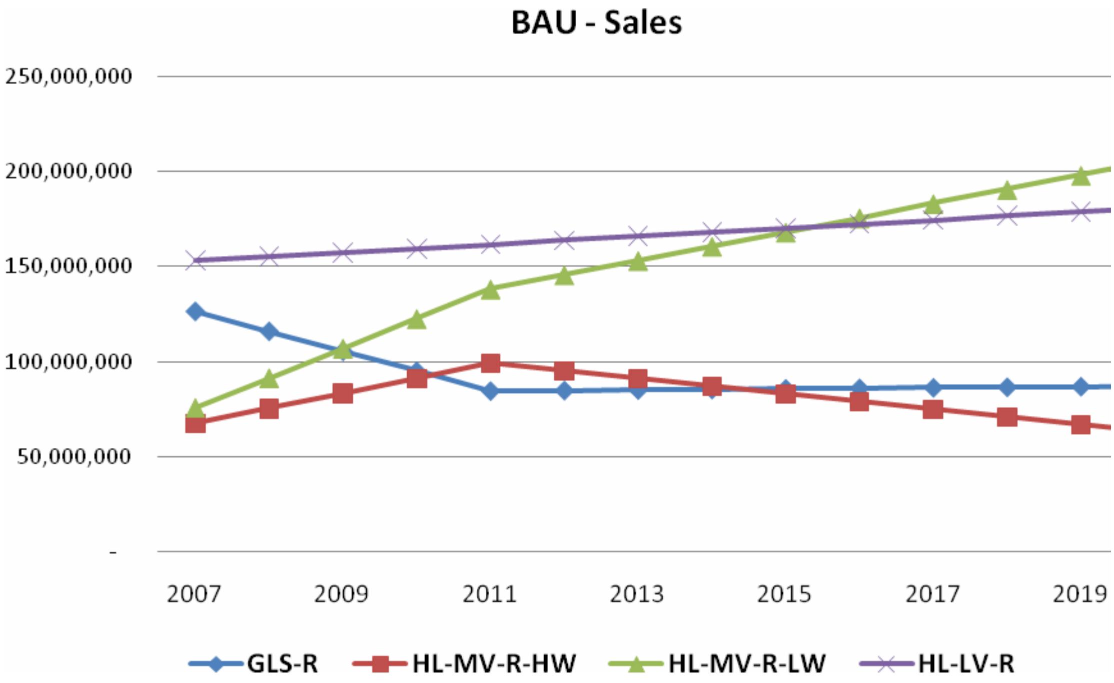

Figure 8.4: BAU – Evolution of lamps sales (in units)

The previous stock and sales analysis is required in order to proceed with the environmental analysis. Three environmental impacts were assessed:

- Electricity consumption during the use phase (this stage represents at least 90% of the total electricity consumption over the whole life cycle for the four base-cases);
- CO_2 emissions due to the electricity consumption during the use phase (proportional to the electricity consumption); and

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- Mercury emissions to air due to the electricity consumption during the use phase and the end-of-life phase for HID-R, as this lamp type contains mercury.

The evolution of these environmental impacts is presented in Figure 8.5 from 2007 to 2020. It can be seen that in the Business-as-Usual scenario, the total electricity consumption will increase despite the slow replacement of GLS-R lamps with more efficient lamps (HL-MV-R-LW and HL-LV-R) because of an increasing use of number of lamps and lighting (in the domestic sector from 4.59 lamps/households in 2007 to 7.07 lamps/household in 2020). Thus, in 2020, the electricity consumption (during the use phase) would reach a level of 51 TWh owing to the use of these four lamp types whatever the sector, i.e. an increase of about 59% compared to 2007. The increases of CO_2 emissions (22.0 Mton in 2020 compared to 13.8 Mton in 2007) and mercury emissions (0.82 Mton in 2020 compared to 0.51 Mton in 2007) are similar.

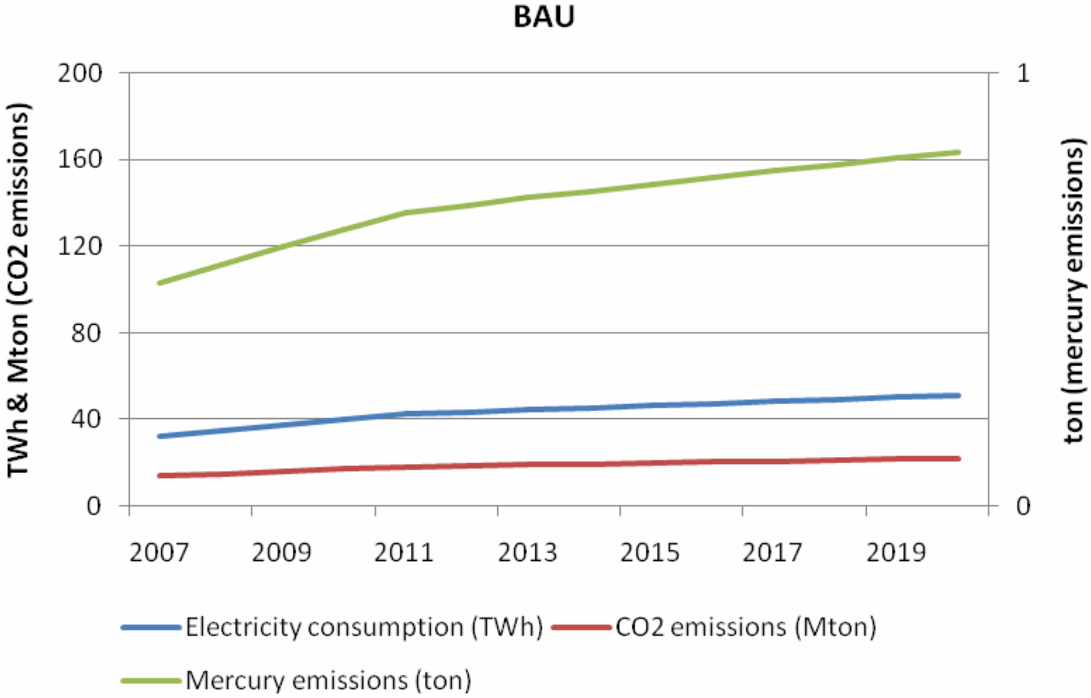

Figure 8.5: BAU – Evolution of annual environmental impacts

For the ‘Electricity consumption’, Figure 8.6 presents the contribution of each lamp technology from 2007 to 2020. Due to the large quantity on the market at that time, it is expected that HL-LV-R be the major consumer of electricity with 39%, followed by HL-MV-R-LW with 28% and HL-LV-R-HW with 24%.

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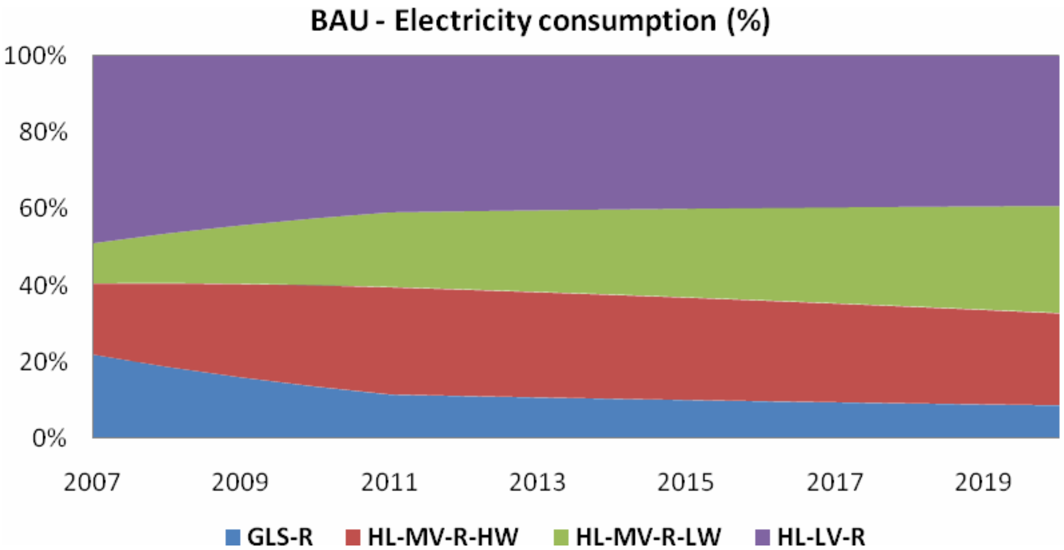

Figure 8.6: BAU - Evolution of the contribution of the lamp types to the electricity consumptions of the total lamp stock

The following sections present the analysis of the 4 scenarios setting minimum lamp efficacy requirements. For each section, the presentation of the analysis is similar and divided in three parts:

a) Presentation of the scenario with the requirements and the Tiers,

b) Presentation of sales and stocks data both in % and in units from 2007 to 2020,

c) Presentation of the environmental impact from 2007 to 2020.

For each scenario, detailed data (sales, stock and electricity consumption) are presented in Annexes.

8.1.2.4 Scenario "BAT with lock-in effect" part 2 lamps

The BAT with lock-in effect scenario is a scenario in which the best available retrofit technology is quickly introduced into the market. A summary of the scenario is shown in Table 8.7 with the recommended requirements expressed in Energy Label classes together with the consequence in terms of replacement technology. Note that the replacement option chosen for HL-MV-R-HW was the HIDi-R. However, the improvement option of CFLi-DLS would also meet the energy standard of B+, and would often be superior in certain applications where less concentrated light is needed. Additionally, the improvement option in 2013 of HL-LV-R to HL-LV-R IRC + silv/dich is not due to an increase in legislative standards, but rather an assumed natural improvement in reflective coatings for this type of lamp.

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Table 8.7: BAT with lock in effect – Replacement lamps for each tier

Present	2010	2013	2016
GLS-R	Level E	Level B	Level B
	HL-MV-R-LW xenon + opt fil + silv/dich + anti-ref	HL-MV-R-LW transf + IRC + silv/dich + anti-ref	HL-MV-R-LW transf + IRC + silv/dich + anti-ref
HL-MV-R-HW	Level B+	Level B+	Level B+
	HID-R[3]	HID-R[3]	HID-R[3]
HL-MV-R-LW	Level E	Level D	Level D
	HL-MW-R-LW xenon + opt fil	HL-MV-R-LW xenon + opt fil + silv + anti-ref	HL-MV-R-LW xenon + opt fil + silv + anti-ref
HL-LV-R	Level B	Level B	Level B
	HL-LV-R xenon + IRC	HL-LV-R IRC + silv/dich[4]	HL-LV-R IRC + silv/dich[4]

The BAT with lock-in effect scenario would imply the complete phase-out of GLS-R and HL-MV-R-HW lamps, with a large portion of HL-LV-R and HL-LV-R-LW, as seen in Figure 8.7. More detailed analysis can be found in Annexe 8-2.

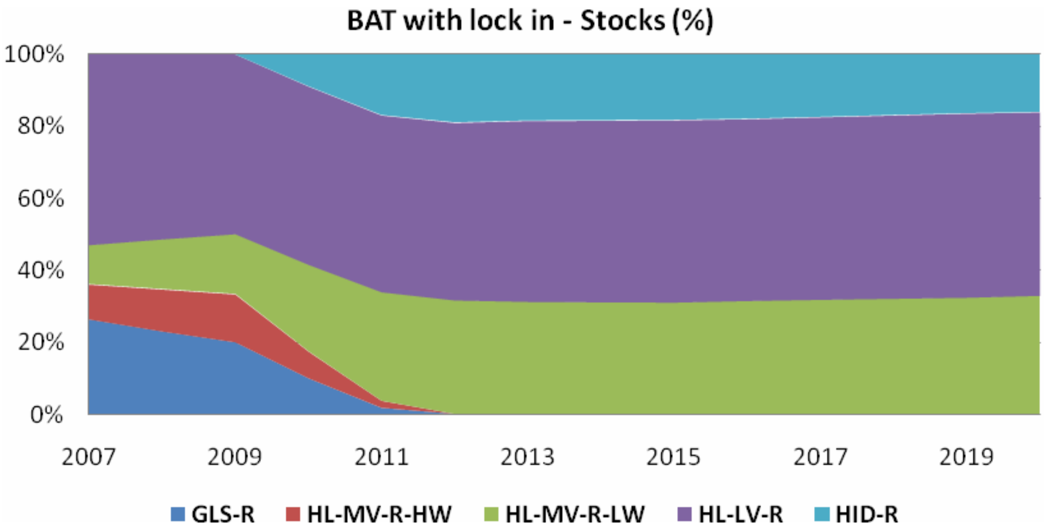

Figure 8.7: BAT with lock in - Evolution of lamps stocks (in %)

[3] CFLi-R would also be a sufficient replacement option.
[4] Natural improvement in relective coatings.

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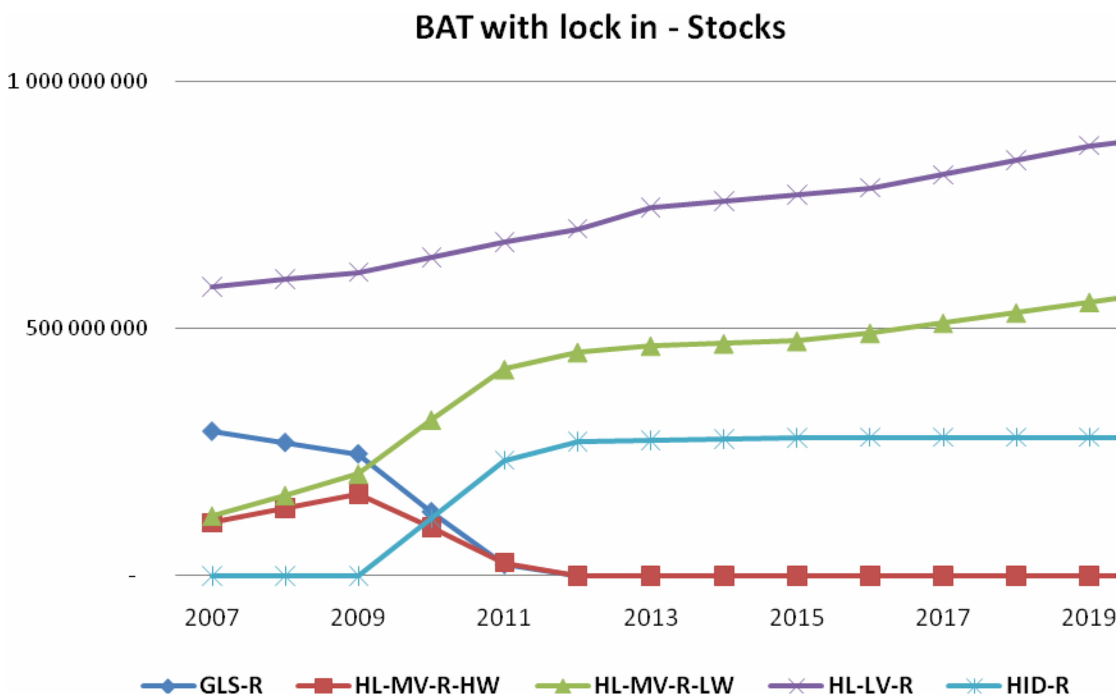

Figure 8.8: BAT with lock in - Evolution of lamps stocks (in units)

The sales of HL-MV-R-LW jump initially order to compensate for the lumen needed during the phase-out of GLS-R, and then again around 2014 as the original lamps need to be replaced.

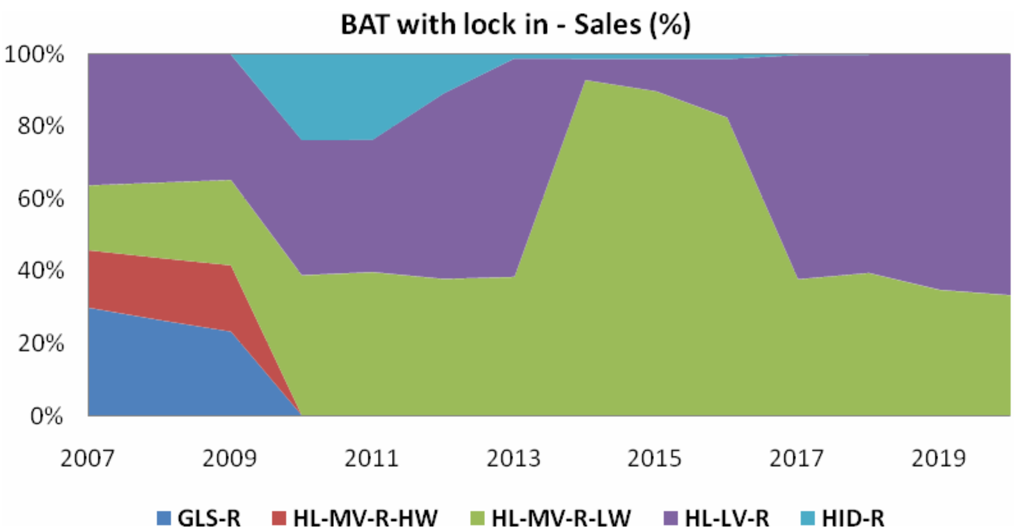

Figure 8.9: BAT with lock in - Evolution of lamps sales (in %)

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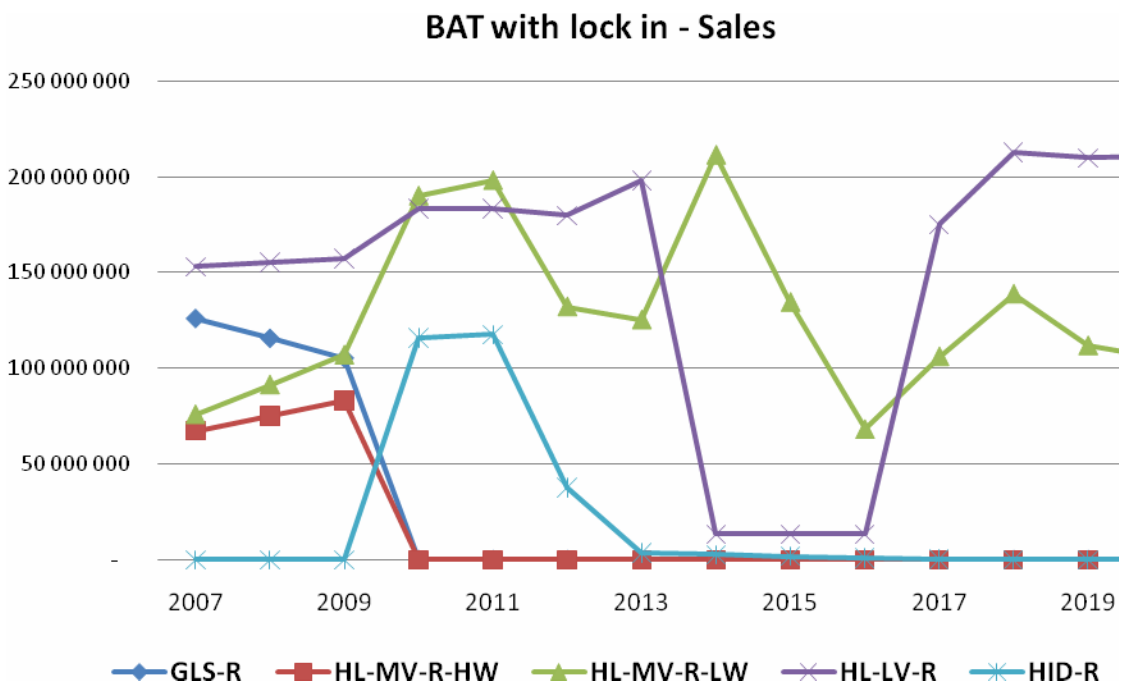

Figure 8.10: BAT with lock in - Evolution of lamps sales (in units)

From 2009 onwards, total electricity consumption (and therefore total CO_2 emissions) decreases until 2014 and then increases slightly until 2020.

In 2020, total electricity consumption is expected to be about 28 TWh, i.e. 45% lower than in the BAU scenario. The reduction is the same for CO_2 emissions (12 Mton in 2020).

Regarding mercury emissions, the total amount increases in 2009 due to the high increase of HID-R sales (since mercury emissions occurring at their end-of-life are attributed to the sales year). Then, the emissions decrease until 2014 and afterwards stay relatively constant. In 2020, total mercury emissions to air due to the electricity consumption of lamps during to the use phase, and due to emissions occurring at EoL of HID-R are about 450 kg, which means a reduction of about 45% compared to the BAU scenario.

Figure 8.12 shows that after 2012, electricity consumption is only due to HL-LV-R (46.7%), HL-MV-R-LW (48.7%) and HID-R (14.6%), as the other lamp types have been phased out.

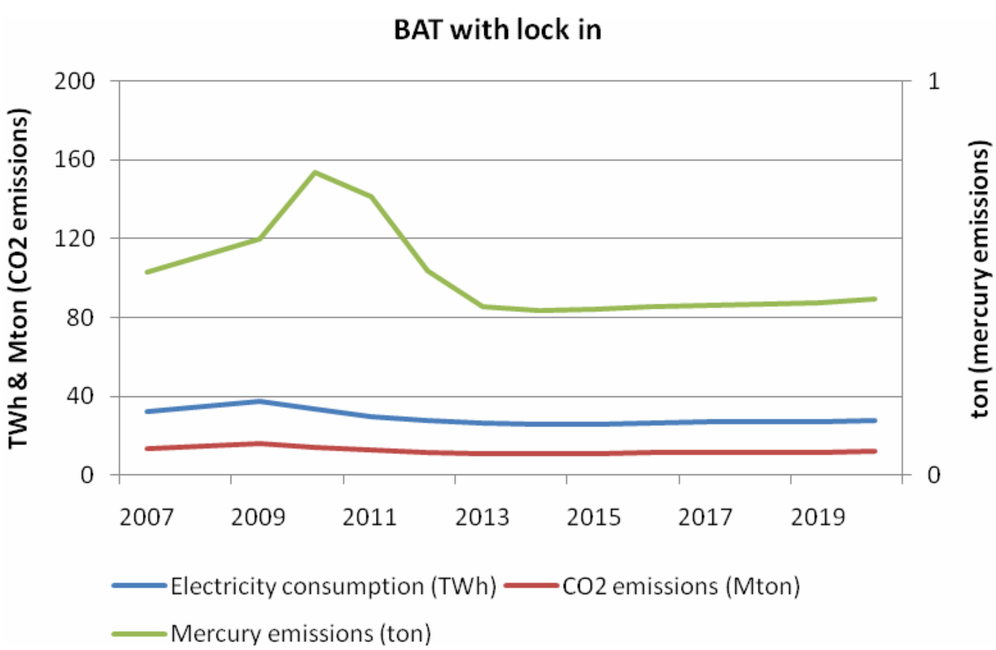

Figure 8.11: BAT with lock in– Evolution of annual environmental impacts

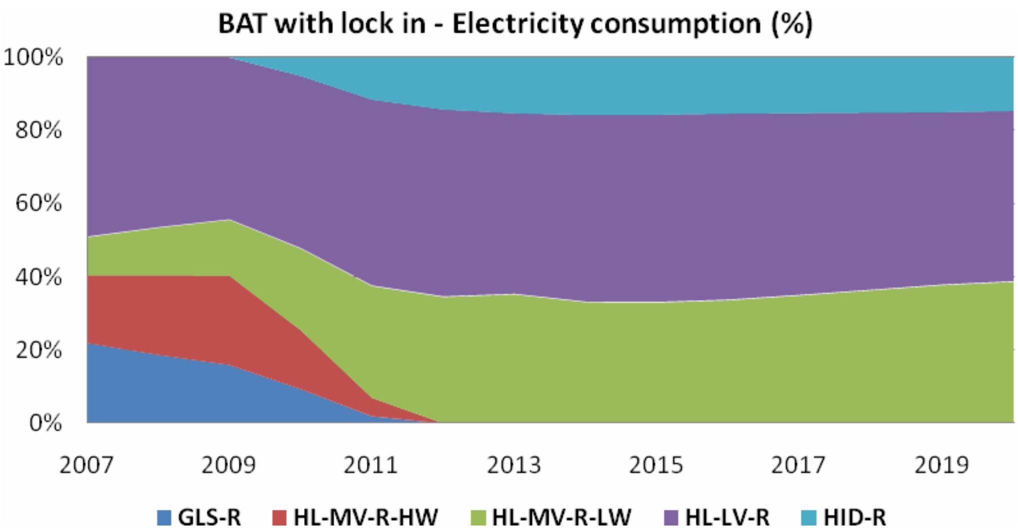

Figure 8.12: BAT with lock in - Evolution of the contribution of the lamp types to the electricity consumptions of the total lamp stock

8.1.2.5 Scenario "BAT without lock-in effect" part 2 lamps

The BAT without lock-in effect is a scenario in which the best available technology is quickly introduced into the market, regardless of retrofit ability or not. A summary of the scenario is shown in It is important to understand that this is an unrealistic scenario in terms of timing, as it is very unlikely that a requirement resulting in luminaire change prior to 2020 could be established. However, in keeping with the time frame of this study, a luminaire change is assessed for 2016 in order to have a preliminary idea of possible outcomes. Additionally, as in

the BAT with lock-in effect scenario, there is an assumed natural improvement in reflective coatings, regardless of legislative standards.

Table 8.8 with the recommended requirements expressed in Energy Label classes together with the consequence in terms of replacement technology. It is important to understand that this is an unrealistic scenario in terms of timing, as it is very unlikely that a requirement resulting in luminaire change prior to 2020 could be established. However, in keeping with the time frame of this study, a luminaire change is assessed for 2016 in order to have a preliminary idea of possible outcomes. Additionally, as in the BAT with lock-in effect scenario, there is an assumed natural improvement in reflective coatings, regardless of legislative standards.

Table 8.8: BAT without lock in effect – Replacement lamps for each tier

Present	2010	2013	2016
GLS-R	Level E	Level B	Level B
	HL-MV-R-LW xenon + opt fil + silv/dich + anti-ref	HL-MV-R-LW transf + IRC + silv/dich + anti-ref	HL-MV-R-LW transf + IRC + silv/dich + anti-ref
HL-MV-R-HW	Level B+	Level B+	Level B+
	HID-R[5]	HID-R[5]	HID-R[5]
HL-MV-R-LW	Level E	Level D	Level B
	HL-MW-R-LW xenon + opt fil	HL-MV-R-LW xenon + opt fil + silv + anti-ref	HL-LV-R IRC + silv/dich[6]
HL-LV-R	Level B	Level B	Level B
	HL-LV-R xenon + IRC	HL-LV-R IRC + silv/dich[7]	HL-LV-R IRC + silv/dich[7]

The BAT without lock-in effect scenario would imply the complete phase-out of GLS-R, HL-MV-R-HW and HL-MV-R-LW lamps by 2016, with all light being provided by HL-LV-R and HID-R, as seen in Figure 8.13. More detailed analysis can be found in Annexe 8-3.

[5] CFLi-R would also be a sufficient replacement option.
[6] Low voltage lamps that do not come with an integrated transformer would require a luminaire change.
[7] Natural improvement in relective coatings.

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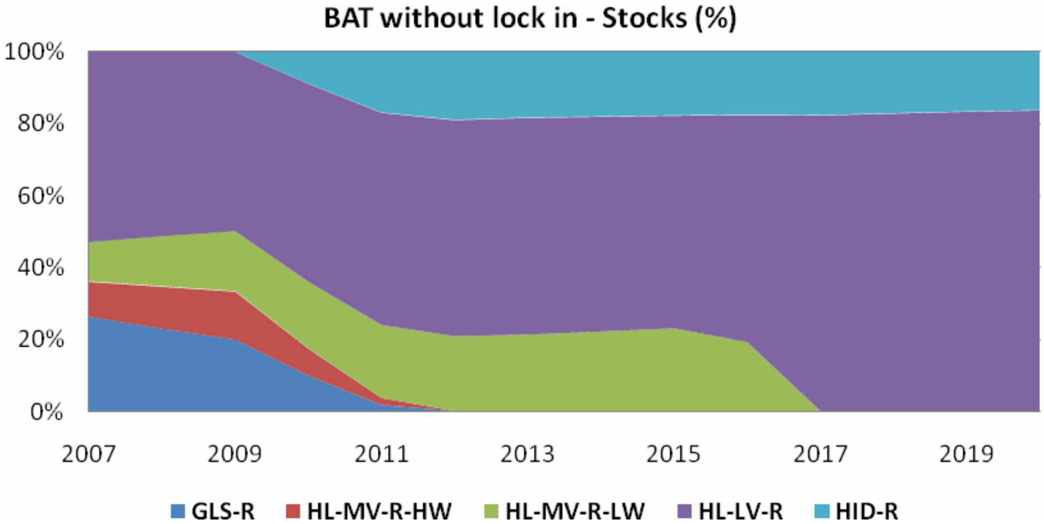

Figure 8.13: BAT without lock in - Evolution of lamps stocks (in %)

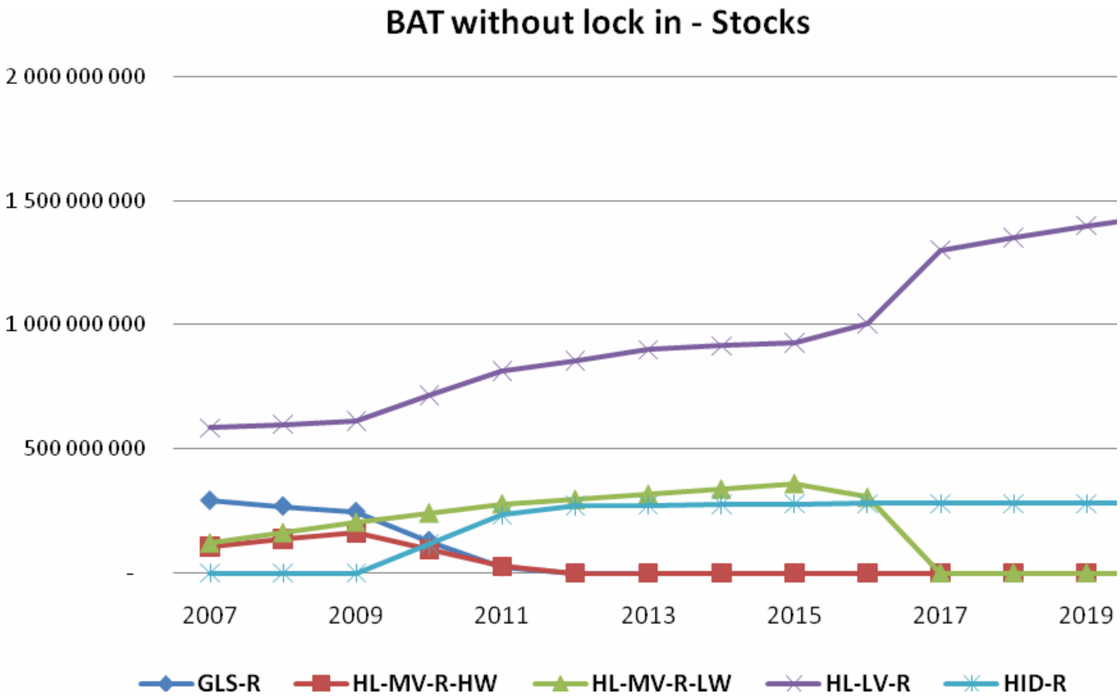

Figure 8.14: BAT without lock in - Evolution of lamps stocks (in units)

The sales of HL-LV-R and HID-R jump initially order to compensate for the lumen needed during the phase-out of the other lamps. HL-MV-R-LW needs to be replaced roughly after 3 years, which causes the small jump in 2014. HL-LV-R need to be replaced roughly every 7 years, and hence the next jump in sales seen in 2017.

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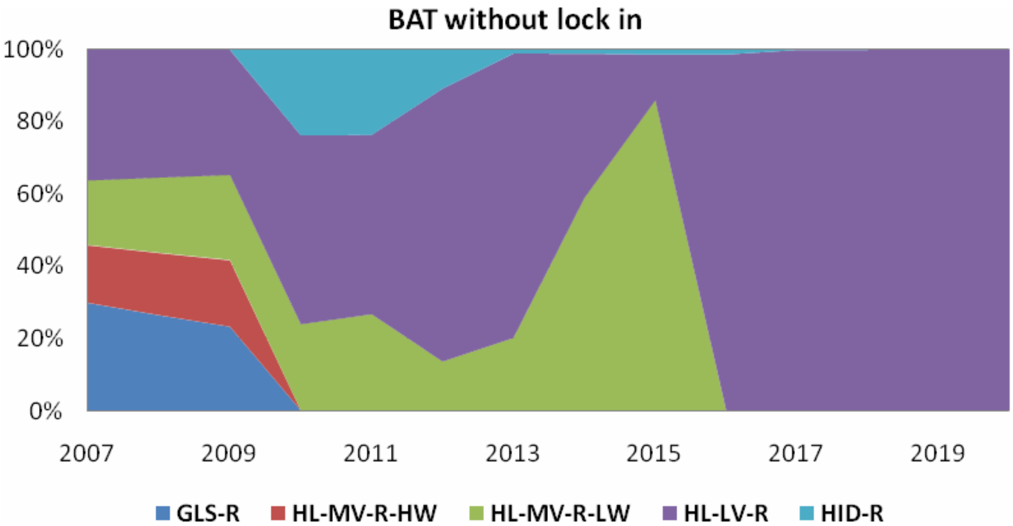

Figure 8.15: BAT without lock in - Evolution of lamps sales (in %)

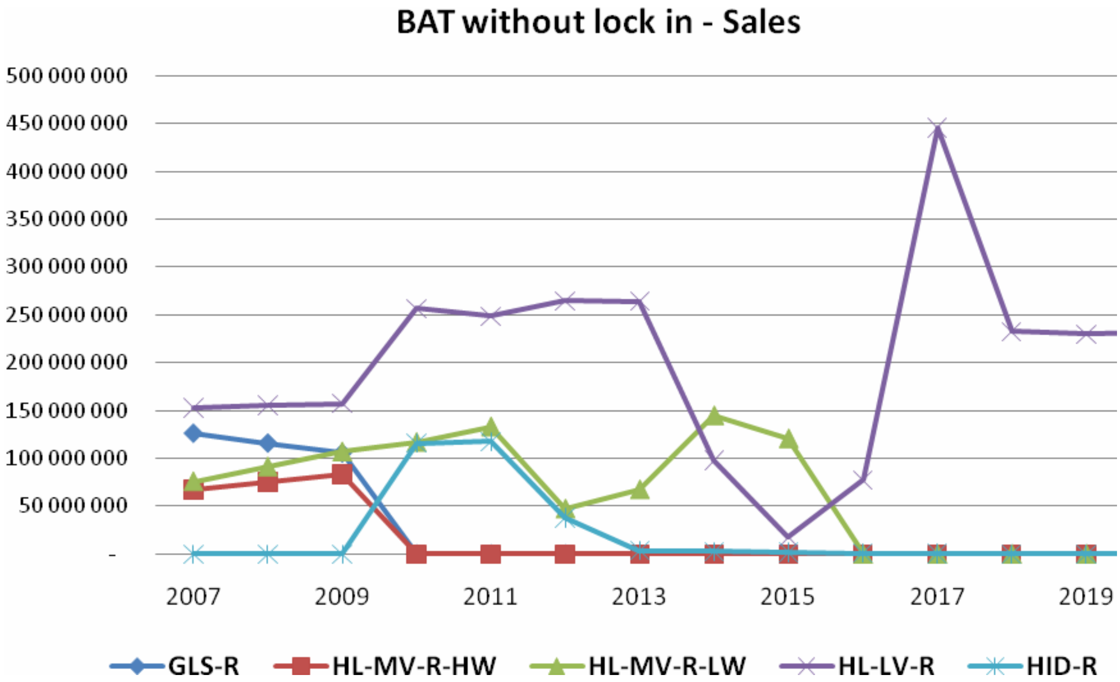

Figure 8.16: BAT without lock in - Evolution of lamps sales (in units)

From 2009 onwards, total electricity consumption (and therefore total CO_2 emissions) decreases until 2012 and again in 2016 with the luminaire change.

In 2020, total electricity consumption is expected to be about 24.5 TWh, i.e. 52% lower than in the BAU scenario. The reduction is the same for CO_2 emissions (10.5 Mton in 2020).

Regarding mercury emissions, the total amount increases in 2009 due to the high increase of HID-R sales (since mercury emissions occurring at their end-of-life are attributed to the sales year). Then, the emissions decrease until 2012 and afterwards stay relatively constant. In 2020, total mercury emissions to air due to the electricity consumption of lamps during to the use

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phase, and due to emissions occurring at EoL of HID-R are about 390 kg, which means a reduction of about 52% compared to the BAU scenario.

Figure 8.18 shows that after 2017, electricity consumption is only due to HL-LV-R (83%), and HIDi-R (17%), as the other lamp types have been completely phased out.

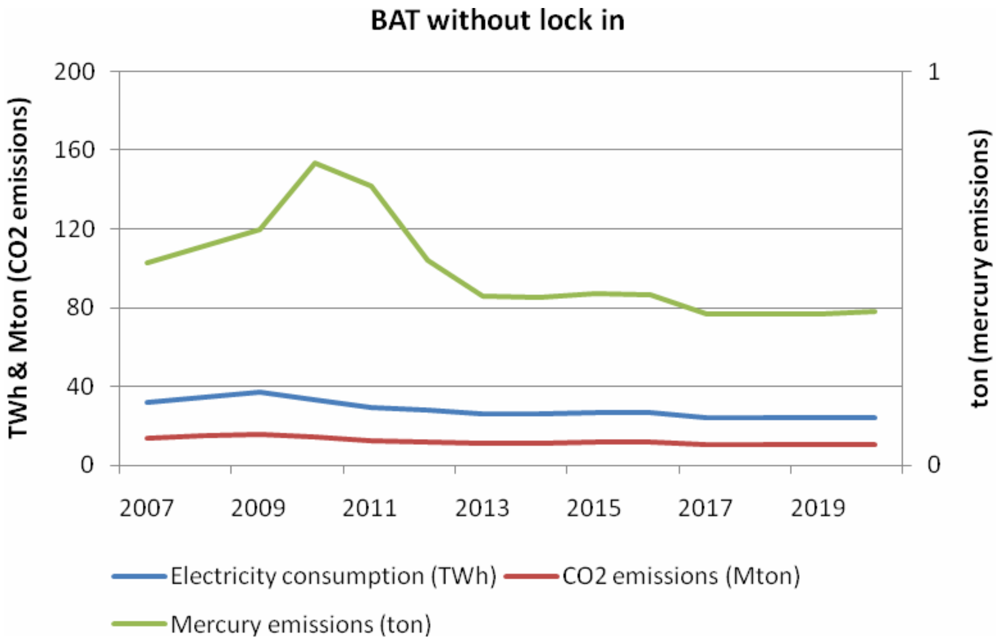

Figure 8.17: BAT without lock in – Evolution of annual environmental impacts

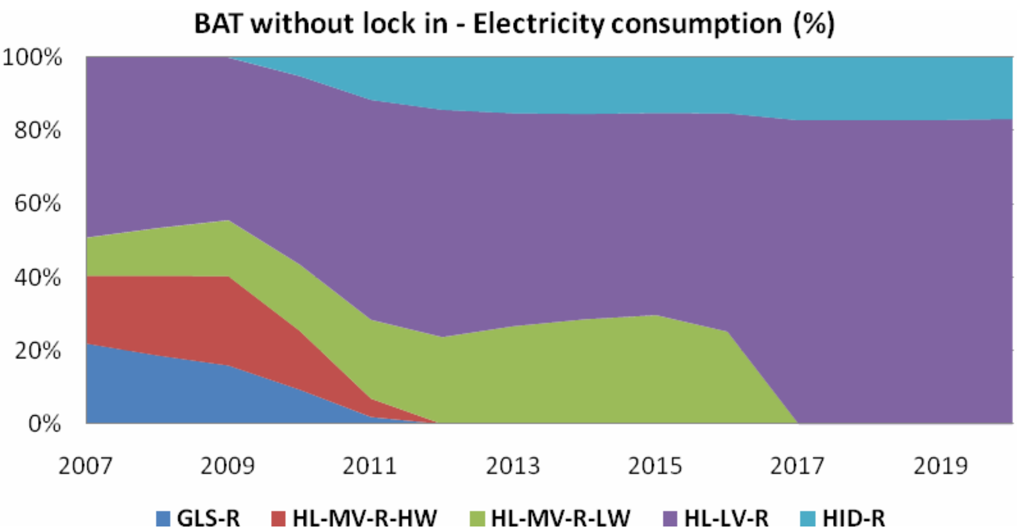

Figure 8.18: BAT without lock in - Evolution of the contribution of the lamp types to the electricity consumptions of the total lamp stock

8.1.2.6 Scenario "BNAT LED" part 2 lamps

The BNAT LED is a scenario in which LEDs are rapidly introduced to the market, assuming a double in efficacy by 2016 (see chapter 6). A summary of the scenario is shown in Table 8.9.

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Note that this scenario is assuming that retrofit available LEDi-R linearly increase in efficacy up to twice the current efficacy in 2016. It is suggested that the European Commission reviews the LEDi-R situation in 2013 in order to consider setting A level standards in order to require the use of LEDi-R on the market. This scenario is an exercise into showing the savings potential of LEDi-R replacements.

Table 8.9: BNAT LED – Replacement lamps for each tier

present	2010	2013	2016
GLS-R	linear increase to 2016	linear increase to 2016	LEDi-R x2 efficacy
HL-MV-R-HW	Level A/B+	Level A/B+	Level A/B+
	HID-R[8]	HID-R[8]	HID-R[8]
HL-MV-R-LW	linear increase to 2016	linear increase to 2016	LEDi-R x2 efficacy
HL-LV-R	linear increase to 2016	linear increase to 2016	LEDi-R x2 efficacy

The BNAT LED scenario would imply the complete phase-out of GLS-R, HL-MV-R-HW, HL-MV-R-LW and HL-LV-R lamps, with all light being provided by LEDi-R and HID-R, as seen in Figure 8.19. More detailed analysis can be found in Annexe 8-4.

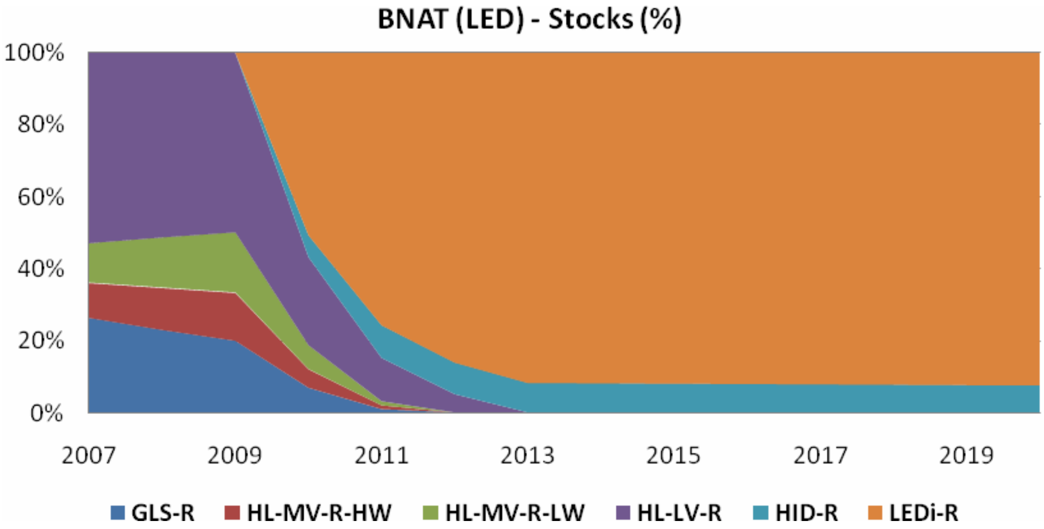

Figure 8.19: BNAT LED - Evolution of lamps stocks (in %)

[8] CFLi-R would also be a sufficient replacement option.

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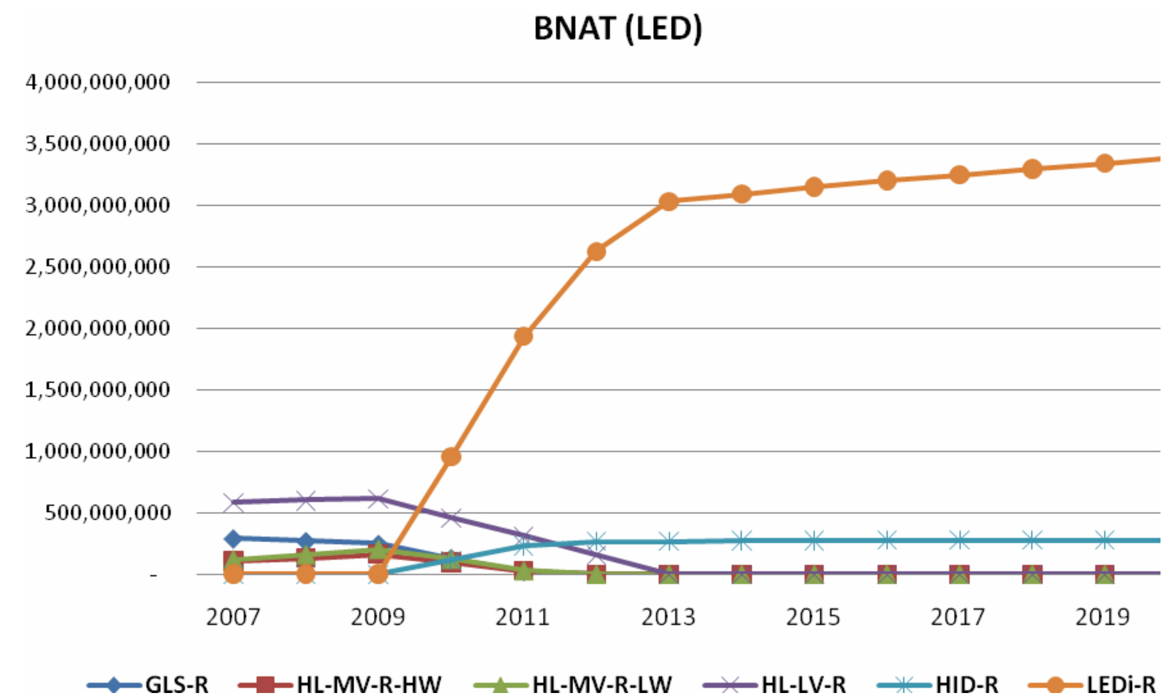

Figure 8.20: BNAT LED - Evolution of lamps stocks (in units)

The sales of LEDi-R and HID-R jump initially order to compensate for the lumen needed during the phase-out of the other lamps. The number of sales is quite high for LEDi-R as the luminous output is still low compared to the base-cases, and thus more lamps are needed to provide the same lumen output. Because of the very long lifetime of both LEDi-R and HID-R (18 years), additional sales are only due to increased lumen demand rather than replacement sales.

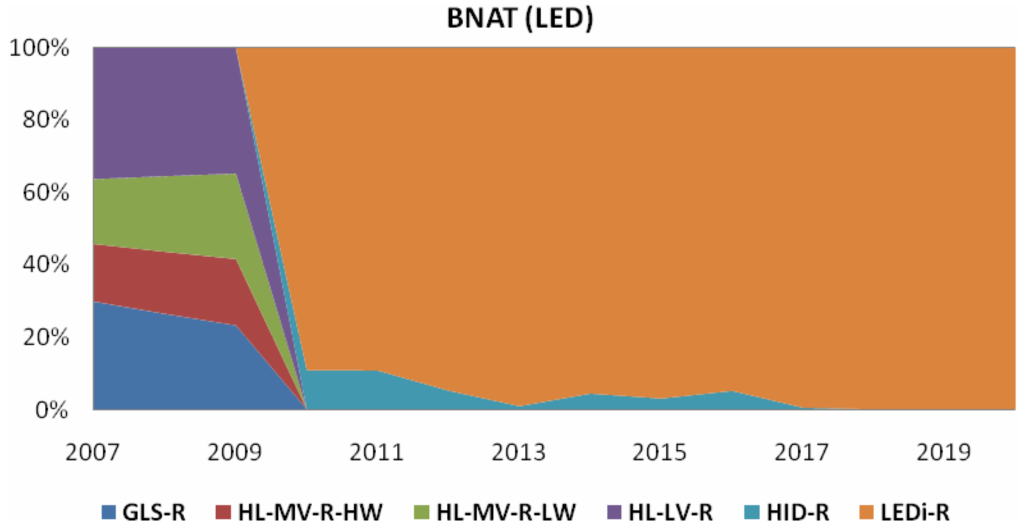

Figure 8.21: BNAT LED - Evolution of lamps sales (in %)

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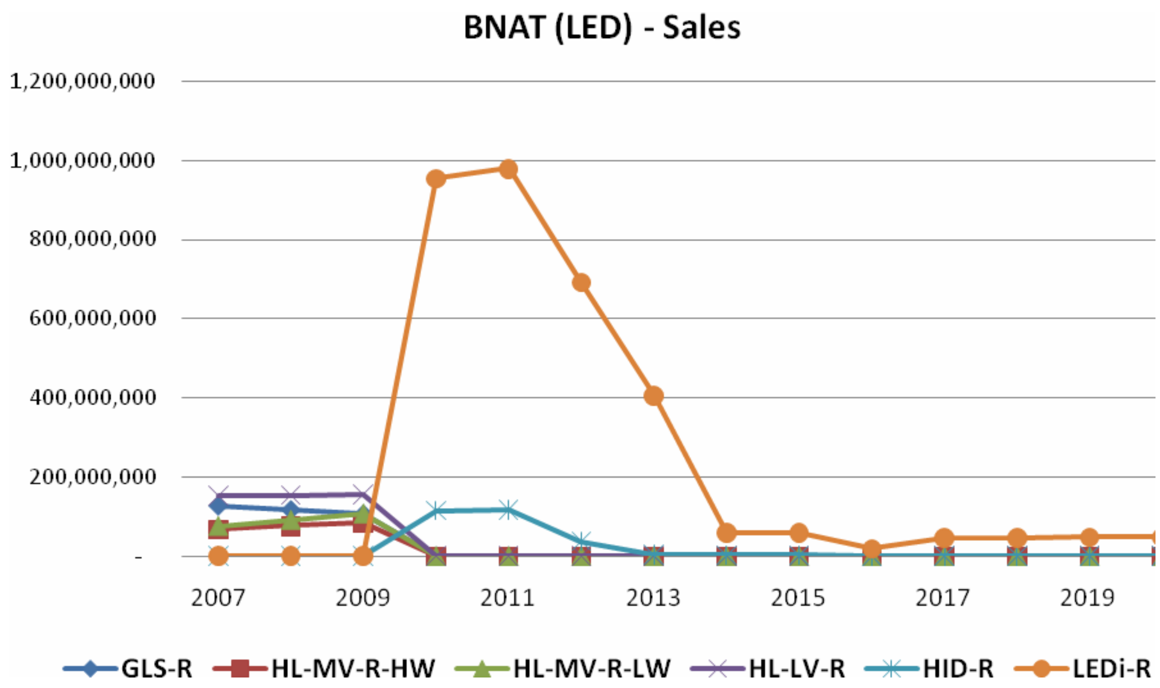

Figure 8.22: BNAT LED - Evolution of lamps sales (in units)

From 2009 onwards, total electricity consumption (and therefore total CO_2 emissions) decreases until 2012 and then increases slightly until 2020.

In 2020, total electricity consumption is expected to be about 15.5 TWh, i.e. 70% lower than in the BAU scenario. The reduction is the same for CO_2 emissions (6.65 Mton in 2020).

Regarding mercury emissions, the total amount increases in 2009 due to the high increase of HID-R sales (since mercury emissions occurring at their end-of-life are attributed to the sales year). Then, the emissions decrease until 2012 and afterwards stay relatively constant. In 2020, total mercury emissions to air due to the electricity consumption of lamps during to the use phase, and due to emissions occurring at EoL of HID-R are about 250 kg, which means a reduction of about 70% compared to the BAU scenario.

Figure 8.24 shows that after 2012, electricity consumption is only due to LEDi-R (74%), and HID-R (26%), as the other lamp types have been phased out.

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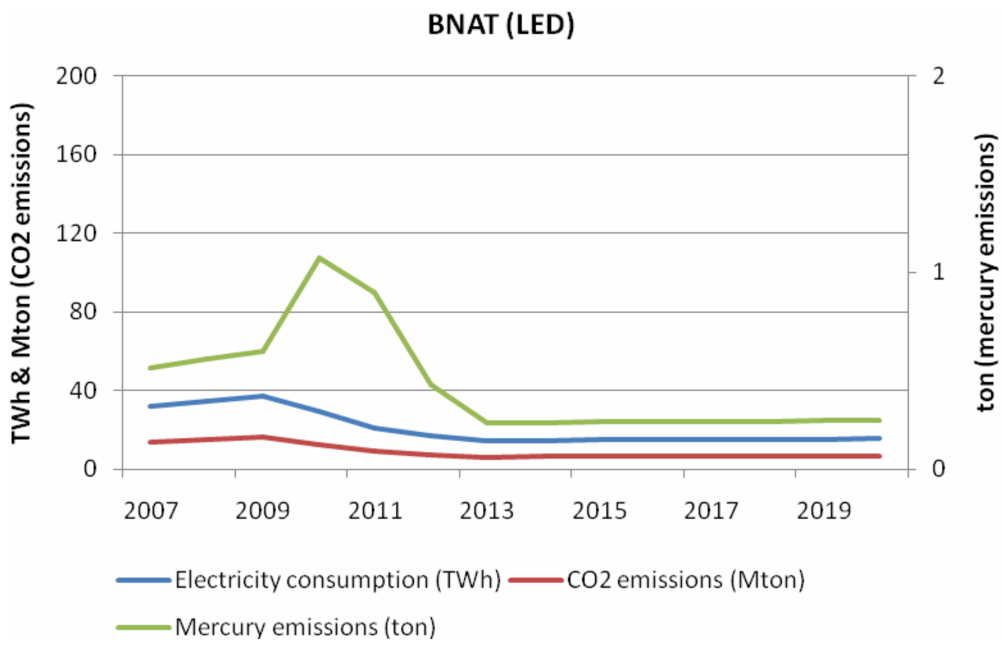

Figure 8.23: BNAT LED – Evolution of annual environmental impacts

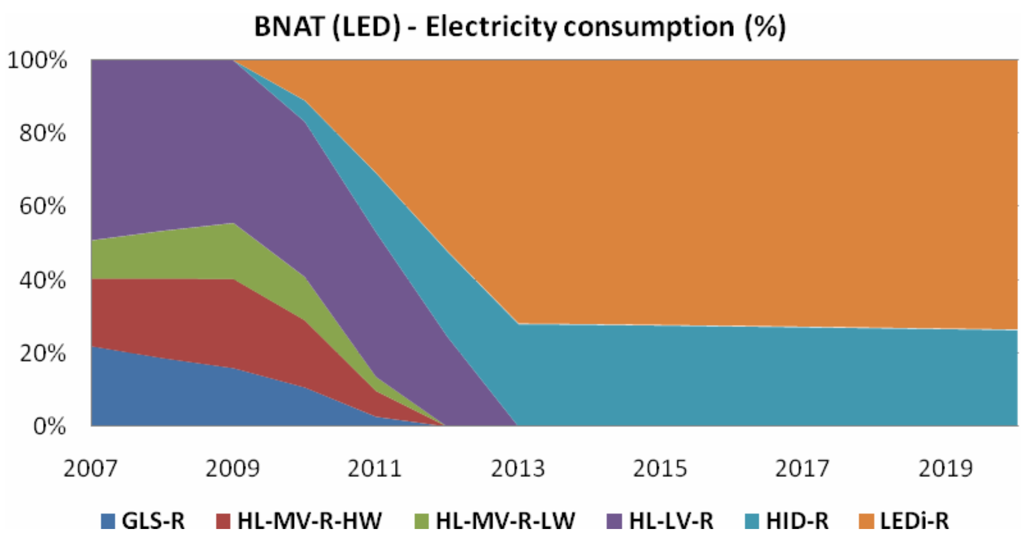

Figure 8.24: BNAT LED - Evolution of the contribution of the lamp types to the electricity consumptions of the total lamp stock

8.1.2.7 Comparison of scenarios part 2 lamps

Based on the analysis of the four scenarios (BAU + 3 'improvement' scenarios), environmental impacts in 2020 are presented in Table 8.10, including variations both in units and in % with reference to the BAU scenario, and illustrated in Figure 8.25.

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Table 8.10: Environmental impacts in 2020 for each scenario

		Electricity consumption (TWh) in 2020	CO2 emissions (Mton) in 2020	Mercury emissions (ton) in 2020
BAU	**Value**	51.1	22.0	0.82
	Difference to BAU	*0.0%*	*0.0%*	*0.0%*
BAT with lock in	**Value**	28.0	12.0	0.45
	Difference to BAU (units)	*-23.2*	*-10.0*	*-0.37*
	Difference to BAU (%)	*-45.3%*	*-45.3%*	*-45.3%*
BAT without lock in	**Value**	24.5	10.5	0.39
	Difference to BAU (units)	*-26.7*	*-11.5*	*-0.43*
	Difference to BAU (%)	*-52.1%*	*-52.1%*	*-52.1%*
BNAT (LED)	**Value**	15.5	6.7	0.25
	Difference to BAU (units)	*-35.6*	*-15.3*	*-0.57*
	Difference to BAU (%)	*-69.7%*	*-69.7%*	*-69.7%*

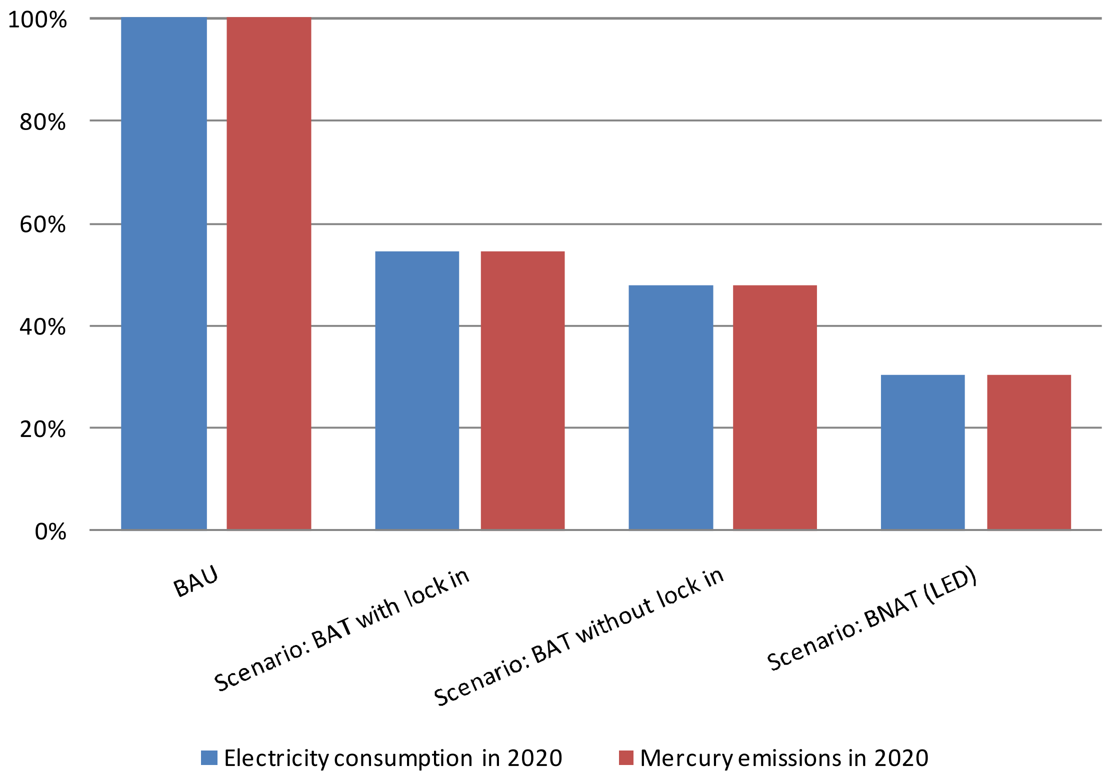

Figure 8.25: Comparison of scenarios in 2020

As already mentioned, looking only at the environmental impacts in 2020 can be confusing. For example, the mercury emissions on 2020 are reduced by the same amount as the electricity consumption because there are few sales of HID-R, which have mercury embedded. Therefore,

in order to allow a 'fair' comparison, cumulated environmental impacts from 2010 (assumed as the entry into force of the legislation) to 2020 need to be analysed. Such a comparison presents more logical results and the resulting ranking of 'the most environmental friendly scenario' is as expected: the BNAT LED scenario presents the greatest reductions in environmental impacts.

Table 8.11: Cumulated environmental impacts from 2010 to 2020 for each scenario

		Electricity consumption (TWh) from 2010 until 2020	**CO2 emissions (Mton) from 2010 until 2020**	**Mercury emissions (ton) from 2010 until 2020**
BAU	**Value**	508.4	218.6	8.1
	Difference to BAU	*0%*	*0%*	*0%*
BAT with lock in	**Value**	304.8	131.1	5.6
	Difference to BAU (units)	*-203.6*	*-87.6*	*-2.6*
	Difference to BAU (%)	*-40.1%*	*-40.1%*	*-31.4%*
BAT without lock in	**Value**	293.9	126.4	5.4
	Difference to BAU (units)	*-214.5*	*-92.2*	*-2.7*
	Difference to BAU (%)	*-42.2%*	*-42.2%*	*-33.5%*
BNAT (LED)	**Value**	186.8	80.3	4.3
	Difference to BAU (units)	*-321.6*	*-138.3*	*-3.8*
	Difference to BAU (%)	*-63.3%*	*-63.3%*	*-46.8%*

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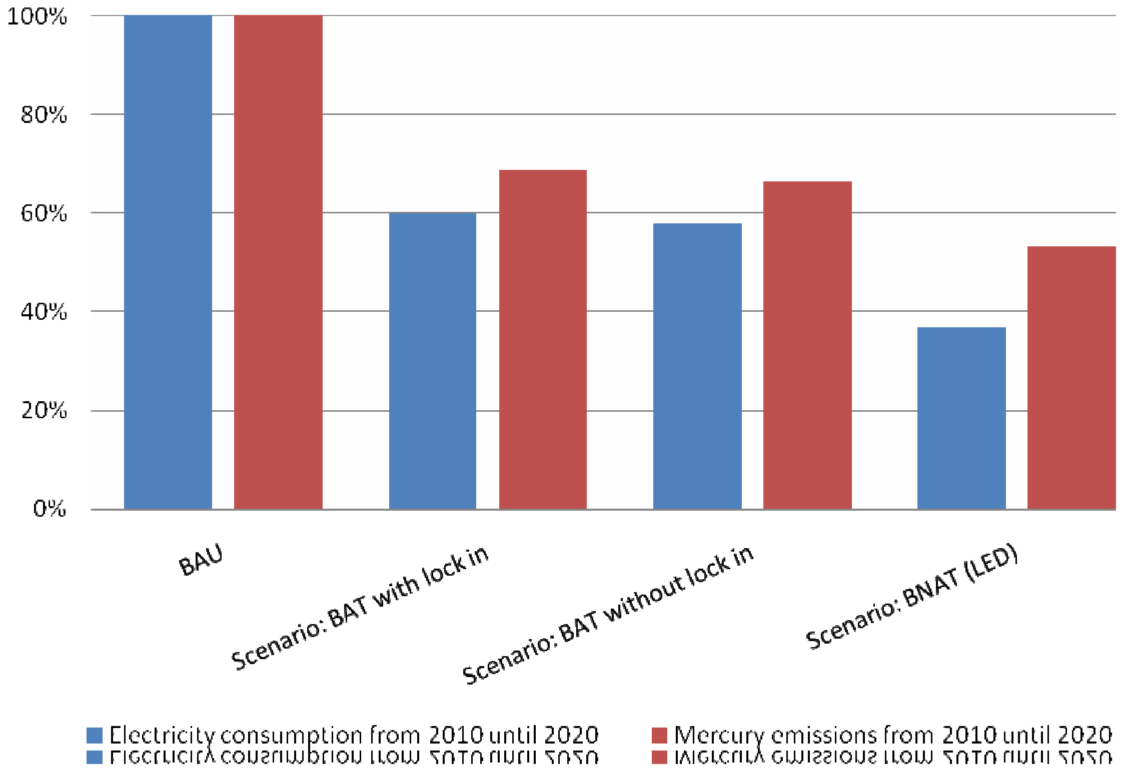

Figure 8.26: Comparison of scenarios between 2009 and 2020

8.1.2.8 Calculation principle used for the luminaire scenario analysis

In addition to improvements related on the lamp efficacy, optic and control system improvements on the luminaire are also possible (see chapter 6 and section 8.1.1.8). Please note that luminaires can also create a positive lock-in effect, e.g. by using a pin based CFLni [see remark on CFLni in 8.1.1.7]. After extensive consultation with CELMA, educated estimations were made in order to determine the quantity of savings currently possible from luminaire improvements. An example of these estimates can be found in Figure 8.27. The full spreadsheet with all calculations is available on the project website[9].

[9] www.eup4light.net

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General comment: all figures in the tables are estimated values with the knowledge of CELMA members as of today.

Option:	dimmable application							
Your country:	CELMA							
Saving method description	Luminaire is only operated at max power for functional use. The rest of the time the luminaire is dimmed. This is applicable for external and internal dimmer systems.							
Sample picture best practice		**Sample picture worst practice**						Energy
Category of luminaires	**Is this option applicable to this category or not**	**How big is the market share [EU27 sales] of improvable luminaires in its category**	**What proportion of the energy can be saved comparing worst to best practice**	**How many luminaires [EU27 sales] are among the worst 30 % performers in the category**	**How many luminaires [EU27 sales] are among the best 30% performers in the category**	**What proportion of the energy can be saved on average assuming all luminaires sold are in the range of 30 % best performers**	**Chararactertic parameter best performer**	**Chararactertic parameter worst performer**
	Y/N	**%**	**%**	**%**	**%**		***max operational energy consumption (W)***	***min operational energy consumption (W)***
Downlights (recessed mounted)	y	75	30	50	25	15	<=30	>=60
Suspension (chandeliers)	y	75	30	70	10	21	<=30	>=60
wall&ceiling	y	70	30	60	10	18	<=30	>=60
Desk	n							
Table	y	30	30	80	20	24	<=20	>=40
Floor	y	75	30	70	20	21	<=50	>=100
Spotlights	y	75	30	80	20	24	<=30	>=60
Outdoor	n							
							lower powerconsumption because used at 50% dimming or use of low wattage lamps	higher powerconsumption because of use of high wattage lamps in not dimmable applications

Note: For dimmable applications cleaning is relevant since the consumer will use more energy in direct relation with the dust on the luminaire
Dimmability is focused on filament lamps, only a very small quantity of CFLI(ni) is dimmable today.

Figure 8.27: Example of CELMA luminaire improvement data

Data was aggregated in the following manner:

- The analysis begins by taking the market share for each category of luminaire, as presented in Table 2.12 of Part 2.
- The average wattages given by CELMA are used to find a weighted average of the total market of 79.75 W.
- The wattage for each category is divided by the weighted average of the total market to obtain the "relative energy weight" for each category. This value means the variation away from the weighted average for each category wattage.
- Multiplying the relative energy weight by market share, a per unit "market average wattage" is obtained. After this, the market shares and wattages have been converted to a more useful "energy share" for each category, which is the percentage of energy out of the total market that each category consumes.
- As we know the total market to use 141.4 TWh/year (for both NDLS and DLS applications), this figure is multiplied by the "market average wattage" to obtain an energy usage in TWh for each category.
- The savings potential in TWh was found by multiplying energy usage by columns "How big is the market share of improvable luminaires in its category?", "how many luminaires are among the worst 30% performers in the category?", and "what proportion of the energy can be saved comparing worst to best practice?". The reasoning is the following:
    - o How big is the market share of improvable luminaires in its category? – defined what part of the market share is improvable.

    - How many luminaires are among the worst 30% performers in the category? – defines the percentage of improvable luminaires that are among the worst 30%.
    - What proportion of the energy can be saved comparing worst to best practice? – defines the percentage of energy that is saved when replacing a worst practice luminaire with a best practice luminaire.
- Rather than summing, this savings potential is multiplied as a weighted percentage in order to avoid overlap of savings. For example, starting with 100% energy use, and 10% energy savings in two separate categories, total energy savings would be 100% - (100%-10%)*(100%-10%) = 100% - 90%*90% = 100% - 81% = 19%.
- Taking the percentage of energy savings, this is then multiplied with energy usage to find the energy savings in TWh.

These improvements with their quantified savings potential are summarised in Table 8.12: Luminaire technical savings potential. Note that only percentage savings can be given, as the luminaire improvement is applied on top of other lamp improvements. Thus, the absolute improvement potential due to luminaires is reduced as lamps become more efficient. For other scenarios please see section 8.1.2.10.

Table 8.12: Luminaire technical savings potential

Luminaire improvement option	**Applicable to part 1**	**Applicable to part 2**	**Savings potential (%)**
Dimmable	y	y	8.32%
Motion sensor	y	y	5.76%
Day/night sensor	y	y	2.44%
Reflectors	y	n	5.64%
Correct application of luminaire (education)	y	y	4.99%
Diffusing material	y	n	1.05%
Total (%)	**25.2%**	**19.9%**	**24.1%**

8.1.2.9 Scenario "Luminaire improvement options introduced on top of scenarios BAT" part 1&2 lamp stock

As additional information on future predictions of implementation of luminaire improvements that are not related to lamp efficacy is not available, the full technical savings potential is assumed to be achieved on a linear basis by 2020. Thus, the scenarios already analysed could see additional improvements.

The accepted luminaire lifetime is assumed to be 13 years (as stated in section 2.2.5). The replacement of luminaires is considered to naturally occur during the scenario. More background information on the impacts is included in section 8.2.

As Table 8.13 shows, the relative savings over BAU (with improved luminaires) remains almost exactly the same as those in Table 8.10. Please note that the most important savings are due to increasing the lamp efficacy. Luminaires can contribute as well by avoiding a negative but creating positive lock-in effect, e.g. pin based CFLni luminaire or efficient LED luminaire (see chapter 3 and 6 for details).

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Table 8.13: Environmental impacts 2020 without and with luminaire improvement for DLS

		Electricity consumption (TWh) in 2020	CO2 emissions (Mton) in 2020	Mercury emissions (ton) in 2020
BAU	Value WITHOUT luminaire improvement	51.1	22.0	0.82
	Value WITH luminaire improvement	40.9	17.6	0.7
BAT with lock in	Value WITHOUT luminaire improvement	28.0	12.0	0.45
	Value WITH luminaire improvement	22.4	9.6	0.4
BAT without lock in	Value WITHOUT luminaire improvement	24.5	10.5	0.39
	Value WITH luminaire improvement	19.6	8.4	0.3
BNAT (LED)	Value WITHOUT luminaire improvement	15.5	6.7	0.25
	Value WITH luminaire improvement	12.4	5.4	0.2

Table 8.14: Environmental impacts 2020 without and with luminaire improvement for NDLS

		Electricity consumption (TWh) in 2020	CO2 emissions (Mton) in 2020	Mercury emissions (ton) in 2020
BAU	Value WITHOUT luminaire improvement	134.7	57.9	3.1
	Value WITH luminaire improvement	100.7	43.3	2.3
Option 2 clear B fast	Value WITHOUT luminaire improvement	96.0	41.3	1.6
	Value WITH luminaire improvement	71.8	30.9	1.2
BAT	Value WITHOUT luminaire improvement	47.5	20.4	0.85
	Value WITH luminaire improvement	35.5	15.3	0.6

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8.1.3 Sensitivity analysis

The robustness of the outcomes of the study depends on the underlying assumptions. These assumptions have been explicitly mentioned at the relevant steps of the study. In this section, the sensitivity of the results to the most critical parameters and assumptions is tested, related namely to:

- The economic data, such as the electricity tariff, the discount rate, and the purchase price of BAT lamps, which have an influence on the LCC when implementing improvement options,
- The behavioural data such as the annual operational hours as well as the maximum lamp lifetime, which have an influence on the LCC of base-cases and their improvement options,
- The replacement of a lamp and its luminaire compared to the replacement of the lamp only.

8.1.3.1 Assumptions related to the electricity tariff

For the base-cases, an average EU-27 electricity tariff of 0.1528 €/kWh was used, based on the data from Eurostat (see chapter 2, section 2.4.2). However, if the lowest electricity tariff (i.e. 0.0658 €/kWh in Latvia) and the highest electricity tariff (i.e. 0.2580 €/kWh in Denmark) are applied, this could lead to different LCC for the base-cases.

As shown in in the following figures, the modifications in the electricity tariff have a strong impact on the LCC. Indeed, the major part of the LCC is due to the electricity costs during the use phase as specified in chapter 5. Because of this, the economics of improvement options changes with the electricity tariff.

The EU-27 average electricity tariff of 0.1528 €/kWh is denoted by the dashed line in the figures, whereas 0.1619 €/kWh represents the average between the lowest and the highest rate.

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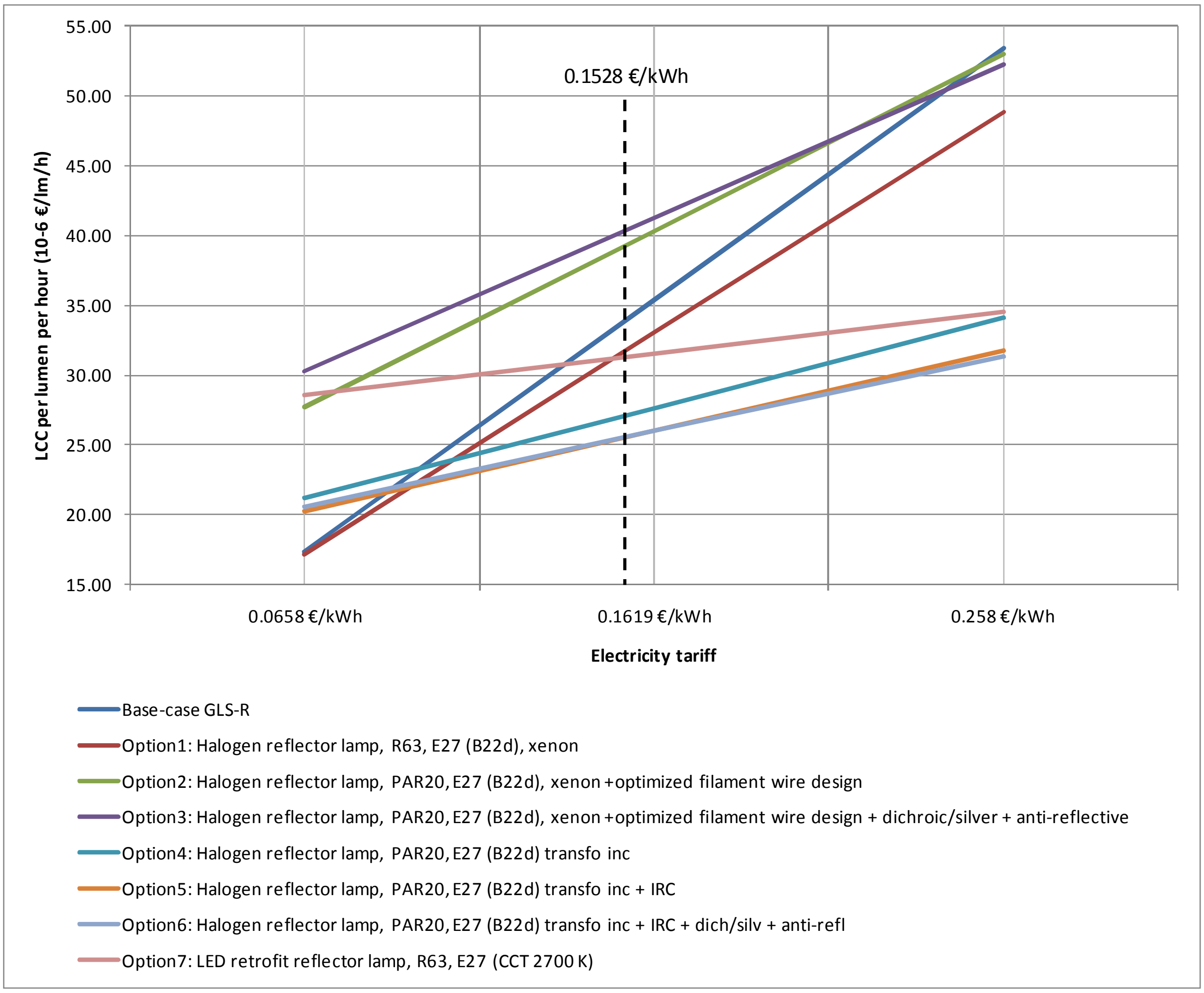

Figure 8.28: GLS-R sensitivity of LCC to electricity tariff

In the case of GLS-R and its improvement options, there is a wide change of LLCC option as the electricity tariff changes. At the low end, option 1 is the LLCC option. In the midrange, option 5 is just barely the LLCC, and afterwards option 6 becomes the LLCC option.

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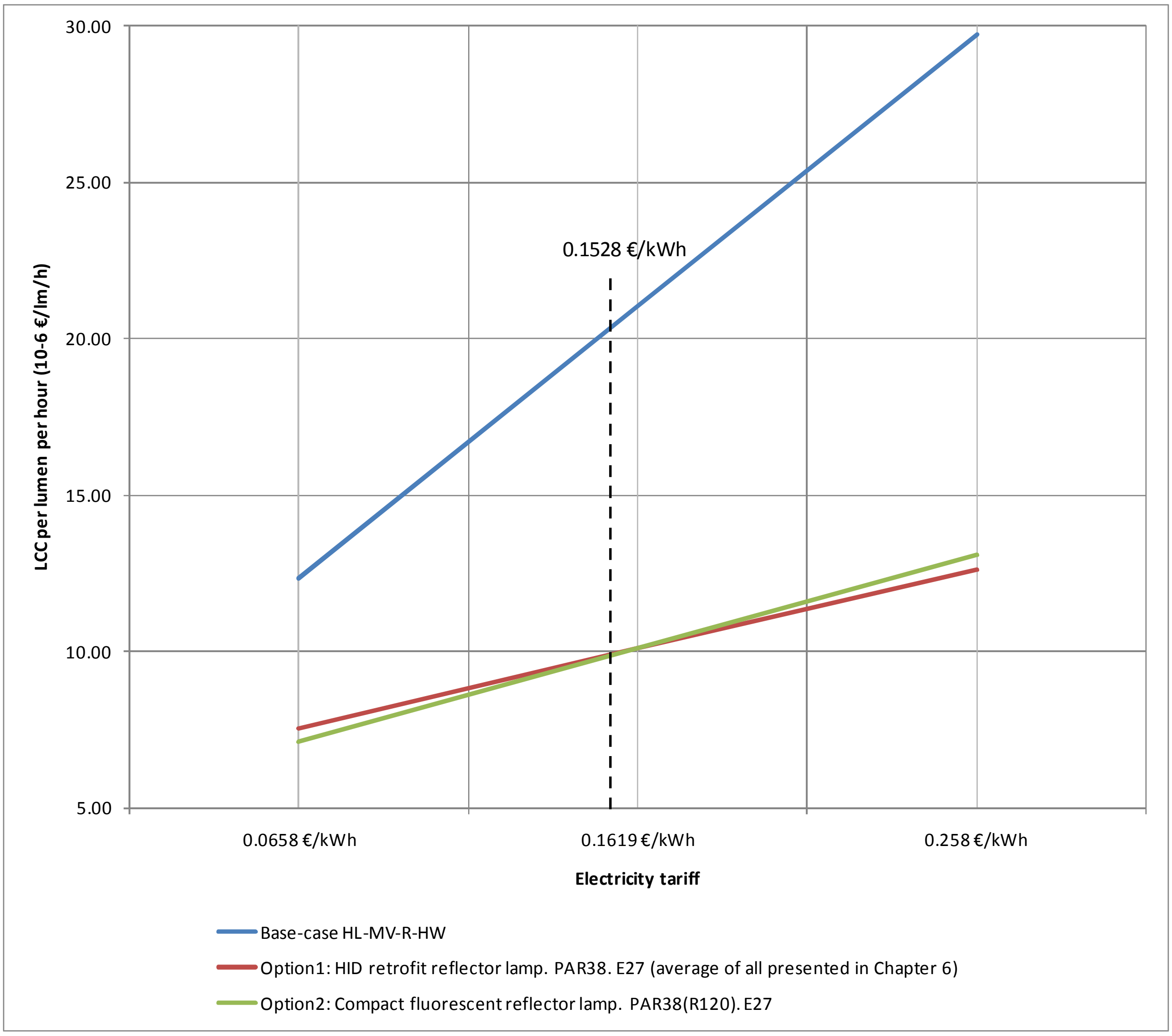

Figure 8.29: HL-MV-R-HW sensitivity of LCC to electricity tariff

As the electricity tariff increases, the LCC of option 1 reduces until it becomes the LLCC option. If the electicity tariff of Latvia is used as reference, however, option 2 leads to the LLCC.

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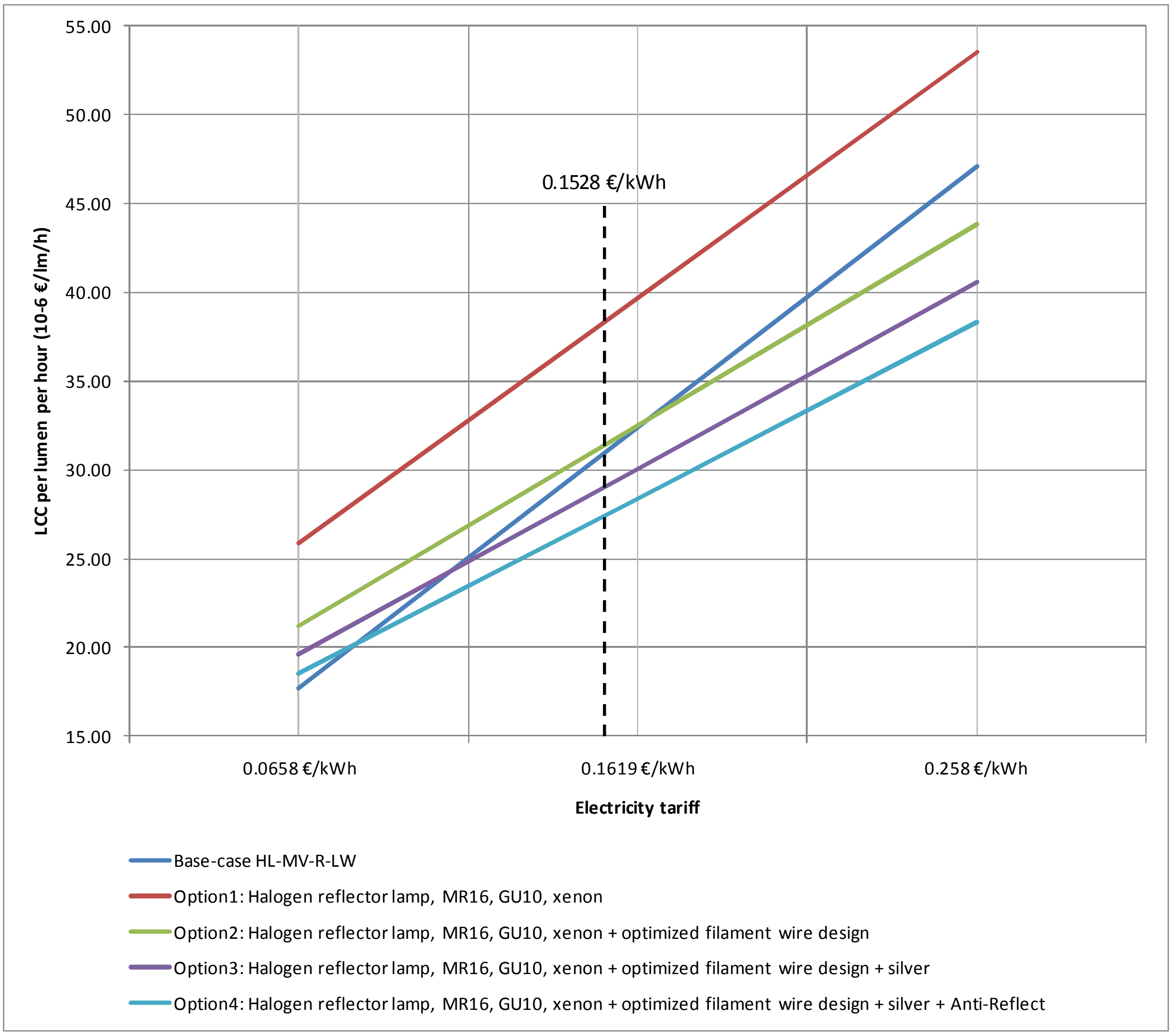

Figure 8.30: HL-MV-R-LW sensitivity of LCC to electricity tariff

With very low electricity tariffs, the base-case is actually the LLCC. Towards higher tariffs, the energy savings of option 4 reduce the costs enough to become the LLCC.

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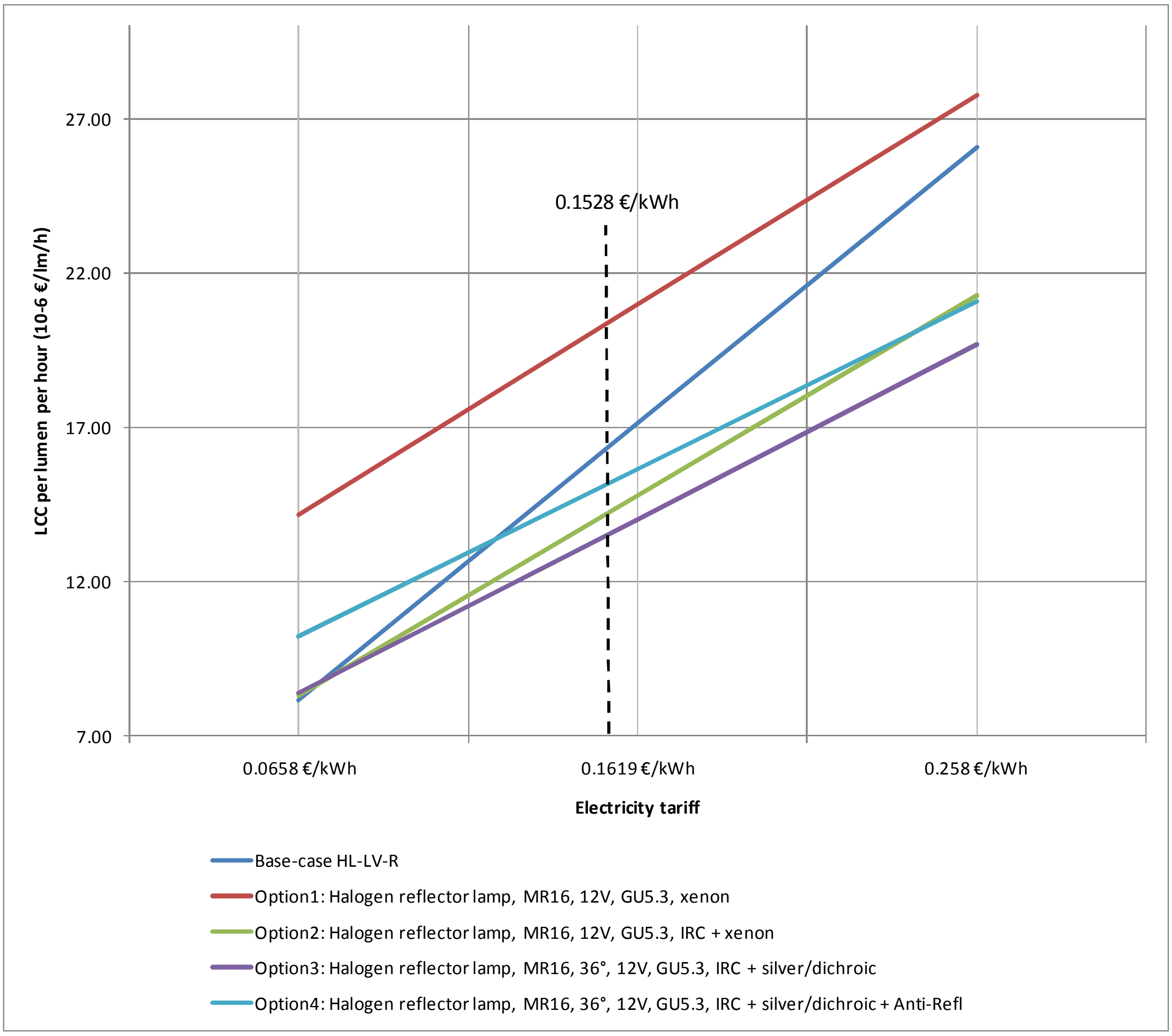

Figure 8.31: HL-LV-R sensitivity of LCC to electricity tariff

At the very lowest electricity tariff, the base-case is the LLCC option. Afterwards, option 3 is the LLCC.

8.1.3.2 Assumptions related to discount rate

For the base-cases, the EU-27 discount rate (interest rate minus inflation rate) was assumed to be 1.8%. This could be considered as very low, especially for the year 2009. Thus, the sensitivity to the discount rate is analyed considering a much wider range of discounts rates of all the Member States, from 1.77% in multiple to 15.54% in Latvia. However, as the following figures show, the discount rate does not have a significant impact on the LCC of the base-cases and improvement options. For all base-cases, the LLCC option remains the same despite changes in the discount rate (keeping the EU-27 averal electricity tariff).

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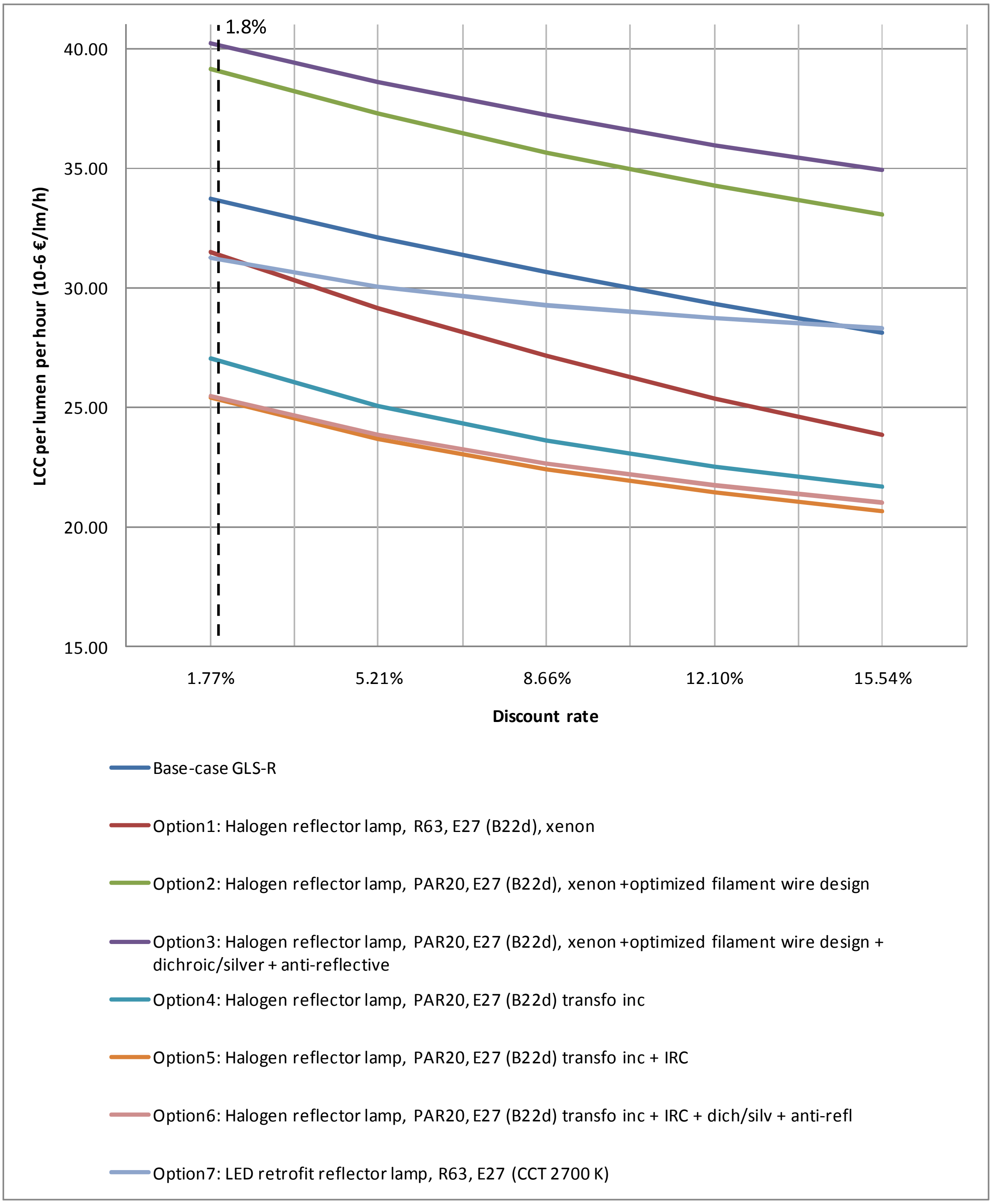

Figure 8.32: GLS-R sensitivity of LCC to discount rate

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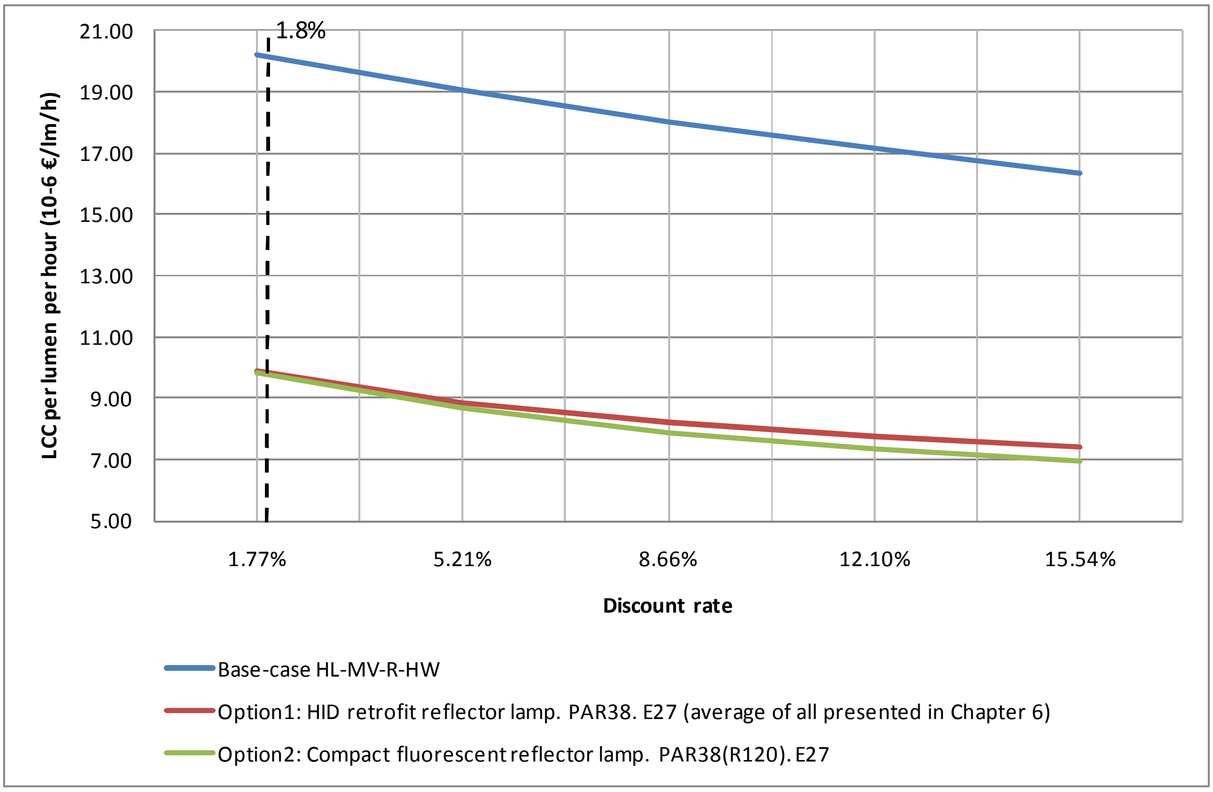

Figure 8.33: HL-MV-R-HW sensitivity of LCC to discount rate

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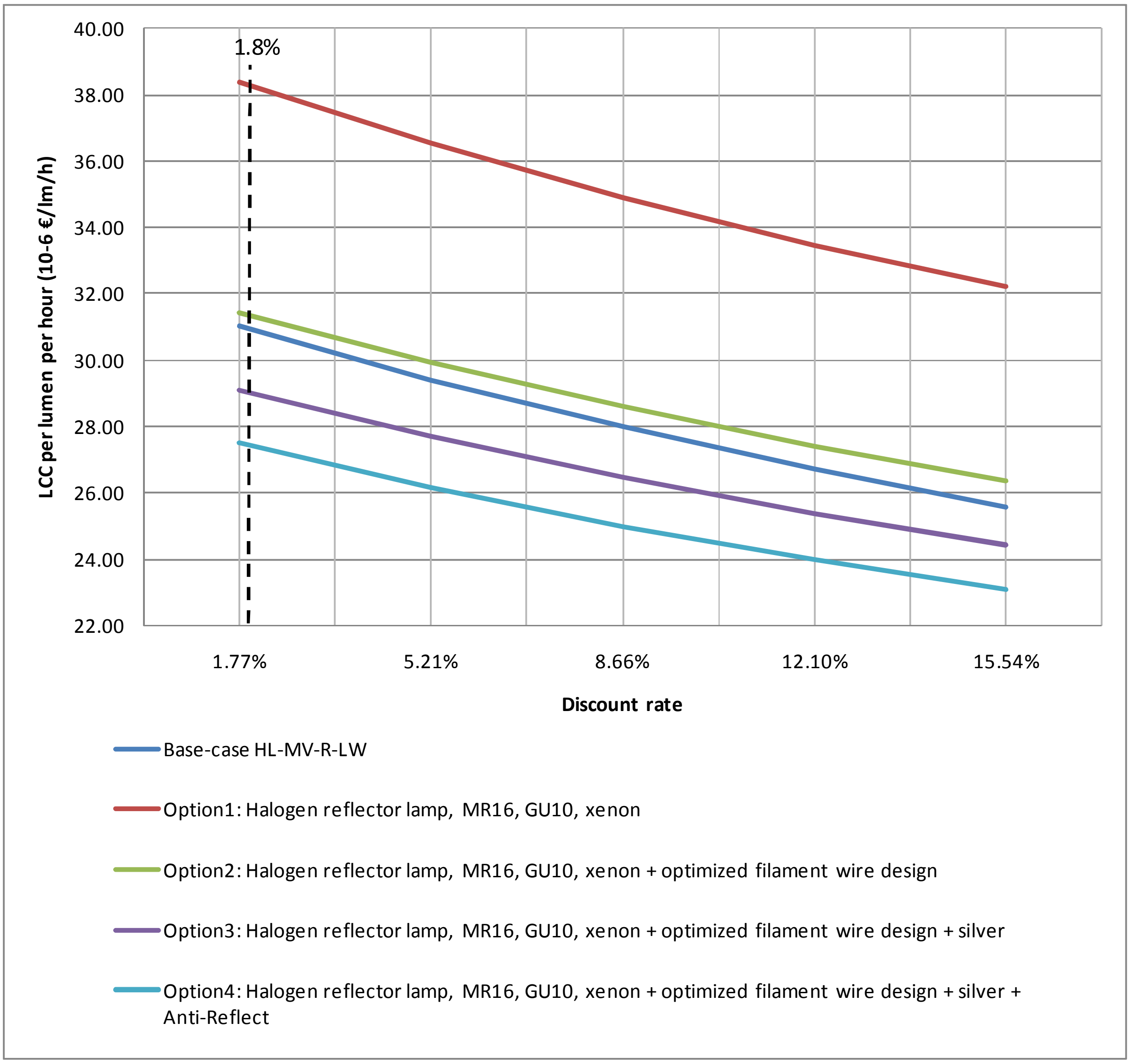

Figure 8.34: HL-MV-R-LW sensitivity of LCC to discount rate

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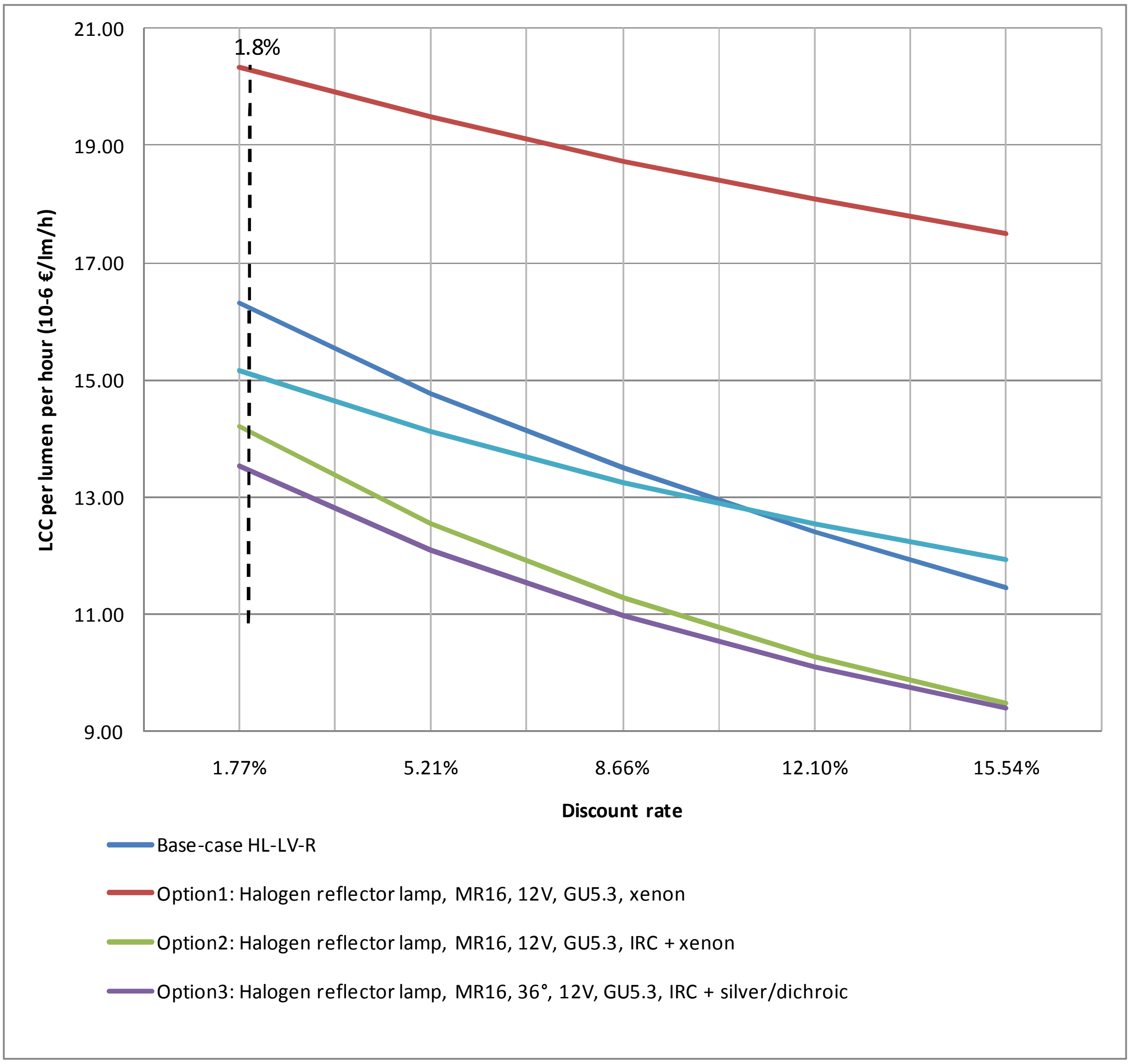

Figure 8.35: HL-LV-R sensitivity of LCC to discount rate

8.1.3.3 Assumptions related to the price of BAT products

Due to uncertainty in the prices of the BAT products used as improvement options, the prices are analysed +/- 30% to determine the effects, if any, on the LLCC option. As seen in the following figures, only the LLCC option of base-case HL-MV-R-HW changes from option 1 to option 2 as price increases.

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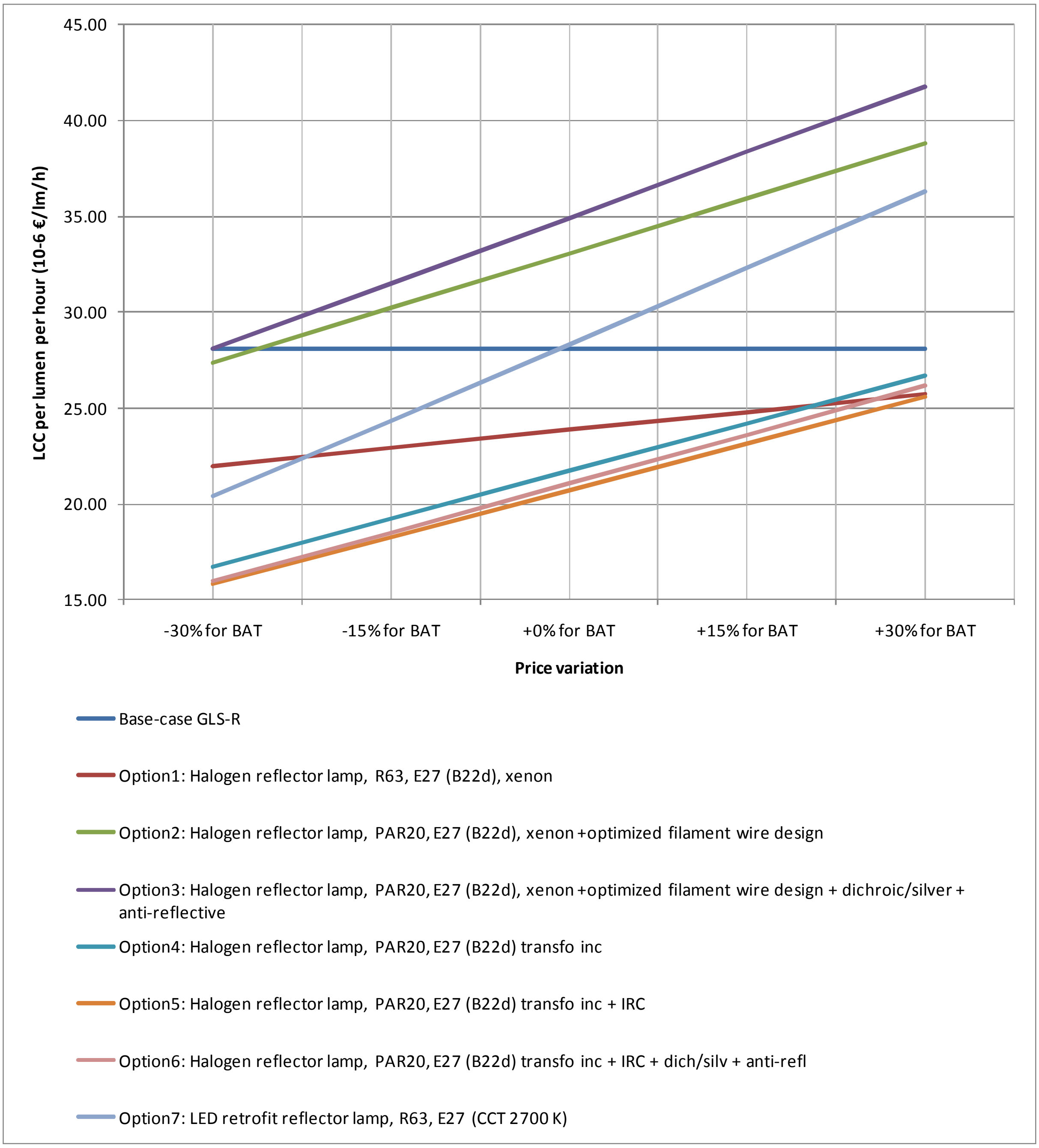

Figure 8.36: GLS-R sensitivity of LCC to BAT product price

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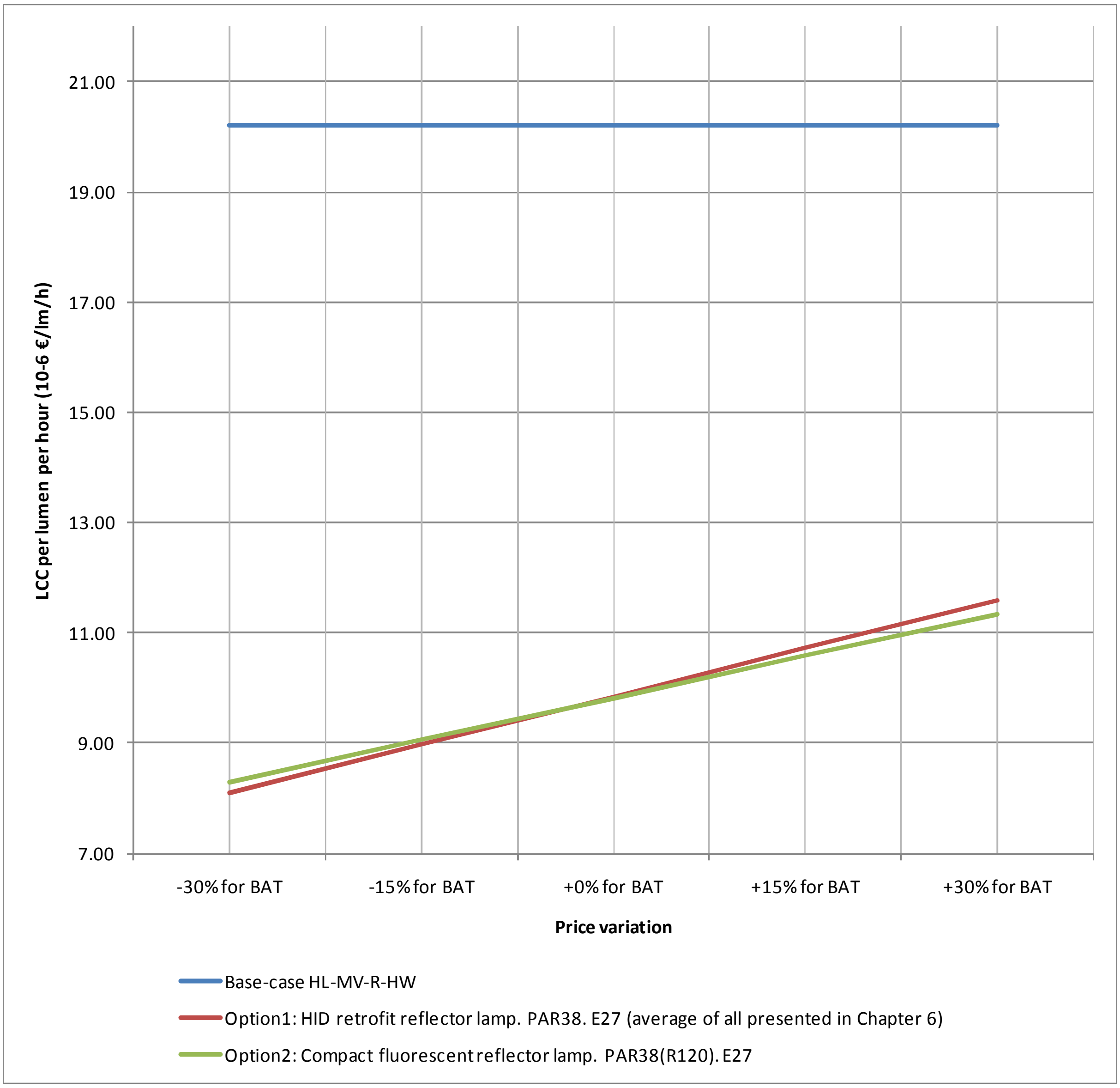

Figure 8.37: HL-MV-R-HW sensitivity of LCC to BAT product price

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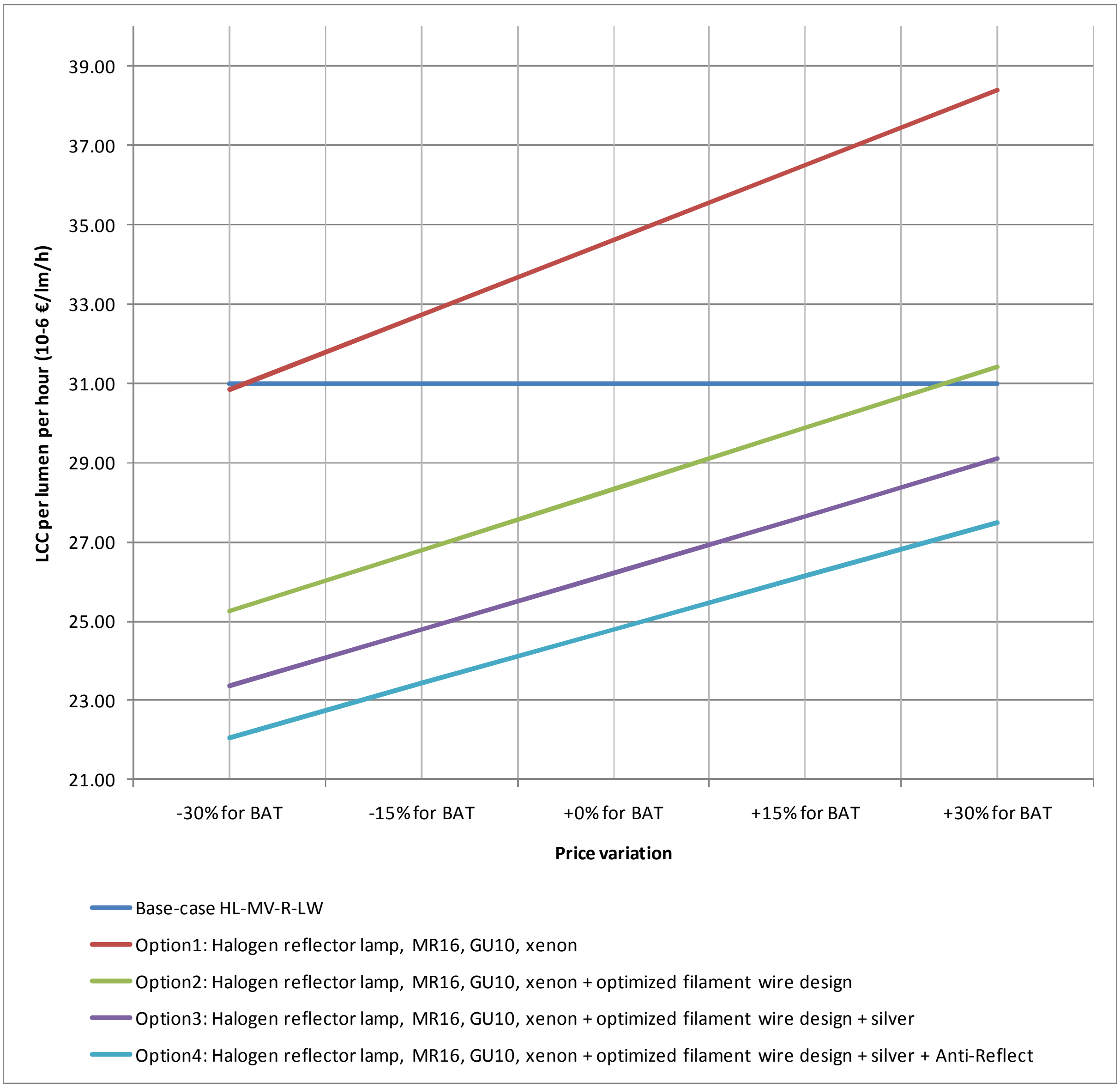

Figure 8.38: HL-MV-R-LW sensitivity of LCC to BAT product price

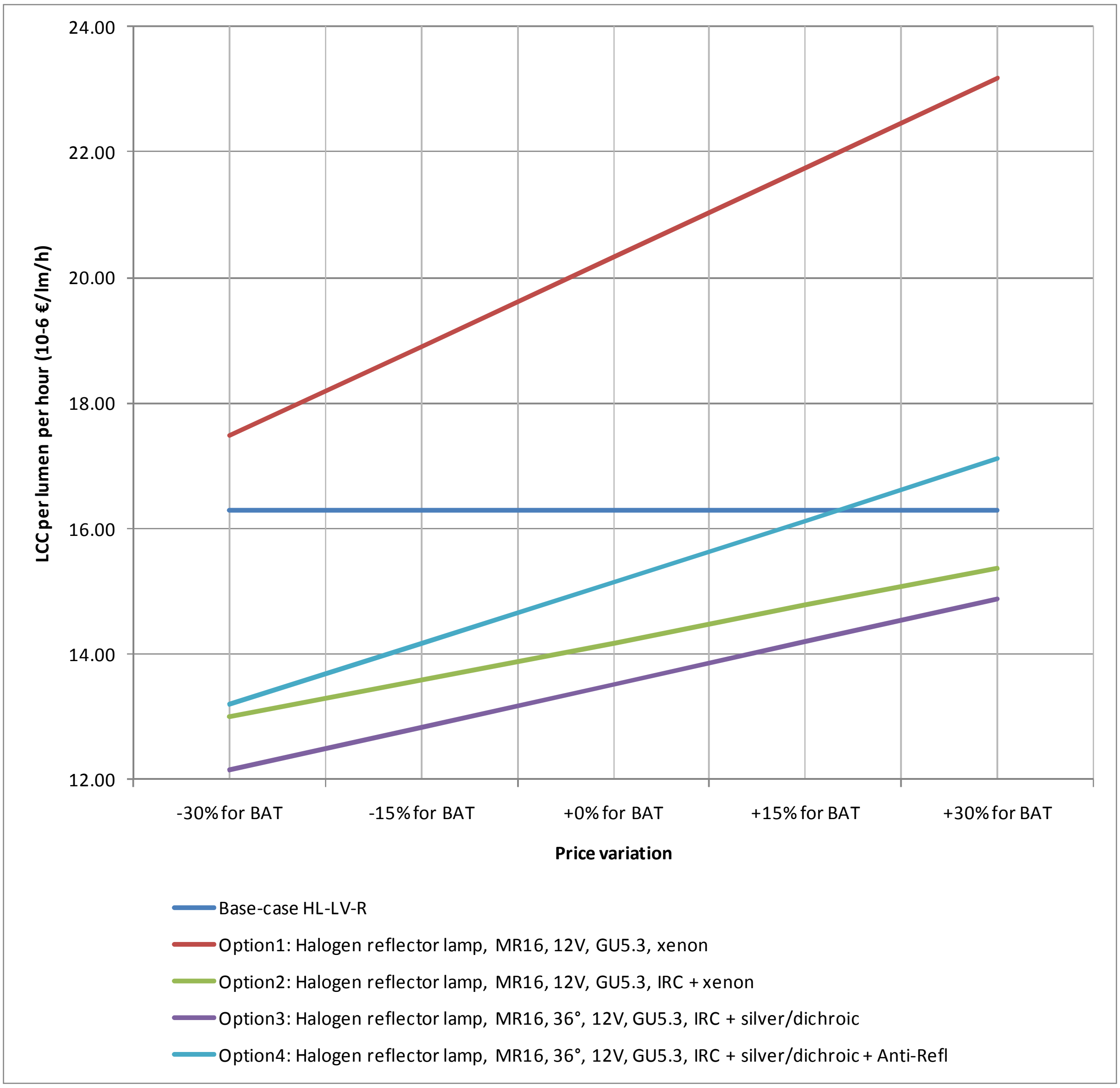

Figure 8.39: HL-LV-R sensitivity of LCC to BAT product price

8.1.3.4 Assumptions related to operational hours

The sensitivity of the life cycle analysis to changes in operation hours per year is conducted by varying operating hours by -20% / +40%. As the figures below show, all lamps generally change in the same manner, thus keeping the differences in LCC relatively constant. However, it is important to note that for the longer lifetime lamps (LEDi-R, CFLi-R, HIDi-R), there are greater changes because of the assumed behavioural lifetime limit of 18 years. As operating hours change, the actual usage hours of these long-life lamps change and therefore the LCC changes more drastically. Nonetheless, only the LLCC option of the GLS-R base-case changes due to variations in operation hours.

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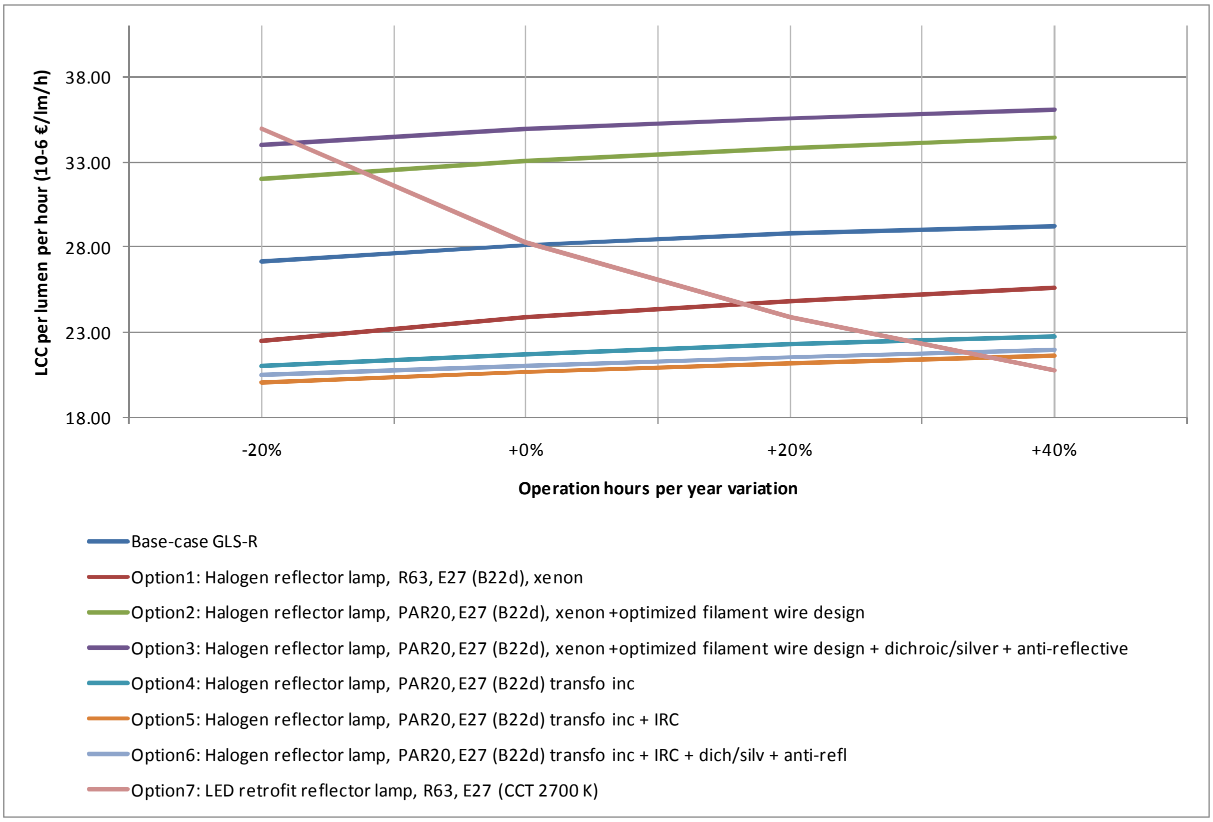

Figure 8.40: GLS-R sensitivity of LCC to operational hours per year

As the lifetime of the LEDi-R is capped by the behavioural lifetime limit of 18 years, there is a very strong variation due to operation hours. At -20%, it has the highest LCC and at 40%, it is the LLCC option.

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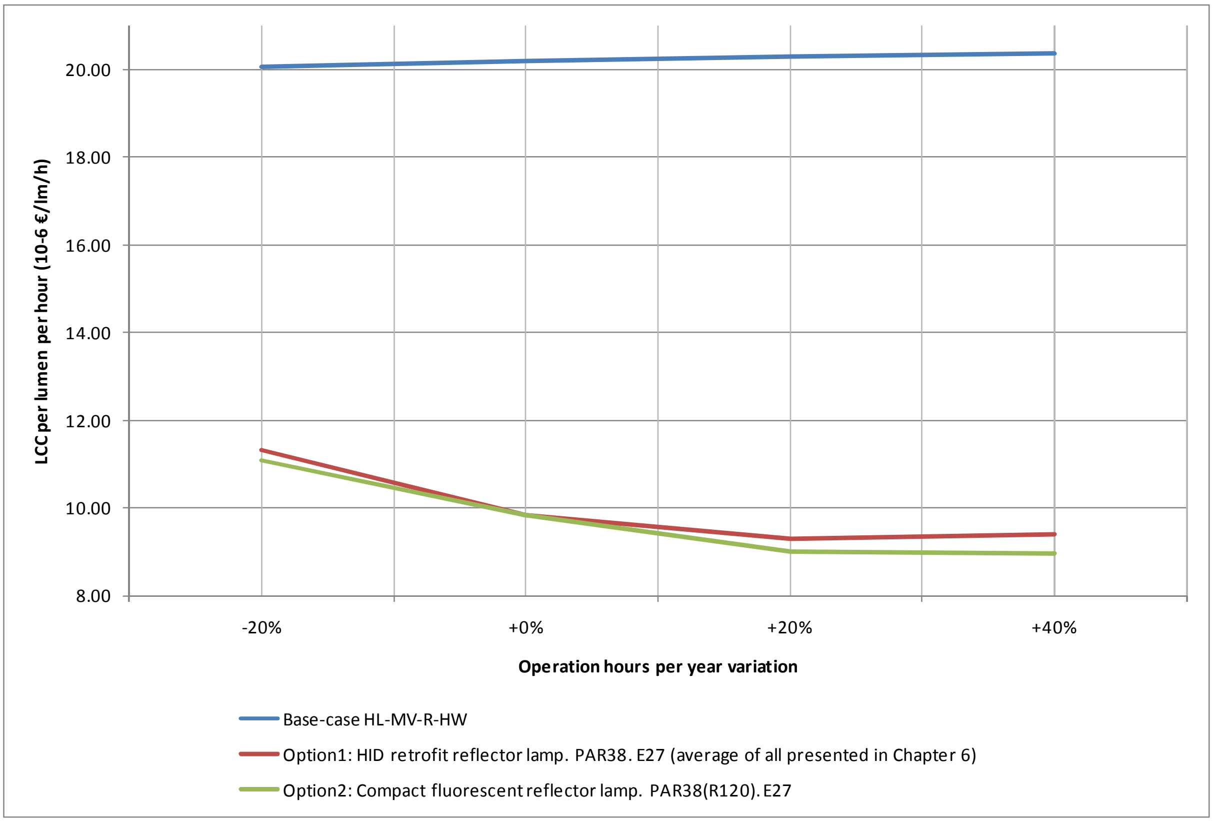

Figure 8.41: HL-MV-R-HW sensitivity of LCC to operational hours per year

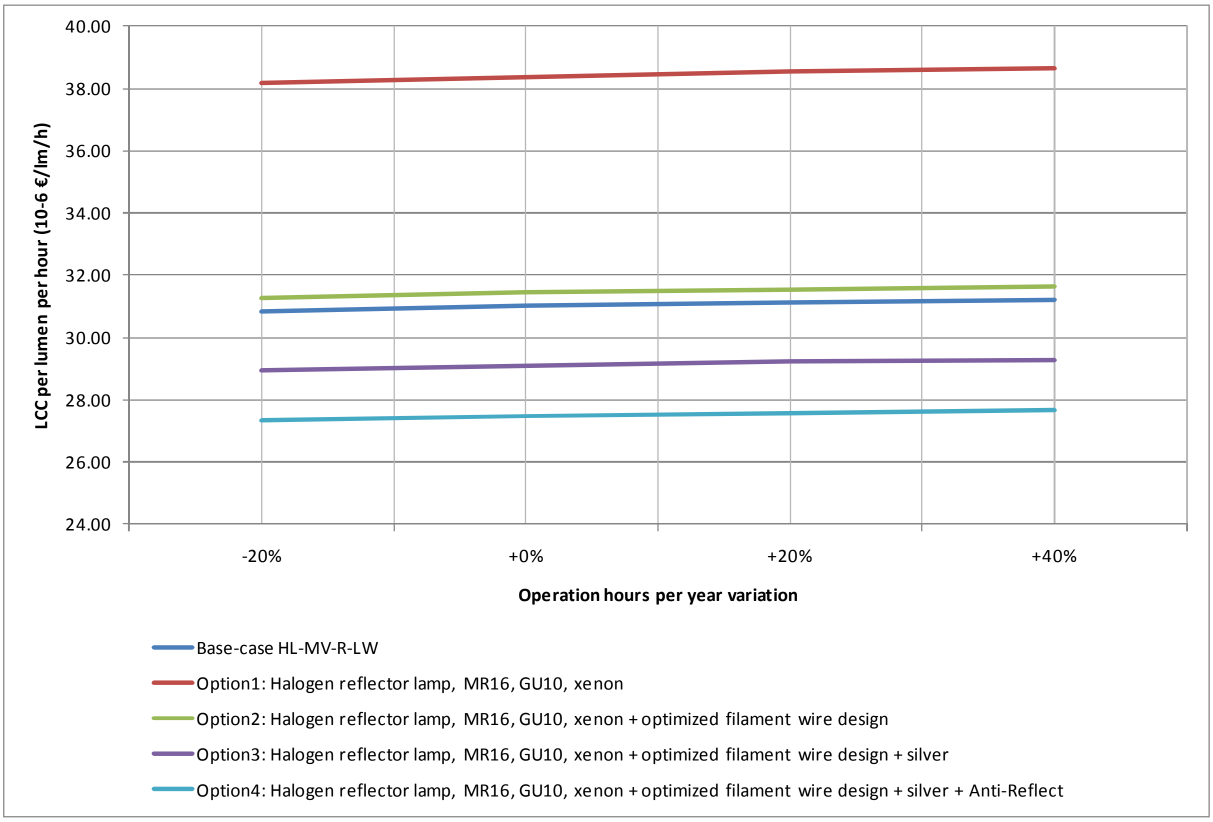

Figure 8.42: HL-MV-R-LW sensitivity of LCC to operational hours per year

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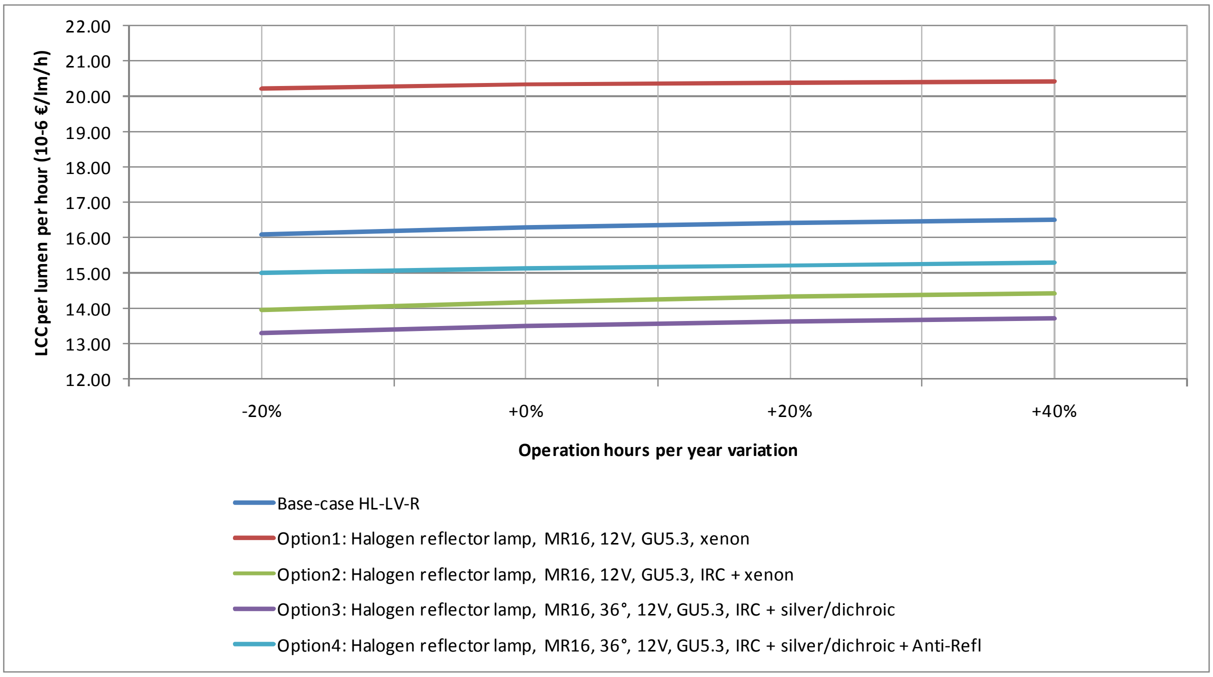

Figure 8.43: HL-LV-R sensitivity of LCC to operational hours per year

8.1.3.5 Assumptions related to behavioural lamp lifetime limit

The behavioural lamp lifetime limit is used because consumers often replace lamps due to renovations or redecorating, rather than at the end of lamp lifetime. Considering this, a preliminary value of 18 years was assumed. The sensitivity of this value is considered -20% (i.e. 14.4 years) / +40% (i.e. 25.2 years) in the following figures. Only the base-cases of GLS-R and HL-MV-R-HW show changes as their improvement options are restricted by the behavioural lifetime limit. The LLCC option of GLS-R base-case changes to the LEDi-R as behavioural lifetime increases, while HL-MV-R-HW has no change in LLCC option.

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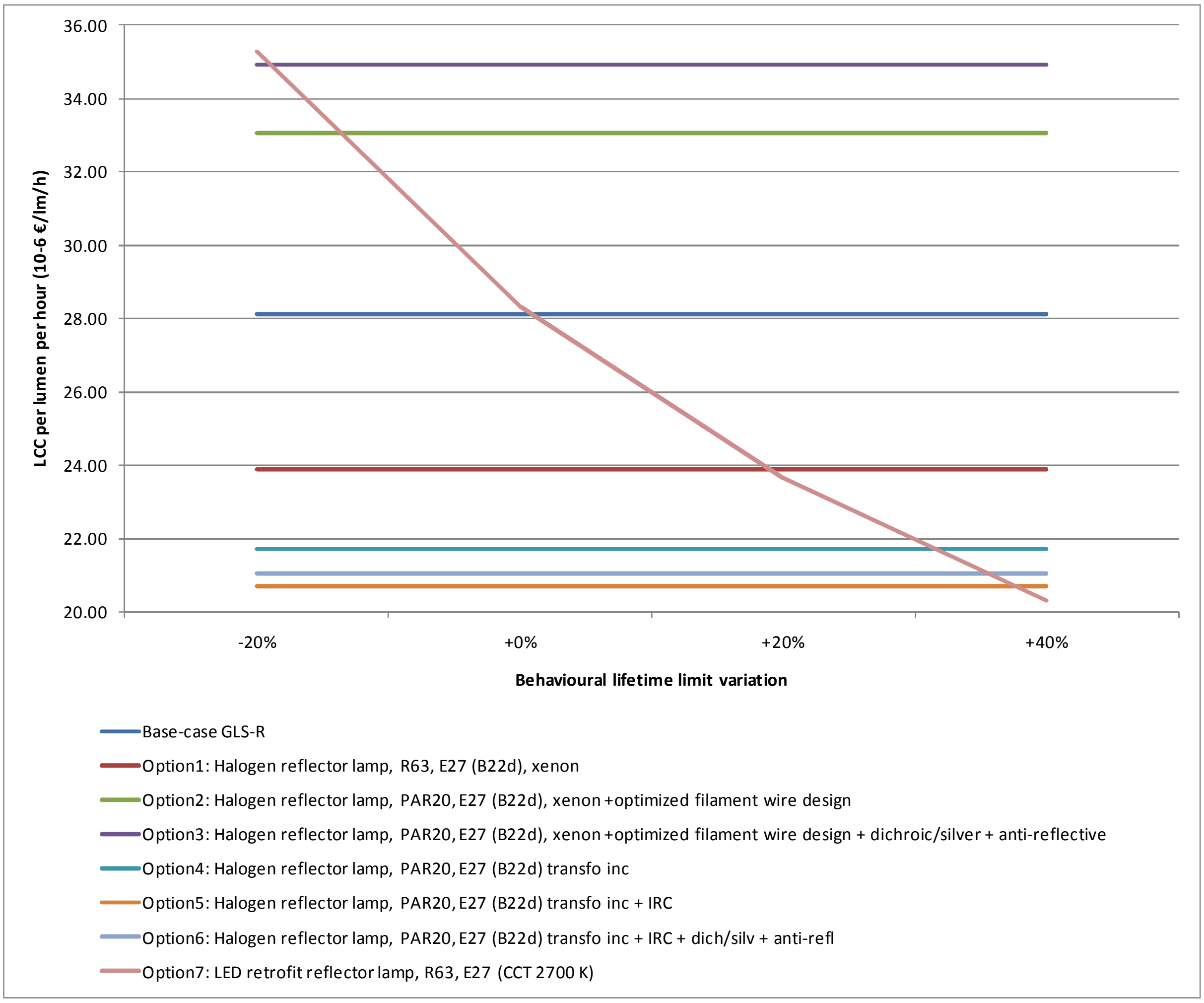

Figure 8.44: GLS-R sensitivity of LCC to operational hours per year

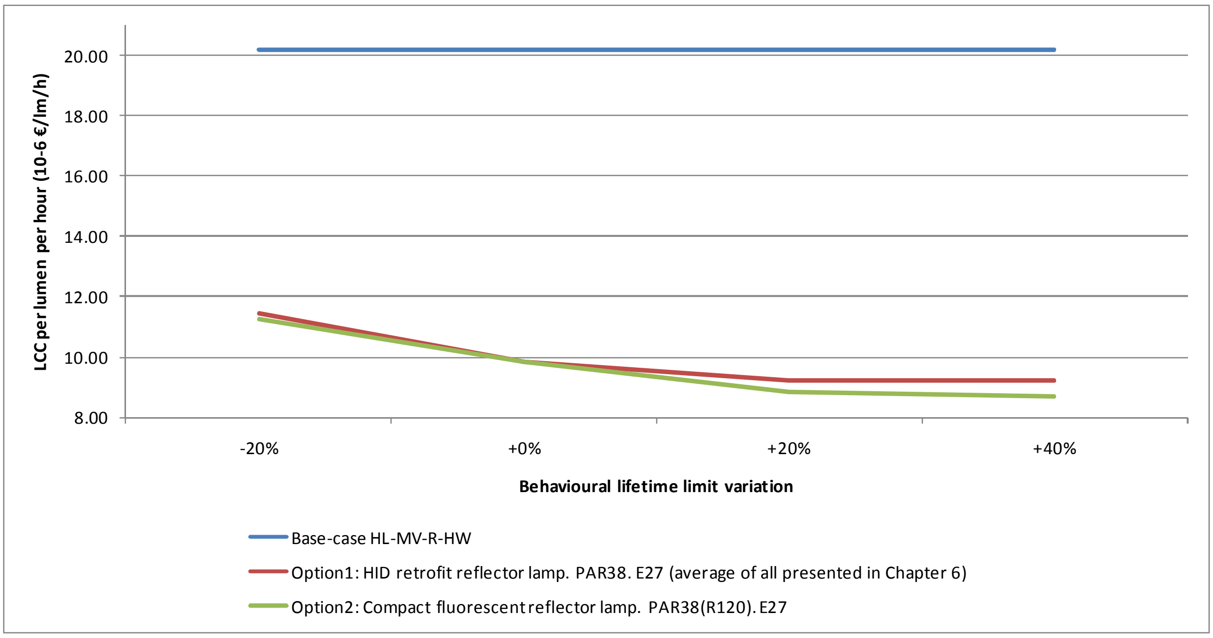

Figure 8.45: HL-MV-R-HW sensitivity of LCC to operational hours per year

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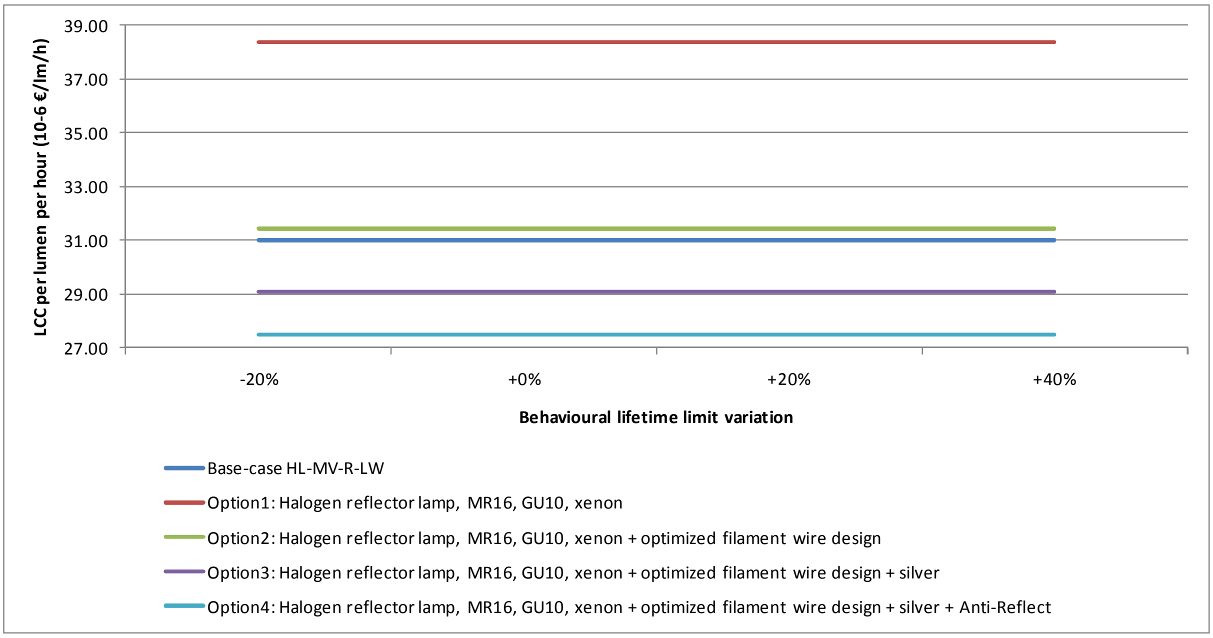

Figure 8.46: HL-MV-R-LW sensitivity of LCC to operational hours per year

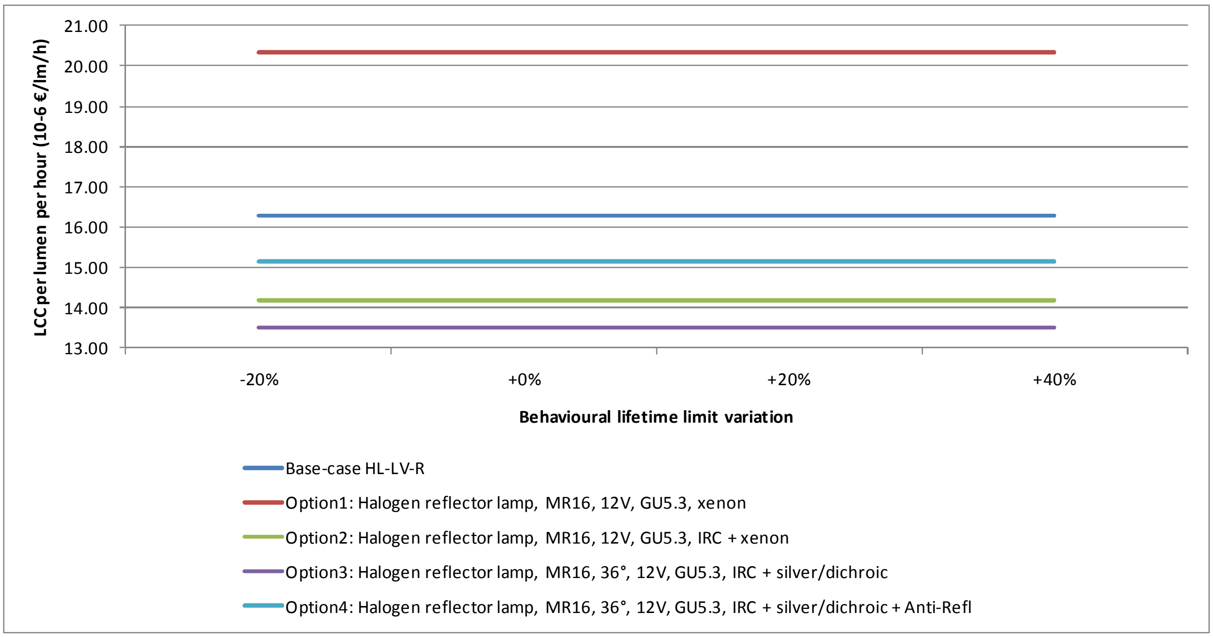

Figure 8.47: HL-LV-R-LW sensitivity of LCC to operational hours per year

8.1.3.6 Impact related to 'lamp' vs 'luminaire + lamp replacement'

As presented in Section 4.1.5, an EcoReport comparison is conducted between a typical lamp and an alternative lamp requiring luminaire change. The lamps chosen were the base-case HL-MV-R-LW, and the HL-LV-R to accompany the luminaire replacement. As the figures below show, the luminaire and lamp replacement offers reduced energy consumption by 34%, as well as decreased LCC by 20%.

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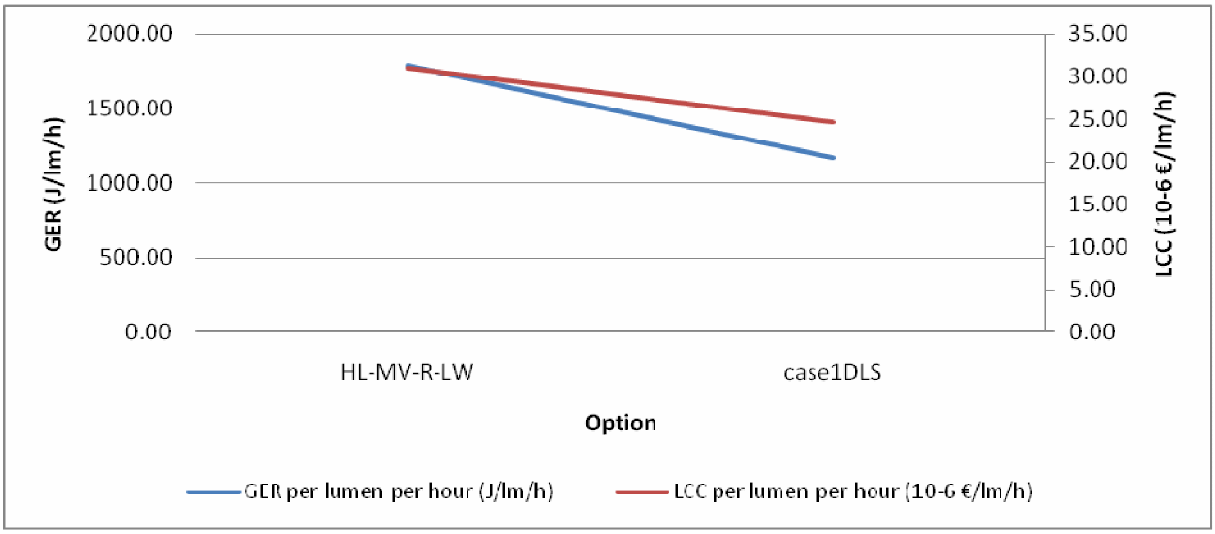

Figure 8.48: Lamp vs luminaire + lamp replacement, GER and LCC comparison

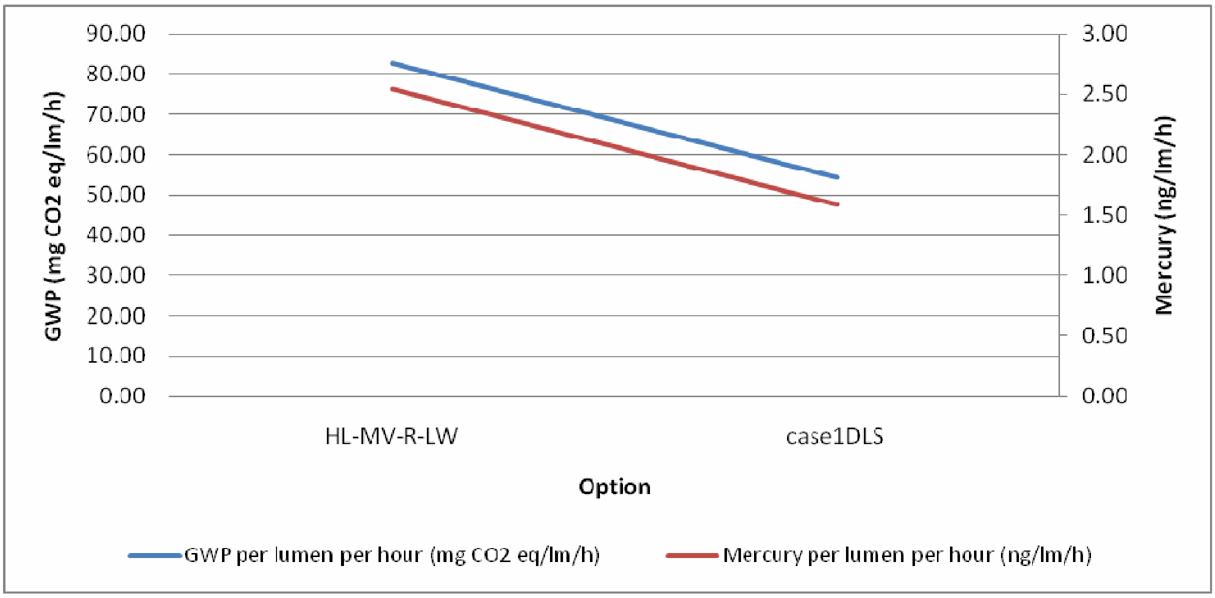

Figure 8.49: Lamp vs luminaire + lamp replacement, GWP and Mercury comparison

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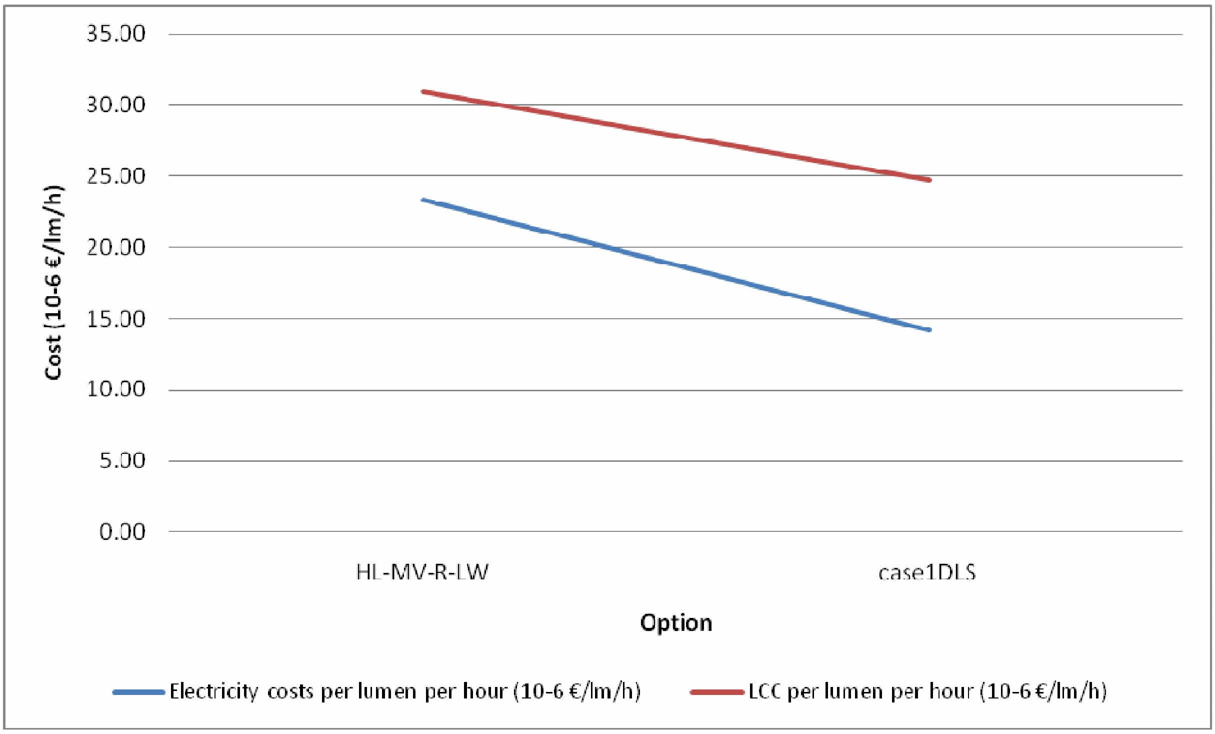

Figure 8.50: Lamp vs luminaire + lamp replacement, Electricity cost and LCC comparison

Table 8.14 shows a more detailed comparison of the environmental impacts. As the table shows, the replacement luminaire often causes increases in environmental impacts. The biggest increases include hazardous waste (+151%), PAHs (+208%), and eutrophication (+251%). This increases are due mainly to the production of materials needed to construct the luminaire.

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Table 8.15: Comparison of luminaire replacement option environmental factors

		Base-case HL-MV-R-LW	*Case 1 DSL*
main environmental indicators	**unit**	**value per lumen per hour**	**value per lumen per hour**
Total Energy (GER)	J	1783.70	1169.41
	variation with the base-case	0.00%	-34.44%
of which, electricity	J	1667.70	1046.13
	variation with the base-case	0.00%	-37.27%
Water (process)	μltr	111.77	77.71
	variation with the base-case	0.00%	-30.47%
Water (cooling)	μltr	4444.46	2788.94
	variation with the base-case	0.00%	-37.25%
Waste, non-haz./ landfill	μg	2165.96	1856.47
	variation with the base-case	0.00%	-14.29%
Waste, hazardous/ incinerated	μg	40.60	101.82
	variation with the base-case	0.00%	150.81%
Emissions (Air)			
Greenhouse Gases in GWP100	mg CO2 eq.	82.86	54.37
	variation with the base-case	0.00%	-34.38%
Acidifying agents (AP)	μg SO2 eq.	456.01	309.09
	variation with the base-case	0.00%	-32.22%
Volatile Org. Compounds (VOC)	ng	775.62	849.20
	variation with the base-case	0.00%	9.49%
Persistent Org. Pollutants (POP)	10^{-3} pg i-Teq	12.26	9.59
	variation with the base-case	0.00%	-21.75%
Heavy Metals (HM)	ng Ni eq.	35.89	27.96
	variation with the base-case	0.00%	-22.08%
PAHs	ng Ni eq.	8.88	27.32
	variation with the base-case	0.00%	207.68%
Particulate Matter (PM, dust)	μg	19.68	36.65
	variation with the base-case	0.00%	86.28%
Emissions (Water)			
Heavy Metals (HM)	ng Hg/20	11.49	15.39
	variation with the base-case	0.00%	33.95%
Eutrophication (EP)	ng PO4	80.15	281.42
	variation with the base-case	0.00%	251.14%

An EcoReport comparison is also conducted for an NDLS example. The lamps chosen were the base-case HL-MV-HW, and the LFL-T5 to accompany the luminaire replacement. As the figures below show, the luminaire plus lamp replacement results in significantly lower energy use (-81%)and LCC (-70%). Mercury emissions are also reduced by 64%, despite the embedded mercury within the fluorescent lamp.

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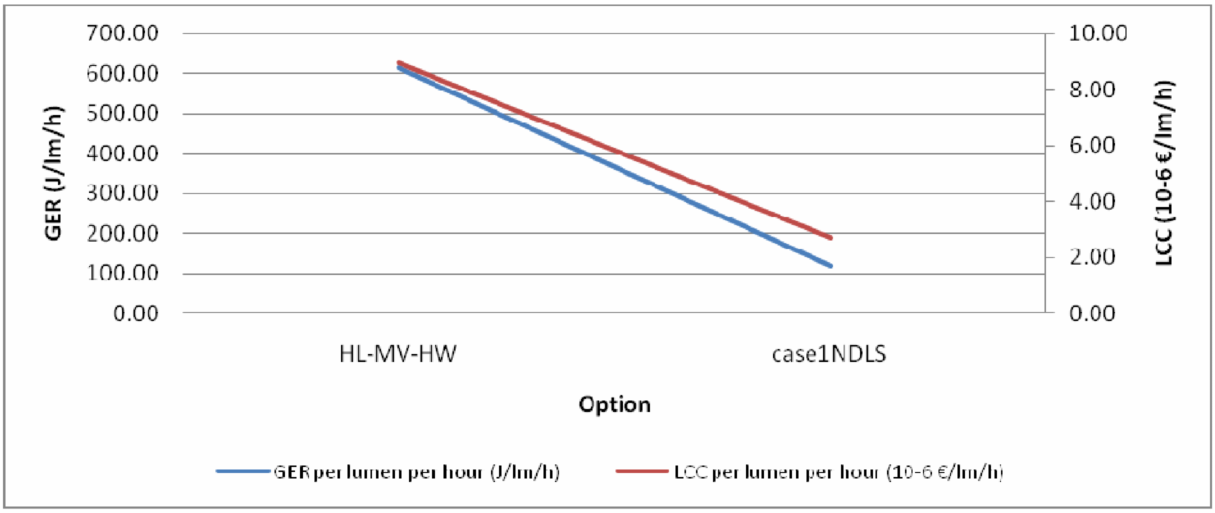

Figure 8.51: Lamp vs luminaire + lamp replacement, GER and LCC comparison

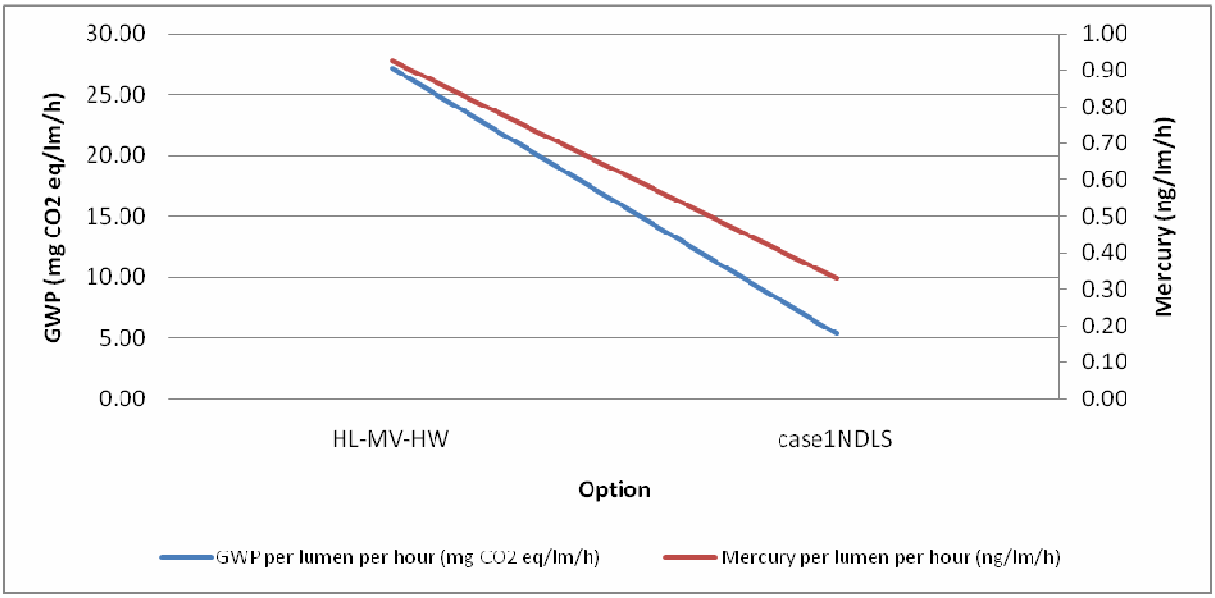

Figure 8.52: Lamp vs luminaire + lamp replacement, GWP and Mercury comparison

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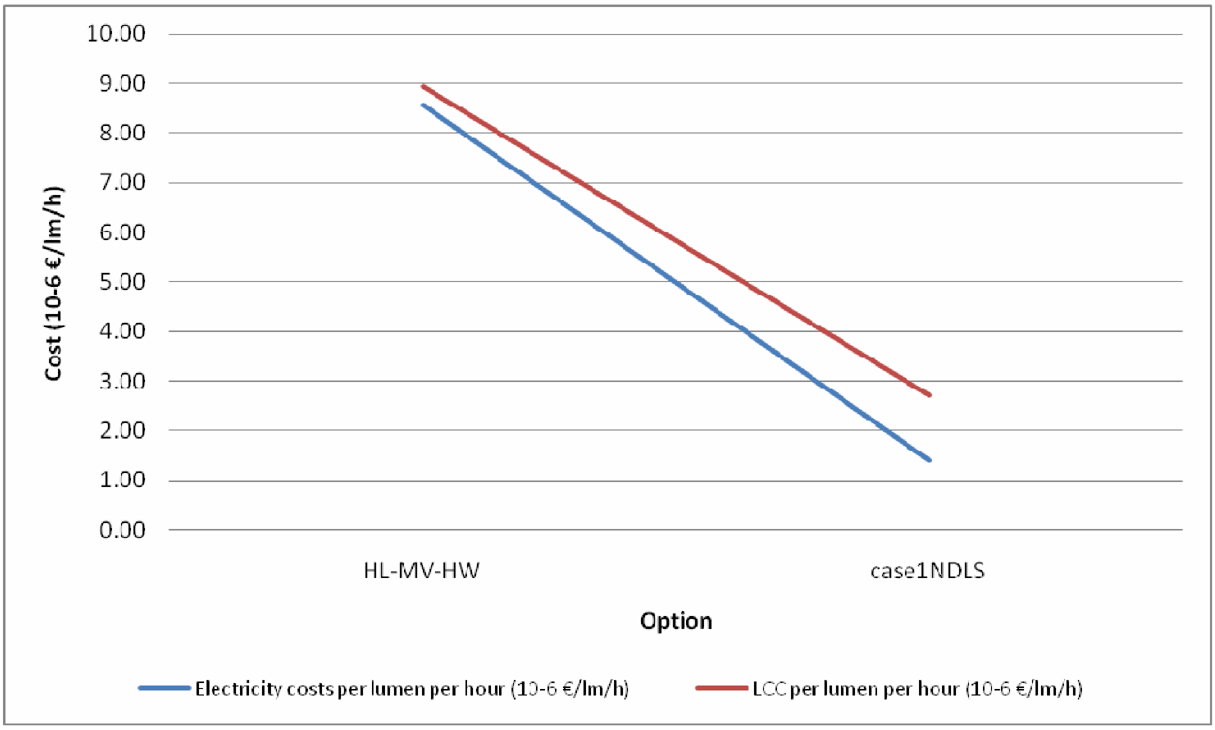

Figure 8.53: Lamp vs luminaire + lamp replacement, Electricity cost and LCC comparison

Table 8.16 shows a more detailed comparison of the environmental impacts. As the table shows, the replacement luminaire causes decrease in environmental impacts of around 60-80% for all categories except PAHs (-36%), Particulate Matter (-38%), and Eutrophication (-24%), which is due to environmental impacts from production.

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Table 8.16: Comparison of luminaire replacement option environmental factors

		Base-case HL-MV-R-LW	*Case 1 NDSL*
main environmental indicators	**unit**	**value per lumen per hour**	**value per lumen per hour**
Total Energy (GER)	J	615.22	118.37
	variation with the base-case	0.00%	-80.76%
of which, electricity	J	608.48	113.17
	variation with the base-case	0.00%	-81.40%
Water (process)	µltr	40.57	7.79
	variation with the base-case	0.00%	-80.80%
Water (cooling)	µltr	1622.56	301.67
	variation with the base-case	0.00%	-81.41%
Waste, non-haz./ landfill	µg	713.54	166.23
	variation with the base-case	0.00%	-76.70%
Waste, hazardous/ incinerated	µg	14.15	5.67
	variation with the base-case	0.00%	-59.96%
Emissions (Air)			
Greenhouse Gases in GWP100	mg CO2 eq.	27.14	5.32
	variation with the base-case	0.00%	-80.40%
Acidifying agents (AP)	µg SO2 eq.	158.24	30.60
	variation with the base-case	0.00%	-80.66%
Volatile Org. Compounds (VOC)	ng	236.44	64.11
	variation with the base-case	0.00%	-72.89%
Persistent Org. Pollutants (POP)	10^{-3} pg i-Teq	4.04	1.03
	variation with the base-case	0.00%	-74.48%
Heavy Metals (HM)	ng Ni eq.	10.80	2.45
	variation with the base-case	0.00%	-77.30%
PAHs	ng Ni eq.	1.54	0.99
	variation with the base-case	0.00%	-35.70%
Particulate Matter (PM, dust)	µg	3.55	2.21
	variation with the base-case	0.00%	-37.65%
Emissions (Water)			
Heavy Metals (HM)	ng Hg/20	3.94	1.03
	variation with the base-case	0.00%	-73.96%
Eutrophication (EP)	ng PO4	19.26	14.68
	variation with the base-case	0.00%	-23.79%

Impact related to 'lamp' vs 'luminaire + lamp replacement' NDLSAs presented in Section 6.1.8, an EcoReport comparison is conducted between a luminaire with HL-LV-R and a luminaire with LED. As the figures below show, the LED offers significantly reduced energy consumption by 80%, as well as decreased LCC by 42%.

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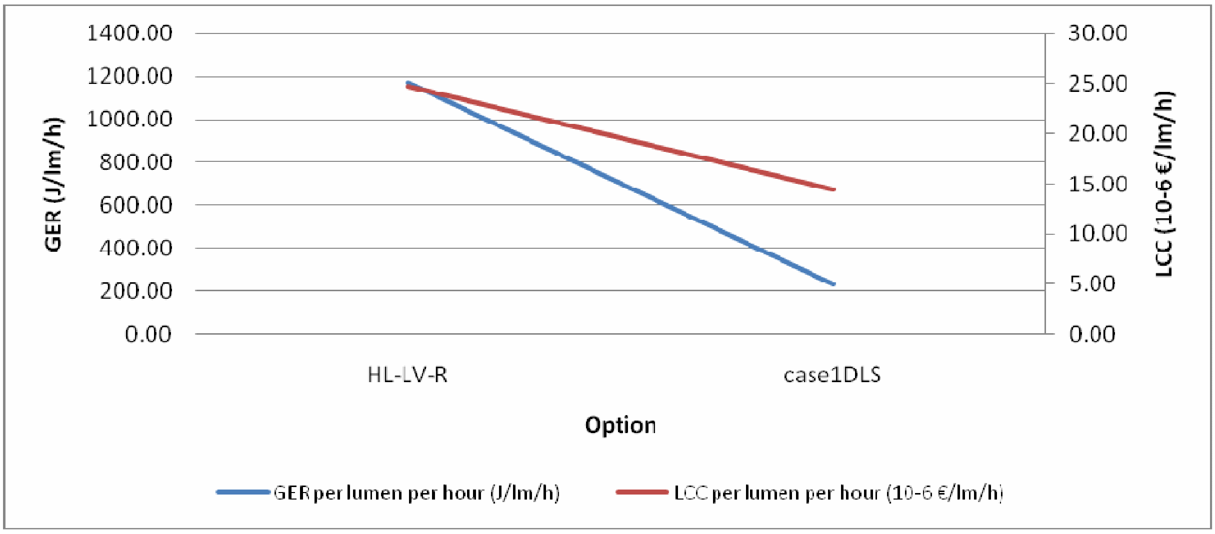

Figure 8.54: Lamp vs luminaire + lamp replacement, GER and LCC comparison

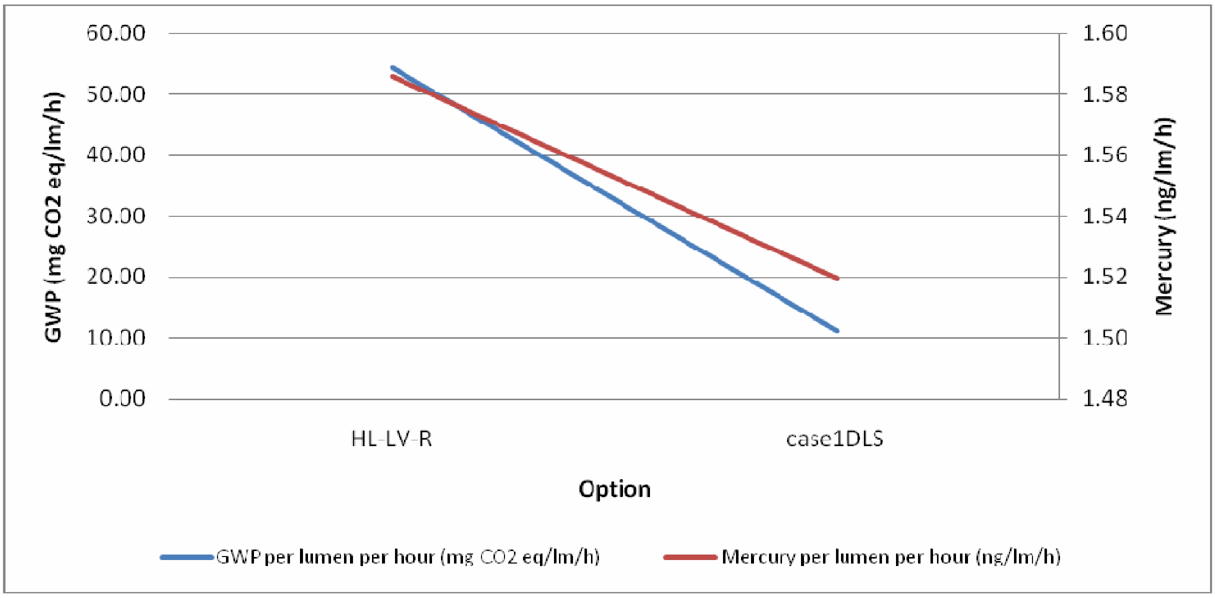

Figure 8.55: Lamp vs luminaire + lamp replacement, GWP and Mercury comparison

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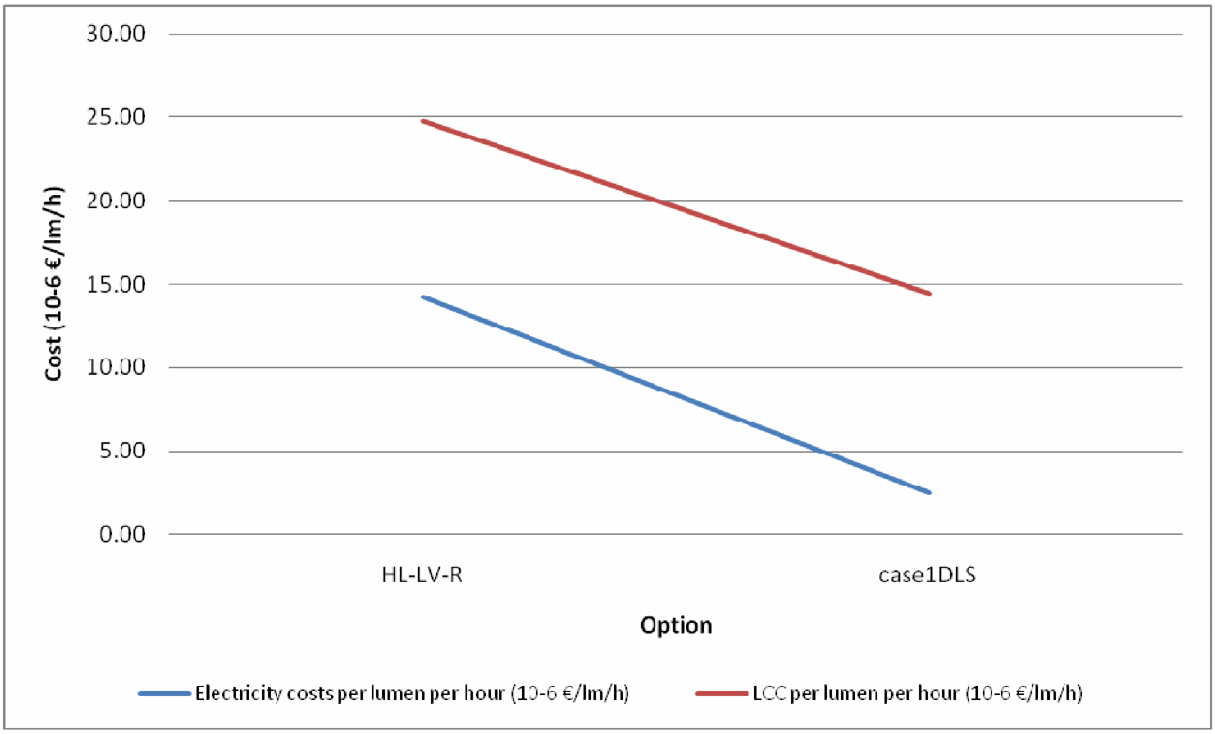

Figure 8.56: Lamp vs luminaire + lamp replacement, Electricity cost and LCC comparison

Table 8.18 shows a more detailed comparison of the environmental impacts. As the table shows again, environmental impacts are reduced significantly, roughly between 75% and 90%, except for POPs at 47% reduction.

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Table 8.17: Comparison of luminaire replacement option environmental factors

		Base-case HL-MV-R-LW	***Case 1 DSL***
main environmental indicators	**unit**	**value per lumen per hour**	**value per lumen per hour**
Total Energy (GER)	J	1169.41	234.64
	variation with the base-case	0.00%	-79.94%
of which, electricity	J	1046.13	207.32
	variation with the base-case	0.00%	-80.18%
Water (process)	µltr	77.71	15.17
	variation with the base-case	0.00%	-80.49%
Water (cooling)	µltr	2788.94	546.72
	variation with the base-case	0.00%	-80.40%
Waste, non-haz./ landfill	µg	1856.47	474.28
	variation with the base-case	0.00%	-74.45%
Waste, hazardous/ incinerated	µg	101.82	23.55
	variation with the base-case	0.00%	-76.87%
Emissions (Air)			
Greenhouse Gases in GWP100	mg CO2 eq.	54.37	11.20
	variation with the base-case	0.00%	-79.40%
Acidifying agents (AP)	µg SO2 eq.	309.09	60.33
	variation with the base-case	0.00%	-80.48%
Volatile Org. Compounds (VOC)	ng	849.20	139.21
	variation with the base-case	0.00%	-83.61%
Persistent Org. Pollutants (POP)	10^{-3} pg i-Teq	9.59	5.05
	variation with the base-case	0.00%	-47.37%
Heavy Metals (HM)	ng Ni eq.	27.96	6.74
	variation with the base-case	0.00%	-75.89%
PAHs	ng Ni eq.	27.32	2.61
	variation with the base-case	0.00%	-90.46%
Particulate Matter (PM, dust)	µg	36.65	11.16
	variation with the base-case	0.00%	-69.56%
Emissions (Water)			
Heavy Metals (HM)	ng Hg/20	15.39	3.48
	variation with the base-case	0.00%	-77.39%
Eutrophication (EP)	ng PO4	281.42	60.28
	variation with the base-case	0.00%	-78.58%

8.1.4 Suggested additional requirements for the appropriate implementation

8.1.4.1 Additional recommendations for the lamp labelling (Directive 98/11/EC)

It is recommended that the labelling also includes:

- lamps not operated on the mains voltage;
- reflector lamps or directional light sources as defined in part 2 of this study (LED modules or luminaires could be voluntary for reducing administrative impact that could hamper the introduction of these new technology that frequently changes in performance).

It is recommended to redefine the label minimum requirements in order to:

- introduce a label between the current B and A as the gap between both is too large (see Figure 8.57 where level 5 = B and level 7 = A);
- streamline the A-label formula with the B label formula;
- have more ambitious labels compared to A;
- it could be considered to introduce a correction factor for lumen maintenance (LLMF), especially for LEDs or HID-R lamps.

Please note that the equivalent 'labels' used in this study are intended for this study alone, the debate on the revision and the format of the label is outside the scope of this preparatory study on the Ecodesign Directive 2005/32/EC. The labels used in part 2 are equivalent to those of part 1 for reasons of comparison. In principle the labels used in this study are in the extend possible similar to those in the current the Label Directive 98/11/EC anno 2009.

The used energy labels in this study are presented in Table 8.18 and they are graphically shown in Figure 8.57 and Figure 8.58.

Table 8.18: New definition of lamp efficacy levels and labels used in this study

Level (this study	**Label (this study)**	**Maximum system power demand (P_{system}) related to lamp luminous flux (Φ[10]) [W]**		**Minimum light source efficacy (including control gear losses) η_{source} = Φ[11] / P_{system} [lm/W]**	
0	G	>1,30			
1	F	1,30		Φ / 1,30	
2	E	1,10		Φ / 1,10	
3	D	0,95		Φ / 0,95	
4	C	0,80		Φ / 0,80	
5	B	0,6		Φ / 0,6	
6	B (B+)*	0,4	x (0,88√Φ+0,049Φ)	Φ / 0,4	x 1/(0,88√Φ + 0,049Φ)
7	***A ****	0,225		Φ / 0,225	
8	***A (A+)****	0,209		Φ / 0,209	
9 =BAT level	***A (A++)****	0,178		Φ / 0,178	
10	***A (A+++)****	0,116		Φ / 0,116	

***** *It must be noted that the formula for the current label* ***A*** *as defined in Directive 98/11/EC does not completely corresponds with the proposed new formula, but the difference is very small (the current formula is 0.24√Φ+0.0103Φ).*
It must also be noted that in the proposed formula, system power (= lamp + control gear / power supply) is used. As a consequence the same formula can be used for all lamps GLS-lamps, CFLi's, HL-MV as well as fluorescent lamps, HL-LV and HID-lamps.

The values should be measured in compliance with EN and CIE standards (see chapter 1) (i.e. lamp lumen output measured after a defined period of operation) with the following additional corrections:

- For halogen reflector lamps, GLS-R or LED-R retrofit lamps the nominal luminous flux in a 90° cone of the lamp multiplied by 1,25;
- For CFLi-DLS lamps claimed to be retrofit lamps to halogen lamps, the nominal luminous flux in a 90° cone multiplied by 1,25;
- For CFLi-DLS lamps that make no claim to retrofit halogen lamps, the nominal luminous flux in a solid angle of π sr or a 120° cone multiplied by 1,25;

Rationale behind this 1,25 correction factor:
In a reflector lamp, there is always lumen loss due to the reflector; a typical LOR for a good reflector lamp, compared to a non reflector lamp can be considered as 0,8. To make a good evaluation for the labelling of a reflector lamp with the same formula as a non-reflector lamp, the rated luminous flux in the 90° cone shall be corrected by multiplying it by 1,25; this correction also reflects the opinion of representative stakeholders.

[10] For reflector lamps Φ_R
[11] For reflector lamps Φ_R

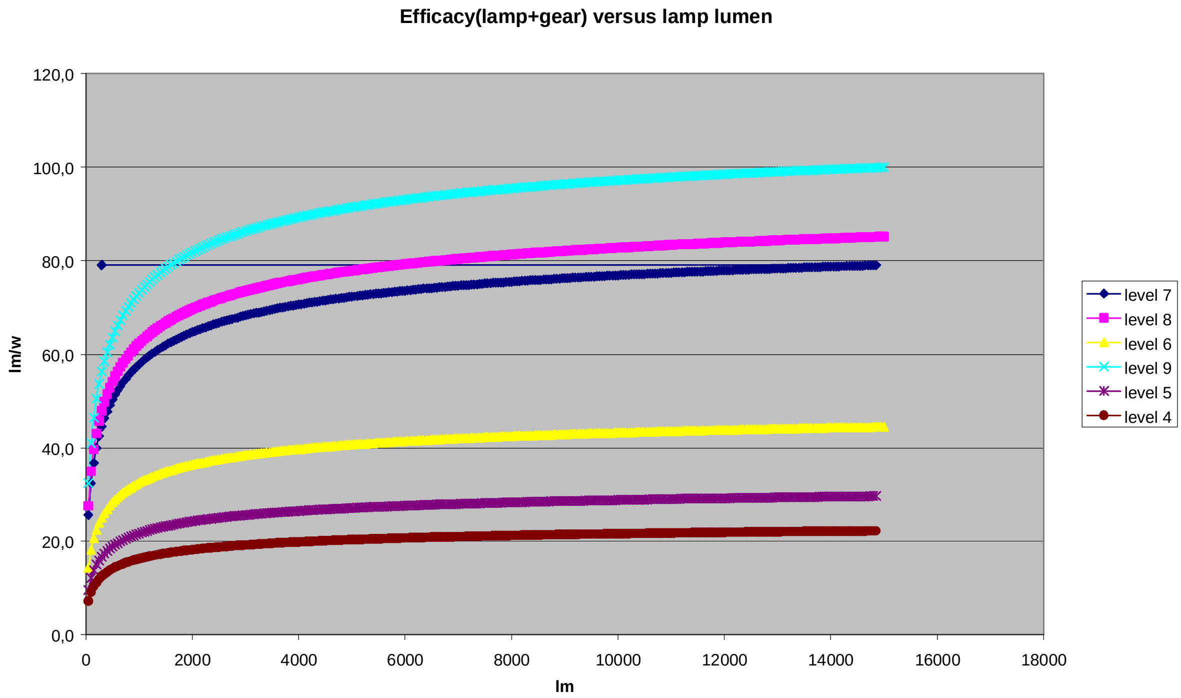

Figure 8.57: Defined lamp efficacy levels 4 - 9

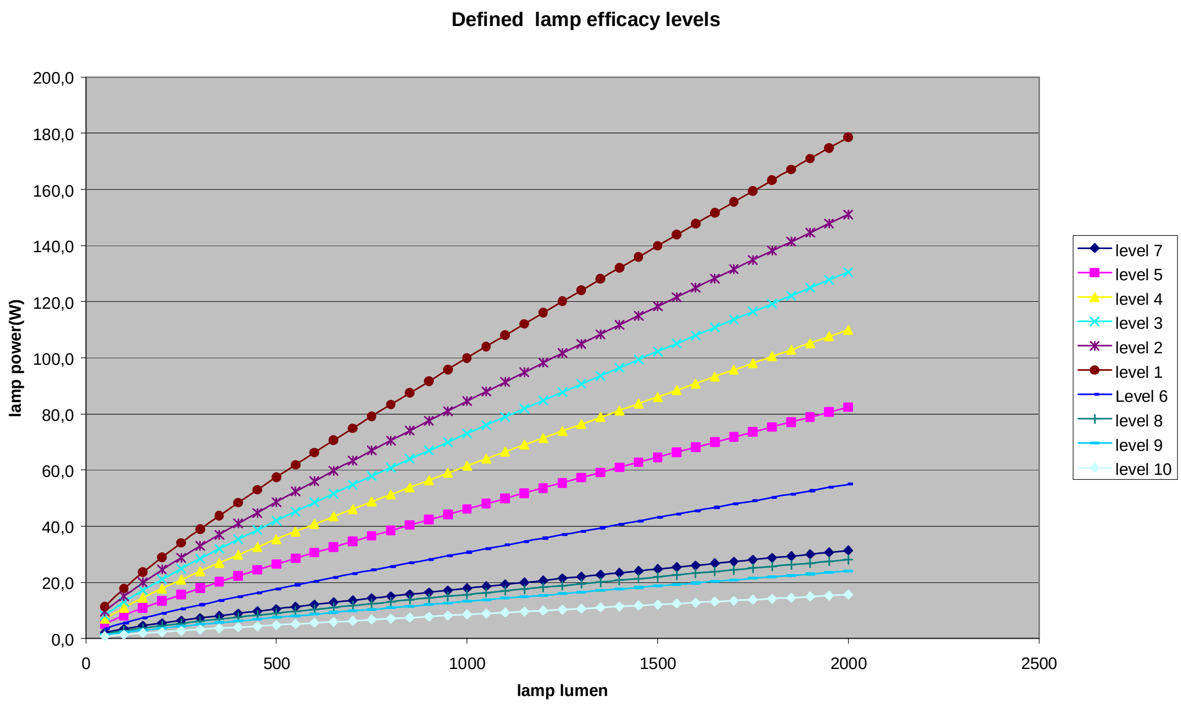

Figure 8.58: Power demand for the defined lamp efficacy levels (except level 0)

A table with corresponding values per defined lamp efficacy level is included in part 1 of this study.

Table 8.19: Examples of efficacy levels and labels for existing lamp types

Level (this study)	Proposed label (this study)	Example for domestic lighting	
0	G		GLS-R HL-MV-R
1	F		HL-MV-R
2	E		GLS-MV-R HL-MV-R-HW HL-LV-R
3	D		HL-MV-R (B*N*AT)
4	C		HL-MV-R-transfo inc HL-LV-R
5	B		HL-MV-R-transfo inc (B*N*AT) HL-LV-R (BAT) CFLi-DLS(R63) as retrofit and non retrofit
6	B (B+)*		HIDi-R CFLi-DLS (R120 - B*N*AT) as retrofit LED-MV-i-R
7	A		
8	A (A+)*		LED-MV-i-R
9 =BAT level	A (A++)*		None
10	A (A+++)*		None

8.1.4.2 Recommendations to promote the most efficient luminaires for general illumination

It is recommended to introduce an ecolabel or other voluntary labelling for the most efficient luminaires, this will facilate horizontal promottional campaigns and rebate programmes (see 8.1.4.3 and 8.1.4.4).

The proposed ecolabel criteria (see Table 8.20) are connected to the luminaire improvement options as discussed in chapter 6. However it is proposed to limit the ecolabel to luminaires that have photometric data available and as a consequence LOR or LER criteria are proposed. Please note that for the tertiary sector similar but often stronger proposals were made in lot 8 and 9 for office and street lighting.
The 'Minimum lock-in label' means that it is proposed to limit the label to those luminaires that have a positive lock-in effect as discussed in chapter 6, e.g. incorporated ballast for CFLni (minimum A label) or incorporated transformer (minimum B label).

Table 8.20: Proposed criteria for awarding an ecolabel to domestic luminaires

	Non LED		LED							
Category of luminaires	min. lock-in label	LOR	LER	Light in phi (120°) CEN flux code N2	DLOR	motion sensor	day/night sensor	dimmer incorporated	dimmer compatible
		%	lm/W	%	%				
Downlights (recessed mounted)	A	80	45	≥80	99	n	n	n	n
Suspension (chandeliers)-D	A	75	45		≥80	n	n	n	y
Suspension (chandeliers)-DLS	A	70	40	≥80	>50	n	n	n	y
Suspension (chandeliers)-DI	A	80	50		<80	n	n	n	y
wall&ceiling	A	70	40	-	-	n	n	n	n
wall&ceiling (uplighter)	A	80	50	-	-	y	n	n	n
Desk	A	70	40	-	-	n	n	n	n
Table	A	70	40	-	-	n	n	y	n
Floor -D or -DI	A	75	45	-	>80	n	n	y	-
Floor-I (uplighter)	A	85	55	-	≤80	n	n	y	-
Spotlights	B(CRI>90) or A	80	30	≥80	95	n	n	n	y
Outdoor -B	B(CRI>90) or A	80	30	≥80	95	y	y	n	y
Outdoor -A	A	70	40	-	95	n	n	n	y

note: D=Direct I = Indirect lighting

Moreover these luminaires should be free of hazardous material, designed for recycling and contain cleaning and maintenance instructions.

Please note that these LOR/LER criteria could be reviewed when more market data is available, see recommendations for further R&D.

8.1.4.3 Recommendations to introduce rebate programmes for efficient luminaires to retrofit luminaires with inefficient lamps lock-in effect

It is recommended to focus rebate programmes on those luminaire categories that show a large lock-in effect and that are not easy to replace.

Desk, Table and Floor luminaires have a plug and can easily be replaced by the end user themselve. Hence the retrofit cost is low and the focus should be on the other categories of luminaires, especially downlights or spotlights.

Downlights or spotlights are designed to closely house the reflector lamps. When considering smaller form factor lamps such as MR16 and AR111, the lamp itself can be a structural part of the fitting. Additionally the beam and field angle of the reflector lamp are key operating factors so replacement lamps have to have identical beam characteristics to the lamp they are replacing.

8.1.4.4 Recommendations to introduce a quality label for LED lighting

Section 8.1.1.6 describes which ten factors that might be included with requirements in a quality label for LED lighting.
LED lighting requirements or a quality label will avoid barriers for sales of LED due to bad consumer experience with LED lamps/luminaires. The minimum requirements(section 8.1.1.5) should include the most important of the ten factors mentioned above while other or more strong requirements could be the subject of a new European quality label for LED lighting.

8.1.4.5 Awareness campaign for luminaire designers

In order to have a maximum effect it is recommended to create an awareness campaign about the proposed ecodesign requirements in section 8.1.1.8 towards luminaire and lighting designers. Complementary to this campaign it is important to collect feedback in order to improve and update any further requirement.

8.1.4.6 Warning about a potential direct rebound effect caused by the introduction of new energy efficient lighting (e.g. LED)

See part 1.

8.1.4.7 Reduced impact caused by lack of market surveillance and loopholes in legislation

See part 1.

8.1.4.8 Complementary recommendations on users information, product developers and service providers skills

See part 1.

8.1.4.9 Complementary recommendations on policy actions to smoothen market transformation and lamp sales

See part 1.

8.1.4.10 Complementary recommendations on policy actions to increase mercury recycling

See part 1.

8.1.4.11 Warning on comparing US with EU minimum lamp efficacy targets

See part 1.

8.1.4.12 Complementary recommendations to reduce the sensitivity of lighting to line voltage variations

See part 1.

8.1.4.13 Complementary recommendations to reduce negative impact from UV radiation

See part 1.

8.1.4.14 Complementary recommendations to reduce barriers for SMEs and market surveillance authorities by improving access to EN standards and standards development related to eco-design requirements

See part 1.

8.1.4.15 Recommendations for the revision

A revision period of 4 years is recommended and special attention should be given to LED light sources and luminaires.

8.1.5 Suggested additional research

This study has been made with the few luminaire performance data and user application data available. It is recommended to perform a more in depth study that includes performance measurements of these luminaires. Moreover also more research is needed to application parameters and user behaviour for domestic luminaires.

See also part 1

8.1.6 Required new or updated measurement or product standards

None of the existing EN or IEC lamp standards refer specifically to reflector lamps; it should be proposed to complete these standards (see chapter 1).

Standard EN 13032 (*Lighting applications — Measurement and presentation of photometric data of lamps and luminaires)* should be adapted by introducing a system power measurement P_{system} [W] in operational conditions together with the LOR measurement; for luminaires that can house different lamp types, it is also necessary to do the measurents for all these types.

It becomes urgent to draw up standards for LED light sources, especially for the sources that claim to retrofit GLS and halogen lamps, to avoid the introduction of incompatible and low

quality products that could create aversion against energy efficient solutions. A start was already taken by introducing a draft EN 62612 (see chapter 1).
In this draft, also the definition of lifetime is not only based on LSF as in other lamp standards; lifetime in this draft standard also takes into account the lumen maintenance (LLMF) of the lamp. It should be suggested to introduce this principle in the existing standards for other lamp types.

See also part 1.

8.2 Impact analysis for industry and consumers

Implementing measures might affect light sources marketed for other applications than general illumination for human vision.

Similar to part 1.

About the projected EU27 annual sales peak and/or periodic waves.

Similar to part 1.

A potential negative impact on EU27 GLS lamp producers, transporters and distributors:

Similar to part 1.

Potential barriers created by protected intellectual property:

All the proposed BAT scenarios rely on basic technology already available for above 20 years, hence for these scenarios there is no expected impact (more info see chapter 6). The BNAT scenario however relies on LED technology wherein above 1000 patents are involved (more info see chapter 6).

Impact of the proposed luminaire measures:

The implementation of the proposed generic ecodesign requirement on luminaires in 8.1.1.8 should be closely monitored. The expected impact should mainly come from creating awareness with the many luminaire designers active in industry. Impact should come from the assumption that there is a general positive attitude towards ecodesign and that awareness will stimulate adoption and motivate material suppliers to increase production of more advanced and efficient optic luminaire materials. After a period of some years, the exceptions applied by the manufacturers and explained in the technical documentation files should be evaluated, to determine whether they are well motivated by ‘functional’, ‘design’ or ‘economic’ reasons (see also R&D recommendation in 8.1.5).

Background information about the impact of mercury brought into circulation with household lamps:

See part 1.

8.3 Annexes

DISCLAIMER: The figures provided on this page have to be read in the context set out in the beginning of section 8.1.2 (General remarks) and in sections 8.1.2.1 and 8.1.2.2

Annexe 8-1: Main economic and environmental data for the scenario "BAU"

		GLS-R		HL-MV-R-HW		HL-MV-R-LW		HL-LV-R		TOTAL	
2007	Total stock	291 591 919	26.4%	107 306 006	9.7%	121 004 645	11.0%	584 873 780	52.9%	1 104 776 349	100%
	Total sales	126 096 260	29.9%	67 257 000	15.9%	75 843 000	18.0%	153 000 000	36.2%	422 196 260	100%
	Electricity consumption (GWh)	7 057	21.9%	5 955	18.5%	3 358	10.4%	15 792	49.1%	32 162	100%
2008	Total stock	268 863 050	23.0%	136 773 513	11.7%	162 562 458	13.9%	599 377 647	51.3%	1 167 576 667	100%
	Total sales	115 731 193	26.5%	75 207 279	17.2%	91 406 649	20.9%	155 109 283	35.5%	437 454 404	100%
	Electricity consumption (GWh)	6 506	18.7%	7 591	21.8%	4 511	13.0%	16 184	46.5%	34 792	100%
2009	Total stock	246 134 181	20.0%	164 383 435	13.4%	205 977 856	16.7%	613 881 514	49.9%	1 230 376 985	100%
	Total sales	105 366 127	23.3%	83 157 558	18.4%	106 970 297	23.6%	157 218 566	34.7%	452 712 548	100%
	Electricity consumption (GWh)	5 956	15.9%	9 123	24.4%	5 716	15.3%	16 575	44.4%	37 371	100%
2010	Total stock	223 405 311	17.3%	190 135 771	14.7%	251 250 840	19.4%	628 385 381	48.6%	1 293 177 304	100%
	Total sales	95 001 060	20.3%	91 107 837	19.5%	122 533 946	26.2%	159 327 849	34.0%	467 970 692	100%
	Electricity consumption (GWh)	5 406	13.6%	10 553	26.4%	6 972	17.5%	16 967	42.5%	39 898	100%
2011	Total stock	200 676 442	14.8%	214 030 522	15.8%	298 381 410	22.0%	642 889 248	47.4%	1 355 977 622	100%
	Total sales	84 635 993	17.5%	99 058 116	20.5%	138 097 595	28.6%	161 437 132	33.4%	483 228 836	100%
	Electricity consumption (GWh)	4 856	11.5%	11 879	28.0%	8 280	19.5%	17 358	41.0%	42 374	100%
2012	Total stock	198 644 874	14.3%	217 465 872	15.6%	319 997 310	23.0%	654 094 289	47.1%	1 390 202 345	100%
	Total sales	84 924 172	17.4%	95 023 187	19.4%	145 576 591	29.8%	163 600 532	33.4%	489 124 482	100%
	Electricity consumption (GWh)	4 807	11.1%	12 069	27.8%	8 880	20.5%	17 661	40.7%	43 418	100%
2013	Total stock	196 613 306	13.8%	220 246 035	15.5%	342 268 397	24.0%	665 299 330	46.7%	1 424 427 069	100%
	Total sales	85 212 350	17.2%	90 988 257	18.4%	153 055 588	30.9%	165 763 931	33.5%	495 020 127	100%

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	Electricity consumption (GWh)	4 758	10.7%	12 224	27.5%	9 498	21.4%	17 964	40.4%	44 443	100%
2014	**Total stock**	194 581 739	13.3%	222 371 012	15.2%	365 194 670	25.0%	676 504 372	46.4%	1 458 651 792	100%
	Total sales	85 500 529	17.1%	86 953 328	17.4%	160 534 585	32.0%	167 927 331	33.5%	500 915 772	100%
	Electricity consumption (GWh)	4 709	10.4%	12 342	27.2%	10 134	22.3%	18 266	40.2%	45 451	100%
2015	**Total stock**	192 550 171	12.9%	223 840 802	15.0%	388 776 130	26.0%	687 709 413	46.1%	1 492 876 516	100%
	Total sales	85 788 707	16.9%	82 918 398	16.4%	168 013 582	33.2%	170 090 730	33.6%	506 811 417	100%
	Electricity consumption (GWh)	4 660	10.0%	12 423	26.8%	10 789	23.2%	18 569	40.0%	46 440	100%
2016	**Total stock**	190 518 603	12.5%	224 655 406	14.7%	413 012 776	27.0%	698 914 455	45.8%	1 527 101 239	100%
	Total sales	86 076 886	16.8%	78 883 469	15.4%	175 492 578	34.2%	172 254 129	33.6%	512 707 062	100%
	Electricity consumption (GWh)	4 611	9.7%	12 468	26.3%	11 461	24.2%	18 871	39.8%	47 411	100%
2017	**Total stock**	188 487 035	12.1%	224 814 823	14.4%	437 904 609	28.0%	710 119 496	45.5%	1 561 325 963	100%
	Total sales	86 365 064	16.7%	74 848 539	14.4%	182 971 575	35.3%	174 417 529	33.6%	518 602 707	100%
	Electricity consumption (GWh)	4 561	9.4%	12 477	25.8%	12 152	25.1%	19 174	39.6%	48 364	100%
2018	**Total stock**	186 455 467	11.7%	224 319 053	14.1%	463 451 629	29.0%	721 324 537	45.2%	1 595 550 687	100%
	Total sales	86 653 243	16.5%	70 813 610	13.5%	190 450 572	36.3%	176 580 928	33.7%	524 498 352	100%
	Electricity consumption (GWh)	4 512	9.2%	12 450	25.3%	12 861	26.1%	19 476	39.5%	49 299	100%
2019	**Total stock**	184 423 900	11.3%	223 168 097	13.7%	489 653 835	30.0%	732 529 579	44.9%	1 629 775 410	100%
	Total sales	86 941 421	16.4%	66 778 680	12.6%	197 929 569	37.3%	178 744 328	33.7%	530 393 997	100%
	Electricity consumption (GWh)	4 463	8.9%	12 386	24.7%	13 588	27.1%	19 779	39.4%	50 216	100%
2020	**Total stock**	182 392 332	11.0%	221 361 955	13.3%	516 511 227	31.0%	743 734 620	44.7%	1 664 000 134	100%
	Total sales	87 229 600	16.3%	62 743 751	11.7%	205 408 565	38.3%	180 907 727	33.7%	536 289 643	100%
	Electricity consumption (GWh)	4 414	8.6%	12 286	24.0%	14 333	28.0%	20 081	39.3%	51 114	100%

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Annexe 8-2: Main economic and environmental data for the scenario "BAT with lock in (slow)"

		BAT with lock in (slow)											
		GLS-R		HL-MV-R-HW		HL-MV-R-LW		HL-LV-R		HID-R		TOTAL	
2007	Total stock (mln)	291 591 919	26.4%	107 306 006	9.7%	121 004 645	11.0%	584 873 780	52.9%	0	0.0%	1 104 776 349	100%
	Total sales (mln)	126 096 260	29.9%	67 257 000	15.9%	75 843 000	18.0%	153 000 000	36.2%	0	0.0%	422 196 260	100%
	Electricity consumption (TWh)	7 057	21.9%	5 955	18.5%	3 358	10.4%	15 792	49.1%	0	0.0%	32 162	100%
2008	Total stock (mln)	268 863 050	23.0%	136 773 513	11.7%	162 562 458	13.9%	599 377 647	51.3%	0	0.0%	1 167 576 667	100%
	Total sales (mln)	115 731 193	26.5%	75 207 279	17.2%	91 406 649	20.9%	155 109 283	35.5%	0	0.0%	437 454 404	100%
	Electricity consumption (TWh)	6 506	18.7%	7 591	21.8%	4 511	13.0%	16 184	46.5%	0	0.0%	34 792	100%
2009	Total stock (mln)	246 134 181	20.0%	164 383 435	13.4%	205 977 856	16.7%	613 881 514	49.9%	0	0.0%	1 230 376 985	100%
	Total sales (mln)	105 366 127	23.3%	83 157 558	18.4%	106 970 297	23.6%	157 218 566	34.7%	0	0.0%	452 712 548	100%
	Electricity consumption (TWh)	5 956	15.9%	9 123	24.4%	5 716	15.3%	16 575	44.4%	0	0.0%	37 371	100%
2010	Total stock (mln)	129 677 433	9.8%	97 126 435	7.3%	342 685 091	25.8%	644 293 569	48.5%	115 876 880	8.7%	1 329 659 408	100%
	Total sales (mln)	0	0.0%	0	0.0%	217 219 329	42.1%	183 412 055	35.5%	115 876 880	22.4%	516 508 265	100%
	Electricity consumption (TWh)	3 138	9.2%	5 391	15.8%	8 116	23.8%	15 822	46.3%	1 688	4.9%	34 155	100%
2011	Total stock (mln)	23 585 751	1.7%	26 689 323	1.9%	468 920 336	32.9%	674 705 625	47.3%	233 401 447	16.4%	1 427 302 482	100%
	Total sales (mln)	0	0.0%	0	0.0%	222 310 989	42.5%	183 412 055	35.1%	117 524 567	22.5%	523 247 611	100%
	Electricity consumption (TWh)	571	1.9%	1 481	4.8%	10 218	33.2%	15 069	49.0%	3 400	11.1%	30 740	100%
2012	Total stock (mln)	0	0.0%	0	0.0%	509 999 801	34.4%	701 505 558	47.3%	270 932 659	18.3%	1 482 438 018	100%
	Total sales (mln)	0	0.0%	0	0.0%	163 785 115	43.0%	179 799 934	47.2%	37 531 212	9.8%	381 116 260	100%
	Electricity consumption (TWh)	0	0.0%	0	0.0%	10 924	37.5%	14 249	48.9%	3 947	13.6%	29 120	100%
2013	Total stock (mln)	0	0.0%	0	0.0%	503 921 483	33.1%	744 514 408	48.9%	274 396 361	18.0%	1 522 832 252	100%
	Total sales (mln)	0	0.0%	0	0.0%	130 693 569	39.4%	197 890 364	59.6%	3 463 702	1.0%	332 047 635	100%
	Electricity consumption (TWh)	0	0.0%	0	0.0%	10 059	37.2%	12 983	48.0%	3 998	14.8%	27 040	100%
2014	Total stock (mln)	0	0.0%	0	0.0%	484 221 717	31.9%	757 865 096	49.9%	277 043 790	18.2%	1 519 130 603	100%
	Total sales (mln)	0	0.0%	0	0.0%	218 145 264	93.2%	13 350 688	5.7%	2 647 430	1.1%	234 143 381	100%
	Electricity consumption (TWh)	0	0.0%	0	0.0%	8 687	33.5%	13 180	50.9%	4 036	15.6%	25 903	100%

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2015	**Total stock (mln)**	0	0.0%	0	0.0%	487 621 177	31.7%	771 215 783	50.2%	278 874 947	18.1%	1 537 711 908	100%
	Total sales (mln)	0	0.0%	0	0.0%	134 843 531	89.9%	13 350 688	8.9%	1 831 157	1.2%	150 025 375	100%
	Electricity consumption (TWh)	0	0.0%	0	0.0%	8 717	33.3%	13 377	51.1%	4 063	15.5%	26 156	100%
2016	**Total stock (mln)**	0	0.0%	0	0.0%	503 706 575	32.1%	784 566 471	50.0%	279 889 832	17.8%	1 568 162 877	100%
	Total sales (mln)	0	0.0%	0	0.0%	68 093 781	82.6%	13 350 688	16.2%	1 014 884	1.2%	82 459 353	100%
	Electricity consumption (TWh)	0	0.0%	0	0.0%	9 074	34.0%	13 573	50.8%	4 078	15.3%	26 725	100%
2017	**Total stock (mln)**	0	0.0%	0	0.0%	523 915 150	32.4%	811 012 445	50.2%	280 088 443	17.3%	1 615 016 038	100%
	Total sales (mln)	0	0.0%	0	0.0%	106 121 586	37.7%	175 009 739	62.2%	198 612	0.1%	281 329 936	100%
	Electricity consumption (TWh)	0	0.0%	0	0.0%	9 523	35.2%	13 416	49.7%	4 081	15.1%	27 019	100%
2018	**Total stock (mln)**	0	0.0%	0	0.0%	544 655 643	32.7%	840 530 152	50.5%	280 088 443	16.8%	1 665 274 239	100%
	Total sales (mln)	0	0.0%	0	0.0%	138 760 725	39.5%	212 929 763	60.5%	0	0.0%	351 690 488	100%
	Electricity consumption (TWh)	0	0.0%	0	0.0%	9 983	36.7%	13 175	48.4%	4 081	15.0%	27 239	100%
2019	**Total stock (mln)**	0	0.0%	0	0.0%	565 928 053	33.0%	869 789 961	50.7%	280 088 443	16.3%	1 715 806 457	100%
	Total sales (mln)	0	0.0%	0	0.0%	111 789 662	34.8%	209 746 045	65.2%	0	0.0%	321 535 708	100%
	Electricity consumption (TWh)	0	0.0%	0	0.0%	10 455	38.1%	12 941	47.1%	4 081	14.9%	27 477	100%
2020	**Total stock (mln)**	0	0.0%	0	0.0%	587 732 379	33.5%	886 151 888	50.5%	280 088 443	16.0%	1 753 972 710	100%
	Total sales (mln)	0	0.0%	0	0.0%	105 109 230	33.3%	210 815 109	66.7%	0	0.0%	315 924 338	100%
	Electricity consumption (TWh)	0	0.0%	0	0.0%	10 939	39.0%	13 057	46.5%	4 081	14.5%	28 076	100%

DISCLAIMER: *The figures provided on this page have to be read in the context set out in the beginning of section 8.1.2 (General remarks) and in sections 8.1.2.1 and 8.1.2.2*

Annexe 8-3: Main economic and environmental data for the scenario "BAT with lock in (fast)"

		BAT with lock in (fast)											
		GLS-R		HL-MV-R-HW		HL-MV-R-LW		HL-LV-R		HID-R		TOTAL	
2007	Total stock (mln)	291 591 919	26.4%	107 306 006	9.7%	121 004 645	11.0%	584 873 780	52.9%	0	0.0%	1 104 776 349	10
	Total sales (mln)	126 096 260	29.9%	67 257 000	15.9%	75 843 000	18.0%	153 000 000	36.2%	0	0.0%	422 196 260	10
	Electricity consumption (TWh)	7 057	21.9%	5 955	18.5%	3 358	10.4%	15 792	49.1%	0	0.0%	32 162	10
2008	Total stock (mln)	268 863 050	23.0%	136 773 513	11.7%	162 562 458	13.9%	599 377 647	51.3%	0	0.0%	1 167 576 667	10
	Total sales (mln)	115 731 193	26.5%	75 207 279	17.2%	91 406 649	20.9%	155 109 283	35.5%	0	0.0%	437 454 404	10
	Electricity consumption (TWh)	6 506	18.7%	7 591	21.8%	4 511	13.0%	16 184	46.5%	0	0.0%	34 792	10
2009	Total stock (mln)	246 134 181	20.0%	164 383 435	13.4%	205 977 856	16.7%	613 881 514	49.9%	0	0.0%	1 230 376 985	10
	Total sales (mln)	105 366 127	23.3%	83 157 558	18.4%	106 970 297	23.6%	157 218 566	34.7%	0	0.0%	452 712 548	10
	Electricity consumption (TWh)	5 956	15.9%	9 123	24.4%	5 716	15.3%	16 575	44.4%	0	0.0%	37 371	10
2010	Total stock (mln)	129 677 433	10.0%	97 126 435	7.5%	315 402 478	24.2%	644 293 569	49.5%	115 876 880	8.9%	1 302 376 794	10
	Total sales (mln)	0	0.0%	0	0.0%	189 936 716	38.8%	183 412 055	37.5%	115 876 880	23.7%	489 225 651	10
	Electricity consumption (TWh)	3 138	9.4%	5 391	16.1%	7 491	22.3%	15 822	47.2%	1 688	5.0%	33 530	10
2011	Total stock (mln)	23 585 751	1.7%	26 689 323	1.9%	417 372 207	30.3%	674 705 625	49.0%	233 401 447	17.0%	1 375 754 353	10
	Total sales (mln)	0	0.0%	0	0.0%	198 045 473	39.7%	183 412 055	36.8%	117 524 567	23.6%	498 982 095	10
	Electricity consumption (TWh)	571	1.9%	1 481	5.0%	9 037	30.6%	15 069	51.0%	3 400	11.5%	29 558	10
2012	Total stock (mln)	0	0.0%	0	0.0%	452 177 611	31.7%	701 505 558	49.2%	270 932 659	19.0%	1 424 615 827	10
	Total sales (mln)	0	0.0%	0	0.0%	132 138 223	37.8%	179 799 934	51.4%	37 531 212	10.7%	349 469 369	10
	Electricity consumption (TWh)	0	0.0%	0	0.0%	9 599	34.5%	14 249	51.3%	3 947	14.2%	27 795	10
2013	Total stock (mln)	0	0.0%	0	0.0%	465 176 763	31.3%	744 514 408	50.2%	274 396 361	18.5%	1 484 087 532	10
	Total sales (mln)	0	0.0%	0	0.0%	125 294 327	38.4%	197 890 364	60.6%	3 463 702	1.1%	326 648 392	10
	Electricity consumption (TWh)	0	0.0%	0	0.0%	9 242	35.2%	12 983	49.5%	3 998	15.2%	26 223	10
2014	Total stock (mln)	0	0.0%	0	0.0%	469 703 943	31.2%	757 865 096	50.4%	277 043 790	18.4%	1 504 612 828	10
	Total sales (mln)	0	0.0%	0	0.0%	211 242 014	93.0%	13 350 688	5.9%	2 647 430	1.2%	227 240 131	10
	Electricity consumption (TWh)	0	0.0%	0	0.0%	8 517	33.1%	13 180	51.2%	4 036	15.7%	25 733	10

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2015	**Total stock (mln)**	0	0.0%	0	0.0%	474 951 599	31.1%	771 215 783	50.6%	278 874 947	18.3%	1 525 042 330	10
	Total sales (mln)	0	0.0%	0	0.0%	134 476 445	89.9%	13 350 688	8.9%	1 831 157	1.2%	149 658 290	10
	Electricity consumption (TWh)	0	0.0%	0	0.0%	8 594	33.0%	13 377	51.4%	4 063	15.6%	26 034	10
2016	**Total stock (mln)**	0	0.0%	0	0.0%	491 036 996	31.6%	784 566 471	50.4%	279 889 832	18.0%	1 555 493 299	10
	Total sales (mln)	0	0.0%	0	0.0%	68 093 781	82.6%	13 350 688	16.2%	1 014 884	1.2%	82 459 353	10
	Electricity consumption (TWh)	0	0.0%	0	0.0%	8 951	33.6%	13 573	51.0%	4 078	15.3%	26 602	10
2017	**Total stock (mln)**	0	0.0%	0	0.0%	511 245 572	31.9%	811 012 445	50.6%	280 088 443	17.5%	1 602 346 460	10
	Total sales (mln)	0	0.0%	0	0.0%	106 121 586	37.7%	175 009 739	62.2%	198 612	0.1%	281 329 936	10
	Electricity consumption (TWh)	0	0.0%	0	0.0%	9 400	34.9%	13 416	49.9%	4 081	15.2%	26 896	10
2018	**Total stock (mln)**	0	0.0%	0	0.0%	531 986 065	32.2%	840 530 152	50.9%	280 088 443	16.9%	1 652 604 660	10
	Total sales (mln)	0	0.0%	0	0.0%	138 760 725	39.5%	212 929 763	60.5%	0	0.0%	351 690 488	10
	Electricity consumption (TWh)	0	0.0%	0	0.0%	9 860	36.4%	13 175	48.6%	4 081	15.0%	27 116	10
2019	**Total stock (mln)**	0	0.0%	0	0.0%	553 258 474	32.5%	869 789 961	51.1%	280 088 443	16.4%	1 703 136 879	10
	Total sales (mln)	0	0.0%	0	0.0%	111 789 662	34.8%	209 746 045	65.2%	0	0.0%	321 535 708	10
	Electricity consumption (TWh)	0	0.0%	0	0.0%	10 333	37.8%	12 941	47.3%	4 081	14.9%	27 354	10
2020	**Total stock (mln)**	0	0.0%	0	0.0%	575 062 801	33.0%	886 151 888	50.9%	280 088 443	16.1%	1 741 303 132	10
	Total sales (mln)	0	0.0%	0	0.0%	105 109 230	33.3%	210 815 109	66.7%	0	0.0%	315 924 338	10
	Electricity consumption (TWh)	0	0.0%	0	0.0%	10 817	38.7%	13 057	46.7%	4 081	14.6%	27 954	10

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Annexe 8-4: Main economic and environmental data for the scenario "BAT without lock in"

		BAT without lock in											
		GLS-R		HL-MV-R-HW		HL-MV-R-LW		HL-LV-R		HID-R		TOTAL	
2007	Total stock (mln)	291 591 919	26.4%	107 306 006	9.7%	121 004 645	11.0%	584 873 780	52.9%	0	0.0%	1 104 776 349	100%
	Total sales (mln)	126 096 260	29.9%	67 257 000	15.9%	75 843 000	18.0%	153 000 000	36.2%	0	0.0%	422 196 260	100%
	Electricity consumption (TWh)	7 057	21.9%	5 955	18.5%	3 358	10.4%	15 792	49.1%	0	0.0%	32 162	100%
2008	Total stock (mln)	268 863 050	23.0%	136 773 513	11.7%	162 562 458	13.9%	599 377 647	51.3%	0	0.0%	1 167 576 667	100%
	Total sales (mln)	115 731 193	26.5%	75 207 279	17.2%	91 406 649	20.9%	155 109 283	35.5%	0	0.0%	437 454 404	100%
	Electricity consumption (TWh)	6 506	18.7%	7 591	21.8%	4 511	13.0%	16 184	46.5%	0	0.0%	34 792	100%
2009	Total stock (mln)	246 134 181	20.0%	164 383 435	13.4%	205 977 856	16.7%	613 881 514	49.9%	0	0.0%	1 230 376 985	100%
	Total sales (mln)	105 366 127	23.3%	83 157 558	18.4%	106 970 297	23.6%	157 218 566	34.7%	0	0.0%	452 712 548	100%
	Electricity consumption (TWh)	5 956	15.9%	9 123	24.4%	5 716	15.3%	16 575	44.4%	0	0.0%	37 371	100%
2010	Total stock (mln)	129 677 433	10.4%	97 126 435	7.8%	125 465 762	10.1%	779 715 634	62.5%	115 876 880	9.3%	1 247 862 144	100%
	Total sales (mln)	0	0.0%	0	0.0%	0	0.0%	318 834 121	73.3%	115 876 880	26.7%	434 711 001	100%
	Electricity consumption (TWh)	3 138	9.8%	5 391	16.8%	3 482	10.9%	18 316	57.2%	1 688	5.3%	32 015	100%
2011	Total stock (mln)	23 585 751	1.9%	26 689 323	2.1%	29 390 019	2.3%	952 588 703	75.3%	233 401 447	18.4%	1 265 655 243	100%
	Total sales (mln)	0	0.0%	0	0.0%	0	0.0%	325 873 068	73.5%	117 524 567	26.5%	443 397 635	100%
	Electricity consumption (TWh)	571	2.2%	1 481	5.6%	816	3.1%	20 187	76.3%	3 400	12.9%	26 455	100%
2012	Total stock (mln)	0	0.0%	0	0.0%	0	0.0%	1 026 045 217	79.1%	270 932 659	20.9%	1 296 977 875	100%
	Total sales (mln)	0	0.0%	0	0.0%	0	0.0%	226 456 514	85.8%	37 531 212	14.2%	263 987 726	100%
	Electricity consumption (TWh)	0	0.0%	0	0.0%	0	0.0%	20 227	83.7%	3 947	16.3%	24 174	100%
2013	Total stock (mln)	0	0.0%	0	0.0%	0	0.0%	1 086 082 090	79.8%	274 396 361	20.2%	1 360 478 451	100%
	Total sales (mln)	0	0.0%	0	0.0%	0	0.0%	214 918 387	98.4%	3 463 702	1.6%	218 382 089	100%
	Electricity consumption (TWh)	0	0.0%	0	0.0%	0	0.0%	19 211	82.8%	3 998	17.2%	23 209	100%
2014	Total stock (mln)	0	0.0%	0	0.0%	0	0.0%	1 116 961 744	80.1%	277 043 790	19.9%	1 394 005 534	100%
	Total sales (mln)	0	0.0%	0	0.0%	0	0.0%	30 879 654	92.1%	2 647 430	7.9%	33 527 083	100%
	Electricity consumption (TWh)	0	0.0%	0	0.0%	0	0.0%	19 666	83.0%	4 036	17.0%	23 702	100%

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2015	**Total stock (mln)**	0	0.0%	0	0.0%	0	0.0%	1 148 342 340	80.5%	278 874 947	19.5%	1 427 217 287	100%
	Total sales (mln)	0	0.0%	0	0.0%	0	0.0%	31 380 596	94.5%	1 831 157	5.5%	33 211 753	100%
	Electricity consumption (TWh)	0	0.0%	0	0.0%	0	0.0%	20 129	83.2%	4 063	16.8%	24 191	100%
2016	**Total stock (mln)**	0	0.0%	0	0.0%	0	0.0%	1 180 223 878	80.8%	279 889 832	19.2%	1 460 113 710	100%
	Total sales (mln)	0	0.0%	0	0.0%	0	0.0%	31 881 538	96.9%	1 014 884	3.1%	32 896 423	100%
	Electricity consumption (TWh)	0	0.0%	0	0.0%	0	0.0%	20 598	83.5%	4 078	16.5%	24 676	100%
2017	**Total stock (mln)**	0	0.0%	0	0.0%	0	0.0%	1 229 823 182	81.5%	280 088 443	18.5%	1 509 911 626	100%
	Total sales (mln)	0	0.0%	0	0.0%	0	0.0%	307 854 942	99.9%	198 612	0.1%	308 053 553	100%
	Electricity consumption (TWh)	0	0.0%	0	0.0%	0	0.0%	20 378	83.3%	4 081	16.7%	24 458	100%
2018	**Total stock (mln)**	0	0.0%	0	0.0%	0	0.0%	1 290 203 623	82.2%	280 088 443	17.8%	1 570 292 066	100%
	Total sales (mln)	0	0.0%	0	0.0%	0	0.0%	384 916 109	100.0%	0	0.0%	384 916 109	100%
	Electricity consumption (TWh)	0	0.0%	0	0.0%	0	0.0%	20 072	83.1%	4 081	16.9%	24 153	100%
2019	**Total stock (mln)**	0	0.0%	0	0.0%	0	0.0%	1 344 104 731	82.8%	280 088 443	17.2%	1 624 193 175	100%
	Total sales (mln)	0	0.0%	0	0.0%	0	0.0%	299 246 768	100.0%	0	0.0%	299 246 768	100%
	Electricity consumption (TWh)	0	0.0%	0	0.0%	0	0.0%	19 963	83.0%	4 081	17.0%	24 043	100%
2020	**Total stock (mln)**	0	0.0%	0	0.0%	0	0.0%	1 380 673 200	83.1%	280 088 443	16.9%	1 660 761 643	100%
	Total sales (mln)	0	0.0%	0	0.0%	0	0.0%	253 679 100	100.0%	0	0.0%	253 679 100	100%
	Electricity consumption (TWh)	0	0.0%	0	0.0%	0	0.0%	20 343	83.3%	4 081	16.7%	24 423	100%

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Annexe 8-5: Main economic and environmental data for the scenario "BNAT (LED)"

		BNAT (LED)												
		GLS-R		HL-MV-R-HW		HL-MV-R-LW		HL-LV-R		HID-R		LED-R		
2007	**Total stock (mln)**	291 591 919	26.4%	107 306 006	9.7%	121 004 645	11.0%	584 873 780	52.9%	0	0.0%	0	0.0%	1 104 7
	Total sales (mln)	126 096 260	29.9%	67 257 000	15.9%	75 843 000	18.0%	153 000 000	36.2%	0	0.0%	0	0.0%	422 19
	Electricity consumption (TWh)	7 057	21.9%	5 955	18.5%	3 358	10.4%	15 792	49.1%	0	0.0%	0	0.0%	32 1
2008	**Total stock (mln)**	268 863 050	23.0%	136 773 513	11.7%	162 562 458	13.9%	599 377 647	51.3%	0	0.0%	0	0.0%	1 167 5
	Total sales (mln)	115 731 193	26.5%	75 207 279	17.2%	91 406 649	20.9%	155 109 283	35.5%	0	0.0%	0	0.0%	437 45
	Electricity consumption (TWh)	6 506	18.7%	7 591	21.8%	4 511	13.0%	16 184	46.5%	0	0.0%	0	0.0%	34 7
2009	**Total stock (mln)**	246 134 181	20.0%	164 383 435	13.4%	205 977 856	16.7%	613 881 514	49.9%	0	0.0%	0	0.0%	1 230 3
	Total sales (mln)	105 366 127	23.3%	83 157 558	18.4%	106 970 297	23.6%	157 218 566	34.7%	0	0.0%	0	0.0%	452 71
	Electricity consumption (TWh)	5 956	15.9%	9 123	24.4%	5 716	15.3%	16 575	44.4%	0	0.0%	0	0.0%	37 3
2010	**Total stock (mln)**	129 677 433	6.9%	97 126 435	5.2%	125 465 762	6.7%	460 881 514	24.5%	115 876 880	6.2%	954 456 184	50.7%	1 883 4
	Total sales (mln)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	115 876 880	10.8%	954 456 184	89.2%	1 070 3
	Electricity consumption (TWh)	3 138	10.7%	5 391	18.4%	3 482	11.9%	12 444	42.4%	1 688	5.8%	3 207	10.9%	29 3
2011	**Total stock (mln)**	23 585 751	0.9%	26 689 323	1.0%	29 390 019	1.2%	307 881 514	12.1%	233 401 447	9.1%	1 934 024 271	75.7%	2 554 9
	Total sales (mln)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	117 524 567	10.7%	979 568 088	89.3%	1 097 0
	Electricity consumption (TWh)	571	2.7%	1 481	7.0%	816	3.9%	8 313	39.5%	3 400	16.2%	6 469	30.7%	21 0
2012	**Total stock (mln)**	0	0.0%	0	0.0%	0	0.0%	154 881 514	5.1%	270 932 659	8.9%	2 626 210 882	86.0%	3 052 0
	Total sales (mln)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	37 531 212	5.1%	692 186 611	94.9%	729 71
	Electricity consumption (TWh)	0	0.0%	0	0.0%	0	0.0%	4 182	24.6%	3 947	23.2%	8 858	52.1%	16 9
2013	**Total stock (mln)**	0	0.0%	0	0.0%	0	0.0%	0	0.0%	274 396 361	8.3%	3 032 637 569	91.7%	3 307 0
	Total sales (mln)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	3 463 702	0.8%	406 426 687	99.2%	409 89
	Electricity consumption (TWh)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	3 998	28.0%	10 285	72.0%	14 2
2014	**Total stock (mln)**	0	0.0%	0	0.0%	0	0.0%	0	0.0%	277 043 790	8.2%	3 091 084 679	91.8%	3 368 1
	Total sales (mln)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	2 647 430	4.3%	58 447 110	95.7%	61 094
	Electricity consumption (TWh)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	4 036	27.8%	10 466	72.2%	14 5

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2015	**Total stock (mln)**	0	0.0%	0	0.0%	0	0.0%	0	0.0%	278 874 947	8.1%	3 150 480 679	91.9%	3 429 3
	Total sales (mln)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	1 831 157	3.0%	59 396 001	97.0%	61 22
	Electricity consumption (TWh)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	4 063	27.6%	10 650	72.4%	14 7
2016	**Total stock (mln)**	0	0.0%	0	0.0%	0	0.0%	0	0.0%	279 889 832	8.0%	3 204 514 685	92.0%	3 484 4
	Total sales (mln)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	1 014 884	5.1%	18 932 656	94.9%	19 94
	Electricity consumption (TWh)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	4 078	27.4%	10 814	72.6%	14 8
2017	**Total stock (mln)**	0	0.0%	0	0.0%	0	0.0%	0	0.0%	280 088 443	7.9%	3 250 485 022	92.1%	3 530 5
	Total sales (mln)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	198 612	0.4%	45 970 337	99.6%	46 16
	Electricity consumption (TWh)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	4 081	27.1%	10 956	72.9%	15
2018	**Total stock (mln)**	0	0.0%	0	0.0%	0	0.0%	0	0.0%	280 088 443	7.8%	3 297 167 027	92.2%	3 577 2
	Total sales (mln)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	46 682 005	100.0%	46 68
	Electricity consumption (TWh)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	4 081	26.9%	11 099	73.1%	15 1
2019	**Total stock (mln)**	0	0.0%	0	0.0%	0	0.0%	0	0.0%	280 088 443	7.7%	3 344 560 700	92.3%	3 624 6
	Total sales (mln)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	47 393 673	100.0%	47 39
	Electricity consumption (TWh)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	4 081	26.6%	11 245	73.4%	15
2020	**Total stock (mln)**	0	0.0%	0	0.0%	0	0.0%	0	0.0%	280 088 443	7.6%	3 392 666 041	92.4%	3 672 7
	Total sales (mln)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	48 105 341	100.0%	48 10
	Electricity consumption (TWh)	0	0.0%	0	0.0%	0	0.0%	0	0.0%	4 081	26.4%	11 393	73.6%	15