European Commission

Preparatory Study on Light Sources
for Ecodesign and/or Energy Labelling Requirements
(‘Lot 8/9/19’).

Final report, Task 7

Scenarios

Energy

Prepared by:

VITO, in cooperation with VHK
Date: 31 October 2015

Prepared for the European Commission, DG ENER.C.3
Contact person: Ruben KUBIAK
SPECIFIC CONTRACT No ENER/C3/2012-418 LOT1/07/SI2.668526
Implementing Framework Contract No ENER/C3/2012-418-Lot 1

Main contractor:
Consortium of VITO NV, VHK BV, Viegand & Maagøe ApS, Wuppertal Institute for Climate, Environment and Energy GmbH, ARMINES, represented by Dirk Fransaer, Managing Director VITO

Technical Team Leader: René KEMNA (VHK)
Contract Manager: Caroline LEMEIRE (VITO)

Other Participants:
Roy VAN DEN BOORN, Leo WIERDA (VHK)
Stuart JEFFCOTT (external collaboration)
Lieven VANHOOYDONCK, Paul VAN TICHELEN, Dominic ECTORS (VITO)
Wai Chung LAM (VITO, Quality Control)

Status: Final report

This report was ordered and paid for by the European Commission, Directorate-General for Energy.

Contents

Executive Summary

This study, assigned by the European Commission, prepares for a comprehensive review of the four existing ecodesign and energy labelling regulations for lighting products in the European Union. It aims at setting more ambitious targets, removing flaws and possibly unifying the existing regulations into one or two improved pieces of legislation.

Task 7 is the final task of the two-year study, building on the opportunities and barriers found in the previous tasks, identifying policy options and analysing their respective impacts.

Major opportunities come from the strong, unforeseen technological progress in LED-lighting (Light Emitting Diodes) as well as availability of new testing equipment and test standards. Major flaws come from the deficiencies in effective market surveillance where streamlined legislation might help the national authorities, speeding up test procedures, removing ambiguities, etc.. Also the effectiveness of the current energy labelling can be drastically improved. A barrier to ambitious timing is compatibility between dimmers and the new LED light sources; new standards are foreseen to be available in 2018.

The policy options initially considered include a baseline ('business-as-Usual' or BAU) with no new EU action, self-regulation, review of ecodesign regulations only, review of only the energy labelling delegated regulation, and a review of both the ecodesign and energy labelling regulations.

The industry has not come forward with a <u>self-regulatory proposal</u>, hence this option, though in principle preferred, had to be discarded. The option of reviewing energy labelling only would not remediate several regulatory and market failures and miss out on considerable savings. Hence, <u>'labelling only'</u> as a self-standing option has been discarded. Labelling is being considered in combination with ecodesign, even if details of the implementation will have to await the pending revision of the energy label framework directive 2010/30/EU. The options for <u>BAU</u>, <u>ecodesign only</u> revision, and <u>combined ecodesign and energy label</u> revision were further detailed and subjected to a scenario- and impact analysis.

The scope of new measures is lighting products, intended as the combination of light source, including integrated control devices, and control gear as well as integrated luminaires, i.e. luminaires where a broken light source cannot be substituted. Exemptions are foreseen for transport applications, following the spirit of the Ecodesign Directive, and applications that are critical in terms of safety and health. These exemptions refer to very specific EU legislation, typically backed up by their own set of standards. For another group of lighting products, instead of using ambiguous qualitative descriptions, it is proposed to base the exemption strictly on measurable technical parameters such as the spectrum ('non-white' X-Y coordinates), lumen output (outside 60-100 000 lm range), relative emitter size (>1000 lm/mm²), colour rendering index (CRI<0 Ra) and ambient temperature (>50°C, <-20°C).

The scenario analysis looks at the BAU and four ECO scenarios: One scenario for the ecodesign only option (ECO80+120) and three scenarios for combined ecodesign and labelling (ECO70+LBL, ECO80+120+LBL, ECO120+LBL).

The ecodesign only option (ECO80+120) follows the targets in line with the Least Life Cycle Cost (LLCC) criterion as described in the Ecodesign Directive 2009/125/EC. The maximum power in on-mode of the lighting product follows a minimum base efficacy, with a correction (a constant) for low-power products and a correction for colour rendering. There is no distinction between directional and non-directional sources, but in case of beam angles smaller than 20 degrees there is a small allowance. The minimum base efficacy is 80 lm/W in 2020, which leaves LEDs, best linear fluorescents and best large high intensity discharge (HID) sources on the market. For control gears sold separately the minimum efficiency is set to 90% at full load. In 2024 the minimum base efficacy is proposed to go to 120 lm/W, leaving only LED or possibly OLED (organic LED).

The ECO70+LBL scenario, one of the scenarios under the combined ecodesign and labelling option, uses a slightly more lenient minimum base efficiency of 70 lm/W, but aims at a review of the energy label to stimulate competition between manufacturers and achieve higher efficacy. The 7-class labelling scheme sets the lowest class at a base value of <85 lm/W and a top class efficiency at >210 lm/W, with an even class-width of 25 lm/W.

The ECO80+120+LBL option uses the same minimum efficacy requirements as the ECO80+120 option, but adds the effects of an improved labelling.

The ECO120+LBL option is a reference for the most ambitious scenario. It uses the same ecodesign criterion as the second stage of the ECO80+120 option, i.e. a base efficacy of 120 lm/W, but anticipates the introduction to 2020. This scenario is intended as a reference only, because its technical feasibility is uncertain.

All ECO scenarios require a limited, up-to-date set of parameters to be tested and anticipate the use of portable, low-cost equipment for the compliance assessment of instantaneous parameters (lm output, power, colour rendering, colour temperature, spectrum, power displacement factor, etc.). For endurance parameters the report proposes accelerated lifetime testing, temperature cycling and switching tests according to the latest standards. Thus endurance testing could be completed in 1000 hours (40-50 days) instead of the current 6000 hours.

Starting point in scenario modelling is the BAU scenario, i.e. where there will be no new action. This scenario includes savings from measures that are already in place. Some of the measures still have to deliver effects in the period 2016-2018: Stage 6 of regulation 244/2009, stage 3 of regulations 1194/2012 and 245/2009 respectively. Furthermore, the BAU scenario assumes the current trend towards LED to continue.

The effect of minimum efficacy requirements in the ecodesign measures is to accelerate substitution by equivalent LED products. Without revised energy labelling the substitution follows the LED efficacy projections by industry. With new energy labelling measures, i.e. more competition on efficacy, the efficacy projections are up to 8% higher for high-end LEDs and up to 39% higher for low-end LEDs, corresponding to a shift of 1 or 2 energy label classes. Prices of LEDs will be proportionally higher than in the industry projections.

Table 1 shows savings in 2020 from anticipation of measures taking effect in that year. Peak savings at the height of LED-substitution occur in 2025. The long term savings in 2030 are the yardstick for many EU policy goals.

The 2030 electricity savings range from 28 TWh (ECO70+LBL) to 65 TWh (ECO120+LBL). The two ECO80+120 scenarios with and without improved labelling bring 61 and 43 TWh annual savings in 2030 respectively, illustrating the significant impact of new label measures.

Any of these scenarios makes lighting products the number one electricity saver amongst ecodesign-regulated products. The relative savings above come on top of 110 TWh/year absolute savings in the BAU since 2015.

The Greenhouse Gas (GHG) emissions follow the same trend with 2030 savings ranging from 10 to 22 Mt CO_2 equivalent, on top of the savings of 55 Mt CO_2 equivalent in the BAU since 2015.

All scenarios, including the BAU, require consumers — including non-residential consumers — to invest before they can reap the benefits in terms of lower electricity costs. The ECO120+LBL scenario costs some 8.8 bn euros extra in 2020 acquisition costs, but will deliver annual overall savings in expenditure (acquisition and energy costs) of 14.3 bn euros in 2030. Lowest initial investments occur in the only scenario without new energy label measures, i.e. the ECO80+120 scenario where industry mainly competes on price and less on efficacy. This scenario still brings 10.3 bn euros net savings on expenditure in 2030, but in the longer run up to 2050 — also analysed in the report — savings will decrease and eventually the BAU will catch up with this scenario.

The ECO scenarios with new labelling measures bring extra business revenues and jobs versus the BAU, i.e. they can compensate the jobs and revenues that are projected to be lost in the BAU scenario over the 2015-2030 period.

Table 1: Electric Energy, GHG Emission, Total Expense and Acquisition costs. Absolute values for the BAU-scenario and savings of the ECO-scenarios with respect to the BAU scenario. EU-28 totals for all sectors (residential + non-residential). Savings are computed as ECO-BAU; negative values indicate savings or reductions in the ECO-scenario; positive values are additional expenses.

ELECTRIC ENERGY in TWh/a		2015	2020	2025	2030
BAU	absolute	324	277	243	214
ECO70+LBL	savings		-10	-31	-28
ECO80+120	savings		-9	-48	-43
ECO80+120+LBL	savings		-15	-63	-61
ECO120+LBL	savings		-21	-78	-65
GHG EMISSION in $MtCO_2eq/a$		2015	2020	2025	2030
BAU	absolute	128	105	87	73
ECO70+LBL	savings		-4	-11	-10
ECO80+120	savings		-3	-17	-14
ECO80+120+LBL	savings		-6	-23	-21
ECO120+LBL	savings		-8	-28	-22
TOTAL EXPENSE in bn euros/a		2015	2020	2025	2030
BAU	absolute	71.4	72.3	71.7	75.9
ECO70+LBL	savings		+3.1	-5.1	-6.6
ECO80+120	savings		+1.7	-8.2	-10.2
ECO80+120+LBL	savings		+4.6	-9.5	-13.8
ECO120+LBL	savings		+6.0	-12.5	-14.7
ACQUISITION COST in bn euros/a		2015	2020	2025	2030
BAU	absolute	18.2	18.8	14.9	14.4
ECO70+LBL	savings		+4.6	+1.7	+0.8
ECO80+120	savings		+3.0	+1.2	-0.3
ECO80+120+LBL	savings		+6.9	+3.3	+1.1
ECO120+LBL	savings		+8.8	+3.0	+1.2

Preface

This is the Task 7 report of the Ecodesign Preparatory Study on Lighting Products, building on the existing Ecodesign and Energy Label (Delegated) Regulations for this product group.

The study started 24.12.2013 (signature date) and runs for two years. Contractor is the consortium specified on the cover page. Active partners are VHK (project leader) and VITO, with the collaboration of Jeffcott Associates.

The Task 7 draft report follows the MEErP [1] structure:

1. Policy analysis

- 1.1 Stakeholder consultation during preparatory study;
- 1.2 Barriers and opportunities for improvements environmental impact and measures (from Tasks 1-4);
- 1.3 Pros and cons of (combinations of) Ecodesign measures and other policy instruments (e.g. self-regulation, energy label, EPBD); overlaps with existing legislation;
- 1.4 Policy scenarios for further analysis, including definition of the scope, timing and target levels, possible energy label classification and implementation aspects, measurement standards, other user/installation information.

2. Scenario analysis

- 2.1 Generic stock model for the 1990-2030 baseline (Business-as-Usual, 'BAU') specifying sales, stock, performance (e.g. lm output, operating hours, product life), significant energy and environmental impacts (e.g. in kWh, kg CO2 eq.);
- 2.2 Scenario (ECO) analysis for the above parameters, in terms of absolute, relative (versus BAU) and accumulative impacts (versus BAU);

3. Impact analysis industry and consumers

- 3.1 BAU stock model extension 1990-2030 for economic impacts (e.g. prices, energy costs, installation and maintenance costs, total consumer expenditure, business revenues)
- 3.2 Scenario (ECO) analysis for the above parameters, in terms of absolute, relative (versus BAU) and accumulative impacts (versus BAU).

4. Sensitivity analysis of the main parameters.

Recalculate selected scenarios for variations in e.g. energy and product prices as appropriate.

5 Summary

- 5.1 Main policy recommendations
- 5.2 Main outcomes of the scenarios for Baseline, 2020 and 2030
- 5.3 Risk of possible negative impacts on health, safety, etc. (+/- table)

For further detailed explanations on each of the tasks, see the MEErP, Part 1, Chapter 7

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

1. Policy analysis

1.1. Stakeholder consultation

A first stakeholder meeting was held on 5 February 2015 to discuss the Task 0, 1, 2 and 3 draft reports. Following this meeting stakeholders had time until 28 February 2015 to provide written comments. The minutes of the meeting can be found in Annex A. The minutes and stakeholders' comments have been published on the project website http://ecodesign-lightsources.eu/. A revision of the Task reports was issued, reflecting these comments.

A second stakeholder meeting was held on 17 June 2015 to discuss the Task 4, 5 and 6 draft reports. Following this meeting stakeholders had time until 15 July 2015 to provide written comments, and until 30 August 2015 to provide inputs for the scenario analyses of Task 7. The minutes of the meeting and the stakeholders' comments and inputs have been published on the project website and can be found in Annex B. The comments have been considered during the work on Task 7 and will be taken into account when issuing the final project report.

Apart from the above, the study team also engaged in several bilateral meetings with stakeholders, both in the context of its main assignment to propose a single lighting regulation as well as in the framework of lateral tasks.[2]

Stakeholder positions can be summarised as follows: The European industry association Lighting Europe (LE) stresses the need to improve the effectiveness of market surveillance, but sees no need for new minimum efficiency requirements. LE believes that their research and development (R&D) priority should be on lowering the production costs and price of LED light sources for residential use rather than on continuing to improve LED-efficiency.

NGOs, some individual manufacturers and national lighting industry associations, as well as most Member States that voiced an opinion, believe that not only surveillance can be improved but also that more ambitious minimum energy efficiency requirements and clearly defined performance requirements can increase the contribution of lighting products to EU energy and environmental policy goals as well as provide a higher level of consumer protection.

1.2. Barriers and opportunities

1.2.1. LEDs (Light Emitting Diodes)

Opportunities

The main opportunity for energy and carbon-emission savings in lighting is the substitution of older light source technology by more efficient retrofit LED light sources or integrated LED luminaires. Over the past 5 years there has been a huge, unforeseen progress in LED-lamp technology. LED lamp efficacy increased from 30 to 150 lm/W.

[2] As a separate part of the study, not directly related to the Task 7 presented here, a draft MV DLS Market Overview was prepared for the Commission, regarding the conditions for the application of Stage 3 of Regulation 1194/2012 to mains-voltage filament lamps. This overview was discussed in the Ecodesign Consultation Forum of 25 June 2015. The report is published on the Commission's website.

LED lamps are in the scope of the existing measures (Task 1), are showing remarkable and unexpected market growth and rapidly decreasing prices (Task 2), have functional characteristics that are attractive to consumers in most applications and have no other significant negative impacts compared to current practice in terms of health, safety and end-of-life (Task 3). Task 4 shows that technically appropriate LED light source alternatives are now available for most of the existing classical light source types and luminaires.

Task 6 indicates that in terms of Life Cycle Costs they are already economically advantageous to many consumers or they are expected to be so by 2020 at the then lower prices. (see paragraph 1.3.5)

Barriers

Despite LED-lamps enjoying considerable commercial success, there are market failures due to the higher acquisition costs of the lamps and the legacy of an existing park of light sources, control gears and luminaires. As regards the former, there are situations where the lamp-buyer is not the one paying the energy bill (landlord-tenant, separate investment and cost budget-owners), where there is not enough money (poor families but also communes, sports clubs, theatres, etc.) or where the consumer just buys a one-on-one replacement for the old lamp out of habit or fear of the unknown.

Habits are not the only legacy from the existing lighting park. There are still applications where the new LED-lamps are not (yet) suitable, either because of the space available (e.g. R7s), special caps or light characteristics (e.g. very high lumen outputs). In professional lighting using e.g. HID or T5 fluorescents there is often the necessity to change/remove the whole existing gear and/or the whole luminaire.

For businesses that only a few years ago, incentivised by government programs, invested in high-frequency ballasts and efficient T5 fluorescent lamps the recuperation of their investments is at stake. Municipalities that have been forced, per 1.4.2015, to change high pressure mercury lamps (and gear/luminaire) in their city street lights to ‘something else’ can now only hope that the legislator will not force them to invest again under a reviewed regulation.

There is the legacy of ‘dimmers’, a phenomenon from half-a-century ago to bring ‘atmosphere’ to the homes. Old dimmers have originally been designed to work with filament lamps (halogen, incandescent bulbs). Already with gas discharge lamps (e.g. fluorescents) dimming is often problematic in the sense that it requires a special ‘dimmable’ design. Also with LEDs, which do exist in ‘dimmable’ version, compatibility between dimmers and lamps can be problematic. It is likely that many consumers with old dimmers would not necessary miss the dimming option, as suggested through their use of non-dimmable lamps in these settings, but there is an issue to ensure –within reason– that citizens that like to dim light sources for ‘atmosphere’ can continue to do so. While already today dimmable LED lamps exist, a new dimmer standard is foreseen to be available in 2018 that would increase the certainty of interoperability between new dimmable lamps with new dimmer installations.

Last but not least, the legislator does not want to repeat the mistakes from the past where a significant part of the general public felt that legislation was ‘pushing’ a light source, the energy-saving CFLs, with real or perceived sub-standard performance in terms of colour rendering, colour temperature, ignition time, mercury hazards, etc.. Even though appropriately built LEDs show no signs of having any of these, or other, deficiencies in performance, there is always a potential risk of certain parties perceiving flaws despite numerous studies, amongst others by SCENHIR (see Task 3), finding no health or safety hazards. If such perceived flaws, or real flaws in case deficient LED-lamps enter the EU market, become common belief it may well have a very negative impact on the uptake of LEDs. Therefore, it remains of the utmost importance to ensure a) a set of strict performance requirements in the legislation, and b) an effective surveillance of compliance with performance.

1.2.2. Special purpose lamps

Opportunities

Special purpose lamps, exempted from legislation, represent an electricity consumption of more than 55 TWh/year (Task 2 report table 22). Within the total of 324 TWh/year consumed by all light sources in 2015 it represents 'only' 17-18% and thus appears to be small.

However, 55 TWh/year is more than the 2015 EU electricity use of household washing machines and household dishwashers put together and thus compared to other ecodesign regulated product groups it is significant.

Due to advances in LED- and possibly OLED-technology they represent an opportunity for energy saving in many applications.

Barriers

However, the special purpose exemptions also represent a possible loophole for non-compliant lamps. This has been the case with certain filament lamps that were sold as 'infra-red' and incandescent lamps that are imported in large quantities as being 'shockproof'. In the latter case, the Commission had to issue Regulation (EU) 2015/1428 [3] to explicitly exclude these types previously marked as 'special purpose':

> Incandescent lamps longer than 60 mm are not special purpose lamps, if they are resistant only to mechanical shock or vibrations and are not incandescent traffic signalling lamps; or they possess a rated power higher than 25 W and claim to have specific features that are also present in lamps having higher energy efficiency classes according to Regulation (EU) No 874/2012 (such as zero EMC emissions, CRI value higher or equal to 95, and UV emissions less or equal than 2 mW per 1 000 lm);'

Despite this negative experience and despite its emphasis on effective market surveillance, Lighting Europe insists in its reaction to the study team to maintain the qualitative, unverifiable definitions of special purpose lamps such as 'food display lighting', 'adjusted to the specific needs of particular technical equipment', 'special protection', etc..

The challenge will be to set hard technical parameters for special purpose lamps that really need to be exempted, like in heating and certain light guidance applications where LEDs are not/less suitable, and at the same time make sure that no misuse of the exemption by non-compliant lighting products is possible. In all cases, the aim should be to formulate the exemptions 'technology-neutral' where possible. Last but not least,

---

[3] COMMISSION REGULATION (EU) 2015/1428 of 25 August 2015
amending Commission Regulation (EC) No 244/2009 with regard to ecodesign requirements for non-directional household lamps and Commission Regulation (EC) No 245/2009 with regard to ecodesign requirements for fluorescent lamps without integrated ballast, for high intensity discharge lamps, and for ballasts and luminaires able to operate such lamps and repealing Directive 2000/55/EC of the European Parliament and of the Council and Commission Regulation (EU) No 1194/2012 with regard to ecodesign requirements for directional lamps, light emitting diode lamps and related equipment.

there should be a 'safe haven' for all future lighting applications that use lighting for technical purposes other than lighting a scene or objects. This could be created by defining a spectrum outside the white light area, which in itself would make it unattractive for use in general lighting.

1.2.3. Control gear efficiency

In the current regulations, the efficiency of integrated control gears (ballasts, transformers, drivers) is considered as part of the lamp efficacy.

In regulations 244/2009 and 1194/2012, there is no minimum efficiency requirement for external control gears, but there are correction factors on the lamp power that take the power consumption of such gears into account. A factor 1.06 is used for filament lamps requiring external power supply, and 1.1 for LED lamps, compact fluorescent lamps and HID-lamps [4].

Regulation 245/2009 deals only with lamps that have external ballasts and sets separate minimum requirements for lamp efficacy and ballast efficiency. Some of these requirements on ballast efficiency still have to take effect. Stage 3 enters into force in 2017 and requires a minimum ballast efficiency for LFL and CFLni lamps of:

$\eta_{ballast} \geq P_{lamp}/(0.333\sqrt{P_{lamp}}+1.055P_{lamp}+1)$.

For HID-lamps the minimum ballast efficiency differs per type, but can be approximated with the equation:

$\eta_{ballast} \geq 0.0437\, LN(P_{lamp})+0.663$.

The minimum efficiency requirements vary but overall fit a band-width of 90±5% for the common wattages of LFL and HID.

1.2.4. Standby and parasitic power

Regulation 245/2009 Annex III point 2.1A (1st Stage, 2010) requires that 'The power consumption of the fluorescent lamp ballasts shall not exceed 1,0 W when operated lamps do not emit any light in normal operating conditions and when other possible connected components (network connections, sensors etc.) are disconnected. If they cannot be disconnected, their power shall be measured and deducted from the result.' In the 2nd Stage (2013) the allowed power is reduced to 0.5 W.

Note that this is limited to ballasts for fluorescent lamps and that there is no similar requirement for ballasts for high-intensity discharge lamps. In addition, the power consumption by network connections and sensors is not regulated.

Regulation 1194/2012 Annex III point 1.2 limits 'the no-load power of a lamp control gear intended for use between the mains and the switch for turning the lamp load on/off' to 1.0 W in Stage 2 (2014) and to 0.5 W in Stage 3 (2016)[5].

As from Stage 3 (2016) the standby power [6] of a lamp control gear shall not exceed 0.5 W.

---

[4] In Regulation 1194/2012, for 'other' fluorescent lamps (not T5 and not 4-pin single-capped) the correction factor is calculated using a formula in function of the luminous flux.

[5] For lamp control gear with output power (P) over 250 W, the no-load power limit shall be multiplied by P/250W.

[6] According to the definitions of regulation 1194/2012: 'standby mode' means a mode of lamp control gear where the lamps are switched off with the help of a control signal under normal operating conditions. It applies to lamp control gear with a built-in switching function and permanently connected to the supply voltage when in normal use.

Note that according to the definitions of regulation 1194/2012, the control gear does NOT include control devices (timer switches, sensors, daylight regulation devices, dimmers) and external power supplies (within scope of Regulation 278/2009). There is no specific reference to the inclusion or exclusion of network connections. Ballasts for fluorescent lamps and high-intensity discharge lamps are excluded.

Already now there are lighting products on the market where the light source(s), control gear and power supply functions, control device functions (sensors, dimming) and network communication functions are highly integrated (e.g. smart lamps). This trend is expected to continue:

- Industry expects that between 2016 and 2020 there will be a massive adoption of LED lamps in the domestic sector. As these lamps have long lifetimes, sales will decrease significantly after that. In an attempt to create a new demand, industry will offer lamps with additional functions (see Task 4 report chapter 4 on smart lamps). For these lamps the energy consumption of these other functions and the energy consumption in no-load or standby mode may be as important as the energy consumption by the lighting function.
- Lighting control systems are being increasingly applied in office lighting and street lighting. The parallel Lot 37 preparatory study on lighting systems is addressing this topic. The energy savings potential of these systems depends on the use of sensors, dimmability, controls and (wireless) communication.

A related topic is that in many situations dimmers have to receive their power supply through the lamp (Task 3 report par. 7.2).

This reinforces the idea that in a new regulation the requirements should address the integrated lighting product, including light source, control gear, and, where present, control device and networking function (Figure 9). The requirements on no-load and standby power consumption should be extended to address the new trend.

1.2.5. Opportunity: integration and simplification

In its assignment for this study the Commission aims at integrating the existing lighting regulations into one (par. 1.3.1). This idea is generally welcomed by stakeholders, but several stakeholders ask that this opportunity be also used to limit the number of regulated parameters to the minimum necessary, in order to reduce the testing efforts and costs, that are a burden in particular for SME's [7]. The reduction of the number of parameters, preferably testable in 1-2 days, would improve market surveillance.

Another problem that should be addressed by a new regulation is the 6000 hours (250 days) test currently required by regulation 1194/2012 to verify the Lamp Survival Factor

[7] In its inputs for Task 7, Lighting Europe suggests the following minimum set of parameters:

1. Energy Efficiency Index (EEI)
2. Color Rendering Index I (CRI) *
3. Color Consistency (SCDM)
4. Lumen maintenance at 2000 hrs (XX%)
5. Initial useful Lumen Output (and equivalency claims)
6. Temporary Light Artefacts * provided that a proper EN standard is in place
7. Power displacement factor (cos phi, instead of power factor) *

Sample size: as standards require but from 4 different places
* = Lighting Europe position paper available

and the Lumen Maintenance Factor for LED lamps. For a dynamic market where LED lamp models are replaced almost yearly, these 6000 h are too long. Such a long test also reduces the efficacy of Market Surveillance.

In addition several stakeholders ask the new regulation to deviate as little as possible from international (IEC) standards, and to use as much as possible the terms & definitions already specified in those standards.

1.2.6. Colour rendering and DLS beam angle

For all light sources there is a negative correlation between efficacy and colour rendering. For most indoor lighting applications a Colour Rendering Index (CRI, Ra8) of 80 is sufficient, and LED lamps have no problems in meeting this requirement. LED lamps with CRI ≥ 90 (up to 95) exist, but their efficacy is lower. With HID lamps the correlation between efficacy and CRI is even more evident. All this indicates that for fair minimum efficacy limits the CRI should play a role.

The question remains whether CRI in Ra8 is the correct measure. Colour rendering issues have been addressed in the study in the Task 1 report, par. 3.1, 4.1.1 and 5.1.6. A discussion is ongoing on the adequacy of the CRI-Ra8 scale for LED lighting products. Alternative colour rendering scales have been studied for many years at the level of global standards (CIE) but no consensus has been reached and thus the CRI is still the only alternative.

Outside the EU not many other regions make the distinction between Directional and Non-Directional Light Sources (DLS and NDLS) or between 'clear' and 'frosted' when regulating efficacy (see Task 1). Especially as LED light sources emit light in only one hemisphere and have as much problems as being non-directional as directional, it seems logical to eliminate this difference. Only for very small 'spot' beam angles, i.e. smaller than 20°, an extra allowance would be justified because of the extra optical losses (reflector, lens).

1.2.7. More effective testing

<u>New equipment</u>

In recent years compact and low-cost testing equipment has come on the market that allows on-the-spot goniophotometric measurement of efficacy (lm/W), spectrum (X, Y), CRI, beam angle, colour temperature, etc. in a matter of minutes, even at ambient light conditions. Equipment prices are in the range of € 8,000 to € 15,000 (excluding training of operators) for a 10% accuracy (as required). Examples are the portable LightSpion by VisioSystems and the compact Goniophotometer 760 by PRC Krochmann. Also according to the lighting industry the accuracy of these and similar devices is sufficient for compliance testing of the main instantaneous parameters.

For large light sources/integrated luminaires and/or more accuracy (e.g. ±5%) the equipment costs would more than double and dedicated lab testing might be required.

In any case, for most lamps the portable test option would avoid time-consuming and expensive lab-testing, the acquisition of integrated spheres, expensive spectrographs, etc. and allows the market surveillance authorities to immediately warn or fine retailers offering incompliant light sources.

<u>Sample size</u>

The current verification procedures require a sample size of 20 lamps for each of the tests. From the stakeholder consultation it is learned that strictly for compliance verification a sample size of 10 lamps would be sufficiently accurate. This would cut testing costs in half and would thus allow market surveillance authorities to test twice as much lamps with the same budget.

Accelerated endurance testing

Endurance testing, relevant in case of suspected non-compliance, still requires laboratory-testing but there are test standards that would allow to perform accelerated endurance testing in a shorter time-frame.

The IEC has a series of such tests (IEC 60068) from which one "selects methods for environmental testing along with their appropriate severities, and prescribes various atmospheric conditions for measurements and tests designed to assess the ability of specimens to perform under expected conditions of transportation, storage and all aspects of operational use." The problem is which test(s) to select when related to lighting products. A preferred option is thus a dedicated light source accelerated endurance test. At the moment there is one such test available for self-ballasted LED performance, i.e. IEC 62612 [8]. It has three tests:

Temperature cycling test (The purpose of this test is to check the mechanical strength of the assembly). Duration: 40 days

Temperature is varied from -10 °C to +40 °C over a 4 h period and for a test duration of 250 periods. A 4 h period consists of 1 h holding at each extreme temperature and 1 h transfer time (1 K/min) between the extreme temperatures. The LED lamp is switched on at test voltage for 34 min and off for 34 min. (If a supplier claims suitability for operation at extended conditions ….) At the end of the test all the LED lamps shall operate and have a luminous flux which stays within the claimed lumen maintenance code for a period of at least 15 min and show no physical effects of temperature cycling such as cracks or delaminating of the label.

Supply switching test (The purpose of this test is to check the endurance of the built-in electronic components). Duration (variable ~ 7 days)

At test voltage, the lamp shall be switched on and off for 30 s each. The cycling shall be repeated for a number equal to half the rated life in hours

Accelerated operational life test (This test is to check for catastrophic failures, but includes the following statement: an accelerated test should not evoke fault modes or failure mechanisms which are not related to normal life effects. For example, a too high temperature increase would lead to chemical or physical effects from which no conclusions on real life can be made.). Duration: 40 days

The LED lamp shall be operated continuously without switching at a test voltage and at a temperature corresponding to 10 K above the maximum specified operating temperature, if declared by the manufacturer and over an operational time of 1 000 h. If there is no declared value then the test shall be performed at 50 °C. Any thermal protecting devices that would switch off the LED lamp or reduce the light output shall

[8] IEC 62612:2013, Self-ballasted LED lamps for general lighting services with supply voltages > 50 V - Performance requirements, TC34/SC 34A.

be bypassed. [At test completion] lamps shall have an allowed decrease of light output of maximum 20 % compared to the initial value for at least 15 min.

Testing requires 10 samples for each test, following the earlier proposal. Lamp acquisition costs for 3 x 10 lamps, at e.g. €10 per lamp would amount to €300. Best estimate of laboratory testing costs per lamp (at a reasonable batch size of e.g. 100 lamps) would be €70 for the Temperature Cycle, €30 for the Supply Switch test and €200 for the Accelerated Operational Lifetime (including pre and post lumen measurement). Thus one lamp might have a total test and purchase cost of around €300. At a sample size of 10 lamps/test this amounts to € 3000,- per lamp. This would be in addition to any standard photometric or other tests. In other words, this type of accelerated testing would not save money with respect of a normal, static endurance test of 6000 hours (or more), but it would allow effective testing within a time frame of 40-50 days and –with the addition of the temperature cycling test—give a more accurate impression of the life expectancy in real-life conditions.

<u>Tolerances</u>

As there is a clear correlation between accuracy and costs it is proposed not to introduce more stringent tolerances but stay at a verification tolerance level of ±10% (for light sources and integrated luminaires) and ±2.5% for control gears.

<u>Family concept</u>

Industry (LE) proposed that further reduction in testing costs may come from applying the 'family concept'. This concept is proposed in the IEC 62717 standard on LED modules [9] and might be aligned with standards on LED lamps like IEC 62504. It is evident that it saves testing costs for manufacturers, but for market surveillance it seems an unworkable concept. The study team finds it unlikely that a manufacturer then accepts complete withdrawal of the whole 'family' of products based on a single assessment.

1.2.8. Ineffective energy label

As opposed to the situation with other household appliances with an energy label, the energy label for lamps –first introduced in 1998—only had a modest contribution to the market transition, if any.

Under Framework Directive 2010/30/EU the Commission Delegated Regulation (EU) No 874/2012 of 12 July 2012 deals with the energy labelling of light sources [10], specifically at the point of sales. The label gives trade mark, model identifier (product code), energy efficiency class with the appropriate arrows and the annual energy consumption per 1000 hours.

Possible formats are given in Figure 1. The format in the upper left corner, with additional information for trade mark and model identifier placed elsewhere, applies to a situation where the label is not printed on the packaging. In that case the label,

---

[9] IEC 62717:2014+AMD1:2015 CSV, Consolidated version, LED modules for general lighting - Performance requirements, TC34/SC 34A.

[10] Commission Delegated Regulation (EU) No 874/2012 of 12 July 2012 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to energy labelling of electrical lamps and luminaires (OJ L 258, 26.9.2012, p. 1).

including white border, measures 36 x 75 mm (width x height). Figure 2 gives the relative proportions and design of the label.

Any of the four formats in Figure 1 can be used in case the label is printed on the packaging. In that case the minimum dimension is 36 x 68 mm or –for the bottom row formats in Figure 1—36 x 62 mm, unless the following applies:

'If no side of the packaging is large enough to contain the label and its blank border or if this would cover more than 50 % of the surface area of the largest side, the label and border may be reduced, but by no more than is required to meet both these conditions. However, in no case may the label be reduced to less than 40 % (by height) of its standard size. If the packaging is too small to take such a reduced label, a 36 mm wide and 75 mm high label must be attached to the lamp or the packaging;'

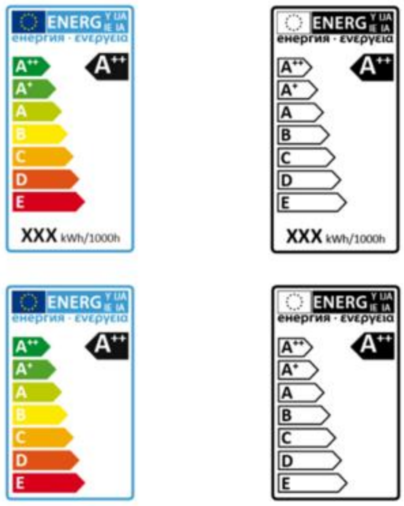


Figure 1: Possible energy label formats CDR 874/2012

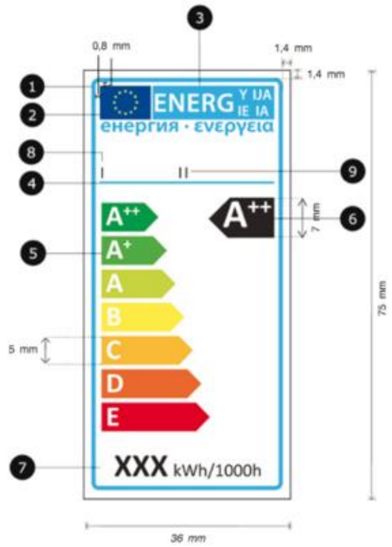


Figure 2: Label default dimensions. Relative proportions are to be maintained also when printed in a different format. The background of the label, both in colour or black-and-white version must be white.

The most evident difference of the unsuccessful lamp-label with the successful energy labels for other energy-related products is its size and above all its position.

A lamp is a much smaller product than e.g. a washing machine or a refrigerator and therefore the regulator has already conceded a much smaller size and a less obtrusive black and white design. To put this in perspective: at 40% reduced size, which is the minimum allowed, the label would be 14.4 x 27.2 mm. This is less than the surface area of a regular small postage stamp (see Figure 3).

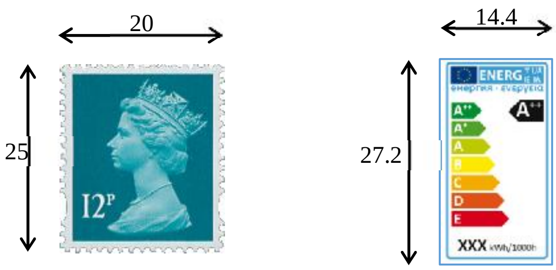


Figure 3: Size of the lamp energy label at minimum size (40% reduced) compared to a small regular postage stamp

The only stipulation in CDR (EU) No 874/2012 regarding the position of the label at the point of sales is that it 'is placed or printed on, or attached to, the outside of the individual packaging'. As manufacturers give priority to commercial information (brand name and features that they believe will attract customers) this means that the label is usually placed on a side that is not normally visible to the consumer:

- either placed at the backside of a blister-pack or,
- when packaged in a box and displayed on a shelf, applied to the side that is not facing the potential customer.

Figure 4 shows the result: the energy label is invisible to the customer at the point of sale, i.e. the energy label is at the back-side of the blister-pack.

Figure 4: Lamps in blister-pack at point of sale (example)

The current energy label classes for light sources according to Annex VI of Regulation 874/2012 are shown in Figure 5. The EEI is calculated as EEI = P_{cor}/P_{ref}.

P_{cor} is the rated light source power. For models working on external control gear this power is corrected by a factor reflecting the control gear losses [11]. So P_{cor} is the power of the combination of light source and control gear (if present).

For models with Φ_{use} < 1 300 lumen: $P_{ref} = 0.88\sqrt{\Phi_{use}} + 0.049\Phi_{use}$

For models with Φ_{use} ≥ 1 300 lumen: $P_{ref} = 0.07341\Phi_{use}$

The useful luminous flux Φ_{use} is the total flux for non-directional lamps and the flux in a 90° or 120° cone for directional lamps.

Energy efficiency classes for lamps

Energy efficiency class	Energy efficiency index (EEI) for non-directional lamps	Energy efficiency index (EEI) for directional lamps
A++ (most efficient)	EEI ≤ 0,11	EEI ≤ 0,13
A+	0,11 < EEI ≤ 0,17	0,13 < EEI ≤ 0,18
A	0,17 < EEI ≤ 0,24	0,18 < EEI ≤ 0,40
B	0,24 < EEI ≤ 0,60	0,40 < EEI ≤ 0,95
C	0,60 < EEI ≤ 0,80	0,95 < EEI ≤ 1,20
D	0,80 < EEI ≤ 0,95	1,20 < EEI ≤ 1,75
E (least efficient)	EEI > 0,95	EEI > 1,75

Figure 5: Energy efficiency classes for lamps according to Regulation 874/2012 Annex VI table 1

Considering that $P_{cor} = \Phi_{use} / Eff_{comb}$ where Eff_{comb} is the efficacy of the combination of light source and control gear in lm/W_{mains}, the equations can be rewritten to obtain an expression for the Eff_{comb}, in function of Φ_{use} and EEI:

$Eff_{comb} = \Phi_{use} / \{(0.88*sqrt(\Phi_{use})+0.049*\Phi_{use})*EEI\}$ for Φ_{use} < 1300 lm

$Eff_{comb} = \Phi_{use} / \{(0.07341\Phi_{use})*EEI\} = 13.624/EEI$ for Φ_{use} ≥ 1300 lm

Calculating these formulas for the lower bounds of the A^{++} label class, i.e. EEI=0.11 for non-directional lamps and EEI=0.13 for directional lamps, the corresponding minimum required efficacies Eff_{comb} of Table 2 are obtained.

Considering the projections for LED efficacy development in the coming years (see hereafter) these efficacy values imply that by 2020 the large majority of LED light sources will be in the A^{++} class.

Table 2: Minimum required efficacies in lm/W_{mains} for a combination of light source and control gear to have an energy efficiency class A^{++} according to Regulation 874/2012

		useful luminous flux as defined in 874/2012 Annex VII					
	EEI (A^{++})	250	500	750	1000	1500	2000
NDLS	0.11	87	103	112	118	124	124
DLS	0.13	74	87	95	100	105	105

This means there will be no possibility for consumers and for industry to distinguish between 'good', 'better' and 'best' energy efficiency LED products based on the label.

[11] For the factors, see regulation 874/2012, Annex VII table 2.

CDR (EU) No 874/2012 was amended by Commission Delegated Regulation (EU) No 518/2014 of 5 March 2014 for labelling of products sold through the internet [12]. The latter regulation introduces the concept of a 'nested display', i.e. if there is not enough room on the website to display the full energy label with the product, the webmaster may decide to use just the arrow with the energy class.

Annex VII, Article 3 c) states:

(3) The image used for accessing the label in the case of nested display shall:

(a) be an arrow in the colour corresponding to the energy efficiency class of the product on the label;

(b) indicate on the arrow the energy efficiency class of the product in white in a font size equivalent to that of the price; and

(c) have one of the following two formats:

Delegated Regulation 874/2012 also prescribes a mandatory label for luminaires that mainly indicates if the luminaire is suitable for –and possibly supplied with—a light source with a certain energy class. The default dimensions are 50 x 100 mm (width x height) and the label has a white background.

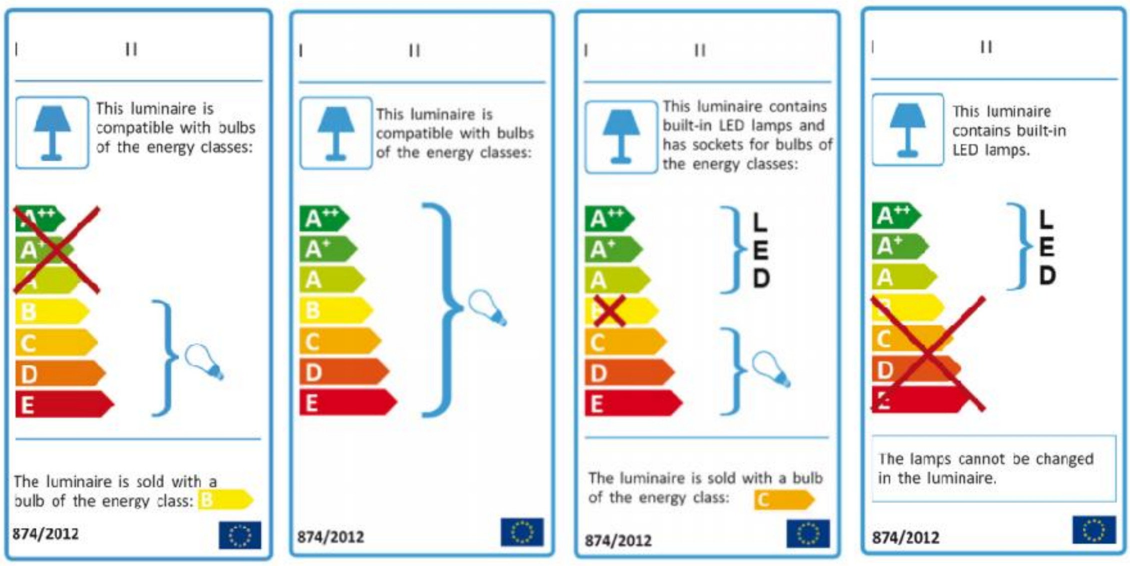


Figure 6: Vertical luminaire label formats in CDR (EU) 874/2012.

The relevance of this luminaire label for the consumer has decreased considerably since its inception in 2011-2012, because today –except for a few very specific cases of G9 and R7s caps—there are LED retrofit lamps for almost every luminaire. Also in view of future developments it can be expected that in a few years a luminaire label in this form only represents an administrative burden for manufacturers and retailers, amongst which there are many SMEs, with little added value.

[12] Commission Delegated Regulation (EU) No 518/2014 of 5 March 2014 ...with regard to labelling of energy-related products on the internet, L 147, 17.5.2014, p.1.

1.3. Possible policy measures

1.3.1. Options overview

In the assignment for this study (Task 0, chapter 1) the Commission requested, amongst others, to:

- Build upon and advance the existing regulations
- Aim at setting more ambitious targets for the products currently regulated
- Identify lighting products not yet regulated to be included in the study
- Explore the feasibility of unifying the existing (Ecodesign) regulations into one.

This indicates the main direction the policy measures should take, i.e. start from the current regulations but move beyond, setting more ambitious targets, e.g. increase the minimum efficacy requirements, and possibly extending the scope, e.g. reduce the current exemptions.

The following paragraph describes the new 'technology-neutral' scope that is proposed for all new actions, and it is followed by a discussion of the details per policy option:

1. No new measures ('Business-as-Usual', BAU)
2. Self-regulation
3. Energy labelling only
4. Ecodesign only
5. Ecodesign and energy labelling

1.3.2. Scope (all options)

The scope of the regulation is lighting products, i.e. a mains-operated configuration of one or more lighting components [13], intended to emit light with the following optical characteristics:

- chromaticity coordinates x and y in the range $0{,}200 < x < 0{,}600$ and $-2{,}3172\, x^2 + 2{,}3653\, x - 0{,}2800 < y < -2{,}3172\, x^2 + 2{,}3653\, x - 0{,}1000$;
- a luminous flux < 1000 lm per mm^2 of projected light-emitting surface area;
- a rated luminous flux between 60 and 100 000 lumen [14];
- a colour rendering index CRI > 0 Ra [15].

This definition describes what is in the scope, but above all this definition was designed to say that all light emitting artefacts that do not comply with the optical characteristics are definitely excluded, i.e. not regulated or by default defined as 'special purpose' [16]. In that sense, the chromaticity limits in the scope definition are intentionally taken wider

[13] Luminaires are not lighting components, unless they are integrated with the lighting product(s). LE suggests to also add that they should be produced in quantities of more than 500 pieces per year and consume more than 3W.

[14] The 60 lm lower boundary for lumen output avoids that a new regulation has to deal with a huge variety of dashboard-, status-display or other pilot-lights as well as purely decorative lamps. Possibly the 60 lumen can also be replaced by a wattage boundary (2 W?). The 100 000 lumen upper limit is roughly the limit of regulation 245/2009, which includes HID lamps in that lumen range. It also clarifies that –if we want to create a single regulation including HID lamps—we have to deal with the area between 20 000 and 100 000 lumens where currently LED lamps are not offered for sale.

[15] The colour rendering index criterion, which should be tightened through the requirements in a new regulation, at least ensures that (almost) single-wavelength-sources such as lasers or LPS lamps are exempted.

[16] See formulation in regulation (EU) 2015/1428.

than those of ‘white light’. This provides an easy to measure criterion and gives manufacturers the opportunity to exclude IR (e.g. red or gold), UV (blue), grow light (purple), collagen (pink) or other light source outside the scope chromaticity area.

In a second instance of the definitions the more narrow Planckian ‘white light’ area is then to be introduced as a requirement, i.e. that the chromaticity coordinates x and y should be in the range $0{,}270 < x < 0{,}530$ and $2{,}3172\,x^2 + 2{,}3653\,x - 0{,}2199 < y < -2{,}3172\,x^2 + 2{,}3653\,x - 0{,}1595$ in order to qualify as ‘white light’.

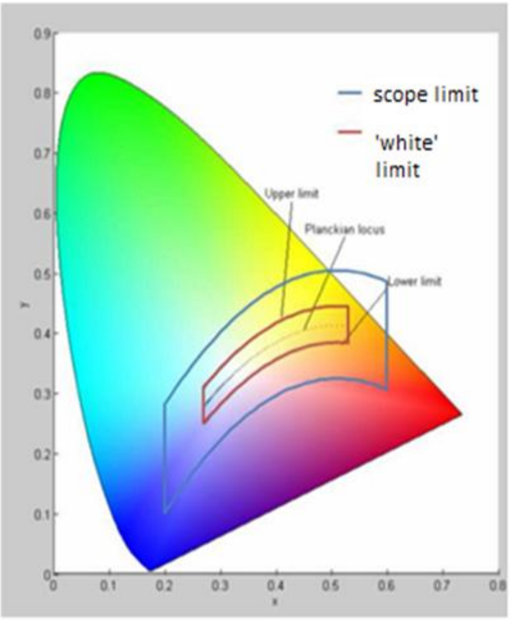
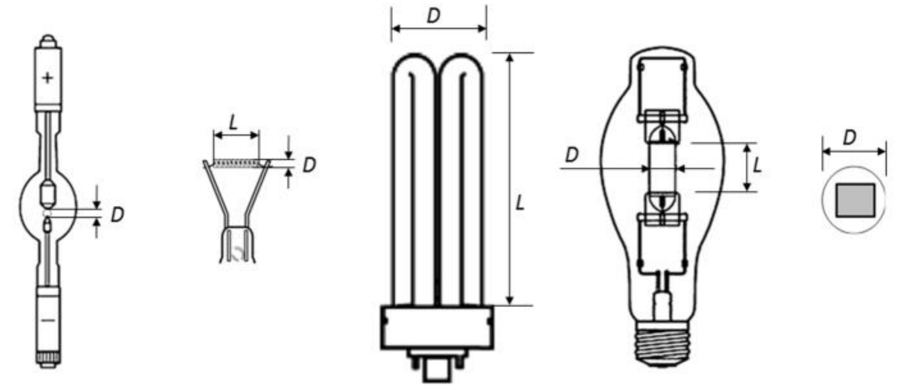


Figure 7: Chromaticity indices considered to be in the scope of a new regulation (for the purposes of scenario analyses in this study) and indices considered to be ‘white’ light.

Likewise, the emitter size criterion mainly intends to exempt light projection and light guidance sources that have light emission densities (lm/mm^2) as yet unattainable by LED-lamps. Figure 8 gives some examples of the definition of emitter size areas.

LE does not support the light emitting surface area definition, because ’it can be different depending upon the lamp design even for the same “base” product. For example GU10 has many designs with different “chip” /optical emitter sizes.’ On the other hand, LE offers no robust alternative definition for lamps that are used for projection and light guidance and thus should be exempted.



(a) $A = \frac{1}{4}\pi D^2$ (b) $A = L \cdot D$ (c) $A = L \cdot D$ (d) $A = L \cdot D$ (e) $A = \frac{1}{4}\pi D^2$

Figure 8: Examples of definitions of emitter sizes. Lighting products with a luminous flux < 1000 lm per mm² of projected light-emitting surface area have been assumed to be out-of-scope for the scenario analysis. This mainly intends to exempt light projection and light guidance sources that have emitter sizes as yet unattainable by LED-lamps.

The exemptions proposed by the study team are listed below. They follow mainly Ecodesign Directive 2009/125/EC Art. 15 point 5, which stipulates that measures shall not have a significant impact on e.g. safety, health, affordability, etc.. Also subsidiarity and precautionary principles may apply:

- For use in potentially explosive atmospheres [17];
- For emergency use only [18];
- For use in radiological and nuclear medicine installations [19];
- For use in military or civil defence establishments [20];
- For use in exterior lighting on motor vehicles, trailers, systems, etc. [21];
- For use in/on civil aviation aircrafts [22];
- For use as railway vehicle lighting [23];
- For use in marine equipment [24];

[17] Precautionary principle (safety). Note that these ATEX products require third party certification, which is a deterrent for possible loopholes. Possible reference: Directive 94/9/EC.

[18] Precautionary principle (safety). Note that these Construction Regulation products require third party certification, which is a deterrent for possible loopholes. Possible reference: Regulation (EU) No 305/2011

[19] Precautionary principle (health, safety). Not sure whether there is a risk of hazardous interference between lamps and nuclear/X-ray radiation, but is not a risk to take. Possible reference: Article 3 of Directive 2009/71/EURATOM

[20] Significant negative impact on functionality cannot be excluded (cf. precautionary principle). There is no EU reference legislation; military or civil defence contracts are regulated mainly at MS level.

[21] For market surveillance purposes these lamps can easily be distinguished by the approval mark that is required under the appropriate UNECE Regulation. Possible reference: Regulation No 661/2009 and its amendments

[22] Approved lamps have either an ETSO mark, EPA mark or are approved under an official standard. There is a list of approved lamps which could be used for surveillance. Possible reference: Regulations 216/2008, 748/2012

[23] Subsidiarity principle: Railway safety of vehicles is (still) mostly regulated at national level. Note that for surveillance most railway lamps can be recognised also because they use a different (non-mains) voltage, e.g. 60 V, without control gear. Apply only to exterior lighting ? Possible reference: Directive 2008/57/EC, MS legislation

[24] Examples: navigation lights; position-indicating lights for life-saving appliances: (a) for survival craft and rescue boats,(b) for lifebuoys, (c) for life-jackets; daylight signalling lamps; low-location lighting systems; evacuation guidance systems; search lights for use in lifeboats and rescue boats. For market surveillance: Compliance can be recognised by the Wheel mark, mark of conformity. Possible reference: Directive 96/98 /EC, Directive 2014/90/EU

- For use in road, railway, marine and air traffic signalling [25];
- For use in electronic displays [26];
- For use in medical devices and in vitro medical devices [27];
- For use in other laboratory or other scientific equipment [28];
- For operation at ambient temperatures higher than 50 °C or lower than – 20 °C;

The above creates a robust, verifiable framework for exemptions.

From the point of view of environmental impacts, it is not relevant if the energy is consumed by the light source itself or by the control gear. When combining all Ecodesign regulations into one, there is an opportunity for simplification by describing default minimum efficacy requirements for the combination of light source plus control gear. In case only a light source (without gear), is placed on the market then the default gear efficiency can be applied. If only the control gear is placed on the market then it has to comply with this same default minimum efficiency of 90%. This would simplify the regulation and facilitate a technology-neutral formulation (Figure 9).

For the scenario analyses this means that the efficacy limits have been applied to the combination of light source and control gear.

[25] Subsidiarity, safety, affordability arguments: Road and rail traffic signalling lights answer to very specific requirements (e.g. for chromaticity, size, light distribution, etc.). Regulation, excluding exterior lighting of vehicles, takes place at MS level. Traffic lights are purchased mainly by municipalities; would be better to leave acquisition when budget is available rather than forcing it upon the municipalities at possible expense of more urgent services.

[26] The functionality of a backlight unit is different from general purpose lighting, i.e. to enhance the visibility of objects, persons, scenes, etc.. The requirements under the electronic display regulation will be anyway stringent enough to ensure that no saving potential is lost from this exemption.

[27] Precautionary principle (health). Also occurs e.g. in RoHS. Possible references: Directives 93/42/EEC, 98/79/EC .

[28] Precautionary principle, e.g. for lights in microscopes or lamps used for calibration and light measurement. However, there is no robust legal reference, nor is there a more extensive description in a standard. This exemption may require more work if indeed these lamps are not already exempted on the basis of their spectrum.

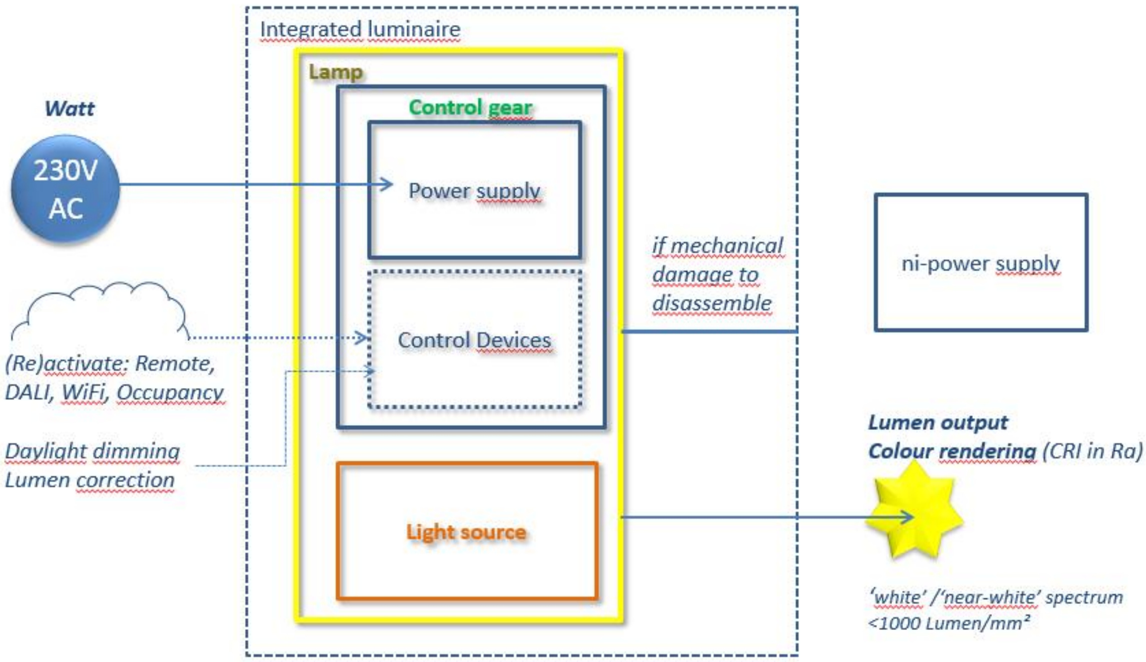


Figure 9 A new regulation could address the integrated lighting product, including light source, control gear, and, where present, control device and networking function. This would simplify the regulation, facilitate a technology-neutral approach and avoid separate ecodesign requirements for light sources and control gears. Energy consumption in standby and no-load modes could be limited at the level of the integrated product.

1.3.3. No new measures (BAU)

The reference scenario for new measures is the so-called 'baseline' or 'Business-as-Usual' (BAU) scenario, i.e. where there will be no new action. However, there may still be savings from measures that are already in place. Some of the measures still have to deliver effects in the coming years:

- Stage 6 of regulation 244/2009, as recently amended by regulation 2015/1428 [3], will phase-out most non-directional halogen lamps starting from September 2018.
- Stage 3 of regulation 1194/2012 will phase-out mains-voltage directional filament lamps from September 2016.
- Stage 3 of regulation 245/2009 will introduce higher efficacy limits for metal halide lamps and higher efficiency limits for ballasts in 2017.

In addition, the analyses in this study indicate that LED-substitutes are available for most of the classical-technology lamps and the market for these efficient light sources is growing rapidly.

The BAU scenario will take the above issues into account and aims to be a realistic reference for new measures. By default, the BAU scenario is one of the options that needs to be analysed. Whether or not it is, in itself, a viable option will depend on whether it follows the mandate from the Ecodesign directive in terms of eligibility and what would be the impact if current market and regulatory failures persist.

1.3.3.1. Eligibility

Regarding the eligibility criteria in Article 15.2 of Directive 2009/125/EC, the analyses in previous tasks indicate that 'light sources' are economically significant (Task 2), environmentally significant (Task 5 and others), that there is still, due to the unforeseen trends in LED efficacy and -price, a significant saving potential economical without excessive costs (Task 6) which is not covered by other Community legislation (Task 1) and that there is a wide disparity in the environmental performance of products available on the market with equivalent functionality (Task 4). Furthermore, there is little doubt that at the moment the saving potential, marked by the least life cycle costs, is not fully realised.

1.3.3.2. Market failures

As mentioned in paragraph 1.2.1 there are still considerable market failures in the adoption of efficient (LED) lamps.

1.3.3.3. Regulatory failure

A regulatory failure is in market surveillance, which is relatively expensive and certainly slow. This results in lower testing activity and results becoming available often at a time when the incompliant merchandise is sold-out and no longer on the market. This creates an uneven playing field for market actors and undermines the credibility of the legislation.

A major cause for the slow process is in the endurance testing for premature failure and lumen maintenance, which may take up to 6000 hours or more. For overall surveillance economy, the minimum required sample size for testing of 20 units certainly does not help. As discussed in the 1st stakeholder meeting of February 2015, there needs to be a different balance between accuracy and effectiveness of the market surveillance. Surveillance would also benefit from straightforward and unambiguous assessment of the exemptions in the regulation.

1.3.3.4. Debate

The main question on eligibility that will always be debatable, but which is not specifically part of Directive 2009/125/EC, is whether or not in the (near) future market or other regulatory forces will realise the available saving potential with the existing legislation and whether or not all market and regulatory flaws will disappear. Market trends are always difficult to predict, but the evaluation of a BAU scenario versus other policy scenarios should give the decision makers the best possible estimate of how much, if any, savings may be missed/delayed without new EU action (see Chapters 2 and 3).

As regards possible future regulatory forces, it can be mentioned that there is a possibility that the RoHS Directive will at some point stop making an exception for mercury light sources and thus effectively phase out compact and linear fluorescent lamps. If it happens the phase-out will take place under the RoHS boundary conditions, which generally speaking are less restrictive in the modality of a phase out than the Ecodesign Directive (e.g. compare phase out of lead in solder for the electronics industry). At the moment this possibility is highly uncertain and cannot be taken into account in the underlying study.

1.3.3.5. Stakeholder views

The European lighting industry association Lighting Europe (LE) has already indicated that, although it insists on improving the surveillance aspects, it does not see a need to update the existing minimum efficacy requirements; it believes that autonomous market forces will be sufficient. Other stakeholders, including some Member States that already voiced an opinion, environmental NGOs, an individual company (not member of LE) and the Netherlands lighting association, have indicated that they think that a more ambitious requirements and other changes to the current regulations will be helpful in reaching the policy objective.

1.3.4. Self-regulation

In Art. 15.3 b) of the Ecodesign Directive 2009/125/EC self-regulation, including voluntary agreements offered as unilateral commitments by industry, is indicated as a preferred option, but it is subject to certain conditions stipulated in Article 17 and Annex VIII to the Directive (e.g. market coverage by signatories, ambition level, etc.).

These conditions are not fulfilled: None of the stakeholders expressed interest in self-regulation nor is it likely that in today's global market the conditions for self-regulation, e.g. regarding minimum market coverage, will be met because the risk of 'free-riders' and thus unfair competition is too big.

1.3.5. Ecodesign measures only

This option entails that only the ecodesign regulations will be revised, in view of considerations in paragraph 1.2. The energy labelling regulation will not be changed.

The study team hypothesized the following general characteristics for a new regulation:

- Single Ecodesign light-source regulation
- Technology-neutral
- Lighting product efficacy = lumen output/mains W input (always with control gear losses, also for LFL/HID, see also Figure 9)
- Enough time for stakeholders to anticipate introduction, i.e. in 2020:
  - Allowing gradual transition for municipalities, sports and theatre facilities, etc. using HID lamps
  - Allowing investors in high-frequency ballasts and high-efficiency (T5) fluorescents to recuperate investments
  - Maximum power requirement formula with variable(s) and a constant. The variable is based on a lm/W target, CRI corrected. The constant provides lower requirements for lower lumen light sources and takes into account parasitic power for control- and network devices. The slope of the formula is similar to the current square-root formula but more clearly linked to technical parameters (see details below).
- Functional requirements: endurance, speed, optics
- Application to lighting products emitting 'white' light (par. 1.3.2)
- Necessary exemptions for health, safety (par. 1.3.2)
- Improved Market Surveillance through:
  - Test results on efficacy and non-endurance aspects within a few hours
  - Endurance test results within 6-8 weeks (ca. 1000h test)
  - Modest investment in –preferably portable– test equipment
  - Easy assessment of exemptions, mainly by:
    - spectrum (IR, UV, grow light, scientific lamps, etc.),
    - relative emitter size (lm/mm),

- coverage by other legislation (medical, transport, traffic, military),
- allowing no generic exemptions for mechanical characteristics (shockproof, shatterproof, etc.), as already implemented through regulation 2015/1428.

1.3.5.1. Efficacy limits

According to the Ecodesign Directive 200/125/EC the preparatory study should propose targets at the level of Least Life Cycle Costs. This was the subject of Task 6, based on inputs for (future) efficacy and costs of light sources firstly addressed in Task 4. Table 3 gives the summary on payback times from Task 6 (June 2015). Figure 10 and Figure 11 give the LED efficacy and cost curves that are used in Task 7, following the considerations described in Annex E.2.4.

The 'High-End without label' and 'Low-End without label' curves are used in the analysis for the ECO80+120 scenario (and for the BAU scenario). They correspond with the curves supplied by Lighting Europe.

The High and Low-End curves 'with label' are used for the combined Ecodesign+Label scenarios (hereafter ECO70+LBL, ECO80+120+LBL and ECO120+LBL) discussed in the next paragraph. New proposed energy efficiency label classes for lamps (par. 1.3.6) are also indicated as a reference. Label class denominations are only illustrative, pending decision making on the energy label framework directive.

The result from Task 6 imply that in 2015 the substitution of LFL, CFLni and HID lamps by LED alternatives is not always economical in terms of least life cycle costs (LLCC). However, at a an implementation date of 2020 the LED-alternatives would be more economical for all types.

Table 3 Survey of main results of the Task 6 analyses. The results are valid only for the analysed conditions (reference power/lumen, operating hours per year), under the assumptions made, and for the prices and costs considered. They are NOT valid for every lighting situation, but indicative for the average EU-28 situation.

Base case (BC) [29] (analysis conditions)	Available option with lowest LCC/Mlmh	Available option with lowest kWh/Mlmh	Payback time for LED 2015 vs. best classic technology (years)	Payback time for LED 2020 vs. best classic technology (years)
LFL T8 tri-phosphor (2400 lm, 2017 h/a)	Long life LFL T8t	LED 2015	may never pay back [30]	4
LFL T5 (2275 lm, 2099 h/a)	High-efficiency T5	LED 2015	may never pay back [30]	4
LFL T8 halo-phosphor (2400 lm, 1398 h/a)	T8 tri-phosphor	LED 2015	may never pay back [30]	3
LFL T12 (2450 lm, 1623 h/a)	T8 tri-phosphor	LED 2015	may never pay back [30]	2.5
CFLni (633 lm, 1197 h/a)	LED 2015	LED 2015	no pay back in CFLni lifetime [31]	3.5
HPM (12000 lm, 4000 h/a) (higher lm for HPS)	HPS BAT	HPS BAT	5 [32]	1
HPS & MH (13200 lm, 4000 h/a) (same lm for all)	HPS BAT MH BAT	HPS BAT	may never pay back [32]	2.5
MV NDLS (GLS-X, HL-E, CFLi) (500 lm, 450 h/a) [33]	LED 2015	LED 2015	3.5-4 (GLS, HL) >12 (CFLi) [34]	1
MV DLS (GLS-R, HL-X) (450 lm, 450 h/a) [33]	LED 2015	LED 2015	2 [35]	0
HL-LV-R (MR16) (490 lm, 450 h/a) [33]	LED 2015	LED 2015	4.5 [36]	< 1
HL-LV-Capsules (490 lm, 450 h/a) [33]	LED 2015	LED 2015	3	2
HL-MV-Capsules (420 lm, 450 h/a) [33]	LED 2015	LED 2015	1	< 1
HL-MV-Linear (R7s) (3000 lm, 450 h/a) [33]	LED 2015	LED 2015	1	< 1

[29] 'LFL'=linear fluorescent lamp, 'CFL'=compact fluorescent lamp, 'HPM'=high-pressure mercury lamp, 'HPS'=high-pressure sodium lamp, 'MH'=metal-halide lamp, 'HL'=halogen lamp, 'GLS'=non-halogen filament lamp, 'MV'=mains voltage, 'LV'=low voltage, 'NDLS'=non-directional lamp, 'DLS'=directional lamp, '-R'=reflector lamp, 'ni'=non-integrated control gear, 'BAT'= best available technology.

[30] The 2015 LED tubes have high initial costs compared to the best available LFL-options while their efficacy advantage over LFL is still relatively small. Useful lifetimes for LED tubes are comparable to those of long life LFL's.

[31] There are few LED retrofit lamp models for CFLni replacement available on the market; data are uncertain

[32] Shorter payback times apply for HPM BC lamps and HPS retrofit lamps. There are few LED retrofit lamp models for HID-lamp replacement available on the market.

[33] For these lamp types a rebound effect of +10% on both capacity (lm) and annual operating hours (h/a) has been applied for the LED options.

[34] This is based on the average 2015 LED prices from Table 1 in the Task 4 report. Taking the lowest prices from the same table, the payback times would reduce to 2 years for GLS X and HL MV E, and to 8-9 years for CFLi.

[35] This is based on the median 2015 LED prices from Table 1 in the Task 4 report. Taking the lowest prices from the same table, the payback time would reduce to less than 1 year.

[36] This is based on the average 2015 LED prices from Table 1 in the Task 4 report. Taking the lowest prices from the same table, the payback time would reduce to 1-1.5 years.

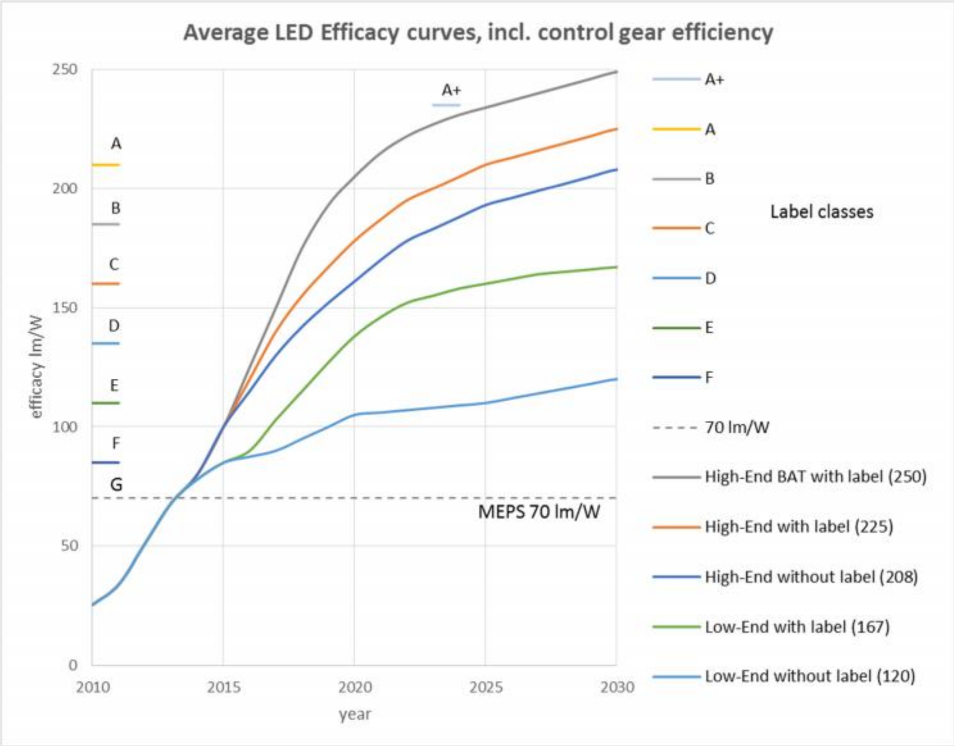


Figure 10: Curves for LED efficacy projections. Efficacies are in lm/W for the combination of light source and control gear.

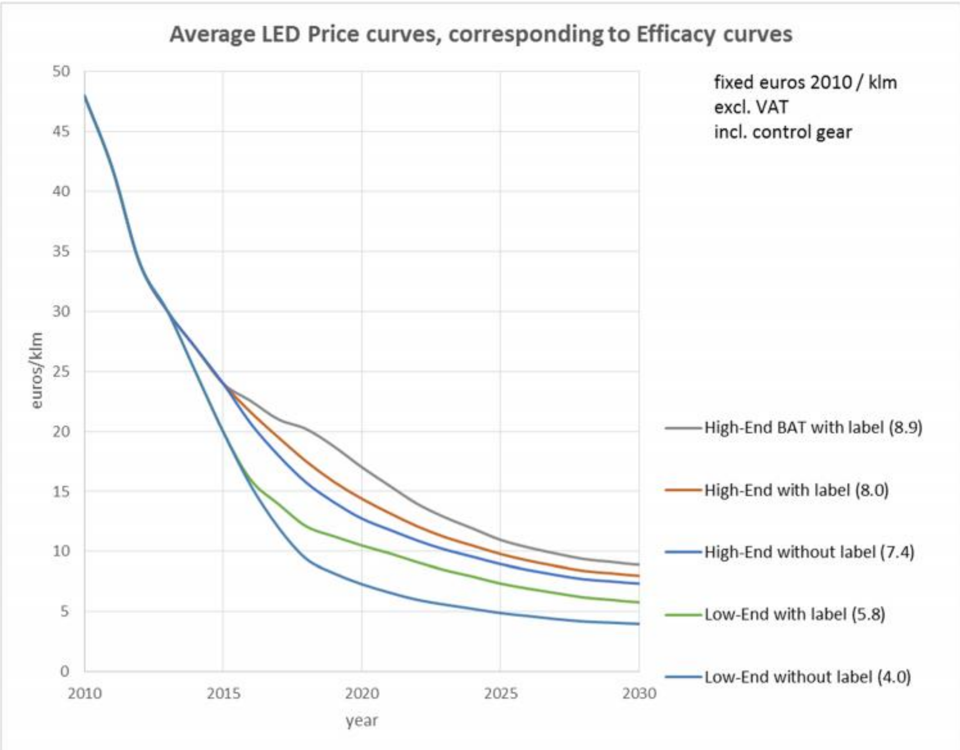


Figure 11: Curves for LED lamp price projections, corresponding to the LED efficacy projections with the same name. Prices are in euros/klm, fixed 2010 euros, excl. VAT, incl. control gears.

Regarding ‘affordability’ the payback-time of T5 and T8-triphosphor lamps at 2020 prices and efficacies for the LEDs is still relatively long, at 4 years, for most non-residential customers compared to other business investments that companies have to make. Probably, according to the best estimate and taking into account projected LED trends, it will take a few years longer before investment in LEDs to substitute T5 and T8-triphosphor will have payback times shorter than 3 years in non-residential applications [37].

For 2020, according to the LLCC-criterion, the minimum a new ecodesign measure should target is the phase-out of all halogen lamps [38] and compact fluorescent lamps (with and without integrated control gear). Using the current minimum requirements for light sources + gear as a first guidance for where to put the limit, this would require a minimum efficacy requirement around 80 lm/W.
A few years later, in 2024, the application of the LLCC-criterion implies the phase-out of LFL T5, LFL T8-triphosphor and most HID-lamps. This would require a minimum efficacy requirement around 120 lm/W.
This leads to the following proposal for the maximum on-mode power P_{on} with base values at 80 and 120 lm/W respectively (ECO80+120 scenario):

$P_{on} \leq (2+\Phi/80)*(CRI+240)/320$ W, proposed to enter into force in 2020

$P_{on} \leq (2+\Phi/120)*(CRI+240)/320$ W, proposed to enter into force in 2024

Where P_{on} is the rated mains power of the lighting product, Φ is the rated luminous flux (entire flux, not in a 90˚ or 120˚cone) and CRI the Ra colour rendering index.
The constant of 2 W at the start of the formula allows for the energy consumption of control devices or network communications during lamp functioning as well as fixed electrode losses in discharge lamps. It also favours low lumen light sources, that are allowed to have a slightly lower efficacy [39].
The second part of the formula is the CRI correction factor. For CRI=80, a value acceptable for most applications, this factor is 1, for CRI=90 it is 1.03 (slightly higher power and lower efficacy allowed), and for CRI=25 (many HPS lamps) it is 0.82 (lower power allowed; higher efficacy requested).
The following graphs illustrate the rationale for this proposal. In these graphs, the minimum values for the current regulations are including the energy losses of the lamp gear (ballast, driver, transformer).

For directional light sources the luminous flux Φ is the full (2π) lumen output. For directional light sources with a beam angle <20° the luminous flux shall be divided by

[37] As also observed by some stakeholders, there are applications where, taking advantage of the directionality of LED-light, a lower lighting capacity (lm) can be installed than with classical technology light sources, while obtaining the same (required) illuminance or luminance in the task area or on the street surface. In those cases, LED lighting products can be economically convenient already today.

[38] As far as still allowed under the existing regulations, i.e. low-voltage lamps and mains-voltage lamps with G9 and R7s cap.

[39] Note that studies by EIA and Australian authorities on the subject indicate that not only for conventional lamps but also for LEDs there is a lower efficacy at lower lumen output per light source.

a correction quotient as given in Table 8 of regulation (EU) 1194/2012 before compliance assessment. [40]

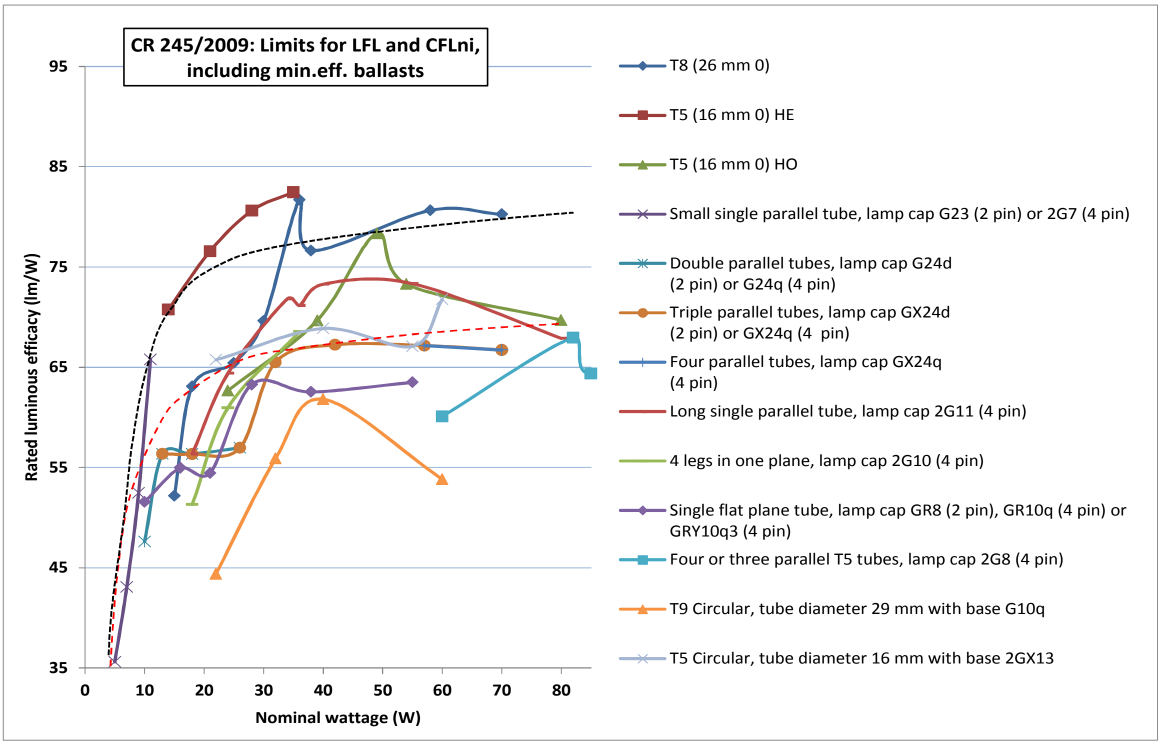


Figure 12 . Minimum efficacy limits for LFL and CFLni, in lm/W at rated power including minimum efficiency of the ballast. Ballast efficiency $=P_{lamp}/(0.333\sqrt{P_{lamp}}+1.055P_{lamp}+1)$. The black dotted line gives the proposed new limit curve at CRI=80

The dotted black graph gives the limit line at a base value of 80 lm/W at CRI=80 Ra.

Figure 12 shows that a limit with a base value of 80 lm/W means that only for T5 and high-power T8-triphosphor lamps the regulation would propose a slightly lower limit than in the existing regulation. Thus there is minimal risk of dumping by extra-EU industry for lamps phased out abroad but still allowed in the EU.
LE points out that a stringent limit would eliminate also T5 lamps shorter than 600 mm, which may be less efficient but do constitute an absolute saving in the popular 600x600 mm modules. However, manufacturer data indicate that still 20% of the best T5 lamps shorter than 600 mm would be able to comply.

Figure 13 indicates that HPS lamps >100W (CRI<60) and MH clear lamps> 200W are the HID-lamps remaining on the market.
As shown in Figure 14, all halogen and CFLi lamps will be phased out in 2020. From 2024 onwards, with a base value limit of 120 lm/W, only LED or OLED lamps remain on the market.

[40] Table 8 gives correction factors for the ‘equivalent luminous flux’, which is equivalent to correction quotients for the actual luminous flux. Values are 1 (≥20°), 0.9 (15-20°), 0.85 (10-15°) and 0.8 (<10°).

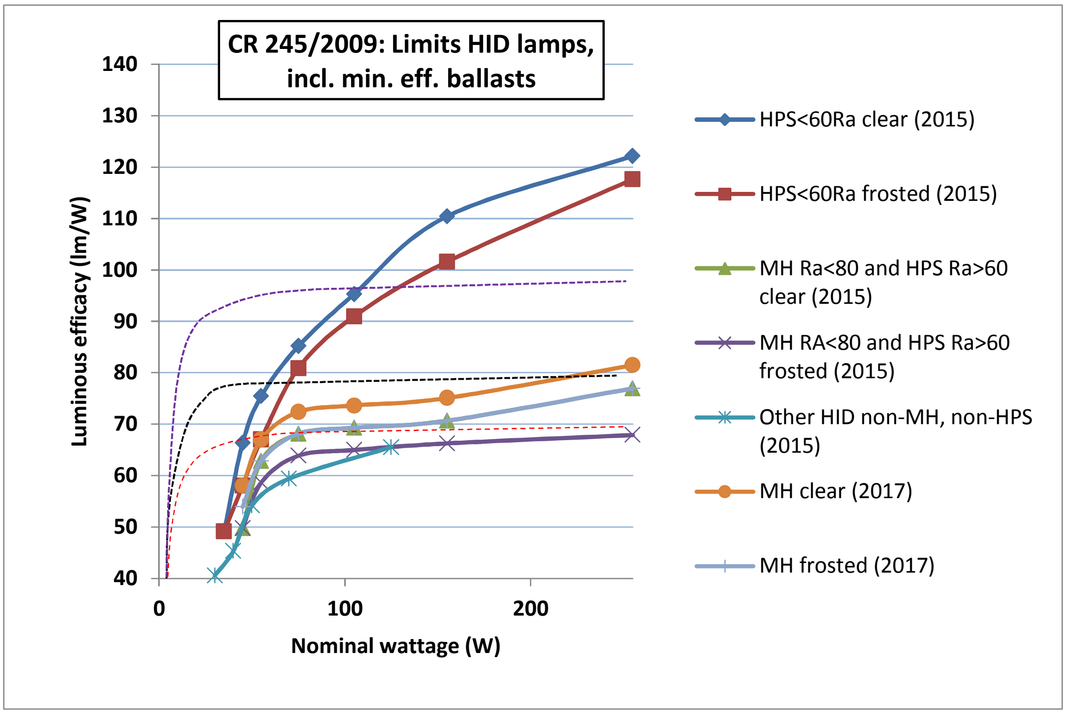


Figure 13 . Minimum efficacy limits for HID lamps, in lm/W at rated power including minimum efficiency of the ballast. Ballast efficiency varies slightly per type and is approximated overall by the expression $\eta_{ballast}$=0.0437 LN(P_{lamp})+0.663. The black dotted line gives the proposed limit at CRI=80. The purple dotted line gives the proposed limit at CRI=25.

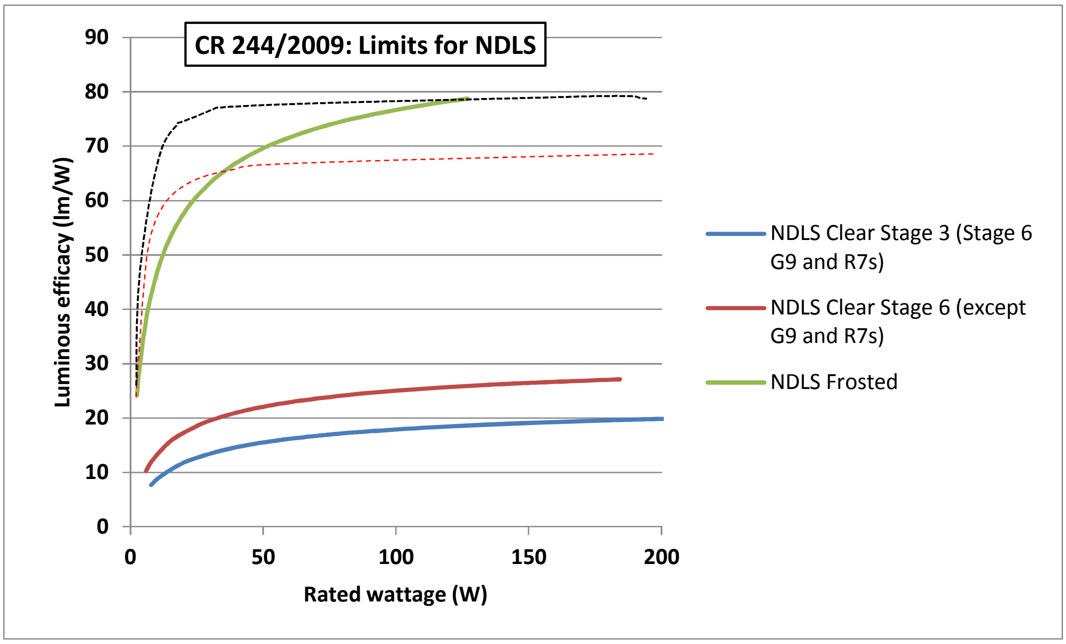


Figure 14 . Minimum efficacy limits for Non-directional (household) lamps, in lm/W at rated power including minimum efficiency of the control gear. Gear efficiency values are 1/1.06 (halogen) or 1/1.1 (other). The black dotted line gives the proposed limit at CRI=80.

1.3.5.2. Other requirements

At the current state of technology (and existing legislation), the following limits are realistic for standby power:

- $P_{standby}$ ≤ 1 W for lighting products with one or more control devices integrated or – when placed on the market with the lighting product;
- $P_{standby}$ ≤ 0,5 W for lighting products without control devices and only reactivation function;

For light sources claiming to emit 'white light', chromaticity coordinates x and y should be in the range $0{,}270 < x < 0{,}530$ and $2{,}3172\,x^2 + 2{,}3653\,x - 0{,}2199 < y < -2{,}3172\,x^2 + 2{,}3653\,x - 0{,}1595$.

'White light', CRI >80 colour rendering and a colour temperature (CCT) between 2 TBD limits, is a minimum requirement to avoid a marking that the lamp is <u>not</u> suitable for general purpose lighting.

Lamps marked as 'dimmable' must be compatible with all new dimmers placed on the market after 2018 (i.e. follow the new standard).

As regards warm-up and ignition time, the study proposes to follow the LE proposal and not set performance or information requirements. These parameters are mainly relevant for CFLs, which will be phased out by the measure.

For the power displacement factor (a.k.a. 'power factor' or 'cos phi') there is a minimum of 0.5 for lamps with output<500 lm, 0.9 for lamps in the range of 0.5-10 klm and no requirement for lamps with >10 klm output.

As regards colour consistency, variation of the chromaticity coordinates shall be within a six-step MacAdam ellipse or less.

For endurance testing the temperature cycling, switching and accelerated operational life testing according to IEC 62612 or similar shall apply. Minimum lumen maintenance after the temperature cycling test is still to be defined, survival rate for 10000 switches is set at 99% and lumen maintenance factor at the end of the accelerated operational life test shall be as defined in the standard, i.e. 0.8 (80%).

The product information requirement shall contain two sets of parameters: instantaneous parameters and endurance parameters (lumen maintenance after temperature cycling and after accelerated operational life tests, failure rate after switching).

1.3.6. Energy labelling only

This option entails that the legislator undertakes action regarding the energy labelling regulation, but does not engage in new action regarding the three existing ecodesign regulations.

A rationale for this policy option could be that a labelling system that makes a more differentiated distinction between low-, medium- and high efficacy LEDs could give a "market pull", i.e. provide an incentive for consumers to buy –at least for the most frequently used luminaires in the house— the most efficient (professional) LEDs. Especially given the current LE-industry stand that they have to prioritise price-reduction over efficacy, an effective energy label could help to counter-act such an all-out price war with low priority for best LED-efficacy. This would be beneficial both for reaching policy goals and for the EU-industry (revenues, jobs).

1.3.6.1. Impact, size and position of light source label

The instrument of a nested display in case of lack of display-space (par. 1.2.8) is in fact also applicable to the case of a small product like light sources. With full understanding of the commercial considerations of the manufacturer it is thus proposed to continue to allow the current practice to put an energy label at the back, but with the obligation to put a ‘nested display’ image as in CDR (EU) No 518/2014 with a minimum size 10 x 16 mm at the front of the blister-pack or box. The ‘front’ is defined as the side with (the largest coloured display of) the brand name.

The proposal is also commercially advantageous. At the moment, the industry is advertising ‘LED’ as the selling feature and it is prominently displayed at the front of the packaging. In a few years this will wear off and the consumer will want to know ‘Which LED?’ and will hopefully pay more for a better lamp.

The pictures in Figure 15 and Figure 16 give a first impression how this can look like at the point of sale.

Please note that the Energy Labelling Directive 2010/30/EU is currently under revision and e.g. the designation with letters ‘A’ to ‘G’ may change and is only used for illustration purposes.

Figure 15: Top left: Energy label today (not visible). Top right and below: Proposal for ‘nested display’ solution at point of sale.

Figure 16: Proposal for 'nested display' solution at point of sale for box-packaging (examples).

1.3.6.2. Energy efficiency classes for light-source labels

For the energy labelling of lamps to continue to have effect also in the future, a rescaling of the energy efficiency classes is necessary. A proposal is shown in Table 4. The class borders are expressed in lm_{tot}/W_{mains}, i.e. the total emitted luminous flux in output divided by the mains power in input, for the lighting product as defined in par. 1.3.2 and Figure 9.

The labelling classification below is in line with the current Commission proposal, i.e. it distinguishes 7 energy classes where the top 2 classes are 'empty' (no products are available that meet the lower class limits). The denomination is illustrative only.

Table 4: Proposal for the rescaling of energy efficiency classes for lighting products. The class borders are expressed in lm_{tot}/W_{mains}, i.e. the total emitted luminous flux in output divided by the mains power in input.

	lm_{tot} / W_{mains}	
Class	min	max
A	210	
B	185	210
C	160	185
D	135	160
E	110	135
F	85	110
G		85

Note that the limit values in lm/W are indicative. It can reasonably be expected that, if the energy labelling review is accepted, the lm/W values will in fact be 'base values' in a more sophisticated equation such as the one proposed for ecodesign in par. 1.3.5.

1.3.6.3. Luminaire labels

It is proposed to eliminate the generic luminaire label that indicates the suitability for efficient lamp types.

Only an energy label for integrated LED luminaires, i.e. a luminaire with a non-replaceable LED light source, will be required. For label intents and purposes these ‘LEDi’ luminaires can be treated as light sources and can use the same labelling criteria and ‘nested display’ features that are proposed for light sources. An example is given in Figure 17.

Figure 17: Imaginary integrated LED luminaire with proposed ‘nested display’ label.

For some light sources, mainly directional light sources, the one-on-one comparison with a LEDi-luminaire is fair, i.e. there is no extra loss of lighting efficacy because of the fact that one is called a ‘luminaire’ (meaning that it incorporates the mechanical means to be attached to the ambient) and the other is called a ‘light source’.

For other light sources, mainly non-directional light sources, one might argue that a one-on-one comparison with a LEDi-luminaire may not seem fair for the latter: The LEDi-luminaire is a finished product with possibly all sorts of energy-consuming features for direction, diffusing, reflection of the light. This is expressed e.g. by the Light Output Ratio (LOR), the percentage of light emitted from the light source that makes it out of the luminaire. The non-directional light source, when measured without a luminaire, does not have these losses, but the consumer will most likely experience these losses once the light source is fitted in the luminaire.

This poses a problem of possibly unfair competition or at least provokes a series of questions: How big is the problem? Should there be a correction factor for LEDi-luminaires to give the consumer the ‘right’ information for his or her purchase decision? Or is the consumer clever enough to figure that out by him/herself? What would be the drawbacks of such a non-universal correction factor, i.e. might it work the other way around and unduly favour certain integrated luminaires over retrofit lamps? Perhaps the decision between a light source and an integrated luminaire does not even occur that often, i.e. the consumer knows what he/she wants before entering a shop? Technically speaking, given the correlation between operating temperature and LED-efficacy, would it be unreasonable to ask of LEDi-luminaire designers, with much larger surfaces to dissipate heat at their disposal, to be e.g. 20% more efficient than a LED retrofit-lamp where everything has to be cramped in a small space? At the moment, at least based on catalogue data, it seems that integrated LED luminaires are more efficient (lm/W) than most light sources.

There is no clear answer to most of these questions. For the moment, it is assumed that having a correction factor might pose at least as large a risk as not having a correction factor for integrated luminaire labels and thus –with a possibility to add a correction at the first review—the former is chosen, i.e. no correction.

Will there be LEDi-luminaires eliminated from the market due to the minimum ecodesign requirements when they are treated as a light source? As an indication some examples of a LOR in existing luminaires are given in Annex C.

1.3.7. Combined ecodesign and energy labelling regulation

This option entails that both the existing ecodesign and energy labelling regulations will be revised.

The revision of the energy labelling follows the proposal as indicated for 'labelling only' (par. 1.3.6).

The revision of the ecodesign limits follows the general format of 'ecodesign only' (par. 1.3.5) but with only the first stage in 2020 and a slightly lower base value of 70 lm/W (ECO70+LBL scenario):

$P_{on} \leq (2+\Phi/70)*(CRI+240)/320$ W, proposed to enter into force in 2020

The slightly lower target value is indicated as a red dotted line in Figure 12 to Figure 14, using CRI=80. The advantage for the slightly lower limit is that it gives allowance for still the best CFLni or a circular T5. Some of the best CFLi might still comply, as well as more types of HID lamps where this limit is a challenge but not impossible. The disadvantage of the lower limit is that the risk of dumping by extra-EU countries increases. At some point in the decision making process one might decide to still choose the 80 lm/W option, but for the scenario analysis it is beneficial to study the effect of this slightly lower value.

In addition two other scenarios including labelling improvements have been analysed:

- The ECO80+120+LBL scenario is the same as the ecodesign-only scenario described in par. 1.3.5, but with addition of the assumed effect of improved labelling. This provides the opportunity to judge the effect of improved labelling by comparison of the scenarios with and without labelling.

- The ECO120+LBL scenario is added as a reference for the most ambitious scenario. It applies only the second stage of the ECO80+120 scenario (par. 1.3.5) but anticipates the introduction from 2024 to 2020. This would create a LED-only market already in 2020 and could be a challenge also for some types of LED-based light sources.

This scenario is presented mainly with the intention to provide an approximate reference for the highest savings that could be theoretically obtained, in particular on the short term. The technical feasibility of the ECO120+LBL scenario is uncertain: With reference to table 1 of the Task 4 report, for some types of LED light sources the best-available technology in 2015 already offers an efficacy of 120 lm/W or above (NDLS LED filament lamps, LED tubes substituting LFL T8, some replacements for HID-lamps). However, for many LED light source types this efficacy level is not yet available on the market, and hence it is speculative if this can be the case in 2020.

For comparison, as several stakeholders were concerned over the difference with the existing square root formula, the figure below gives a comparison with close EEI values.

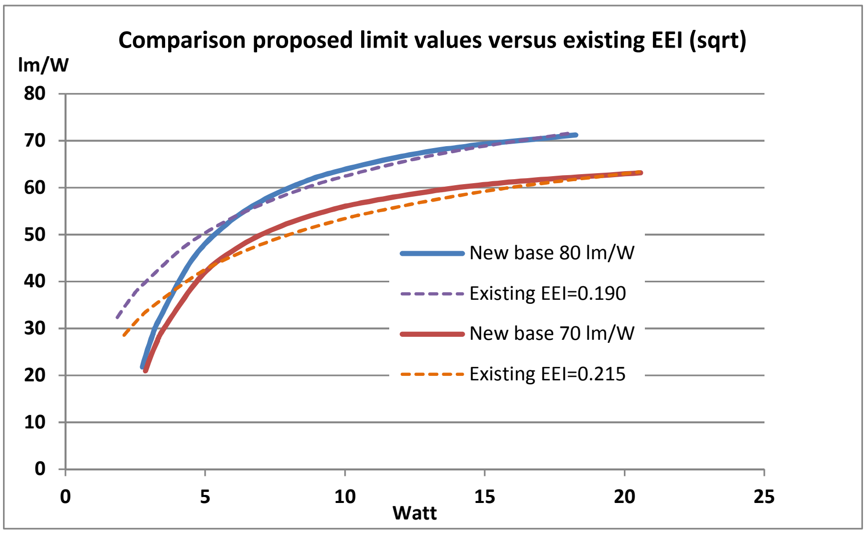


Figure 18: Comparison between proposed limit values and EEI according to the existing square root equation up to 1300 lm.

1.4. Policy measures selected for analysis

The policy options initially identified include a baseline ('business-as-Usual' or 'BAU') with no new EU action, self-regulation, review of ecodesign regulations only, review of only the energy labelling delegated regulation, and a review of both the ecodesign and energy labelling regulations.

The industry has not come forward with a self-regulatory proposal, hence this option, though in principle preferred, had to be discarded. The option of reviewing energy labelling only would not remediate several regulatory and market failures and miss out on considerable savings. Hence, the 'labelling only' option has been discarded. The options for BAU, 'ecodesign only' revision (ECO80+120 scenario) and combined ecodesign and energy label revision (ECO70+LBL, ECO80+120+LBL and (ECO120+LBL scenarios) were further detailed and subjected to a scenario and impact analysis.

2. Scenario analysis

2.1. Introduction to scenario analysis

The ‘Model for European Light Sources Analysis’ was first introduced in the Task 2 report (MELISA version 0). For use in the scenario analysis of Task 7 the model has evolved, as described in detail in Annex D.

Basic input data

The basic input data for the analyses (average capacity, power, efficacy, operating hours, price, etc.) are the same as those presented in the Task 2 and 3 reports, and as summarized per base case in the tables of chapter 5 of the Task 4 report. Any (minor) changes are explained in Annex E.

These basic input data are the same for all scenarios.

The difference between the scenarios consists in:

- Differences in the shift in sales from classical technology lighting products to LED lighting products;
- Different assumptions regarding the future projections for LED efficacy and LED price.

Shift in sales towards LED

The sales data for the period 1990-2013 are the same as those presented in the Task 2 report. For later years, separately for each base case, the model first determines the potential sales for that base case, as the sum of:

- lamps reaching their end-of-life (based on average lifetimes),
- lamps for new applications (based on growth rates), and,
- in some cases, lamps substituting those from other base cases (e.g. HPS- or MH-lamps substituting HPM-lamps, or LFL T5 substituting LFL T8).

In a second step these potential sales are subdivided as actual sales over:

- sales maintaining the same technology (e.g. LFL T8t replaced by LFL T8t),
- sales shifting to other non-LED technology (e.g. LFL T8t replaced by LFL T5),
- sales shifting to LED retrofit (e.g. LFL T8t replaced by LED retrofit tube),
- sales shifting to integrated LED luminaire (e.g. entire LFL luminaire replaced).

This subdivision is made based on sales shift scenarios. Most importantly, these scenarios indicate, for each given year, which part of the potential sales for each classical technology base case is shifting to LED technology.

Following stakeholder comments to further differentiate the LED base case, five LED lighting product groups are now distinguished in the model, i.e. LED products for substitution of LFL, HID, CFLni, DLS and NDLS.

The sales shifts assumed for the BAU scenario are presented and motivated in Annex E, and summarized in Table 5. These shifts represent the expected market development if no new ecodesign or labelling measures are introduced. They include the (partial) shift to LED products that will anyway take place, also in absence of new measures, but with different speeds for different classical technologies. They also include the future effects of the existing regulations, such as the phase-out of HPM-lamps in 2015 (regulation 245/2009), the phase-out of mains-voltage directional filament lamps in 2016 (regulation 1194/2012 stage 3), and the phase-out of many mains-voltage non-directional filament lamps in 2018 (regulation 244/2009 stage 6). These lamps have been grouped near the bottom of Table 5; they are phased-out already in the BAU scenario, and hence there is no difference between the BAU and the ECO scenarios as regards the shift towards LED products.

Table 5: Percentage of the potential sales for a non-LED base case technology that is assumed to shift to LED products (retrofit or luminaire) in the BAU scenario, ECO70 scenario, ECO80+120 scenario and ECO120 (2020) scenario, for years 2015, 2020, 2025 and 2030.

	2015	2020				2025				2030			
Base Case	All scenarios	BAU	ECO70	ECO80+120	ECO 120 (2020)	BAU	ECO70	ECO80+120	ECO 120 (2020)	BAU	ECO70	ECO80+120	ECO 120 (2020)
LFL T8 & T12	5	20	26	50	60	40	49	94	100	60	66	100	
LFL T5	0	10	10	21	55	40	40	94	100	60	60	100	
LFL X	0	10	33	44	55	40	70	94	100	60	80	100	
HPS	6	18	30	38	58	40	58	94	100	60	72	100	
MH	18	20	26	31	60	40	49	88	100	60	66	100	
CFLni	15	40	50			60	100			80	100		
CFLi (NDLS)	25	80	90			90	100			90	100		
HL LV R (DLS)	15	30	65			50	100			70	100		
HL LV C (NDLS)	10	50	75			70	100			90	100		
HL MV C (G9, NDLS)	10	50	50			70	85			90	100		
HL MV L (R7s, NDLS)	10	50	50			70	85			90	100		
HPM	42	99				100				100			
HL MV X (DLS)	30	100				100				100			
GLS R (DLS)	50	100				100				100			
HL MV E (NDLS)	15	90				100				100			
GLS X (NDLS)	30	100				100				100			

In the <u>ECO70 scenario</u> all remaining GLS and halogen lamps (HL) and all CFLs are assumed to be gradually phased out, starting around 2020 and reaching a 100% LED share in substitution of these lamps by 2025 (see central part of Table 5) [41]. For these lamps all ECO-scenarios use the same sales shift towards LED, but these shifts are different from those in the BAU scenario.

In addition a part of the LFLs and HID-lamps does not meet the ECO70 criterion. For the purposes of scenario analysis it has been assumed that this regards 15% of the LFL T8 models, 0% of the LFL T5 models, 30% of the HPS-models, and 15% of the MH-models (50% of quartz versions, none ceramic). This leads to an acceleration in the shift towards LED lighting products. The corresponding sales shift scenarios are presented and explained in Annex F. The phase-out of a part of the HPS models is mainly due to their low CRI (typically 25).

The effect of the <u>ECO80 scenario</u> (first stage of the ECO80+120 scenario, in 2020) on GLS, HL and CFL is the same as in the ECO70 scenario, but the share of the LFLs and HID-models that cannot meet the ECO80 criterion is higher. It is estimated that this regards 75% of the LFL T8 models, 25% of the LFL T5 models, 50% of the HPS-models, and 27% of the MH-models (90% of quartz versions, none ceramic). This leads to an

[41] Exception: in the scenario modelling, light sources with G9 or R7s cap have been assumed to be allowed on the market until 2025, with sales shift towards LED becoming 100% in 2030.

acceleration in the shift towards LED lighting products that is somewhat higher than in the ECO70 scenario. The corresponding sales shift scenarios are presented and explained in Annex F.

The ECO120 scenario, as a second stage of the ECO80+120 scenario in 2024, has been assumed to create a LED-only market (100% sales shift to LED) by 2030.

The ECO120 scenario, as a single stage scenario in 2020, has been assumed to create a LED-only market by 2025.

Difference in projections for LED efficacy and price.

As described in par. 1.3.5.1 and in Annex E.2.4, different projection curves for LED efficacy and corresponding LED price are available in MELISA, both for High-End LED products (substituting LFL, HID-lamps, CFLni in the non-residential sector; high annual operating hours) and for Low-End LED products (substituting GLS, HL, CFLi in all sectors and LFL and CFLni in the residential sector; low annual operating hours).

In the scenarios WITHOUT new improved labelling, the curves corresponding to 120 lm/W and 4 euros/klm in 2030 are used for Low-End products, while the curves reaching 208 lm/W and 7.35 euros/klm in 2030 are used for the High-End LED products (Table 6).

In the scenarios WITH new improved labelling, the curves corresponding to 167 lm/W and 5.79 euros/klm in 2030 are used for Low-End products, while the curves reaching 225 lm/W and 8 euros/klm in 2030 are used for the High-End LED products (Table 6).

This means that the effect of improved labelling on the average sales efficacy of Low-End LED products is assumed to be an increase of two energy label classes (par. 1.3.6.2). This is based on the experience with other ecodesign product groups that have effective labels. For High-End LED products that are sold predominantly in the non-residential sector, the assumed increase in efficacy due to improved labelling is more modest.

Table 6 Effect of improved labelling assumed in the scenario analyses. High-End LED products are those substituting LFL, HID, CFLni in the non-residential sector (high annual operating hours). Low-End LED products are those substituting GLS, HL, CFLi in any sector, and LFL and CFLni in the residential sector (low annual operating hours).

parameter	Scenarios WITHOUT improved labelling	Scenarios WITH improved labelling
Low-End LED average sales efficacy	Curve reaching 120 lm/W in 2030	Curve reaching 167 lm/W in 2030
Low-End LED average sales price	Curve reaching 4.00 euros/klm in 2030	Curve reaching 5.79 euros/klm in 2030
High-End LED average sales efficacy	Curve reaching 208 lm/W in 2030	Curve reaching 225 lm/W in 2030
High-End LED average sales price	Curve reaching 7.35 euros/klm in 2030	Curve reaching 8.00 euros/klm in 2030

Separation of effects

The phase-out of classical technology lamps and the corresponding shift of sales towards LED products (with different speeds for different ecodesign requirements) is assumed NOT to change the characteristics (efficacy and price) of those LEDs.

On the contrary, the introduction of new improved labelling is assumed to change ONLY the characteristics of the LED products, and NOT to lead to (additional) changes in sales shift towards LED.

2.2. Business-As-Usual (BAU) scenario

The results of MELISA for the BAU scenario are summarized in Table 7 and in the graphs for EU-28 total sales, stock, installed power and electric energy following the table.

The data show a decrease in the annual sales quantities of light sources in EU-28, passing from 1.7 billion units in 2015 to 0.87 billion in 2030 (-49%). The share of LED light sources in these sales increases from 22% in 2015 to 82% in 2030. The decrease in sales is mainly due to the higher average lifetime of the light sources (LED lifetimes are longer than lifetimes for classical technology lamps), so that consumers have a lower need to buy replacement lamps.

In the same period the quantity of light sources installed (stock) in EU-28 increases from 11.4 billion units in 2015 to 14.7 billion in 2030 (+29%), implying an (assumed) annual growth rate around 1.7%. In 2015, 7% of the stock are LED-based products; in 2030 this increases to 84%.

The consumption of electric energy for lighting in EU-28 continuously increased over the period 1990-2010 from 225 to 328 TWh/a [42].

In the period 2010-2015, the energy consumption remained more or less constant, even if the demand for lighting continued to increase (see values for capacity (lm) and operating hours). In large part this is due to ecodesign measures taken in 2009, that enforced e.g. the substitution of less efficient incandescent (GLS) lamps by more efficient halogen lamps and CFLs.

For future years, the BAU scenario indicates a continuing increase in lighting demand, but a significant decrease in energy consumption, down to 277 TWh/a in 2020, 243 TWh/a in 2025, and 214 TWh/a in 2030. This is due to the substitution of classic technology light sources by higher efficacy LED-based light sources, that is assumed to take place also in absence of new ecodesign measures.

The greenhouse gas (GHG) emissions are directly linked to the energy consumption and consequently show a similar trend. The decrease is from 128 MtCO_2eq. in 2015 to 73 MtCO_2eq. in 2030.

The share of the stock that is installed in the residential sector is predicted to slightly decrease from 56% in 2015 to 51% in 2030. This is due to the difference in assumed growth rates: the non-residential lighting sector is assumed to grow faster (2.5% per year) than the residential sector (0.9% per year).

As regards light source sales, the residential share decreases from 58% in 2015 to 24% in 2030. In addition to the difference in assumed growth rates between the residential and non-residential sector, this is mainly due to the difference in annual operating hours

[42] Excluding energy for control devices, for networking, in standby and no-load mode, for special purpose lamps

(e.g. 500 h/a residential vs. 2000 h/a non-residential). In the baseline approach, the lifetime of the LED lighting products has been assumed 20,000 h for both sectors, which translates in e.g. 40 years lifetime in the residential sector and 10 years lifetime in the non-residential sector. Consequently, replacement sales are much lower in the residential sector. The light source acquisitions per household are expected to pass from 6 lamps/household/year in 2015 to only 0.9 in 2030.

The residential share of electricity consumption for lighting is also expected to decrease, from 25% in 2015 to 15-17% in the period 2020-2030. This is mainly because household lamps (GLS, HL, CFL) are expected to be substituted by LED products in an earlier stage than non-residential LFL and HID-lamps (also due to the phase-out of many halogen lamps by existing regulations, in 2016 and 2018). In addition, the efficacy gain (and energy advantage) is larger for typical household lamps (e.g. halogen lamps or CFLs substituted by LED) than for typical non-residential lamps (e.g. LFLs and HID-lamps substituted by LED).

Table 7: Results of MELISA for the BAU scenario

EU-28 Totals (all sectors)		1990	2010	2015	2020	2025	2030
Sales	mln units	2112	2353	1717	1828	1057	873
Stock	mln units	5579	10078	11427	12534	13577	14731
Installed Capacity	Tlm	6	10	12	14	15	17
Installed Power (excl. CG)	GW	263	326	292	202	158	140
Operating Hours (full-power equivalent)	Th/a	5	9	10	11	12	13
Average Efficacy (excl. CG)[43]	lm/W	43	56	65	87	113	144
Electric Energy (incl. CG)[44]	TWh/a	225	328	324	277	243	214
Primary Energy	PJ/a	2026	2956	2918	2490	2187	1929
GHG Emissions	$MtCO_2eq$	113	135	128	105	87	73
LED shares		1990	2010	2015	2020	2025	2030
Sales	%	0%	0%	22%	63%	67%	82%
Stock	%	0%	0%	7%	42%	70%	84%
Electric Energy	%	0%	0%	6%	18%	36%	58%
Residential shares		1990	2010	2015	2020	2025	2030
Sales	%	68%	58%	58%	51%	32%	24%
Stock	%	62%	56%	56%	55%	53%	51%
Electric Energy	%	37%	29%	25%	17%	15%	16%
Quantities per Household		1990	2010	2015	2020	2025	2030
Sales	units	8.4	7.4	6.0	4.3	1.5	0.9
Stock	units	20	27	30	31	32	33
Electric Energy	kWh/a	483	450	381	219	160	146

[43] The average efficacy (of the stock) is computed as the lighting load in lm.h divided by the light source energy in Wh (excluding energy consumed by external control gear).

[44] The reported energy does NOT match the product of Average Unit Power (=Installed Power/Stock) * Average Unit Operating hours (=Total Hours/Stock) * Stock. This is partly due to the fact that Installed Power is without external control gear power while Energy includes external control gear energy. However, more importantly, calculating with the unit averages gives the wrong result if low operating hours are coupled to low powers and high operating hours to high powers, and this is generally the case for lighting products. Consider e.g. household lamps with low power and low hours and HID-street lighting with high power and high hours.

This mechanism can be simply verified by assuming e.g. a combination of two 50 W lamps burning 500 h/a and one 200 W lamp burning 2000 h/a. The energy would be (2*50*500+1*200*2000)/1000 = 450 kWh. However, average power would be (50+50+200)/3=100 W, average hours would be (500+500+2000)/3=1000 h/a, and using these averages to compute the total energy would give 100*1000*3/1000 = 300 kWh, a completely different and wrong result. On a larger scale, something similar occurs for the entire lighting stock.

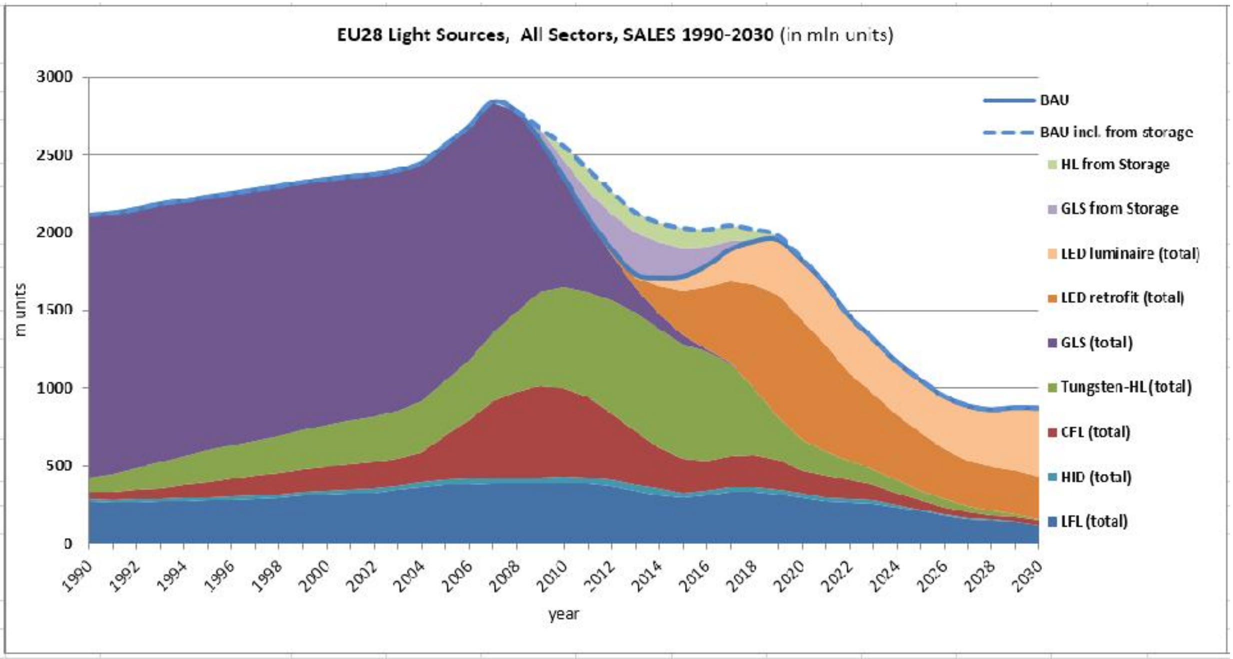


Figure 19: Sales of light sources, EU-28 total, sum of all sectors, in mln units for the BAU scenario. Note that GLS and HL 'from storage' are not actually sales in the shown year, but lamps being installed from household storages, see par. E.7.7

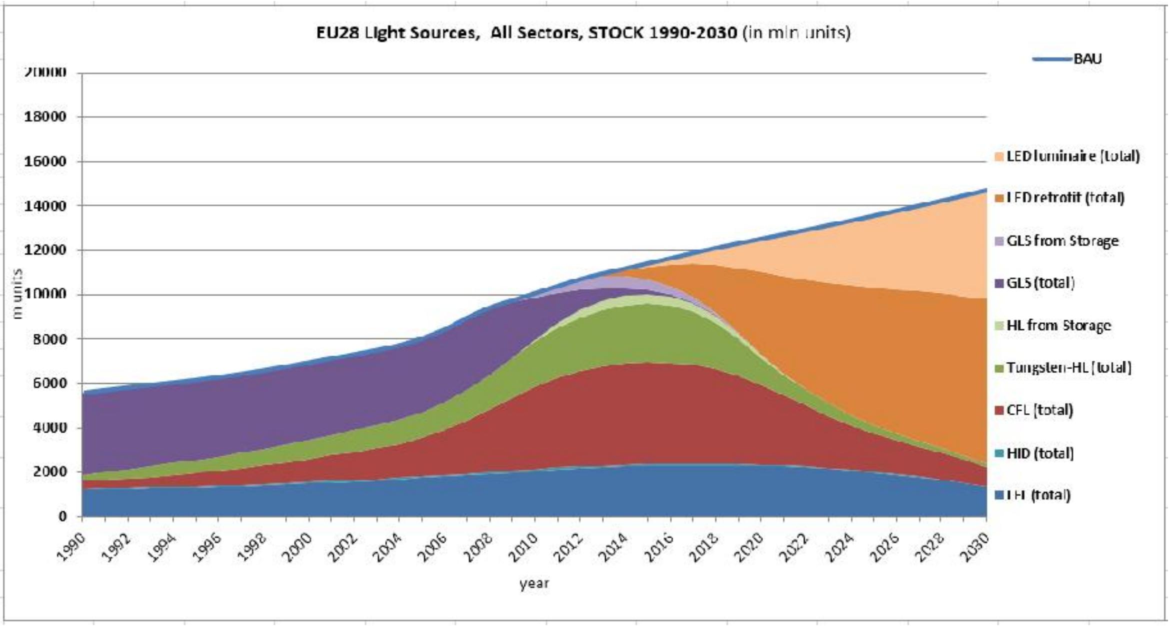


Figure 20: Installed stock of light sources, EU-28 total, sum of all sectors, in mln units for the BAU scenario.

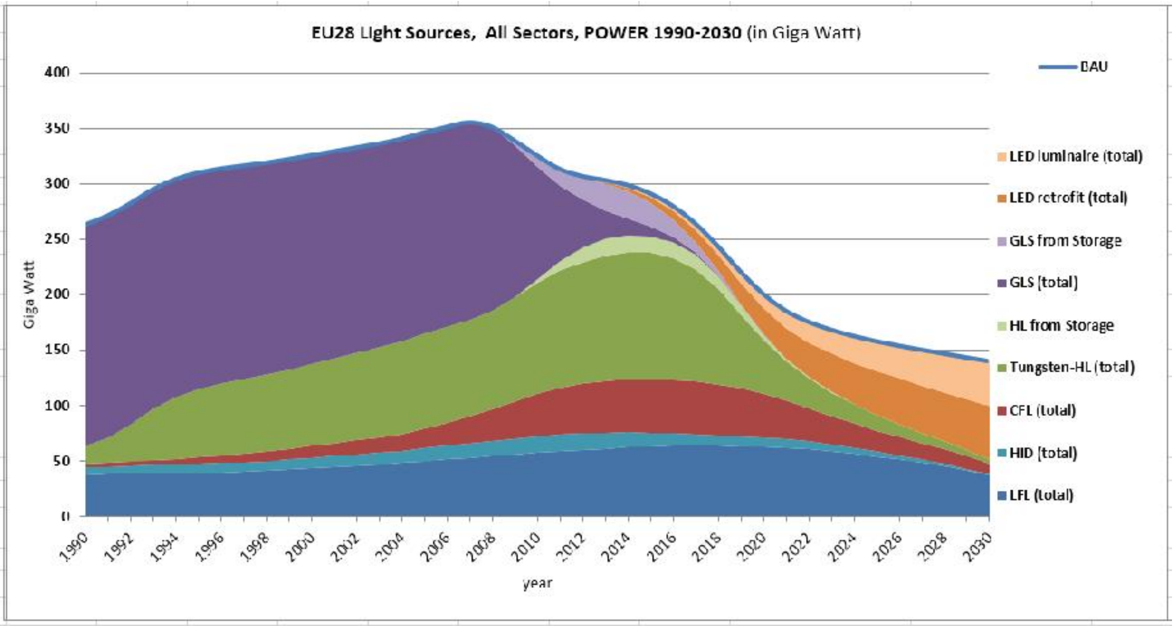


Figure 21: Installed power for lighting (exclusive external control gear), EU-28 total, sum of all sectors, in Giga-Watt (GW) for the BAU scenario.

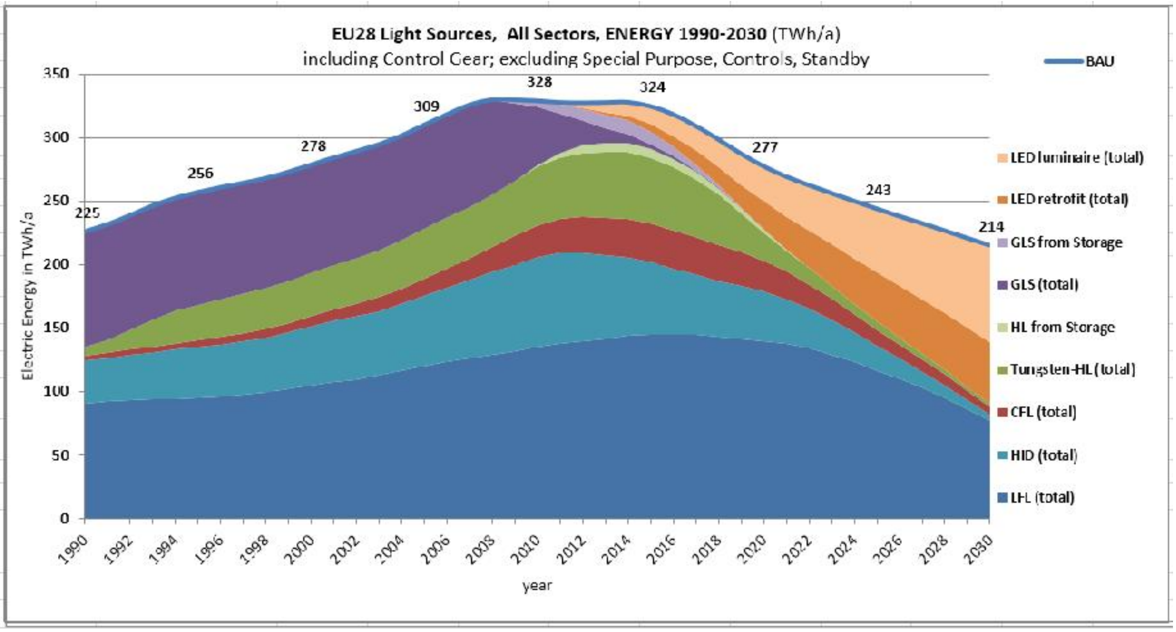


Figure 22: Annual electric energy consumption for lighting (inclusive external control gear), EU-28 total, sum of all sectors, in Tera-Watt-hours per year (TWh/a) for the BAU scenario.

2.3. ECO scenarios

The trends for the ECO-scenarios are similar to those described for the BAU-scenario in the previous paragraph, i.e. increasing stock, installed capacity and total annual operating hours, but decreasing sales, installed power and energy consumption.

The main difference is that the shift of sales from classical technology to LED lighting products occurs faster in the ECO-scenarios: The higher the minimum efficacy required by the Ecodesign measure, the more classical technology light sources are being phased out, and hence the higher the share of LED products in the sales.

As shown in Table 8, the accelerated adoption of (long lifetime) LEDs in the ECO scenarios leads to a further decrease in sales quantities after 2020. In 2030 the total sales volume of the ECO-scenarios is 12-15% lower than that of the BAU-scenario. The share of LED products in the sales gradually increases with time and with the degree of ambition of the Ecodesign measure, reaching 100% in 2030 for the ECO80+120 scenario and in 2025 for the ECO120 scenarios (LED-only market).

The projected volume of the stock does not change between scenarios, but the composition changes: In 2030 there is an 84% LED share for BAU, 90% for ECO70, 96% for ECO80+120, and 97% for the ECO120 scenario.

As a result, notwithstanding an increase in installed lighting capacity, also the installed power drops from 140 GW for the BAU scenario in 2030 to 99-117 GW for the ECO-scenarios (17-30% lower).

The accelerated substitution by LEDs and – for the scenarios with label improvement – the higher efficacy, can also be noted in the average (stock) efficacy of the light sources, that is higher in the ECO scenarios than in the BAU scenario, e.g. in 2030: 144 lm/W for BAU, 166 lm/W for ECO70+LBL, 183 lm/W for ECO80+120, 202 lm/W for ECO80+120+LBL, and 207 lm/W for ECO120+LBL [45].

For further details and for the subdivision of data over the residential and non-residential sector, see Annex G.

Table 8: Overview of Sales, Stock, Installed Capacity and Power, and average light source Efficacy for all scenarios. The share of LED lighting products in the Sales and in the Stock is also specified.

EU-28 Totals for ECO scenarios		2015	2020					2025					2030				
		BAU	BAU	ECO70+LBL	ECO80+120	ECO80+120+LBL	ECO120+ LBL (2020)	BAU	ECO70+LBL	ECO80+120	ECO80+120+LBL	ECO120+ LBL (2020)	BAU	ECO70+LBL	ECO80+120	ECO80+120+LBL	ECO120+ LBL (2020)
Sales	mln units	1717	1828	1828	1827	1827	1826	1057	961	929	929	914	873	769	743	743	751
LED Share in Sales	%	22%	63%	71%	75%	75%	79%	67%	81%	98%	98%	100%	82%	88%	100%	100%	100%
Stock	mln units	11427	12534					13577					14731				
LED Share in Stock	%	7%	42%	44%	45%	45%	46%	70%	78%	83%	83%	86%	84%	90%	96%	96%	97%
Installed Capacity	Tlm	11.9	13.6	13.6	13.6	13.6	13.7	15.3	15.4	15.6	15.6	15.6	17.1	17.2	17.4	17.4	17.3
Installed Power (excl. CG)	GW	292	202	193	195	191	189	158	129	129	116	110	140	115	117	101	99
Efficacy= Load/ Energy excl. CG	lm/W	65	87	90	90	92	94	113	129	143	154	168	144	166	183	202	207

[45] The average efficacy (of the stock) is computed as the EU-28 total lighting load in lm.h divided by the EU-28 total light source energy in Wh (excluding energy consumed by external control gear). This provides an 'energy-weighted' average for the efficacy. Dividing the installed Capacity by the installed Power leads to lower average efficacy values because these are not 'energy-weighted', see details in Annex G.

The accelerated adoption of LED lighting products in the ECO-scenarios also leads to lower electric energy consumption and lower greenhouse gas emissions, as summarized in Table 9, Figure 23 and Figure 24. The table provides the absolute values, the savings with respect to the BAU-scenario of the same year, and the cumulative savings with respect to the year 2015.

Table 9: Electric Energy and GHG Emission results for the ECO-scenarios. Absolute values, annual savings with respect to the BAU scenario, and cumulative savings with respect to year 2015. EU-28 totals for All Sectors.

ALL SECTORS, ENERGY			2015	2020	2025	2030
BAU	**Energy**	**TWh/a**	324	277	243	214
ECO70+LBL	Energy	TWh/a	324	267	212	186
ECO80+120	Energy	TWh/a	324	267	195	172
ECO80+120+LBL	Energy	TWh/a	324	262	180	154
ECO120+LBL	Energy	TWh/a	324	256	165	149
ECO70+LBL	Savings, BAU-ECO	TWh/a	0	10	31	28
ECO80+120	Savings, BAU-ECO	TWh/a	0	9	48	43
ECO80+120+LBL	Savings, BAU-ECO	TWh/a	0	15	63	61
ECO120+LBL	Savings, BAU-ECO	TWh/a	0	21	78	65
ECO70+LBL	Cumulative savings	TWh	0	19	143	294
ECO80+120	Cumulative savings	TWh	0	14	184	421
ECO80+120+LBL	Cumulative savings	TWh	0	27	256	578
ECO120+LBL	Cumulative savings	TWh	0	36	338	706

ALL SECTORS, EMISSIONS			2015	2020	2025	2030
BAU	**GHG emissions**	**$MtCO_2eq/a$**	128	105	87	73
ECO70+LBL	GHG emissions	$MtCO_2eq/a$	128	101	76	63
ECO80+120	GHG emissions	$MtCO_2eq/a$	128	102	70	58
ECO80+120+LBL	GHG emissions	$MtCO_2eq/a$	128	99	65	52
ECO120+LBL	GHG emissions	$MtCO_2eq/a$	128	97	59	51
ECO70+LBL	Savings, BAU-ECO	$MtCO_2eq/a$	0	4	11	10
ECO80+120	Savings, BAU-ECO	$MtCO_2eq/a$	0	3	17	14
ECO80+120+LBL	Savings, BAU-ECO	$MtCO_2eq/a$	0	6	23	21
ECO120+LBL	Savings, BAU-ECO	$MtCO_2eq/a$	0	8	28	22
ECO70+LBL	Cumulative savings	$MtCO_2eq$	0	7	53	105
ECO80+120	Cumulative savings	$MtCO_2eq$	0	5	68	150
ECO80+120+LBL	Cumulative savings	$MtCO_2eq$	0	10	94	206
ECO120+LBL	Cumulative savings	$MtCO_2eq$	0	14	124	253

In the ECO scenarios savings start appearing from 2019, assuming that industry is anticipating the new measures.

In 2030 the ECO70+LBL scenario is saving 28 TWh/yr (13%) with respect to the BAU.

The ECO80+120 scenario (without improved labelling) is saving 42 TWh/yr (20%), after a peak in 2025 where the difference with the BAU was even 48 TWh/yr. Adding the effect of new improved labelling, the savings for the same scenario further increase to 61 TWh/yr (29%) in 2030 (with peak of 63 TWh/yr in 2025). Consequently the effect of new improved labelling is an additional energy saving of 15-18 TWh/yr.

The most ambitious ECO120+LBL scenario leads to an energy saving of 65 TWh/yr (30%) in 2030 (with peak of 78 TWh/yr savings with respect to BAU in 2025).

These savings come on top of the 110 TWh/yr savings between 2015 and 2030 that come from the existing measures and market forces.

These figures make light sources the number one electricity saver in comparison to other ecodesign and energy labelling measures.

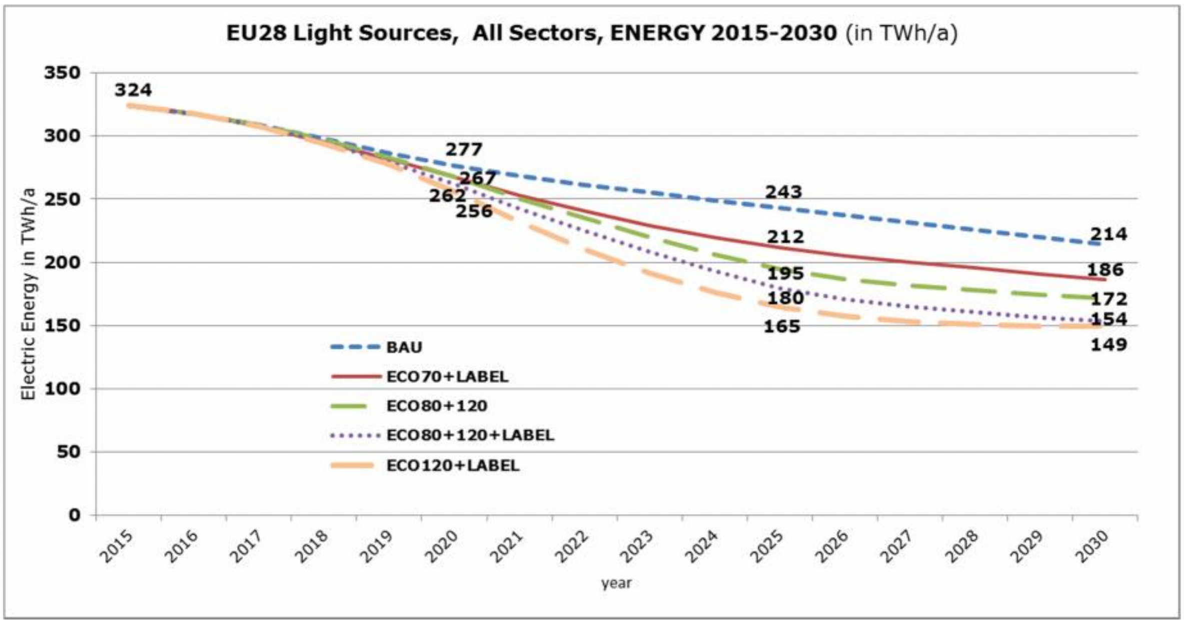


Figure 23: Electric Energy in TWh/a for the BAU- and the ECO-scenarios.

The GHG emissions (Figure 24) are directly linked to the energy consumption and consequently follow the same trends as discussed above. The link is provided by the Global Warming Potential (GWP) in kgCO_2eq/kWh (par. E.2.7).

For the ECO70+LBL scenario the annual GHG emission reduction is 10-11 MtCO_2eq in 2025 and 2030 (-14%).

For the ECO80+120 (without label) scenario the annual GHG emission reduction is 14-17 MtCO_2eq in 2025 and 2030 (-20%). This increases to 21-23 MtCO_2eq when the effect of new labelling is included.

For the ECO120+LBL scenario the reduction is 22-28 MtCO_2eq.

These savings come on top of the 55 MtCO_2eq saving due to existing measures and market forces over the period 2015-2030.

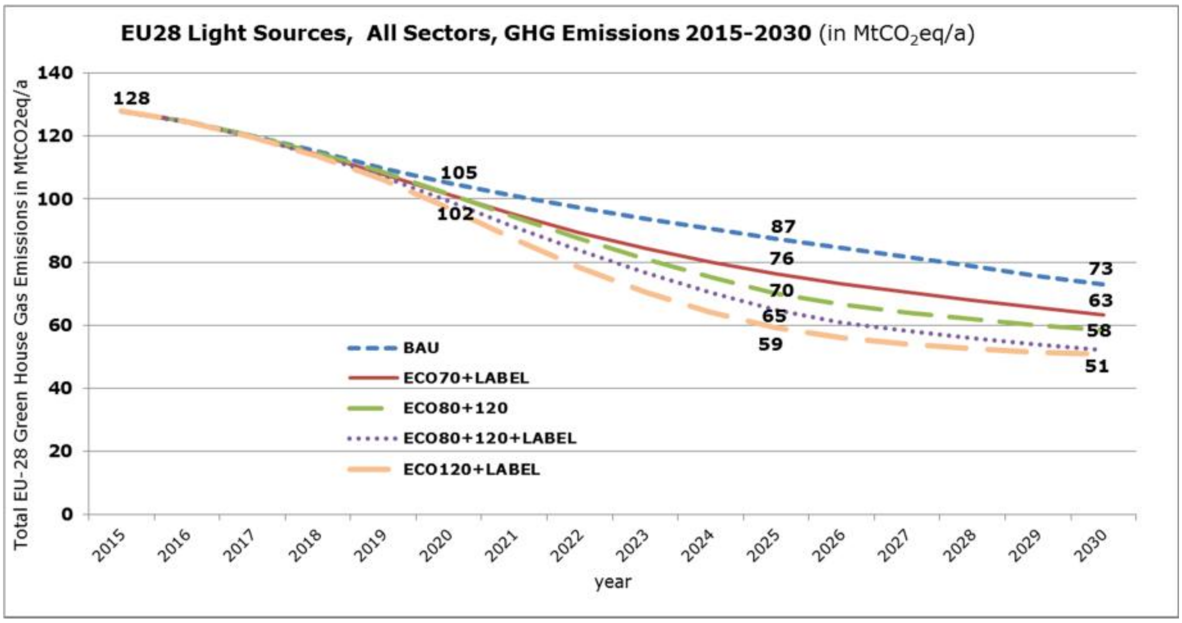


Figure 24: Greenhouse gas (GHG) emissions in $MtCO_2$ equivalent, for BAU, ECO70+LBL and ECO80+120 scenarios

2.4. Extension of the time horizon to 2050

The MEErP requests a qualitative discussion of the trends up to year 2050. To this end the projections in the MELISA model were extended to 2050, based on the assumption that LED-efficacies stay at the 2030-level. For the scenarios without labelling effect (BAU and ECO80+120) this means an efficacy 120 lm/W for Low-End and 208 lm/W for High-End LED products. For the scenarios with labelling effect, the market pull of the labelling gives an efficacy of 167 lm/W and 225 lm/W for respectively Low-End and High-End LED products. All other input data for the 2030-2050 period remain the same as in the years before 2030, including assumed growth rates. Note that by 2050, all scenarios (BAU and ECO alike) are assumed to lead to a LED-only market.

The result in terms of annual and cumulative electricity consumption up to 2050 is given in the figures below. The GHG-emissions will follow a similar trend.

Over this long time period the graphs clearly show a fundamental difference between the scenarios with and without introduction of new improved labelling.

The ECO80+120 scenario (without new label), accelerates the substitution-process, but in the long term –all other things being equal—the BAU scenario will eventually catch up and arrive at the same savings before 2050. The reason for this is that both assume a LED-only market in 2050 and that both use the same (lower) LED efficacy curves.

For the ECO-scenarios that include the effect of improved labelling a similar effect can be noted. The more ambitious the ecodesign measure, the higher the savings in earlier years, but eventually all three scenarios have the same energy consumption (and GHG emission) towards 2050. The reason for this is that all scenarios assume a LED-only market in 2050 and that they all use the same (higher) LED efficacy curves.

However, in these label-scenarios, the increased competition on efficacy between manufacturers provokes a higher level of efficacy that will also last until 2050, thus explaining the difference in 2050 between the scenarios with and without improved label. In other words, for policy makers the choice between the scenarios will also depend on the time horizon for the policy objectives.

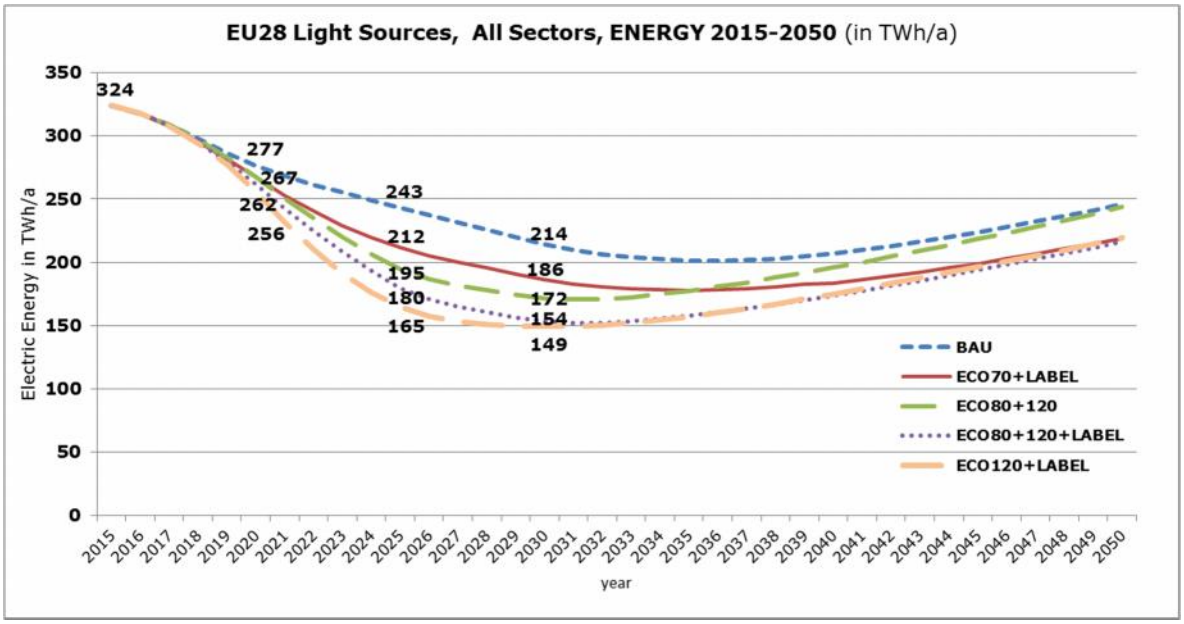


Figure 25: Electric Energy in TWh/a for the BAU- and ECO-scenarios, extension to period 2030-2050.

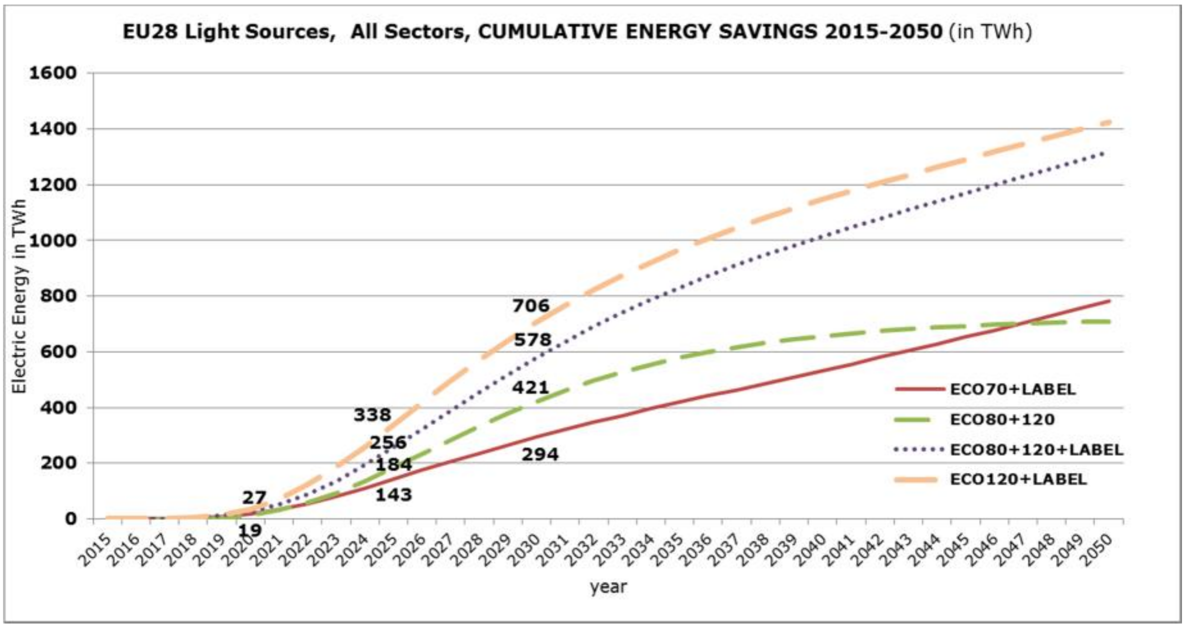


Figure 26: Cumulative Electric Energy Savings with respect to BAU, in TWh for all ECO-scenarios, extension to period 2030-2050.

3. Impacts on industry and consumers

3.1. Business-As-Usual (BAU) scenario

The economic results of MELISA for the BAU scenario are summarized in Table 10 and in the graph for total consumer expense following the table. All values in this chapter are inflation corrected to Euro 2010.

The data show a peak in purchase costs (15.1 billion euros) in the period 2015-2020. This is a consumer investment in LED-based lighting products that leads to energy cost savings in the future. In later years the purchase costs decrease (11.5 bn euros in 2025; 11.0 bn euros in 2030) because sales quantities decrease (first line in the table) and because the price of LED-based products goes down (see Figure 11). Note that the residential share of the purchase costs is continuously decreasing, from 46% in 2015 to only 8% in 2030.

The energy costs (total EU-28 expenses for electricity for lighting) are 48.1 billion euros in 2015; they remain more or less stable in 2020 and then increase to 50.4 billion in 2025 and 54.3 billion in 2030 (+13% compared to 2015).
Although energy consumption goes down in the same period (from 324 TWh/a in 2015 to 214 TWh/a (-34%) in 2030, see Table 7), a 4% escalation price has been applied to the electricity rates, that consequently increase from 0.207 euros/kWh in 2015 to 0.372 euros/kWh (+80%) in 2030 in the residential sector and from 0.129 euros/kWh in 2015 to 0.232 euros/kWh (+80%) in 2030 in the residential sector (see Annex E.2.1). In addition the residential share of energy (with higher electricity rate) decreases after 2020 so that on average the applied rate gets smaller. The combined effect gives the 13% increase in energy cost.

The total consumer expense (sum of purchase, installation, energy and maintenance costs; see also Figure 27) shows an oscillating trend. The 71.4 billion euros of 2015 first increase to 72.3 billion in 2020, mainly due to the peak in purchase cost, then go down to 71.7 billion in 2025, and then up again to 75.9 billion in 2030 due to the increasing electricity rates. In 2030 the residential share of these expenses is only half (17%) of what it is now (34%).

As regards LED lighting products, in 2030 they are responsible for 89% of the purchase costs and 59% of the energy costs.

Table 10 also specifies the subdivision of the purchase cost over the revenue sectors (industry, wholesale, retail, and VAT), and the corresponding quantity of jobs. For the assumed revenue shares and the jobs per revenue, see Annex E.2.7. Obviously, revenues and jobs show the same trend as discussed for the purchase cost above. After a peak in 2020, there is a decrease of 6-7% in 2030 with respect to 2015.
Please note however that a large part of the industry revenue and of the associated jobs is expected to be outside the EU-28. The Omnibus study [46] provided more details on this.

[46] "Omnibus Review Study on Cold Appliances, Washing Machines, Dishwashers, Washer-Driers, Lighting, Set-top Boxes and Pumps Final Report", VHK (NL) / VITO (B) / Viegand Maagøe A/S (DK) / Wuppertal Institut für Klima, Umwelt, Energie GmbH (D), Brussels/Delft 01.04.2014, prepared for the European Commission DG-ENER-C3.

Table 10: Economic results of MELISA for the BAU scenario

EU-28 Totals (all sectors)		1990	2010	2015	2020	2025	2030
Sales	mln units	2112	2353	1717	1828	1057	873
Purchase Cost	mln euros	4623	10393	15127	15093	11506	10965
o/w Industry Revenue	mln euros	2886	5957	9948	10928	8838	8600
o/w Wholesale Revenue	mln euros	752	1921	2106	1733	1233	1123
o/w Retail Revenue	mln euros	709	1773	1909	1577	1184	1097
o/w Taxes (VAT)	mln euros	277	742	1164	855	252	144
Installation Cost	mln euros	2524	3975	3127	3673	3429	3406
Energy Cost	mln euros	31699	40868	48122	47875	50418	54346
Maintenance Cost	mln euros	1852	4528	5020	5656	6399	7240
Total Consumer Expense	mln euros	40699	59764	71421	72256	71682	75862
Total Jobs	thousands	116	241	321	345	300	301
LED shares		1990	2010	2015	2020	2025	2030
Sales	%	0%	0%	22%	63%	67%	82%
Purchase Cost	%	0%	2%	52%	70%	78%	89%
Energy Cost	%	0%	0%	6%	18%	37%	59%
Total Consumer Expense	%	0%	0%	16%	31%	47%	66%
Residential shares		1990	2010	2015	2020	2025	2030
Sales	%	68%	58%	58%	51%	32%	24%
Purchase Cost	%	36%	43%	46%	34%	13%	8%
Energy Cost	%	47%	39%	35%	25%	22%	23%
Total Consumer Expense	%	40%	34%	34%	24%	17%	17%
Quantities per Household		1990	2010	2015	2020	2025	2030
Sales	units	8.4	7.4	6.0	4.3	1.5	0.9
Purchase Cost	euros	10	21	32	23	7	4
Energy Cost	euros	86	77	79	55	49	54
Total Consumer Expense	euros	96	98	111	78	56	58

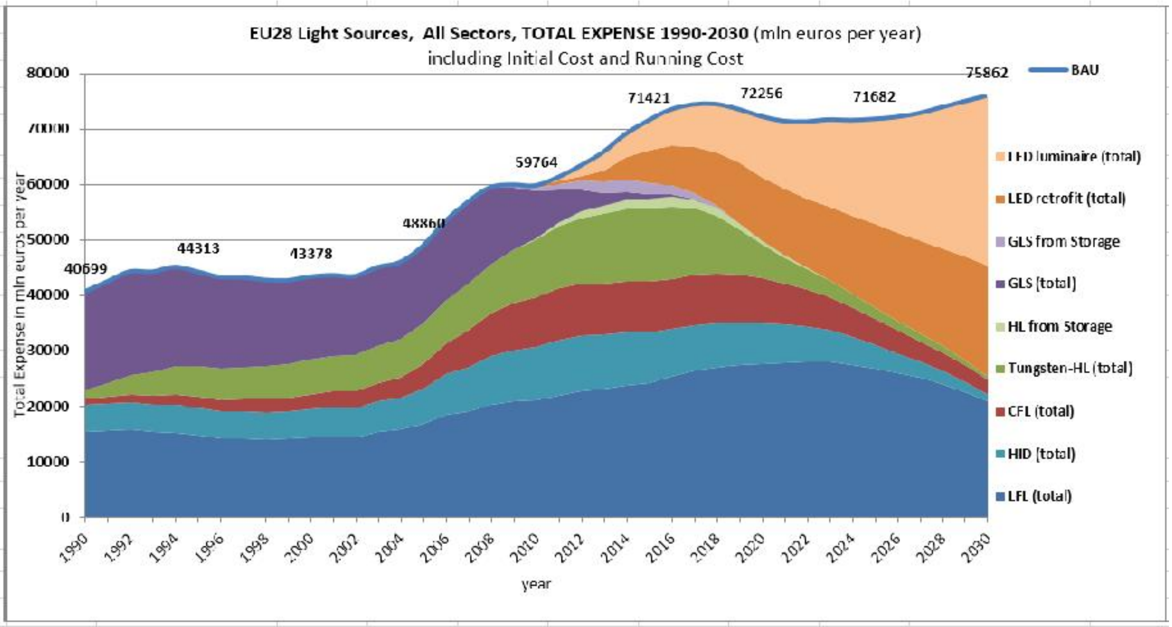


Figure 27: Total Consumer Expense for lighting, sum of Purchase, Installation, and Running Costs, EU-28 total, all sectors, in mln euros per year, fixed 2010 euros, incl. VAT, for the BAU scenario.

3.2. ECO scenarios

The economic results of MELISA for the ECO-scenarios are summarized in Table 11 and in the graphs for acquisition costs, running costs and total consumer expense following the table. BAU values are also indicated for comparison.

Table 11: Overview of economic impacts for the ECO-scenarios, in comparison with the BAU scenario.

EU-28 Totals for ECO scenarios		2015	2020					2025					2030				
		BAU	BAU	ECO70+LBL	ECO80+120	ECO80+120+ LBL	ECO120+ LBL (2020)	BAU	ECO70+LBL	ECO80+120	ECO80+120+ LBL	ECO120+ LBL (2020)	BAU	ECO70+LBL	ECO80+120	ECO80+120+ LBL	ECO120+ LBL (2020)
Sales	mln units	1717	1828	1828	1827	1827	1826	1057	961	929	929	914	873	769	743	743	751
Total Expense	bn euros	71	72	75	74	77	78	72	67	64	62	59	76	69	66	62	51
o/w Purchase Cost	bn euros	15	15	20	18	22	24	12	13	13	15	15	11	12	11	13	13
o/w Energy Cost	bn euros	48	48	46	46	45	44	50	44	41	37	35	54	47	44	39	38
o/w Installation	bn euros	3.1	3.7	3.7	3.7	3.7	3.6	3.4	3.2	3.0	3.0	2.9	3.4	3.1	3.0	3.0	3.0
o/w Maintenance	bn euros	5.0	5.7	5.7	5.7	5.7	5.7	6.4	6.4	6.4	6.4	6.4	7.2	7.2	7.2	7.2	7.2
Split of Purchase cost																	
Industry Revenue	bn euros	9.9	11	15	13	16	18	8.8	10	10	12	12	8.6	9.5	8.8	9.9	9.9
Wholesale Revenue	bn euros	2.1	1.7	2.1	1.9	2.3	2.5	1.2	1.3	1.3	1.5	1.5	1.1	1.2	1.1	1.3	1.3
Retail Revenue	bn euros	1.9	1.6	1.9	1.8	2.1	2.3	1.2	1.3	1.3	1.5	1.5	1.1	1.2	1.1	1.2	1.2
Taxes (VAT)	bn euros	1.2	0.9	1.2	0.9	1.2	1.2	0.3	0.3	0.2	0.3	0.3	0.1	0.2	0.1	0.2	0.2
Jobs related to revenues																	
Total Jobs	thousands	321	345	423	400	464	499	300	332	327	362	359	301	319	301	325	326
o/w Industry	thousands	199	219	290	269	325	357	177	208	206	237	235	172	190	176	198	198
o/w Wholesale	thousands	8	7	8	8	9	10	5	5	5	6	6	4	5	4	5	5
o/w Retail	thousands	32	26	32	30	36	39	20	21	21	24	24	18	20	18	20	20
o/w Install	thousands	31	37	37	37	37	36	34	32	30	30	29	34	31	30	30	30
o/w Maintenance	thousands	50	57	57	57	57	57	64	64	64	64	64	72	72	72	72	72

As regards purchase costs, the trend for the ECO-scenarios is similar to that described for the BAU-scenario, with a peak expenditure around 2020, but for the ECO scenarios this peak is 20-60% higher, 20% higher (+3 billion euros) for the 'price war' scenario ECO80+120 (without label improvements) and 30-60% higher (+5 to +9 billion euros) for the labelling 'quality' scenarios [47]. The more ambitious the scenario, i.e. the more classical technology light sources are being phased-out and substituted by LED-based products, the higher the peak in purchase costs. This is clear in particular in Figure 28 [48].

Comparing the ECO80+120 scenarios with and without label improvement, the additional effect of labelling measures is estimated in 4 billion euros additional purchase

[47] It is recalled that improved labelling is assumed to lead not only to a higher average efficacy of LED light sources, but also to a higher corresponding purchase price.

[48] The graph is for acquisition costs, i.e. purchase costs + installation costs

costs in 2020 (2 billion extra in 2025 and 2030). These are compensated in later years by lower energy costs.

Higher purchase costs mean higher business revenues and thus extra jobs. In the scenarios with improved labelling, there is a short term 23-45% rise in 2020 which then evens out to 6-8% extra revenue and jobs in 2030 [49]. For the ECO80+120 scenario without labelling improvement the growth in revenues and jobs will be around 16% in 2020 while there is hardly any growth with respect to the BAU scenario in 2030.

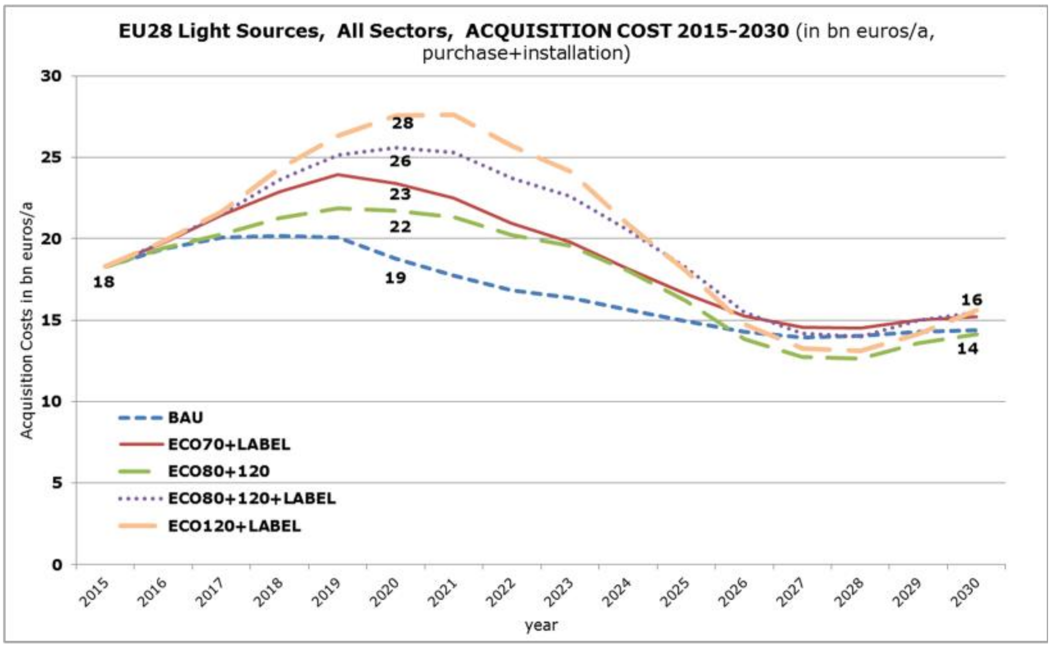


Figure 28: Acquisition costs (purchase + installation) in bn euros/a for all scenarios

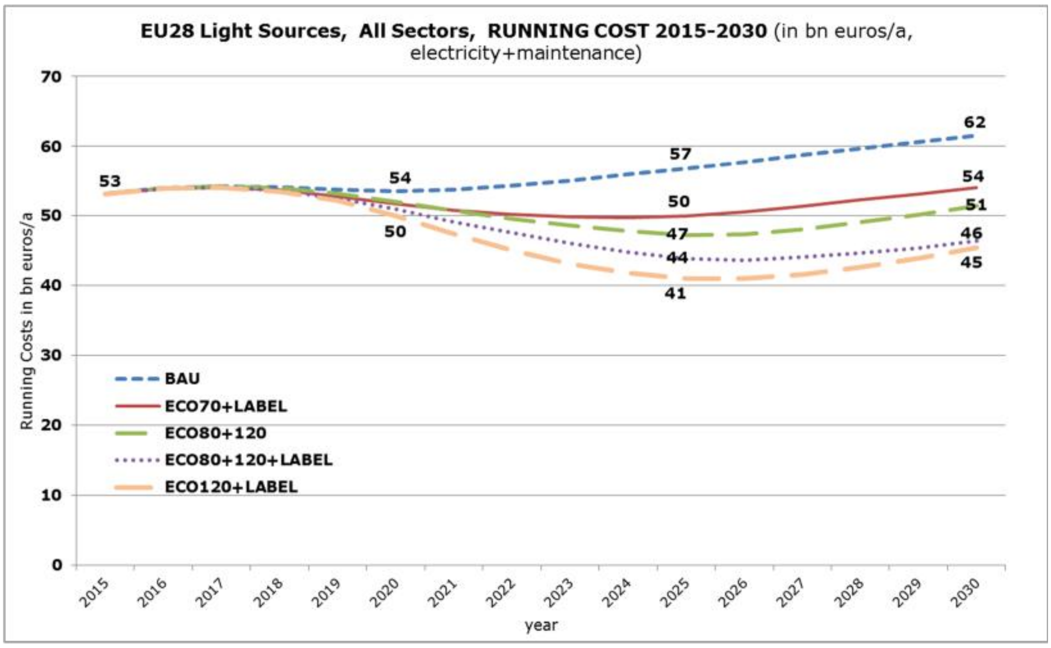


Figure 29: Running costs (electricity + maintenance) in bn euros/a for all scenarios. Note that the figures use different scales !

[49] Note that especially industry jobs will be mostly outside the EU.

Energy costs in the ECO-scenarios are lower than in the BAU scenario (Figure 29 [50]), due to the higher share of LED products in the lighting stock, and, in the case of improved labelling, due to the higher average efficacy of these LEDs.

In 2020 the money saving is modest, i.e. 4-8% (2-4 billion euros), but in later years it becomes substantial. In 2030 the energy cost savings are 7 bn euros for ECO70+LBL (-13%), 10 bn euros for ECO80+120 without label improvement (-19%), 15 bn euros for ECO80+120+LBL (-28%) and 16 bn euros for ECO80+120+LBL (-30%).

Comparing the ECO80+120 scenarios with and without label improvement, the additional effect of labelling measures is estimated in 4-5 billion euros additional energy cost savings per year in 2025-2030.

In 2020, the total consumer expenditure ('consumer' including non-residential sector purchasers) is higher for the ECO scenarios (Figure 30), due to the peak in purchase costs in that year. In later years the ECO-scenarios offer savings due to lower energy costs. In 2030 the saving on total expenditure is 7 bn euros for ECO70+LBL (-9%), 10 bn euros for ECO80+120 (-13%), 14 bn euros for ECO80+120+LBL (-18%) and 15 bn euros for ECO120+LBL (-20%). See also additional information in the next paragraph.

Comparing the ECO80+120 scenarios with and without label improvement, the additional effect of labelling measures on the total expenses is estimated in 4 billion euros additional savings per year in 2030.

For the subdivision of costs and savings over the residential and non-residential sectors, see Annex G.

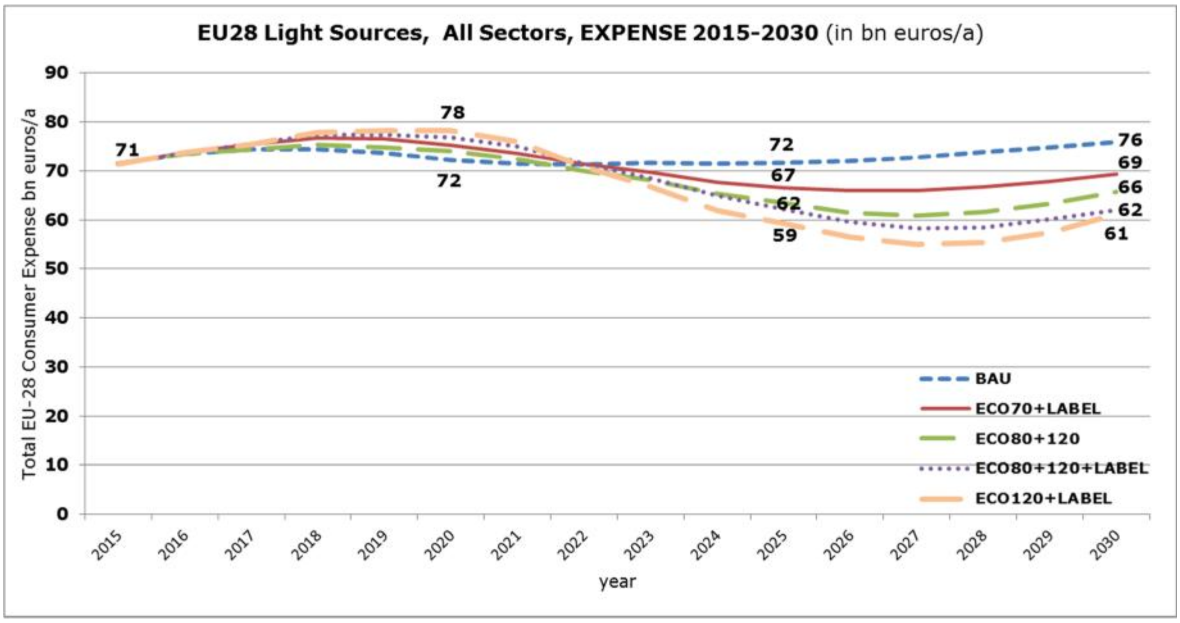


Figure 30: Total Consumer Expense in bn euros/a for all scenarios

[50] The graph is for running costs, i.e. electric energy costs + maintenance costs

3.3. Extension of the time horizon to 2050

For the assumptions made in the model for the period 2030-2050 and for a qualitative description of the trends in this period, see par. 2.4.

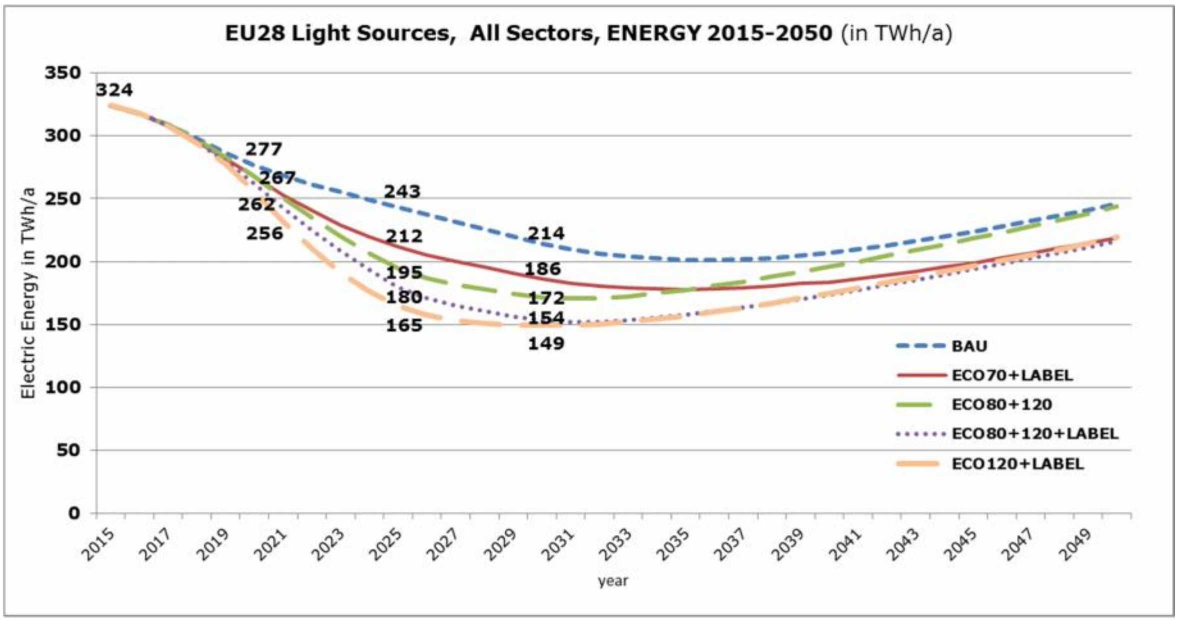
The conclusions are similar to those in par. 2.4, i.e. on the long term the total expenses for the ECO80+120 scenario (without labelling improvement) become identical to those for the BAU scenario, while all ECO-scenarios with labelling improvement continue to provide annual savings also in years after 2030.

Comparing e.g. the ECO80+120 scenarios with and without labelling, before year 2030 the option without improved labelling provides the highest cumulative savings on total expense. Around 2030 there is a 'break-even' point where cumulative savings are identical for both options. In later years the option with improved labelling continues to provide additional annual savings and thus shows increasing cumulative savings, while in the option without improved labelling the annual savings with respect to the BAU scenario go to zero and the cumulative savings reach a limit (around 160 billion euros).

Due to the initial investment in LED lighting products, around 2020 all ECO-scenarios show negative savings, i.e. an additional expense with respect to the BAU scenario. This additional expense varies from 5 billion euros in the ECO80+120 scenario in 2021 to 20 billion euros for the ECO120+LBL scenario in 2021-2022.
In the ECO80+120 scenario the cumulative savings become positive around year 2023; for the scenarios with labelling improvement this occurs around year 2025-2026.

Table 12: Overview of Economic impacts for the ECO-scenarios, in comparison with the BAU scenario.

ALL SECTORS, EXPENSE			2015	2020	2025	2030	2035	2040	2045	2050
BAU	**Consumer Expense**	**bn euros /a**	71	72	72	76	86	104	131	169
ECO70+LBL	Consumer Expense	bn euros /a	71	75	67	69	79	96	121	156
ECO80+120	Consumer Expense	bn euros /a	71	74	64	66	78	100	128	168
ECO80+120+LBL	Consumer Expense	bn euros /a	71	77	62	62	73	93	117	154
ECO120+LBL	Consumer Expense	bn euros /a	71	78	59	61	72	94	118	157
ECO70+LBL	Savings, BAU-ECO	bn euros /a	0.0	-3.1	5.1	6.6	6.8	7.6	10.3	13.0
ECO80+120	Savings, BAU-ECO	bn euros /a	0.0	-1.7	8.2	10.2	7.6	3.5	3.4	0.1
ECO80+120+LBL	Savings, BAU-ECO	bn euros /a	0.0	-4.6	9.5	13.8	13.0	11.2	14.1	14.6
ECO120+LBL	Savings, BAU-ECO	bn euros /a	0.0	-6.0	12.5	14.7	13.5	9.7	13.6	11.6
ECO70+LBL	Cumulative savings	bn euros	0	-10	-1	33	65	101	147	206
ECO80+120	Cumulative savings	bn euros	0	-4	14	71	112	139	155	162
ECO80+120+LBL	Cumulative savings	bn euros	0	-13	3	74	138	199	261	334
ECO120+LBL	Cumulative savings	bn euros	0	-15	7	91	155	216	272	336



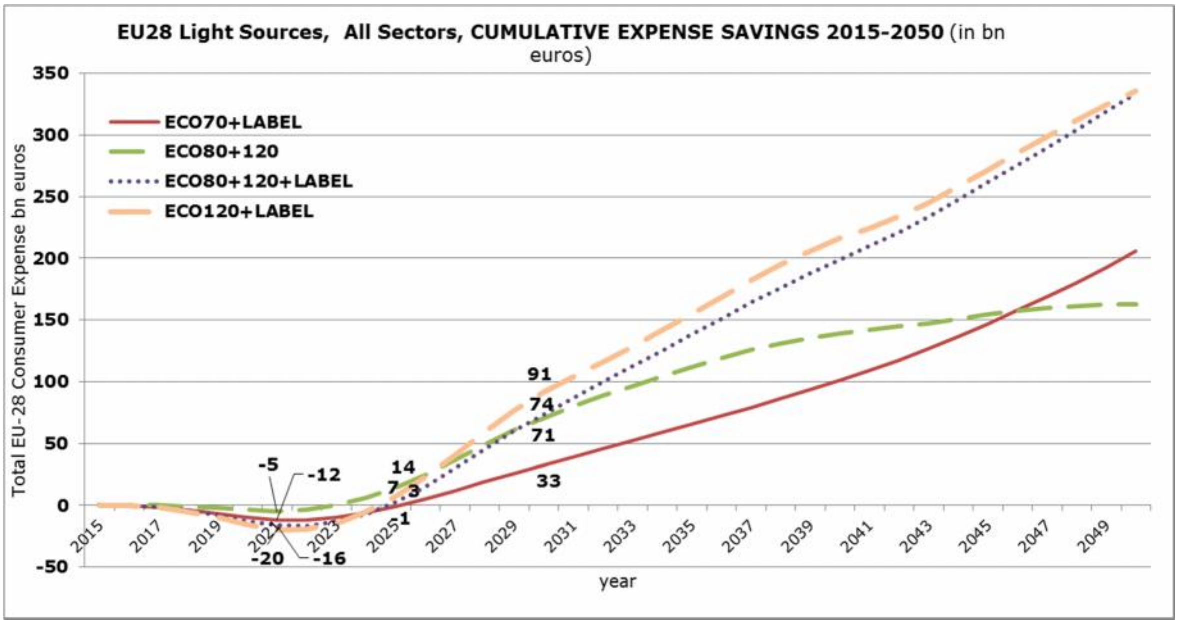


Figure 31: Cumulative Expense Savings with respect to BAU, in bn euros, for ECO70+LBL and ECO80+120 scenarios, extension to period 2030-2050

4. Sensitivity analysis

The sensitivity analysis will be performed in the impact assessment, as it highly depends on the comments received by stakeholders at the Consultation Forum.

5. Summary and conclusions

Table 13 shows the differences (in-/decrease) between the ECO-scenarios and the BAU scenario for a selected number of volume-, environmental- and economic parameters. The values are computed as ECO-BAU, implying, in particular for energy and emissions, that negative values represent savings or reductions.

Table 13: Comparison of scenario results for volume-, environmental- and economic parameters, relative values (ECO-BAU of same year). Negative values indicate reductions or savings.

Scenario comparison, Relative values ECO-BAU (of same year)		2020				2025				2030			
		ECO70+LBL	ECO80+120	ECO80+120 +LBL	ECO120 +LBL	ECO70+LBL	ECO80+120	ECO80+120 +LBL	ECO120 +LBL	ECO70+LBL	ECO80+120	ECO80+120 +LBL	ECO120 +LBL
All Sectors, EU-28 totals, ECO-BAU													
Sales	mln units	0	0	0	-2	-96	-128	-128	-142	-104	-130	-130	-122
Stock	mln units	0	0	0	0	0	0	0	0	0	0	0	0
Installed Capacity	Tlm	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.1	0.2	0.2	0.2
Installed Power (excl. CG)	GW	-9	-6	-11	-13	-29	-29	-42	-48	-25	-23	-39	-41
Efficacy = Load/ Energy excl. CG [51]	lm/W	3	3	5	7	17	31	41	56	22	39	58	63
Electric Energy	TWh/a	-10	-9	-15	-21	-31	-48	-63	-78	-28	-43	-61	-65
Primary Energy	PJ/a	-87	-83	-135	-188	-283	-436	-569	-705	-253	-383	-546	-585
GHG Emissions	MtCO2eq	-4	-3	-6	-8	-11	-17	-23	-28	-10	-14	-21	-22
Total Consumer Expense	mln euros	3089	1740	4631	5999	-5111	-8161	-9442	-12486	-6639	-10239	-13840	-14727
o/w Purchase Cost	mln euros	4612	2976	6871	8827	1873	1641	3691	3550	1104	182	1572	1602
o/w Industry Revenue	mln euros	3551	2515	5346	6905	1585	1484	3030	2916	913	214	1281	1304
o/w Wholesale Revenue	mln euros	380	216	606	802	107	84	289	275	84	-9	131	133
o/w Retail Revenue	mln euros	332	220	556	750	103	96	283	269	83	-2	128	131
o/w Taxes (VAT)	mln euros	348	24	364	371	79	-23	90	91	25	-22	33	33
o/w Installation Cost	mln euros	-8	-13	-13	-31	-198	-405	-405	-508	-266	-438	-438	-389
o/w Energy Cost	mln euros	-1750	-1518	-2597	-3518	-6827	-9593	-12932	-15829	-7506	-10170	-15166	-16181
o/w Maintenance	mln euros	0	0	0	0	0	0	0	0	0	0	0	0
Total Jobs	thousands	78	55	118	153	32	28	62	59	17	0	24	25
o/w Industry	thousands	71	50	107	138	32	30	61	58	18	4	26	26
o/w Wholesale	thousands	2	1	2	3	0	0	1	1	0	0	1	1
o/w Retail	thousands	6	4	9	13	2	2	5	4	1	0	2	2
o/w Install	thousands	0	0	0	0	-2	-4	-4	-5	-3	-4	-4	-4
o/w Maintenance	thousands	0	0	0	0	0	0	0	0	0	0	0	0
Residential, EU-28 totals, ECO-BAU													
Sales (excl. from storage)	mln units	0	0	0	0	-37	-37	-37	-37	-36	-36	-36	-36
Electric Energy	TWh/a	-2.5	-0.8	-2.6	-2.6	-7.3	-3.2	-7.6	-7.8	-7.1	-2.1	-7.8	-7.9
Total Consumer Expense	mln euros	1458	-64	1535	1569	-1760	-1126	-1801	-1834	-2480	-925	-2698	-2749
o/w Purchase Cost	mln euros	2091	144	2183	2225	473	-141	537	545	150	-131	198	198
o/w Energy Cost	mln euros	-632	-207	-648	-656	-2233	-985	-2338	-2379	-2630	-795	-2896	-2947
Non-Residential, EU-28 totals, ECO-BAU													
Sales (excl. from storage)	mln units	0	0	0	-2	-59	-91	-91	-105	-68	-94	-94	-86
Electric Energy	TWh/a	-7	-8	-12	-18	-24	-45	-56	-71	-21	-40	-53	-57
Total Consumer Expense	mln euros	1631	1804	3097	4430	-3351	-7036	-7641	-10653	-4159	-9314	-11142	-11978
o/w Purchase Cost	mln euros	2521	2832	4688	6602	1401	1782	3154	3005	954	313	1374	1403
o/w Energy Cost	mln euros	-1118	-1311	-1948	-2862	-4593	-8608	-10593	-13450	-4876	-9375	-12270	-13234

[51] This is an energy-weighted average efficacy of the lighting stock in lm/W, computed as the EU-28 total lighting load in lm.h divided by the EU-28 total energy of the light sources (excl. control gear energy) in W.h.

The table shows that the total EU-28 electric energy savings in 2025 and 2030 for the various scenarios are:

	2025	2030	
▪ ECO70+LBL:	31	28	TWh/a
▪ ECO80+120:	48	43	
▪ ECO80+120+LBL:	63	61	
▪ ECO120+LBL:	78	65	

These savings are in addition to the 110 TWh/a savings in 2030 already included in the BAU scenario.

The corresponding total EU-28 reduction in GHG emission in 2025 and 2030 are:

	2025	2030	
▪ ECO70+LBL:	11	10	$MtCO_2eq./a$
▪ ECO80+120:	17	14	
▪ ECO80+120+LBL:	23	21	
▪ ECO120+LBL:	28	22	

These savings are in addition to the 55 $MtCO_2eq.$ reduction in 2030 already included in the BAU scenario.

The above savings and reductions are obtained due to an investment in LED lighting products that leads to a peak in additional purchase costs around 2020:

	2020	
▪ ECO70+LBL:	4.6	bn euros/a
▪ ECO80+120:	3.0	
▪ ECO80+120+LBL:	6.9	
▪ ECO120+LBL:	8.8	

These additional purchase costs are in addition to the 4-5 billion euros higher purchase costs already included in the BAU scenario.

This 2020 investment leads to savings on energy costs and on total expenses in later years:

bn euros/a	2030 Energy cost saving	2030 Total Expense saving
▪ ECO70+LBL:	7.5	6.6
▪ ECO80+120:	10.2	10.2
▪ ECO80+120+LBL:	15.2	13.8
▪ ECO120+LBL:	16.2	14.7

These savings on total consumer expense more than compensate a 5 billion euros increase included in the BAU scenario.

The 2020 peak in purchase costs also generates additional industry revenue and additional jobs, from 55 000 to 153 000 in 2020. On the long term these positive impacts are reduced but an additional 17 000 to 25 000 jobs remain, only in the scenarios with improved labelling. These revenues and jobs are not necessarily all inside the EU-28.

The scenarios that include a labelling improvement require higher additional investments around 2020 but also provide higher savings in later years. In addition these scenarios continue to provide annual savings also on the long term, while the ECO80+120 scenario (without improved labelling) provides annual savings only on the short and medium term (approximately until 2040).

As shown at the bottom of Table 13, the major part of the savings is obtained in the non-residential sector. The effect of the scenarios in this sector is similar to that discussed for all sectors together.

In the residential sector the effects of the scenarios are different (see also additional information in Annex G) and there is a clear distinction between those with improved labelling and those without. The ECO80+120 scenario (without label improvement) has hardly any additional purchase costs with respect to the BAU scenario (+0.14 billion euros in 2020), but also the savings obtained are modest (3.2 TWh/a in 2025 and 2.1 TWh/a in 2030). All scenarios that include label improvements have similar effects, with 1.5-1.6 billion euros additional investment around 2020 and annual energy savings of 7-8 TWh/a in 2025 and 2030.

Table 14 provides the cumulative savings on electric energy, GHG emissions and total expenses, for the ECO scenarios with respect to the BAU scenario. The data are for 'all sectors', i.e. the sum of savings for the residential and non-residential sectors.

Table 14: Cumulative savings on electric energy, GHG emissions and total expenses for the ECO scenarios, with respect to the BAU scenario (all sectors: sum of residential and non-residential savings)

			2015	2020	2025	2030
ECO70+LBL	Electric energy	TWh	0	19	143	294
ECO80+120	Electric energy	TWh	0	14	184	421
ECO80+120+LBL	Electric energy	TWh	0	27	256	578
ECO120+LBL	Electric energy	TWh	0	36	338	706
ECO70+LBL	GHG emissions	$MtCO_2eq$	0	7	53	105
ECO80+120	GHG emissions	$MtCO_2eq$	0	5	68	150
ECO80+120+LBL	GHG emissions	$MtCO_2eq$	0	10	94	206
ECO120+LBL	GHG emissions	$MtCO_2eq$	0	14	124	253
ECO70+LBL	Total expense	bn euros	0	-10	-1	33
ECO80+120	Total expense	bn euros	0	-4	14	71
ECO80+120+LBL	Total expense	bn euros	0	-13	3	74
ECO120+LBL	Total expense	bn euros	0	-15	7	91

All ECO-scenarios provide savings on electric energy and GHG emissions starting from 2019. For the ECO70+LBL scenario the cumulative savings over the 2015-2030 period are 294 TWh on energy and 105 $MtCO_2eq$ on emissions, for the ECO80+120 scenario 421 TWh and 150 $MtCO_2eq$, for the ECO80+120+LBL scenario 578 TWh and 206 $MtCO_2eq$, and for the ECO120+LBL scenario 706 TWh and 253 $MtCO_2eq$.

All ECO-scenarios show negative savings on total consumer expense, i.e. additional expenses, around 2020. In the scenarios with labelling improvement the initial investments are larger and the first positive cumulative savings appear in 2025-2026.

In the ECO80+120 scenario (without label improvement) where initial investments are lower, the cumulative expenses start to show a saving from 2021-2022.

References

See footnotes in text

List of figures

List of tables

Acronyms

a	Annum, year
BAT	Best Available Technology
BAU	Business As Usual
BC	Base Case (as used in MEErP)
bn / bln	Billion (10^9)
BNAT	Best Not (yet) Available Technology
BOM	Bill Of Materials
CFL	Compact fluorescent lamps
CFLi	CFL with integrated ballast
CFLni	CFL without integrated ballast

CG	Control gear
DLS	Directional light sources
E14, E27	Screw-type lamp caps for general purpose lamp
EC	European Commission
ECEEE	European Council for an Energy Efficient Economy
ECG	Electronic Control Gear
ECO	Scenario considering ecodesign or energy labelling measures
EEI	Energy Efficiency Index
EoL	End-of-Life
ErP	Energy related Product
EU	European Union
G4, GY6.35	Low-voltage halogen lamp types, 2 pin cap, single ended
G9	Mains-voltage halogen lamp, 2-pin cap, single ended
GHG	Greenhouse gas
GLS	General Lighting Service (a.k.a. incandescent lamp)
GW	Giga Watt (10^9)
h	Hour
HE	High efficiency
Hg	Mercury
HID	High-Intensity Discharge
HL	Halogen or Halogen lamp
HO	High output
HPM	High-Pressure Mercury
HPS	High-Pressure Sodium
Hz	Hertz
klm	Kilo lumen (see lm)
LBL	Energy Label
LCC	Life Cycle Cost
LE	LightingEurope (lighting manufacturers association)
LED	Light Emitting Diode
LENI	Lighting Energy Numerical Indicator
LFL	Linear Fluorescent Lamp
LLCC	Least Life Cycle Cost
LLMF	Lamp Lumen Maintenance Factor
lm, Φ	Lumen, unit of luminous flux Φ
LMF	Luminaire Maintenance Factor
LOR	Light Output Ratio
LPD	Lighting Power Density [W/(m².lx)] (Pr EN 13201-5)
LV	Low Voltage (typical 12V, 24V)
L70	Lifetime, lumen output decreased to 70% of original value
max	maximum
MELISA	Model for European Light Sources Analysis

MEErP	Methodology for Ecodesign of Energy-related Products
MEPS	Minimum Efficacy Performance Standard
MF	Maintenance Factor
MH	Metal Halide
min	minimum
mn / mln	Million (10^6)
Mt	Mega tonnes (10^9 kg)
MV	Mains Voltage (typical 230V)
MYPP	Multi-Year Program Plan (from US Doe)
NACE	Nomenclature statistique des activités économiques dans la Communauté européenne (coding)
NDLS	Non-directional light sources
OJ	Official Journal of the European Union
OLED	Organic Light Emitting Diode
P	Rated power
par	paragraph
R7s	Mains voltage linear halogen lamp, double ended
R9	Saturated red colour used as rendering reference
Ra	Colour rendering index, unit
ref	reference
RGB	Red Green Blue
s	Second (as unit for time)
SPL	Special Purpose Lamp
SPP	Special Purpose Product
sr	steradian
SSL	Solid State Lighting
TBW	To Be Written / To Be Worked
TWh	Tera Watt hour (10^12)
UF	Utilisation Factor
V	Volt
VHK	Van Holsteijn en Kemna
VITO	Vlaamse Instelling voor Technologisch Onderzoek
W	Watt
yr	year

Annex A Minutes 1st stakeholder meeting

Final Minutes 1st Stakeholder meeting Ecodesign Light Sources study (Lot 8/9/19)

Date: 5 February 2015
Location: Conference Centre Albert Borschette, room 2D, Brussels.
Time: 9:30 - 16:30h.

Study team:
Chair: René Kemna, VHK (RK). Presentations: Leo Wierda, VHK (LW), Stuart Jeffcott, Jeffcott Associates (SJ). Technical expert: Paul van Tichelen, VITO (PvT)
Total 32 participants (see Annex). Meeting recorded on audio-file (as announced in meeting) strictly for facilitating the writing of minutes.

Meeting documents (Task 0/1/2/3 reports) published on project website November/December 2015.
Agenda: Discussion Task 0/1 in the morning, Task 2/3 and AOB in the afternoon.
Presentation slides (122) published 6.2.2015 on project website "http://www.ecodesign-lightsources.eu".
Reference overview between report-tables and slides to be published 12.2.2015.

Deadline for the reaction on these draft minutes is 16 February 2015.
Deadline for written comments on the Task reports is 28 February 2015.

Minutes

Welcome, agenda and announcements by RK. LW presents slides of the Task 0 report and the first part of the Task 1 report.

[Task 0: Assignment, Tasks, Timing, link with light systems study Lot 37]

Observation by Hans-Paul Siderius (HP) (Netherlands Enterprise Agency) redirected to Task 1 discussion. No other comments from participants.

[Task 1, Part 1: Scope, definitions]

Floris Akkerman (FA, BAM, DE) asks how light sources integrated in non-lighting products should be defined. Some of the current exemptions are based on the concept being integrated (e.g. in range hoods which could have integrated LEDs or E14 sockets. There is a request by importers whether they are covered or integrated lamps are excluded. LW answers that in our study we considered that lamps in range hoods are explicitly stated to be excluded. RK asks if FA intends more generally the rules whether lamps-without-sockets are covered. FA answers that in those cases, e.g. backlight of a TV, these would be excluded. RK explains that the Task 1 report looks at definitions that exist and that we might well have to add new definitions/rules in that sense. He also asks if we really should consider every possible integrated light [shows example of glasses with integrated lighting].

Peter Bennich (PB, Swedish Energy Agency) thinks that in principle they should be included in the regulation but acknowledges that there are testing problems (e.g. Xmas lights) which might make it impossible to assess compliance. If we cannot enforce it, we shouldn't do it.

HP is not worried about changing definitions, because standards and regulation can co-exist and need not always to be identical. Following the last two slides of the presentation with a matrix of 'lamp-definitions by elements', which were added following his e-mail (not in the

Task reports yet), HP mentions that it seems like a good first basis to work on the definitions, identify gaps, etc.. He is still missing 'controls' in the matrix. RK answers that this is not so easy because it affects various elements, but will be addressed. As regards integrated light-sources HP thinks that they should be included in the scope only if they can be tested independently (e.g. have a cap as often in a range hood) because at the very least they would represent a loophole if you didn't include them.

Simonetta Fumagalli (SF, ENEA Italy) emphasizes the problem of longevity-measurements, considered to be a very important aspect. We need many hours of testing and this problem should be addressed.

RK asks for (written) comments on the list of special purpose lamps. Should we include more? Do the sales/energy figures seem plausible or can you propose better figures?

PB mentions that 'decorative lighting' is very often misused and very difficult to define. How to deal with that? RK answers that our approach would be to have 1) technical characteristics (e.g. spectrum, relatively simple to measure), 2) technical characteristics + 'intended use' and only if unavoidable 3) only 'intended use'.

HP does not know yet whether it can be completely avoided, but emphases that only 'intended use' creates loopholes and should really be a last resort. As regards different product types in general: The less the better, even if that means that fine-tuning of requirements might slightly suffer.

RK mentions that some currently excluded lamps will not need new definitions if they will be no longer excluded. But in the study we use this detailed list also as a checklist to get your feedback. Already we made the decision not to include certain things in the study, e.g. chemical lamps, low-radioactive exit-signs, etc. are already proposed to be excluded and there are more decisions on the study-scope that you might want to take a look at.

FA asks if the study team can already (normally in Task 6/7) work on preliminary definitions. It is important to know whether these could imply loopholes and/or unintended regulation. RK mentions that this is normally part of Task 6 (design measures/options) or 7 (scenarios), but we can do this earlier and –also with input from industry—put forward a first set of definitions for feedback from stakeholders.

Otmar Franz (OF, OSRAM/Lighting Europe) stresses the importance of quick testing methods. At the moment the assessment of non-compliance takes far too long to effectively stop free-riders, especially. Unfair for EU industry. Whatever we define: It should be possible to do an effective market surveillance and this is at the moment with the parameters in the current regulation not possible.

Angeliki Malizou (ANEC/BEUC) promises to provide written comments.

Task 1 is presented by SJ.

[Task 1, Part 2: Test methods and existing legislation]

PB states that the flicker requirement is important. Also the induction lamp, previously only used in professional applications, is coming to the homes.

Casper Kofod (CK, Energy Piano Denmark) mentions that they have done a recent research and pleads to no longer use the square root formula for the minimum limits but just a simple lm/W measure. Many of the labels were wrong (supposedly because of the complicated formula?).

OF reacts that the experience from Israel and Russia shows that the lm/W does not work. For CFLs (compact fluorescent lamps) become more efficient at higher power. It leads to people buying higher-power lamps. SJ mentions that in Australia, where they use the lm/W, there are also these problems, which now prompts Australia to put a cap on the power consumption of certain lamps.

Mike Rimmer (MR, DECC UK) on lm/W: Will consumers understand the new metric?

SF will come back to the issue in the 2nd edition of the Task 1 report.

Regarding the simplicity of testing with an integrating sphere versus a full goniophotometric measurement (as today), SF mentions the problem that first it needs to be established whether it is a directional lamp through goniometric testing and only then one could use an integrating sphere, but at that point it would no longer make much sense (because you already have the goniometric equipment). Also you would need a spectrometer (for UV, IR). SJ said that it is true at this level of detail, but if you need a quick cheap check, the sphere is good.

SF: In Italy, we use 3 labs for DLS testing, 2 with goniophotometres and 1 with a sphere, but the price we get for testing is the same for all three [52].

PB: You could set lm/W in different lm classes, so it is solvable. On the square root formula, PB would agree that for the new technology it does not make much sense to use the square root. Would also be easier to compare between regions. To be studied.

Paul van Tichelen (PvT) mentions that also with goniophotometres quick testing is possible (<1min.). But every investment in equipment and maintaining a lab in Europe is expensive.

Fabio Pagano (Lighting Europe) mentions that the new standard EN 13032-4 (on LED lamps and luminaires, developed in parallel with CIE) sets the test to determine NDLS or DLS. Near field or far field testing is both possible; depending on the size of the lamp and the accuracy. Furthermore, the harmonisation from IEC standards to CENELEC is difficult, i.e. to ensure so that there is no conflict with the EU regulation. There is a contrast between quality inspection during manufacturing and market surveillance procedures set out in EU regulations. There is a conflict there, where the former tries to be very precise and the latter should actually aim to be quick enough to be effective. Simplicity and clarity would help here.

Regarding possible overlap between regulations:

PB: Standardisation bodies should focus on the test methods because e.g. on colorimetric testing this is key. There is no conflict in itself: Both standards committees and regulators stand to gain.

Nils Borg (NB, ECEEE) we are making comparisons between test methods regarding their practical application.

RK asks comments on CRI or alternative colorimetric test methods (critical in the past).

PB: Asks comment of industry on how to combine CRI with gamut-testing

[52] to be more specific (this has not been told in the meeting, but it can be useful) an upper limit for costs has been fixed in the public tender.

OF: For the moment no changes foreseen on CRI-measurements. There is no consensus on an alternative.

RK asks more info on the LED label. On colour accuracy: were that MacAdam-ellipses? MS says it uses CRI for colour accuracy (perhaps better than how EU is handling this aspect).

On options for legislative improvements, HP says the luminaire label is a 'disaster', both in terms of consumer understanding and market surveillance. Simplification should be a goal. Regulation should be suitable, achievable and more directed towards the new technology.

Break

On request of some participants the Task 3 presentation by LW is moved forward and now first on the afternoon-agenda.

[Task 3, Part 1: MELISA model introduction]

Reacting to the question on the average Wattage of CFLs in the presentation, PB mentions that the 9.5 W is a bit low. He believes the most common lamp was 11 W in the Swedish study and that of course the study is somewhat older. LW is quite convinced of the average mentioned and also the British measurement study was at roughly the same level. So the high GfK figure was a bit of a surprise.

Bram Soenen (BS, Belgian Government) asks why the 'lumens to fit' value of LEDs in the table change over the years. LW answers that –over the years—the lamp-wattages/lumens that are being replaced change, e.g. in the beginning the LEDs substitute the lower-wattages/lumens and are gradually moving towards replacing higher wattage/lumen lamps. The LEDs have the lumen of the lamps they substitute plus a small rebound-effect. BS also asks if the model makes the distinction between new sockets/buildings and existing ones. LW: No, we don't have information that would allow that differentiation.

SG asks how all these values relate to the table of 'lumen equivalence' in the current regulation. Is that taken into account ?

Michael Scholand (MS, CLASP) cites the table, which mentions –to claim a 60W bulb equivalence—702 lumen for HL, 741 lumen for CFL and 806 lumen for an LED. He does not know the science behind these values but it is intriguing.

OF mentions that the background was that –at the time—the LED (and CFL) had higher lumen depreciation also considering the longer lifetime.

MS then suggests that the study team should look at some of the more recent lumen maintenance studies that have been conducted on LEDs and perhaps review whether those equivalence numbers are still appropriate. He informs that in the US the Philips LPrice lamp has been tested for 25 000 hours and the lumen depreciation was less than 3%.

On another subject, MS mentions that he has done a calculation on the basis of GfK data and finds different outcomes for especially CFLs (our study 123% higher) and MV-HL (16% lower). LW mentions that various, similar checks on the model data versus various sources were performed and we drew some first conclusions from that. The problem is that you never know how correct the reference data are. The MELISA model will be published in the coming months and it would be easier to evaluate and discuss. Anyway the study team considered the GfK data to be purely residential (measured at POS in shops) and for some lamp types also to be used with caution.

[Task 3, Part 2: Health, environment, etc.]

Regarding the influence of energy saving in lighting on the heating and cooling demand, BS asks how much of heating and cooling would be influenced. What does the 0.23 °C difference actually mean? For the case of heating, RK illustrates (with rounded figures) that –at an average heating season outdoor temperature of 6 °C and a (internal and solar gain corrected) indoor temperature of 16 °C—the average indoor/outdoor temperature that a heating boiler has to compensate would be around 10°C. So this 0.23 °C (at 50% saving, which is still far from reality) would represent around 2% extra heating effort. This is not much, but it is also not nothing and thus has been analysed in the report.

BS thinks the 30% collection rate is too low. LW answers that this is the best we can find, but agrees that uncertainty is high. Also other participants confirm that there is a high uncertainty there.

Fabio Pagano mentions that for luminaires the collection rates are unknown, because they are statistically just grouped as small and medium-size electric appliances.

Mike Rimmer (DECC,UK) urges that health issues and the SCENHIR report are being taken into account in the review.

[Task 3, Part 3: Dimming]

Christoph Mordziol (CM, UBA Germany) mentions a lamp with an internal dimmer that can be operated step-wise (e.g. 0-25-50-75-100-75-50-25% etc.) by pressing a normal light-switch 2 seconds for each step. So less problems than with external dimmers and this may give a good solution for many consumers. LW mentions that in the report dimming of smart lamps is discussed, with consumption estimates for the dimming. CM mentions that dimming may save energy, but because of the parasitic energy this is not always the case. RK asks for more information on the lamp that CM mentioned, because it is not actually a 'smart lamp' with WiFI or BlueTooth.

How many dimmers are still out there and will be used in the future? There may be 200 million installed out there, but HP and others doubt that there are still many consumers that will use them at some stage and instead will use the smartphone for smart lamps. RK mentions that the study cannot simply make such an assumption without proof. The study has anyway to make an estimate for the decision makers on how many citizens would go for hardware dimmer-substitution. RK mentions that the current sales number (5.5million/year) and sales-trend can be an indicator of how many people still value this technology. Rony Haentjes (RH, NIKO/ CECAPI) will try to come up with more information on the issue.

NB mentions that when estimating costs it should be considered that these dimmers don't live forever and will anyway be replaced on a regular basis. So don't overestimate this demand.

Casper Kofod informs that in the project Premium Lights we found a certain number of dimmers installed and when scaled up to the EU-28 this number would amount to 180 million dimmers installed. So on average almost 1 dimmer per household. When we hear 110-120 million phase-cut (97% 2-wire) dimmers installed, this is roughly what we found.

Another matter is how many lamps are connected to 1 dimmer. CK does not know the exact answer to that; in the project the lamps were mapped per room and then it was asked if there was a dimmer in the room, but there is no data on the number and type of lamps on that dimmer.

RH mentions that there is a strong regional influence: In Northern Europe dimmers are much more popular than in Southern Europe. He also mentions that not just the dimmers will have problems with 2 wire (non-capacitive) installations, but also other control devices like occupancy sensors.

There is a suggestion by BS that the max. wattage could be an indicator, but RH states that this is no longer true. There are more lamp types and variations in transformers/drivers than in the past.

RK asks if all agree to the time-schedule for dimmer-compatibility. [No reaction, but nodding]

HP asks if the standardisation deals with the smart lamps, etc.. RH answers it only deals with switched dimming (not wireless).

SF understands that the 15913 standard is not calculated in the same way as MELISA. But could there be some point of agreement between the two. LW explains that 15913 gives default hours, so only if you do not know anything. For some buildings the 15913 gives plausible values, but for special cases the values are not clear. Also the 15913 gives first potential hours, but they can also be filled in by daylight and then there is an occupancy factor. General impression is that the hours in 15913, even with corrections, are too high (e.g. 2300 h according to standard versus 1500h in MELISA).

Pagano remarks that the services are not always obvious. For instance, an office may be open from 8 to 5, but the actual lighting, including cleaning, may be from 5 to 8.

BS do you take dimming into account in the model. LW answers that the model makes the accounting with full-power equivalent hours, so it is in there. But we do not have detailed assumptions on dimmer parasitic consumption or average use. BS also asks, even if he suspects that it is small, if the impact on cooling is calculated. RK answers that this is very difficult. It will on average be considerably less than heating in the EU, but there may be peak-situations especially in Southern Europe offices where it could be a noticeable factor. And in this case the saving on lighting energy is of course working in favour of active cooling demand.

RK presents a slide, illustrative of both the light sources and system aspects, with a Sankey-diagram of fairly efficient office lighting (T8 LFLs with 80-90 lm/W) that was made some 4 years ago, showing that a 100% primary energy input at the power plant actually results in 1% useful light. The slide is not (yet) in the reports but will be added in the slide presentation as very last slide.

Task 2 is presented by LW

[Task 2: Market analysis, MELISA model]

Signe Friis Cristensen (SFC, Danish Energy Agency) asks for information on which tables in the slides correspond to which tables in the reports. LW answers that he will do his best to provide such a table as an extra document on the project website next week. But not all tables correspond 1 to 1.

BS asks whether they are Lighting Europe data and if it is an industry model. RK answers that the model is made by the study team and that we use all possible sources for inputs and check outputs against available (and reliable) sources. Lighting Europe data are also included but not reported directly for confidentiality reasons.

Any other business

PB mentions that the report on light sources will be ready next week.

SFC mentions that they also have the report on their study ready.

Both PB and Denmark will send the report to the study team (LW or RK) and these reports will then be put on the project website for download.

RK announces, for the benefit of NGOs and Member State participants that the project website on household refrigeration www.ecodesign-fridges.eu was launched a few days before.

Ruben Kubiak mentions that, although no exact date is fixed yet, the Commission aims to hold a Regulatory Committee meeting on the proposed "Stage 6" amendment after the Easter break.

Angeliki Malizou asks if (and why) the Lighting Strategy effort was stopped? Ruben Kubiak explains that this was started under the old Commission but does not seem to be a priority under the new Commission.

RK thanks all and wishes a good trip home.

RK/VHK 6.2.2015

Deadline for the reaction on these draft minutes is 16 February 2015.
Deadline for written comments on the Task reports is 28 February 2015.

Stakeholder meeting Ecodesign Light Sources study (Lot 8/9/19)
Participants
Date: 5 February 2015
Location: Conference Centre Albert Borschette, room 2D, Brussels
Time: 9:30 - 16:30h.

First Name	Surname	Company / organisation name	Nationality
Hans-Paul	Siderius	Netherlands Enterprise Agency	Dutch
Philippe	Carpentier	Schneider-Electric	French
Lars	Koch	Orgalime	Danish
Kees	van Meerten	Philips Lighting	Dutch
Fabrizio	Tironi	LightingEurope	Italian
Fabio	Pagano	LightingEurope (Associazione Nazionale Produttori Illuminazione)	Italian
Angeliki	Malizou	ANEC and BEUC	Greek
Simonetta	Fumagalli	ENEA	Italian
Peter	Bennich	The Swedish Energy Agency	Swedish
Rony	Haentjens	NIKO / CECAPI	Belgian
Otmar	Franz	LightingEurope	Germany
Chloé	Fayole	ECOS	French
Kaisa-Reeta	Koskinen	Energy Authority, Finland	Finnish
Bram	Soenen	Environmental product policy unit Belgium	Belgian
Markus	Bleuer	Swiss Federal Office of Energy	Swiss
Michael	Scholand	CLASP	UK
Marie	Baton	CLASP	French
Casper	Kofod	Energy piano	Danish
Martin	Bachler	OSRAM GmbH	German
Mike	Rimmer	Dept of Energy and Climate Change	British
Bizhan	Zhumagali	ICF International (on behalf of UK DECC)	USA
Floris	Akkerman	BAM Federal Institute for Materials Research and Testing	DE / NL
Christoph	Mordziol	Umweltbundesamt (Federal Environment Agency Germany)	German
Signe Friis	Christensen	Danish Energy Agency	Danish
Paul	Van Tichelen	VITO	Belgian
Nils	Borg	eceee	Swedish
Nicolas	Fuentes Colomer	IALD	Spanish
Wilkins	Carla	IALD	German
Gyöngyvér	Jakab	LightingEurope	Hungarian
Stuart	Jeffcott	Jeffcott associates	British
Leo	Wierda	VHK	Dutch
René	Kemna	VHK	Dutch
Ruben	Kubiak	European Commission	German

Annex B Minutes 2nd stakeholder meeting

Final Minutes 2nd Stakeholder meeting Ecodesign Light Sources study (Lot 8/9/19)

Date: 17 June 2015
Location: Berlaymont building, Schumann room, Brussels.
Time: 9:30 - 15:30h.

Study team:
Chair: Rene Kemna, VHK (RK). Presentations: Leo Wierda, VHK (LW). Technical experts: Stuart Jeffcott, Jeffcott Associates (SJ), Paul van Tichelen, VITO (PvT).
Policy Officer: Ruben Kubiak, European Commission DG
ENER (RKU) Total 26 participants (see Annex).
Meeting recorded on audio-file strictly for facilitating the writing of minutes.

Meeting documents (Task 4/5/6 reports) published on project website May 2015.
Agenda: Discussion on Time schedule and Task 4 in the morning, Task 5/6 and AOB in the afternoon. Presentation slides (76) published 27.6.2015 on project website www.ecodesign-lightsources.eu .

Deadline for written comments on the Task 4/5/6 reports is 15 July 2015.
Deadline for stakeholder input to Task 7 (scenario analysis) is 30 August 2015.

Minutes

Welcome, agenda and announcements by RK.
LW presents slides of the Introduction, Task 4, 5 and 6.

[Introduction and time schedule]

Mike Scholand (MS,CLASP) asks when the Task 7 report is expected to be issued and what opportunities stakeholders will have to comment on it.
RK: The final report of the study, including Task 7, is scheduled for October 2015. The Commission prefers to discuss that report in a Consultation Forum (CF), not in a stakeholder meeting (SM). This anyway guarantees the democratic process. Stakeholders are invited to provide their input for the Task 7 scenario analysis before the end of August.
RKU: The Commission wants to avoid to discuss the same topic twice, i.e. first in a SM and then in a CF. The SM s serve to get the input data for the scenario analyses right. Once you have these data, the Task 7 activities and conclusions follow more or less automatically. The full study will be presented to the CF together with a first opinion of the Commission and maybe a draft of a new regulation. At that point the CF can comment on the entire study.
Floris Akkerman (FA, BAM, DE) asks the EC to provide sufficient time between the publishing of the final report and the convocation of the CF so that industry and member states can seriously study it and issue their comments.
RKU responds that normally documents are made available one month before the CF; in this case it might be a bit earlier. The EC intends to have the CF before the end of 2015, but this also depends on when the study will finish (contractual deadline is October).

[Task 4, LED technology and time-line for efficacy and price]

Kees van Meerten (KvM, LightingEurope) (in reaction to the statement in the presentation that Philips is slowing down LED activities [1]) explains that LED-chip production in Lumileds was spinned-off, but Philips Lighting, as a separate company, remains strongly involved in LED lighting technology and is not slowing down LED lighting production. Philips will not have its own brand of LED-chips, but even today Philips is using chips from Lumileds as well as from other brands.

In the opinion of MS , the concern raised in the presentation that the halogen phase-out, with associated loss in revenues for industry, will lead to a slowdown in investments in LED R&D and thus to a slowdown in efficacy improvements, is not valid. There are only few manufacturers that have revenues from both halogens and LEDs, while many have interests only in LEDs, so the loss of halogen revenues cannot be expected to have an influence on LED improvements.

KvM asks if the study team can be more specific on how the projection for LED efficacy was derived.

LW answers that the trend of the US DoE curve was more or less accepted, but the curve was lowered to make it pass through the point that was identified as current average for all LEDs (89 lm/W in 2014/2015). The proposed projection is intended to represent the average efficacy of new sold LEDs in each year, not the best available efficacy that seems to be represented by the US DoE curves. It is important that stakeholders agree with this curve, so the study team is open to change the curve based on comments.

PvT adds that the conviction of the study team that the projected efficacies can be met is also based on the announcement of Philips and Osram that 200 lm/W LED tubes have already been realized in laboratory.

Otmar Franz (OF, LightingEurope) explains that these tubes use special phosphors and special chips and reach these high efficacies under special conditions. What manufacturers can do, and what they have to do to stay in business, are different things and should not be mixed up when defining projections.

MS notes that major American lamp manufacturers have been directly involved in the process that led to the US DoE projections, so these are not just data invented internally by government officials. Even if the American market is different from the European market, LED technology is global, and the US DoE data are a good base for EU-projections.

Peter Bennich (PB, Sweden) says that the proposed efficacy line seems reasonable, also considering the results of testing performed in Sweden before Christmas 2014 that already showed efficacies up to 134 lm/W.

KvM observes that the efficacy projection and the price projection should be considered together. High- power chips reach high efficacies, but lower prices are also necessary and therefore mid-power chips and low-power chips are increasingly being applied. However these chips also have lower efficacy. This ongoing trend towards low-power chips is missing in the report. Some of the low prices on the current market are introduction prices, and these lamps are typically based on lower-lifetime and lower-efficacy chips.

RK clarifies that the proposed curves assume a lifetime of 20,000 hours, which is rather modest as compared to average claims by manufacturers. The study team does not have indications on trends towards lower efficacies and lower lifetimes, just the opposite. Does

LE have any evidence for this?

OF remarks that residential users have no sensibility for a difference in lifetime between e.g. 10,000 h and 20,000 h, so the study team should not expect to see complaints. In the non-residential sector this might be different, but also there it is too early to already have complaints on lifetimes.

KvM adds that LE does not say that LED efficacy is going down; in general it is going up. However, in order to enable lower prices, the LED-chips being used are not those having the highest possible efficacy. LightingEurope has its own projections on LED efficacies and will present the study team with input on this topic by mid-July.

RK observes that the Task 4 report was issued a month ago and that stakeholders already had the time to form an opinion. It would be important to reach a consensus on the projections during this meeting. Otherwise, if, latest mid-July, there is no clear evidence of the contrary, the study team will consider the proposed curves as best possible estimates and use them in the Task 7 scenario analysis.

KvM reacts that there are too many reports to be read and commented in a too short time. In a preliminary reaction the efficacy curve seems rather ambitious. LE will most likely not propose a curve that is half of the one proposed by the study team. However, the two LED projection curves are probably the most important ones of the entire study and deserve a close examination. The contents should be more important than the process-times here. Therefore LE asks sufficient time to seriously study the topic and come up with good information.

MS notes that there is an offer in the US Home Depot retail stores now for 2 lamps at 5 US dollars. True that this is an introductory price, but after 90 days it will be 1 lamp for 5 dollars and that is less than half of what the study team proposal assumes, while efficacy is in line with the proposal. The curves proposed by the study team seem excellent.

Yifaat Baron (YB, Oeko-Institut) suggests to present two price options in the scenarios – one high price/high efficacy, one low price/low efficacy. This would make it easier for stakeholders to comment.

RK answers that this could be done as part of a sensitivity analysis, but a choice will have to be made soon and this will for sure be somewhere in the middle. In addition the proposal graphs already indicate a range for the current average values and shifting the curves in that interval already gives a good idea of the uncertainties we are dealing with.

RK concludes that the study team had hoped to reach a consensus on the LED timeline during this meeting. Clearly this was not possible, which is a pity. Therefore, the team will await the feedback from the industry and from other stakeholders before 15 July 2015, and then autonomously decide on whether the proposed timeline has to be amended. There is no space in the time-schedule for a second discussion with the stakeholders.

[Task 4, Other new lighting technologies]

Andrea Harrer (AH, BAM, DE) asks how standby energy consumption and energy consumption of non- lighting functions of smart lamps will be regulated. Lighting is exempted from the horizontal regulation on network standby. Will these aspects be integrated in the new lighting regulation or will that be limited to the lighting efficacy ?

LW expects most of these aspects to be handled in the eco-design study on smart appliances, but there is no information yet on what type of regulation they have in mind.

PvT: the EC and the CF will have to decide what to do with these hybrid products that have different functions and that would fall in different eco-design product categories.

RKU: lamps integrated into other products, e.g. refrigerators, are considered in current regulations and that might continue to be the case. In addition a study is ongoing on lighting systems that will cover aspects related to control devices and sensors, including smart lamps. Lamps in a refrigerator have an illumination function, but nobody would buy a refrigerator for that function. For smart lamps, e.g. a lamp with integrated loudspeaker, this is somewhat different. The EC has no solution for this yet, but the number of products challenging such a solution is still small, so for the moment we would regulate only the lighting function and then see what the future brings.

PB raises the topic of the security of smart lamps, i.e. the possibility to hack into the WiFi system through the lamps. Associated to that the topic of data protection, i.e. smart lamps reporting back usage data to someone else than the user. Will these aspects be handled in a lighting regulation?

RKU: these topics are not related to energy efficiency and have to be addressed elsewhere.

MS observes that there is no testing standard for the light generation efficacy of smart lamps that can produce different light colours. At which colour point should the lamp be tested? The EC might need to issue a mandate to look into this matter. The IEA 4E SSL Annex is looking at this issue through a project headed by Casper Kofod in Denmark, so keep an eye on information from there.
RK suggests to take the white colour in the centre of the range, but the remark from MS has been noted and will be taken into account.

[Task 4, Classic lighting technologies, Linear Fluorescent Lamps and their LED retrofits]

OF asks if eco-design studies also have to consider light quality aspects or if they only address energy efficacy.

RK answers that possible negative impacts of energy efficient products on consumers and industry are explicitly included in the studies. Functionality of lighting and light quality are certainly being taken into account.

OF points out that a LED tube cannot generally be retrofitted into a fluorescent lamp luminaire without affecting the light quality, in particular when the existing luminaire involves indirect lighting. Directional LED tubes that emit in a 120-150 degree angle will not deliver this indirect light and thus will not satisfy the light planning for the room.

LW answers that LE-members are also offering plug-and-play LED retrofit tubes, so they must be useful for some applications.

OF confirms that for some applications LED tubes are an adequate substitute, but not for all.

PB confirms that the light distribution problem of LED tubes exists. Maybe the future regulation could address this by means of information requirements. Anyway, 360 degree emitting LED tubes are now also becoming available.

Catherine Lootens (CL) reports that in 2010 several tests have been performed at KU Leuven regarding LED tubes. Negative impacts from the difference in light distribution have been found, in addition to aspects related to the colour of the light, glare, contrast and visual comfort in general. The consumer should be made aware of these aspects. In addition the substitution of LFL s by LED tubes has been noticed to lead to insurance problems in some cases in Belgium.

MS notes that there has been considerable progress in LED tubes since 2010 and that tests might have to be repeated. At the Light and Building fair of 2014, Osram presented prototype LED tubes that emit over 360 degrees, and the Task4 report announces that these tubes should come to the market in 2015. So maybe the directionality and insurance problems have already been solved ?

OF cannot guarantee that this type of LED tube will actually come to the market this year.

RK specifically invites the lighting designers to comment on the topic of LFL substitution by LED tubes in their written comments.

[Task 4, Classic lighting technologies, High-Intensity Discharge lamps and their LED retrofits]

PB: in Sweden LED for street lighting is certainly coming, but metal halide lamps are also often used by municipalities because they are brighter. If you don t need dimmability, that is an option.

CL misses plasma lamps in the study. They are used e.g. as an alternative to HID-lamps in street lighting applications.

LW asks if there are any data on how widespread the use of plasma lamps actually is.

CL does not have these data but knows they are being applied in Belgium. In addition induction lamps are not mentioned in the study. There has been a wave of induction lighting coming into Belgium, even if these lamps were confusingly publicized, hiding a promise of lower energy use for the same lighting quality in an overall marketing ‘mist difficult to understand for consumers. Both types of lamps should at least be addressed in the reports.

Anders Peder Øbro (APØ, Danish Energy Agency, DEA) has seen plasma lamps and induction lamps being publicized in Denmark for road lighting. A future regulations should at least mention them and clarify if they are included or not.

PB: induction lamps have also been seen on the market in Sweden, but they had EMC problems and do not seem to be popular anymore. Induction lamps are not a problem in Sweden.

RK: when they first came to the market the advantage of induction lamps was their long product life of
60,000 hours. However, nowadays it seems easier and cheaper to realize these long lifetimes using LEDs, and induction lamps do not seem to have other advantages.

KvM confirms this and also clarifies that PHILIPS stopped selling induction lamps years ago (PHILIPS sold the production unit of these lamps). Third parties still produce and sell these lamps. Typical niche applications: warning lights on oil rigs, high buildings etc..

[Task 4, Classic lighting technologies, Other lamp types and their LED retrofits]

No comments.

[Task 4, Packaging, Bill-of-Materials and End-of-Life]

CL asks if the study team is aware of the CYCLED project on recycling of products containing LEDs.

LW and PvT answer that they have considered some of the CYCLED publications during the study.

RK welcomes additional information and CL promises to forward it to the study team.

KvM observes that many different classic lighting types have been distinguished, while there is a single bill-of-materials for 1000 lm LEDs. This has implications during the use of the data in Task 5. More granularity is required within the LED technology. KvM suggests to subdivide at least in a linear LED lamp, a consumer LED lamp and a professional LED lamp.

RK points out that LCA data are not widespread and what is presented in the reports is the best the study team was able to do. If LE has additional information that enables a further breakdown, this would be welcome. The topic will be further discussed after the Task 5 presentation.

MS signals the existence of a 2012 US DoE LCA on the Philips Luxeon Rebel LED with remote phosphor on the plastic bulb. The result is compared with the LCA for a CFL, for an incandescent lamp and for an assumed 2017 LED version.

LW answers that he is aware of this study.

RK tries to temper the enthusiasm on the possibilities of LCA s. Subdividing in more types of LEDs maybe could make the study look more credible to people that don t know the details, but the reality is that the composition of LEDs is changing every month and that many details, such as the (now) much discussed quantum dots with 50 atoms of Cadmium, are not included. Another example is that we are now considering only one type of substrate, while many different types are being used. In addition, any eco- design measures will most likely not have any effects before 2020 and we don t know what the composition of LEDs will be then. So we should not exaggerate with the level of detail and precision required in the LCA s.

[Task 5, Environment and Economics]

KvM repeats his remark made during the Task 4 discussion that he would have preferred to see a further category breakdown of the LEDs, distinguishing at least LEDs for typical consumer applications from LEDs for professional applications. In addition the large LCC difference between directional halogen lamps (category HL MV X) and comparable GLS lamps is not realistic (see presentation slide 59).

As regards the last point LW answers that the HL MV X is an atypical base case, being the collector of all halogen lamps not contained in the other halogen base cases. There are many relatively cheap and small lamps with GU10 cap in there but also relatively expensive and large PAR lamps so that is it difficult to compute average prices and characteristics. LW also noted the LCC peak value for HL MV X and promises to check the underlying data.

As regards the choice of the study team to have a single LED base case, LW explains that this derives mainly from a data availability problem. The study team already had problems finding LCA data for this one base case, and those problems would increase when further splitting the category. In particular the detailed breakdown on the bill-of-materials presented problems for LEDs. For one LED filament lamp the study team performed own weight measurements in laboratory, but it was not feasible, given time and resources, to do this for all LED lamp types. Additional input from industry would be welcome on this point.

KvM remarks that consequently the reliability of the data and outcome presented for LEDs is questionable. Is it the role of the industry to provide material breakdown data? He expected the study team to determine the material breakdown for several LED lamp types in laboratory and then to divide these data between typical consumer products and typical professional products.

RK clarifies that the LED outcomes in the report, in particular as regards the small substances, have been based for a large part on data from an Oekopol study, and they probably invested 50-100k euros in breaking down this one lamp, without having the actual information that industry has. There is a wide variety of material compositions being used for LED lamps, e.g. different substrate types, and compositions are rapidly changing in time. It is highly speculative to say what the composition of LED lamps will be in some years from now. The best the study team could ever do, even given infinite resources, is to give a plausible, indicative LCA, but it is not an exact science. Consequently it is not so easy to state if outcomes are reliable or not.

KvM understands this, and it also clear that whatever the outcome is, LEDs will be beneficial from the LCA point of view. However, the reports suggest reliability, and the Commission will base policy decisions on these reports, so it would be preferable to indicate that due to the lack of information we should be careful in comparing LCA s for LED lamps to LCA s for other lamp types.

RK answers that if it is not already clear from the reports, it can be further clarified that the LED data are indications, that not every BoM for LEDs exactly looks like this, and that there is a spread in the results.

As regards further differentiation within the LED category, RK answers that even given more resources, the study team would probably not be able to increase the quality of the data in the available time. If industry wants a further category split up, input on this will have to come from them. Any such information would be welcome and would be taken into account.

KvM answers that LE will see what they can provide.

CL agrees with the conclusions of the report that LFL s use more phosphors than LED lamps, but the study should differentiate between remote phosphor LEDs and use of phosphors directly on the die or package. This makes a large difference for the rare-earth-material (REE) content. At the University of Gent research is ongoing to develop other phosphor types that use less REE.

RK: this example further confirms the existence of the spread in LED material composition mentioned before. Another example is that Blue LEDs with phosphors are different from RGB LEDs. Regarding phosphors, even if we would exactly know their composition, there is anyway a lack of data on the environmental impacts of the materials involved, e.g. Yttrium.

[Task 6, Design options]

CL asks if in the substitution options for LFL the lumen equivalence at end-of-life was considered. After say 50,000 h of life LED lamps will only have 70-80% of their initial lumens while LFL T5 have at least 90% after 20,000 h.

LW answers that, for all lamp types, the study team tried to choose the lifetimes such that maintained lumens at the end-of-life are equivalent for the compared options.

CL notes that in the LFL design options the high-efficiency (HE) and long-life (XL) versions were considered, but was the ECO-version also taken into account ? LW answers that he is aware of the ECO- versions and their characteristics. It may also be that ECO-characteristics have been used for e.g. the HE- option. This can be verified through the references in the report.

APØ observes that the report gives the impression that LEDs should payback within the lifetime of the lamps they replace. Rather, the payback within the entire lifetime of the LEDs should be considered.

LW answers that he will take this suggestion into consideration for the final version of the report, taking also into account the written comments that DEA already delivered.

APØ asks to start the curves for the 2020 LED option at 5 years and not at 0 years, because this option does not exist at 0 years. It is confusing to present the 2015 and 2020 curves together in a single graph.

LW explains that intentionally the years on the graph are not 2015, 2016, etc., but 0, 1, 2 etc. The graph intends to show what payback times would be possible in 2020 if it is assumed that characteristics of the classic technologies remain the same while a 2020 LED with the projected characteristics would then be available. For the 2015 situation the graph should be interpreted without the 2020 LED curve, reading year zero as 2015; for the 2020 situation the graph should be interpreted without the 2015 LED curve, reading year zero as 2020.

RK adds that the million-lumen-hour basis may seem simplistic, but it actually is a good measure for representing the life-cycle costs. The further you look into the future, the more complex life-time calculations for LEDs become. You have to discount future purchases and energy costs while lamp price and electricity cost developments are actually unknown. There are a lot of assumptions involved and that will give a wide spread in results. It is well possible to consider longer time-spans, but not necessarily more exact.

[Any other business]

On behalf of the study team RK explicitly invites stakeholders to provide inputs and ideas as regards the scenario analyses in Task 7. Suggestions on that would be very welcome. Stakeholders are invited to be creative in this, but also to try to have their suggestions supported by others. Having these inputs before 30 August would enable the study team to perform the right calculations. This is also in the interest of the stakeholders themselves and would make future decisions in the Consultation Forum easier.

KvM asks if it is possible to extend this deadline to mid-September, because there are holidays in between that make it difficult to have a combined industry answer by the end of August. The contents of the proposals, and of the study, should be more important than maintaining a strict deadline. RK outlines the activities the study team and the Commission have to perform after receiving the input from the stakeholders, concluding that mid-September is too late. The contractual deadline for the study of October 2015 is not so easy to change. Stakeholders should really try to provide their inputs by the end of August. If this is really not possible, let the study team know and we will see what can be done but there are no guarantees.

Francisco Zuloaga (Topten, FZ) announces that Topten intends to submit comments on the Task 4, 5, 6 reports before 15 July 2015, but some of these comments will be related to energy labels for luminaires. Is this the right occasion to give comments on this topic, or would it have to be postponed to the lighting systems study ?

RK answers that the people working on the light sources study and the lighting systems study are the same, only in a different hierarchy, so comments will arrive anyway. If the topic of energy labels for luminaires will be subject of a new regulation on light sources is still to be seen.

RKU recommends to submit the comments now, within the timetable of the light sources study. The Commission anyway intended to reconsider the energy labelling directive in the light of the outcomes of this study. The sooner the comments are available, the better.

CL wonders how the current study is related to the eco-label.

RK answers that there is no mandate in the current study to work on the eco-label. The Commission is obviously free to use the results of the light sources study for any considerations on the eco-label.

CL informs that DG Environment very recently communicated that there will be no new eco-label criteria for light sources; the current criteria remain valid until the end of 2015.

RK thanks all and wishes a good trip home.

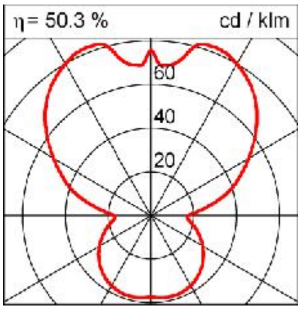
LW/VHK 29.6.2015

2nd Stakeholder meeting Ecodesign Light Sources study (Lot 8/9/19)
Date: 17 June 2015, Time: 9:30 - 15:30h.
Location: Berlaymont building, Schumann room, Brussels
Participants

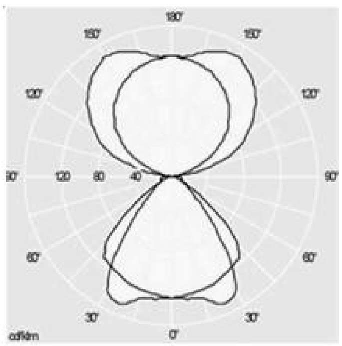
First	Surname	Company / organisation name	Nationality
Floris	Akkerman	Federal Institute for Materials Research and Testing	German
Martin	Bachler	OSRAM GmbH	German
Yifaat	Baron	Oeko-Institu e.V	Israeli
Peter	Bennich	Swedish Energy Agency	Swedish
Chiara	Briatore	LightingEurope	Italian
Otmar	Franz	LightingEurope	Germany
Nicolas	Fuentes	International Association of Lighting Designers	Spanish
Simonetta	Fumagalli	ENEA	Italian
Andrea	Harrer	BAM Federal Institute for Materials Research and	German
Casper	Kofod	Energy piano - consultant for DEA	Danish
Catherine	Lootens	KU Leuven, Light&Lighting Laboratory - Groen Licht	Belgium
Nicole	Loysch	Neonlite International LTD	Belgium
Felix	Mailleux	CECED	Belgium
Kees	van Meerten	Lighting Europe / PHILIPS Lighting	Dutch
Christoph	Mordziol	Umweltbundesamt (Federal Environment Agency)	German
Anders	Øbro	AF Lighting / Representing DEA	Denmark
Laura	Pereira	ICF International	Brazilian
Michael	Scholand	CLASP	United
Bram	Soenen	Belgian Administration Environmental Product	Belgian
Fabrizio	Tironi	LightingEurope/Flos	Italian
Francisco	Zuloaga	Topten	Spanish
Rene	Kemna	VHK	Dutch
Leo	Wierda	VHK	Dutch
Paul	van Tichelen	VITO	Belgium
Stuart	Jeffcott	Jeffcott Associates	British
Ruben	Kubiak	European Commission	German

Annex C Luminaire Light Output Ratio, examples

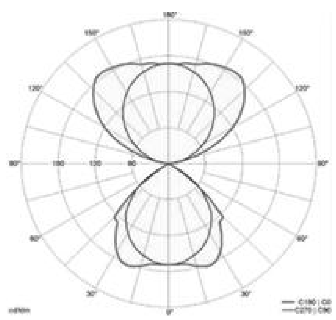
Lamp: PH 5
Manufacturer: Louis Poulsen
Design: Poul Henningsen (1958)
Light source: Incandescent/CFL.
Light Output Ratio (1958): 19 %
Light Output Ratio (2015, improved): 36-41 %



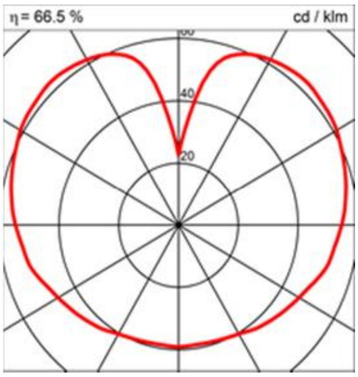
Flatliner Pendant luminaire (FL- 2 x 24/36W)

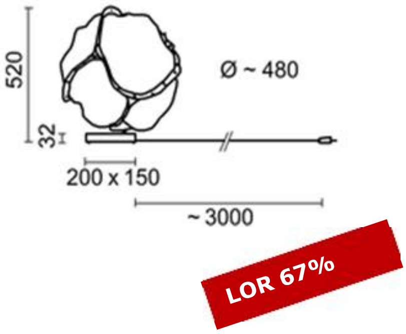


Semi-indirect office Luminaire

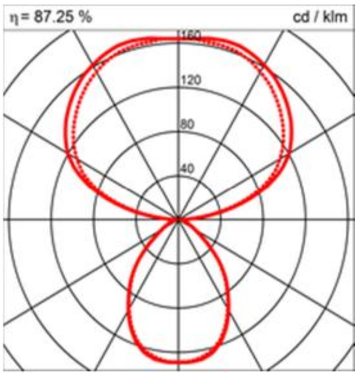


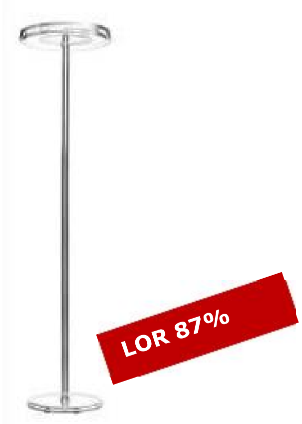
Semi-indirect office Luminaire (LED)

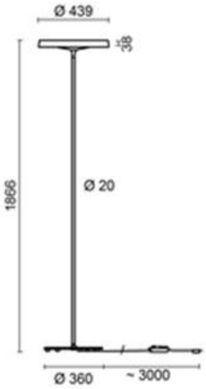




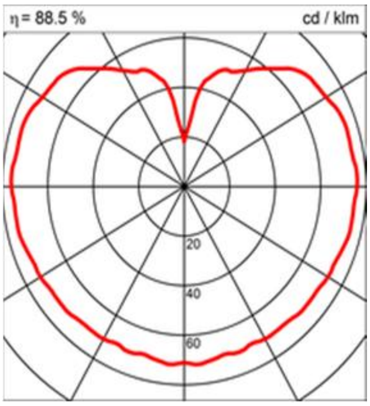
Shaded light object

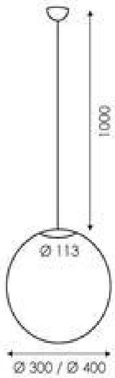




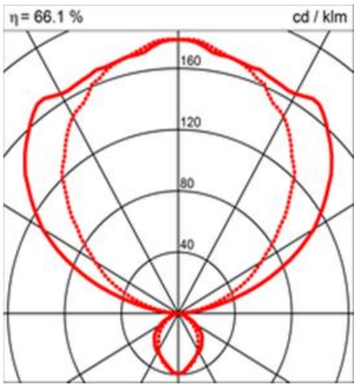


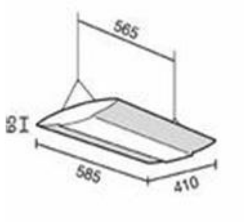
Semi-indirect torchiere



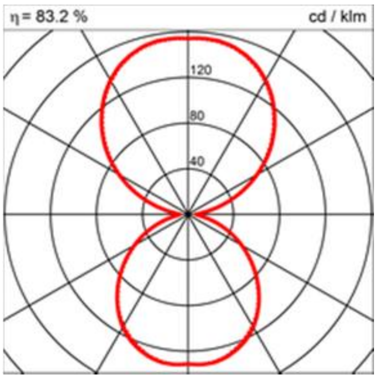


Pendant Luminaire (MV HL 70W)

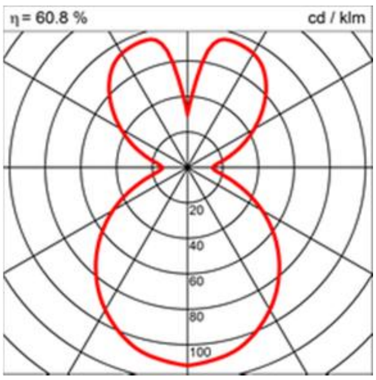




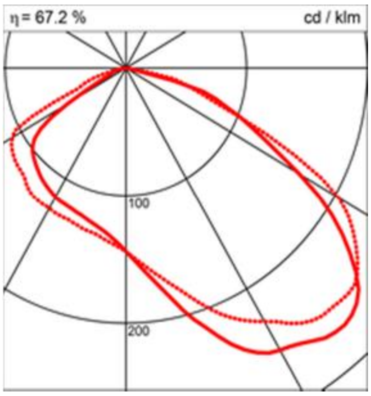
Semi-indirect office Luminaire (LFL)



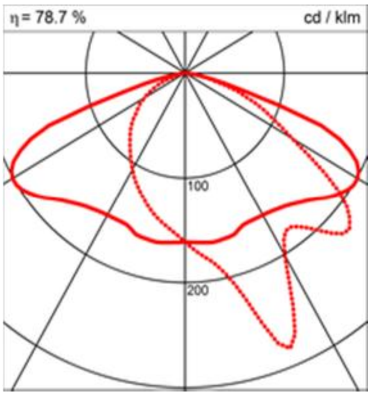
Lamp shade luminaire

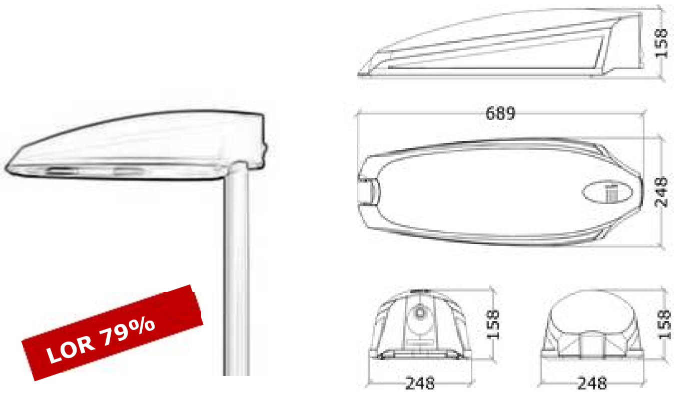


Direct (white) + indirect (colour) downlight

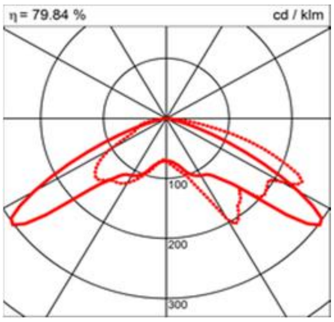


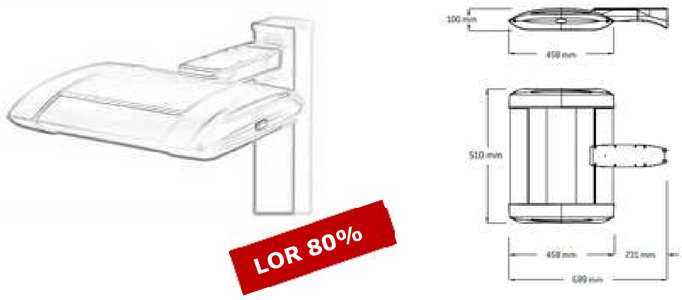
Urban lighting fitting, lower part: HID-MH 150W



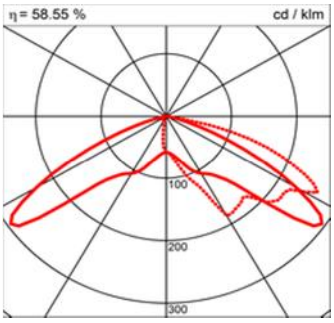


Luminaire for street lighting Application, HID-MH 100W





Street light (120 x LED, 129W)



Street light (LED, 45W)

Annex D Description of MELISA

D.1 Introduction

The ‘Model for European Light Sources Analysis’ was first introduced in the draft Task 2 report (MELISA version 0). For use in the scenario analysis of Task 7 the model has evolved, and the main changes in MELISA version 1 are:

- Extension to 2030.
  Version 0 covered the period 1990-2013. The new version extends this to 2030 to enable the scenario analysis [53].

- Input flexibility.
  In version 0, at least for the non-LED base cases, all input parameters (e.g. lifetime, capacity, efficacy, price) had a single value valid for all years. For the scenario and sensitivity analyses more flexibility is required. In particular it should be possible to change parameter values in the period 2013-2030 without affecting their values in the period 1990-2013.
  In the new version all input parameters can be defined per year. This involved a major change in the input-section of MELISA: the central input sheet Life&Use of version 0 has disappeared, and input-parameters are now defined per year on separate sheets for each of the base cases.

- Shift of sales to LED.
  A major part of the scenario analyses is based on the shift of sales from classical lamp technologies to LEDs. The LED light sources are modelled to have the same annual operating hours and the same capacity (lm) as the light sources that they replace, except for rebound factors.
  In version 0 this shift in sales was not explicit and the determination of the average LED operating hours and capacity was not implemented in Excel, requiring manual calculations for each new sales-shift assumption.
  This has been significantly improved in version 1, as explained further below.

- LED base cases.
  In MELISA v0 there were two LED base cases: LED NDLS and LED DLS. Stakeholders requested that a distinction should be made between professional lamps and consumer lamps, and that LED retrofit lamps should be considered separately from integrated LED luminaires.
  This request has been implemented in MELISA version 1, that distinguishes LEDs for former LFL-applications, HID-applications, CFLni-applications, NDLS-applications and DLS-applications. In addition, each of these five groups is split in retrofit lamps and integrated luminaires.
  This further subdivision of the LED base case also helped in making sales-shifts more explicit (see previous point).

- Standby and Controls.
  MELISA v0 considered the energy consumption in standby and the energy consumption of controls only on the Energy sheet. These data were direct input values and not traceable to the underlying assumptions.

[53] The model actually covers the period up to 2050, but in most cases results are presented only for the period 1990-2030.

This has been improved in version 1. The standby power and annual standby hours are now separate inputs. An additional power when lights are on can also be defined to cover consumption by sensors, controls, etc. [54]

- Installation and Maintenance Cost.
  MELISA v0 did not consider installation costs and maintenance/repair costs. These costs were taken into account in the Task 5 and 6 reports and they can now also be defined in MELISA v1.

- Change of data reported in previous Tasks.
  Outcomes of MELISA v0 for the period 1990-2013 have been reported in Tasks 2, 3 and 4 and these data were then used in Tasks 5 and 6. These data have been compared with those from other sources (see Tasks 2 and 3) and they were critically reviewed by the study team itself (Tasks 2, 3, 4). In few cases comments from stakeholders have been received.
  As a consequence, in MELISA v1 some of the data for the 1990-2013 period have been adapted, leading to (minor) differences between the values reported in this Task 7 and values reported in earlier Task reports, see details in Annex D.

- Preparation for use in the Lighting Systems study.
  MELISA is intended both for use in the ecodesign preparatory study on light sources (Lot 8/9/19) and for use in the ecodesign preparatory study on lighting systems (Lot 37). In particular, the latter study should be able to start from the scenarios in the former study and then verify what additional impact savings can be obtained from improvements in the lighting systems. New parameters have been introduced in the model to enable such an approach. These parameters are exclusively for use in the systems study.

D.2 MELISA version 1, overview

The Excel model for MELISA v1 contains the following sheets:

0 'General Input'
0 'Option Control'
0 'Scenario Summary 1'
0 'Scenario Summary 2'

1 'LFL T12', 'LFL T8h', 'LFL T8t', 'LFL T5', 'LFL X'
2 'LED retro for LFL', 'LED lum for LFL'
3 'LFL Overview'

1 'HPM', 'HPS', 'MH'
2 'LED retro for HID', 'LED lum for HID'
3 'HID Overview'

1 'CFLni'
2 'LED retro for CFLni', 'LED lum for CFLni'

[54] However, in the baseline scenario analyses, standby power and additional power of controls have not been considered. The possibility to insert these data has been used in sensitivity analysis only.

3 'CFLni Overview'

1 'HL LV R', 'HL MV X (DLS)', 'GLS R (DLS)'
2 'LED retro for DLS', 'LED lum for DLS'
3 'DLS Overview'

1 'CFLi', 'HL MV E (NDLS)', 'GLS X (NDLS)', 'HL LV C', 'HL MV C', 'HL MV L'
1 'GLS Storage', 'HL Storage'
2 'LED retro for NDLS', 'LED lum for NDLS'
3 'NDLS Overview'

4 'Sales', 'Stock', 'Lumen', 'Power', 'Hours', 'Load', 'Energy 1', 'Energy 2'
4 'Market 1', 'Market 2', 'EnergyCost', 'RunCost', 'Expense 1'

Sheet 'General Input' (dark blue label in Excel)

This sheet contains input data that is used for all base cases or for more than one base case:

- Hours in a year
- Percentage VAT
- Hourly Labour Cost
- Electricity prices (residential, non-residential, escalation rate)
- Relationships between revenues and number of jobs involved
- Global Warming Potential (GWP) for electricity
- Growth rates (residential, non-residential) -> number of new applications
- Common data for High-End LED lamps (efficacy, control gear efficiency, price) [55]
- Common data for Low-End LED lamps (efficacy, control gear efficiency, price)
- Maximum lifetime for lamps (residential, non-residential) [56]

Sheet 'Option Control' (dark blue label in Excel)

This sheet centralizes the input required to get the different scenarios.

For each base case the BAU, ECO70, ECO80+120 or ECO120 scenario can be chosen. This choice will lead to different shifts in sales towards LEDs, reflecting the influence of ecodesign measures. A feedback of the sales shifts is presented on the sheet Option Control.

In addition the effect of labelling measures can be defined by choosing between different LED efficacy curves and corresponding price curves. The choice can be made separately for High-End LEDs and for Low-End LEDs.

[55] Data for High-End LED lamps are applied to lamps with high annual operating hours:
- LFL sold in the non-residential sector
- CFLni sold in the non-residential sector
- HID lamps (assumed sold only in the non-residential sector)

Data for Low-End LED lamps are applied to lamps with low annual operating hours:
- GLS, HL and CFLi sold in any sector
- LFL sold in the residential sector
- CFLni sold in the residential sector

[56] The computed lifetime in years can be limited to a maximum value. This can be used in particular to avoid the very long lifetime of residential LEDs of 40 years or more, that could be considered as unrealistic.

Sheet 'Scenario Summary 1' (dark orange label in Excel)

This sheet summarizes all data for the current scenario and for the saved (fixed) values of the BAU scenario. The difference between the current scenario and the BAU scenario is also displayed.

Sheet 'Scenario Summary 2' (dark orange label in Excel)

This sheet provides spaces to save the data for up to six different scenarios. Comparison tables between the various scenarios are derived from these data: absolute values for all scenarios, relative values as ECO-BAU (savings) and relative values of any scenario with respect to the BAU scenario in 2015 (BAU2015=100%). Cumulative savings for energy, GHG emissions and total expenses are also computed on this sheet. The data are presented for years 2015, 2020, 2025 and 2030. This sheet has been used to produce the summary tables presented in the report.

Sheets for non-LED base cases (blue label in Excel; code '1' in list above)

Each non-LED base case [57] has a separate sheet in the Excel model. All the input for the base case has to be provided on this sheet (fields indicated by cyan coloured background) and the calculations for the base case are also performed here (fields with white background; italic font).

All sheets have the same structure, with the same parameters, on the same row numbers. The sheets have a Residential section, a Non-Residential section, an All Sectors section (sum of Residential and Non-Residential), and an Options section.

As part of the calculations, these sheets determine the quantity of light sources required in each year following 2013, as the sum of lamps reaching end-of-life and lamps for new applications. In the Options section the user has to define what part of these required lamps will be LEDs (retrofit or luminaire) and what part will remain classic technology.

See section D.3 for further details.

Sheets for LED base cases (green label in Excel; code '2' in list above)

For each group of lighting applications (LFL, HID, CFLni, NDLS, DLS) two LED base cases are distinguished, one for retrofit lamps and one for integrated LED luminaires. The corresponding Excel sheets have the same structure, parameters and row numbers as those for the non-LED base cases. The main differences are:

- Light source efficacy, control gear efficiency, and lamp price are taken from the sheet 'General Input' (following a choice on sheet 'Option Control').
- Sales are determined from lamps reaching end-of-life, from lamps for new applications, and, most importantly, from lamps replacing classic technology lamps (sum of sales-shift-data on the non-LED sheets in the same group).
- Operating hours, Standby hours (h/a) and Capacity (lm) are determined as the weighted average of those for the lamps that are being replaced. The Options section of the sheet allows the definition of a rebound factor (that can also be used to introduce other correction factors for the hour- and lumen-equivalence).

See section D.4 for further details.

Overview sheets per application group (orange label in Excel; code '3' in list above)

For each group of lighting applications (LFL, HID, CFLni, NDLS, DLS) an overview sheet summarizes the EU-28 total data for that group. These sheets do not require input. The

---

[57] The base cases are the same as used in the other Tasks, see Task 4 report Table 3 for a survey.

information from the non-LED and LED base cases of the group is copied here and then summed. The parameters reported are the EU-28 group-totals for: Sales, Stock, Capacity, Hours, Power, Load, Energy, Market, Energy Cost, Running Cost and Consumer Expense. These parameters are reported separately for the Residential sector, the Non-residential sector, and the sum of both (All sectors). For the latter, graphs are also presented.

Overview sheets per parameter (purple label in Excel; code '4' in list above)

These sheets provide the EU-28 totals per parameter, for the sum of all application groups. The tables and graphs are the same as presented in the Task 2 and Task 3 reports, but extended to 2030.

The main difference with MELISA v0 is that data are no longer calculated on these sheets: they are copied from other sheets and then summed up.

D.3 Description of the sheets for the non-LED base cases

Each non-LED base case has a separate sheet in MELISA on which all associated input is defined and on which the calculations are made.

All sheets are identical as regards structure, parameters and row numbers.

The sheets have four sections for the Residential sector, the Non-residential sector, the sum of both (All sectors), and Options.

Input fields have a cyan background. Calculated fields have a white background and italic font.

	LFL T8t	info			2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
	RESIDENTIAL																
RES	Lifetime (Lh)	info	info	h	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000
RES	*potential lighting hours (tpot)*	info		h/a	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*
RES	Hour factor (Fhour)	info		%						100%	100%	100%	100%	100%	100%	100%	100%
RES	full power equivalent hours (tfpe)	info		h/a	700	700	700	700	700	700	*700*	*700*	*700*	*700*	*700*	*700*	*700*
RES	standby during tpot-tfpe (SBpot)	info		%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
RES	standby during 8760-tpot (SBnpot)			%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
RES	*standby hours (tsb)*	info		h/a	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
RES	*Lifetime (Ly)*	info		yr	*18.6*	*18.6*	*18.6*	*18.6*	*18.6*	*18.6*	*18.6*	*18.6*	*18.6*	*18.6*	*18.6*	*18.6*	*18.6*
RES	reference luminous flux (phiref)	info		lm	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400
RES	Flux factor (Fphi)	info		%							100%	100%	100%	100%	100%	100%	100%
RES	*installed luminous flux (phi)*	info		lm	*2400*	*2400*	*2400*	*2400*	*2400*	*2400*	*2400*	*2400*	*2400*	*2400*	*2400*	*2400*	*2400*
RES	luminous efficacy, average (LSeffavg	info	info	lm/W	80	80	80	80	80	80	80	80	80	80	80	80	80
RES	*light source power (Pls)*	info		W	*30*	*30*	*30*	*30*	*30*	*30*	*30*	*30*	*30*	*30*	*30*	*30*	*30*
RES	*external control gear efficiency (CGef*	info	info	%	*85%*	*85%*	*85%*	*85%*	*86%*	*85%*	*87%*	*88%*	*88%*	*89%*	*90%*	*90%*	*91%*
RES	additional power during tfpe (Padd)	info		W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RES	standby power during tsb (Psb)	info		W	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
RES	purchase price (2010, incl. VAT)	info		€	10.10	10.10	10.10	10.10	10.10	10.10	10.10	10.10	10.10	10.10	10.10	10.10	10.10
RES	share industry			%	66%	66%	66%	66%	66%	66%	66%	66%	66%	66%	66%	66%	66%
RES	share wholesale			%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
RES	*share retail*			%	*7%*	*7%*	*7%*	*7%*	*7%*	*7%*	*7%*	*7%*	*7%*	*7%*	*7%*	*7%*	*7%*
RES	*share VAT*			%	*17%*	*17%*	*17%*	*17%*	*17%*	*17%*	*17%*	*17%*	*17%*	*17%*	*17%*	*17%*	*17%*
RES	installation costs	info		€	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RES	repair & maintenance costs	info		€/a	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 32 Extract 1 from a sheet for a non-LED base case. The example is for the LFL tri-phosphor base case and for the residential part, but the structure and the parameters are the same for other lamp types and for the non-residential sector. On the full sheet, years are from 1990 to 2030 (with hidden extensions back to 1974 for some parameters)

Figure 32 shows a first partial extract for LFL tri-phosphor, residential section, but the parameters are the same for other lamp types and for the non-residential section. All parameters can be defined in function of the years. A description of the parameters follows.

Lifetime (Lh, Input, in hours):

Average useful lifetime of the base case light source, after which it is replaced.

For further information see Task 3 report, par. 3.3.

Full power equivalent hours (tfpe, Input, in hours/year):

These are the annual hours with light sources emitting at least some light, that, when multiplied by the installed (full) power Pls, provide the correct annual energy consumption.

Example: if lights burn at full power for 450 h/a, and dimmed at 40% lumen output corresponding to e.g. 50% power consumption for 100 h/a, tfpe = 450 +100*0.5 = 500 h/a.

For further information see Task 3 report, par. 3.2.

For year 2013 and before, tfpe is an input parameter.

For later years tfpe=tpot*Fhour, where tpot are the potential annual lighting hours (compare daytime hours td + night-time hours tn from EN15193, but values used are different from EN15193) and Fhour (hour factor) is the ratio tfpe/tpot. In the Lot 8/9/19 light sources study Fhour=1 (100%) and consequently tfpe = tpot [58].

Standby hours (tsb, Input, in hours/year):

These are the annual hours with light sources NOT emitting any light, but in standby. The quantity is NOT calculated as suggested in prEN15193 [59], but as SBpot*(tpot-tfpe) + SBnpot*(8760-tpot), where the model user has to provide:

- SBpot, the percentage of the time tpot-tfpe during which lights are off (i.e. not dimmed) but standby power is consumed.
- SBnpot, the percentage of the time 8760-tpot during which lights are off (per definition) but standby power is consumed.

In the Lot 8/9/19 study tpfe=tpot so that only SBnpot is relevant.

As average standby hours are largely unknown, this feature of the model is mainly intended to be used for sensitivity analyses.

If not explicitly stated otherwise, SBnpot =0 % (-> tsb= 0 h) has been assumed.

Lifetime (Ly, Computed, in years):

Average useful lifetime in years of the base case light source, after which it is replaced.

[58] Fhour has been introduced in the model for use in the Lot 37 lighting systems study. It can be used to express the reduction in *tfpe* as compared to the current situation due to improvements in lighting controls (constant illuminance dimming, increased daylight use, light management during non-occupancy of rooms).

[59] EN15193 considers *8760 - tpot* to be the standby hours in a year, to be multiplied by the standby power consumption. This is generally NOT correct:
- during a fraction of *tpot* lights may be off because of daylight use or non-occupancy, while standby power is consumed (not counted in EN15193).
- during a fraction of *8760-tpot* the whole lighting system might be off so that not even standby power is being consumed (wrongly counted in EN15193).

Computed as Ly = Lh / tfpe, but limited to the maximum lifetime that can be specified on the sheet 'General Input' [60].

For further information see Task 3 report, par. 3.3.

Luminous Flux (phi, Input, in lm):

This is the average initial rated flux for the base case lamp, corresponding to the rated power of the light source in standard testing conditions.

The flux should be such that when divided by the light source efficacy it gives the full power Pls that when multiplied by the full-power equivalent hours tfpe gives the correct energy consumption.

For directional lamps, either the total flux or the flux in a 90° or 120° cone can be used, as long as efficacy is compatible and lumen-equivalence with lamp substitutes is handled consistently. In principle, MELISA v1 now uses the flux in a cone [61], but see remarks on the DLS base cases for details.

A distinction is made between a reference flux phiref and the actually installed flux phi.

For years up to 2013, phi = phiref.

For years 2014 and later, phi = phiref * Fphi.

The Flux Factor Fphi is intended for use in the Lot 37 lighting systems study to express the effect of design improvements. In particular, if lighting layout, luminaire design, or surface reflectance are improved, less light source flux could be installed to have the same light level in the task area. In the Lot 8/9/19 study Fphi=1 (100%) [62].

For further information see Task 3 report, par. 3.5.

Luminous Efficacy (LSeff, Input, in lm/W):

This should be the average initial efficacy for the base case light source in standard testing conditions, such that dividing the luminous flux by the efficacy yields the correct (full) power consumption.

The efficiency of external control gears should NOT be taken into account here.

For directional lamps the efficacy should be compatible with the flux definition.

For further information see Task 3 report, par. 3.6.

Light Source Power (Pls, Computed, in W):

This is the average rated power for the base case lamp in standard test conditions and assumed to be the actually consumed power by the light source alone when no dimming is applied. Any dimming effects should be expressed through tfpe.

External ballast power, power consumption by controls, and standby power is excluded.

Computed as Pls = phi / LSeff

For further information see Task 3 report, par. 3.4.

External Control Gear Efficiency (CGeff, Input, in %):

For lamps with integrated control gear the efficiency should be included in the value for the luminous efficacy of the light source. For these lamps CGeff should be put to 100%.

The light source power Pls will be divided by CGeff to get the total power during the time tfpe.

---

[60] Note that this assumes that the useful lifetime depends linearly on the full power equivalent hours. This is not necessarily true for all lamp types, but an acceptable approximation, considering other uncertainties regarding lifetimes.

[61] This is different from the approach followed in MELISA v0.

[62] This factor should NOT be used if the number of light sources is reduced due to design improvements while each light source more or less has the same flux as before: that should be expressed by means of the Sales factor.

For further information see Task 3 report, par. 2.7.

Additional Power during tfpe (Padd, Input, in W):

Additional power consumption during the time tfpe, not included in the light source power, nor considered in the external control gear efficiency. Power consumed by e.g. control devices like dimmers and sensors when light sources are emitting at least some light.

Note that this power will be multiplied by tfpe and by the quantity of light sources in the stock. The input should be given accordingly.

If not explicitly stated otherwise, Padd=0 W has been assumed.

Standby Power during tsb (Psb, Input, in W):

This should be the total power consumed during the standby time tsb, by the light source itself, by control gears, dimmers, sensors, network communications, etc.

As this is multiplied by the light source stock, the standby power should be provided per light source.

If not explicitly stated otherwise, Psb=0.5 W has been assumed, but see also tsb.

Purchase price (Price, Input, in euros/unit):

The average prices for the base case should be provided in fixed 2010 euros per light source (inflation corrected and not discounted).

For residential use the VAT defined on the sheet 'General Input' should be included.

For non-residential use VAT should be excluded.

Installation costs should be excluded (they are defined separately).

In principle, costs for external control gears, luminaire costs, and costs of control devices should be excluded.

For further information see Task 2 report, par. 2.3.

Shares (Input or Computed, in %):

The user has to provide the shares of the Price that form revenue for Industry and for the Wholesale sector. The program will compute the VAT share (=VAT%/(100+VAT%) for residential and 0 % for non-residential) and then compute the share for the Retail sector as 100 – Industry share – Wholesale share – VAT share %.

Revenues for the sectors are computed from these data, and this is linked to the number of jobs involved trough the conversion factor defined on sheet 'general Input'.

For further information on Industry shares see Task 2 report, par. 2.5.

Installation Cost (Input, in euros/unit):

The installation costs for the base case should be provided in fixed 2010 euros per light source (inflation corrected and not discounted). The Hourly Labour Costs defined on the sheet 'General Input' should be used as part of the input.

For further information see Task 3 report, par. 7.5 and the base case descriptions in the Task 4 report. Zero installation costs are considered for the residential sector.

Maintenance and Repair Cost (Input, in euros/unit/year):

The maintenance costs for the base case should be provided in fixed 2010 euros per light source per year (inflation corrected and not discounted). The Hourly Labour Costs defined on the sheet 'General Input' should be used as part of the input.

For further information see Task 3 report, par. 7.5 and the base case descriptions in the Task 4 report. Zero maintenance costs are considered for the residential sector.

Sales

Figure 33 shows a second partial extract for LFL tri-phosphor, residential section, sales-related parameters. The parameters are the same for the non-residential section, and similar for other lamp types.

Sales up to year 2013 (Input for All sectors, in mln units)

In the same way as in MELISA v0, for the years 1990-2013, the total sales for All sectors are the input values (not shown in the figure), while the residential sales and non-residential sales are defined as a share of the total sales.

If not explicitly stated otherwise, the sales are the same as those presented in the Task 2 report.

	LFL T8t	info			2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
RES	residential sales fraction	info			0.064	0.064	0.064	0.064	0.064	0.064							
RES	Sales Factor	info		%							100%	100%	100%	100%	100%	100%	100%
RES	EU-28 Residential Sales (units)	info		mln	10	11	14	16	17	16	15.8	10.8	9.5	7.8	6.3	4.9	3.4
RES	Year in which Lamps reach EoL	info			2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
RES	Lamps reaching EoL	info		mln			4.7	4.9	5.0	5.2	5.4	5.5	5.7	5.9	6.2	6.5	6.6
RES	Lamps for new applications	info		mln			3.8	5.0	5.5	4.3	3.4	2.5	2.5	2.2	2.1	1.9	1.6
RES	Lamps substituting LFL T12			mln			2.1	2.1	2.0	1.7	1.5	1.3	1.1	1.0	0.8	0.7	0.6
RES	Lamps substituting LFL T8h			mln			8.4	12.1	13.5	12.6	12.4	12.7	12.1	11.4	10.5	9.7	8.2
RES	% sales maintaining current type		info	%			79%	78.7%	80.0%	76.5%	70%	50%	44%	38%	32%	26%	20%
RES	% sales shifted to LFL T5		info	%			21%	20.5%	17.5%	17.5%	10%	8%	6%	5%	4%	3%	0%
RES	% sales shifted to LED retrofit		info	%			0%	0.7%	1.5%	4.0%	12%	25%	29%	32%	35%	37%	40%
RES	% sales shifted to LED luminaire		info	%			0%	0.1%	1.0%	2.0%	8%	17%	21%	25%	29%	34%	40%
RES	sales current type (units)			mln			15.1	28.9	20.8	18.2	15.8	10.8	9.5	7.8	6.3	4.9	3.4
RES	sales shifted to LFL T5			mln			4.0	4.9	4.6	4.2	2.3	1.7	1.3	1.0	0.8	0.6	0.0
RES	sales shifted to LED retrofit (units)			mln			0.0	0.2	0.4	1.0	2.7	5.4	6.2	6.6	6.8	6.9	6.8
RES	sales shifted to LED luminaire (units)			mln			0.0	0.0	0.3	0.5	1.8	3.6	4.5	5.2	5.8	6.4	6.8

Figure 33 Extract 2 from a sheet for a non-LED base case. The example is for the LFL tri-phosphor base case and for the residential part, but the structure and the parameters are the same for other lamp types and for the non-residential sector. On the full sheet years are from 1990 to 2030 (with hidden extensions back to 1974 for some parameters)

Sales after year 2013 (Computed, in mln units)

For the years 2014-2030, the model first computes the potential sales, separately for the residential and the non-residential sector, as the sum of:

- Lamps of the base case type that reach their average end-of-life in the given year (EoL lamps),
- New applications similar to those using the base case type of lamp (New lamps),
- Lamps of other technologies that are being replaced by those of the current base case, if any (in the example of the LFL T8t shown in Figure 33, these are quantities of LFL T12 and LFL T8h lamps that have been determined on the sheets for those base cases).

These potential sales are then subdivided according to a scenario (% shares) over:

- Lamps maintaining the current base case type (if still for sale),
- Lamps being substituted by another non-LED type (in the example of the LFL T8t shown in Figure 33, there are sales shifting to LFL T5),
- Lamps being substituted by LED retrofit lamps,
- Lamps being substituted by integrated LED luminaires.

Three scenarios (blue percentages in Figure 33 are for the chosen scenario) can be defined by the user in the Options section of the sheet with the choice being made on the sheet 'Option Control'.

The base case sales are then computed as:

Sales = Potential Sales * Share maintaining current type * Sales Factor.

For the Lot 8/9/19 study the Sales Factor is always 1 (100%). The Sales Factor has been introduced for use in the Lot 37 lighting systems study to express that improvements in lighting system layout and improvement in luminaire design can lead to installing less light sources than before. See also earlier remarks on the Flux Factor.

The shares of potential sales covered by other lamp types are transferred to the corresponding sheets.

Lamps reaching End-of-Life (Computed, mln units)

For any sales year X, the program determines the future year Y in which the lamps sold in year X will reach their average end-of-life, using year Y = year X + Lifetime (Ly) (see row 'Year in which Lamps reach EoL').

For a sales year Y in the period 2014-2030, the program will then search back the row 'Year in which Lamps reach EoL' for the appearance of year Y and find the corresponding sales in year X, which will be taken as the 'Lamps reaching EoL' in year Y [63].

Lamps for new applications (Computed, mln units)

The quantity of new applications, similar to those for which the base case type lamps are used, is computed as:

New lamps (year Y) = Stock (year Y-1)*Growth% (year Y)

The growth percentage is taken from the definitions on the sheet 'General Input', for the residential sector or for the non-residential sector.

Stock, Stock averages, and EU-28 totals

Figure 34 shows a third partial extract for LFL tri-phosphor, residential section, for calculated parameters, i.e. the installed stock, average parameter values for the stock, and EU-28 total values. The parameters are the same for the non-residential section, and for other lamp types.

[63] The underlying Excel formulas are rather complex and not discussed here in detail. Lifetimes containing fractions of years are also taken into account. When lifetimes are made to be variable with the years, some years may appear more than once on the row 'Year in which Lamps reach EoL' while others may not appear at all. In these cases the program will still work, but the quantity of EoL lamps may be approximate.

	LFL T8t	info		2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
RES	stock average luminous flux		lm	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400
RES	stock average efficacy		lm/W	80	80	80	80	80	80	80	80	80	80	80	80	80
RES	stock average power		W	30	30	30	30	30	30	30	30	30	30	30	30	30
RES	stock average CG efficiency		%	83%	83%	83%	84%	84%	84%	85%	85%	85%	85%	86%	86%	86%
RES	stock average additional power		W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RES	stock average standby power		W	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
RES	***EU-28 Residential Stock (units)***		**mln**	**119**	**126**	**135**	**146**	**158**	**168**	**179**	**184**	**188**	**190**	**190**	**188**	**185**
RES	Installed Luminous Flux	info	Tlm	0.29	0.30	0.32	0.35	0.38	0.40	0.43	0.44	0.45	0.46	0.46	0.45	0.44
RES	Installed Power (excl. control gear)		GW	3.6	3.8	4.0	4.4	4.7	5.1	5.4	5.5	5.6	5.7	5.7	5.6	5.5
RES	Operating hours	info	Th/a	0.08	0.09	0.09	0.10	0.11	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.13
RES	Lumen Hours	info	Tlmh/a	200	211	226	246	265	283	300	309	315	319	319	316	311
RES	***Total Electric Energy***	info	**TWh/a**	**3.02**	**3.18**	**3.40**	**3.67**	**3.95**	**4.20**	**4.44**	**4.56**	**4.64**	**4.67**	**4.66**	**4.61**	**4.52**
RES	o/w Light Source Energy	info	TWh/a	2.50	2.64	2.83	3.07	3.31	3.54	3.76	3.87	3.94	3.98	3.98	3.95	3.88
RES	o/w Control Gear Energy (lights on)	info	TWh/a	0.52	0.54	0.57	0.60	0.63	0.66	0.69	0.69	0.69	0.69	0.67	0.66	0.63
RES	o/w Other Energy (lights on)	info	TWh/a	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RES	o/w Standby Energy	info	TWh/a	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RES	***Total Initial Consumer Costs, incl. VAT***	info	**mln €**	**99**	**113**	**140**	**164**	**169**	**159**	**160**	**109**	**96**	**79**	**63**	**49**	**34**
RES	o/w Industry Revenue	info	mln €	65	75	92	108	111	105	105	72	63	52	42	32	23
RES	o/w Wholesale Revenue	info	mln €	10	11	14	16	17	16	16	11	10	8	6	5	3
RES	o/w Retail Revenue	info	mln €	7	8	10	12	12	12	12	8	7	6	5	4	3
RES	o/w Value Added Tax	info	mln €	16	19	23	27	28	26	27	18	16	13	11	8	6
RES	o/w Installation Cost, incl. VAT	info	mln €	0	0	0	0	0	0	0	0	0	0	0	0	0
RES	***Total Running Costs, incl. VAT***	info	**mln €**	**511**	**531**	**577**	**650**	**726**	**802**	**882**	**942**	**996**	**1043**	**1082**	**1113**	**1135**
RES	o/w Electricity costs, incl. VAT	info	mln €	511	531	577	650	726	802	882	942	996	1043	1082	1113	1135
RES	o/w Maintenance costs, incl. VAT	info	mln €	0	0	0	0	0	0	0	0	0	0	0	0	0
RES	***Total Annual Consumer Expense***	info	**mln €**	**609**	**644**	**717**	**814**	**895**	**960**	**1042**	**1050**	**1092**	**1122**	**1146**	**1162**	**1169**

Figure 34 Extract 3 from a sheet for a non-LED base case. The example is for the LFL tri-phosphor base case and for the residential part, but the structure and the parameters are the same for other lamp types and for the non-residential sector. On the full sheet years are from 1990 to 2030 (with hidden extensions back to 1974 for some parameters)

EU-28 total installed stock (Computed)

For years 1990-2013, the EU-28 total installed stock for a base case light source is computed from the sales in the preceding years, considering the lifetime in years (Ly) for the type of lamp. Decimal years are also taken into account. This is the same approach as in MELISA v0.

The formula implemented in the MELISA Excel-file to compute the stock is quite complex and difficult to understand, but at the end, the stock is simply the sum of sales over a number of preceding years that corresponds to the life in years of the lamp-type:

$$\text{Stock (year N)} = \left\{ \sum_{N-INTlife+1}^{N} Sales\ year \right\} + \text{DEClife} * Sales\ N - INTlife$$

where INTlife = integer part of the lamp life in years

DEClife = decimal part of the lamp life in years

For example, if the year considered is N=2013 and the life in years for the lamp type has been computed as 3.2 years (INTlife=3 and DEClife=2): Stock (2013) = Sales(2013)+Sales(2012)+Sales(2011)+0.2*Sales(2010)

For years 2014-2030 the new stock is computed from the one in the preceding year by considering the variations in that year:

$$\text{Stock (year N)} = \text{Stock (year N-1)} + \text{Sales (year N)} - \text{EoL lamps (year N)}$$

Stock average data (Computed)

In cases where luminous flux, power or efficacy vary with the years, the stock in a given year is a mix of light sources with different characteristics.

For the years 1990-2013, the average characteristics of the stock are calculated as sales-weighted averages over a period corresponding to the lifetime of the light sources. The formula is similar to the one used for the stock calculation:

Stock Average Parameter (year N) =

$$[\ \{ \textstyle\sum_{N-INTlife+1}^{N} Sales\ year\ * Parameter(year)\ \}$$
$$+\ \text{DEClife} * Sales\ N - INTlife\ * Parameter\ N - INTlife\ \}\ ]$$
$$/\ \text{Stock (year N)}$$

Where 'Parameter' can be luminous flux, efficacy, power, external control gear efficiency, additional power (controls), or standby power [64].

For the years 2014-2030, the new average stock characteristics in year N are computed from those in the previous year N-1 by considering the variations in year N, similar to what is done in the calculation for the stock:

Stock Average Parameter (year N) =
[Stock (year N-1) * Stock Average Parameter (year N-1)
+ Sales (year N) * Sales Average Parameter (year N)
– EoL lamps (year N) * Average Parameter of EoL lamps]
/ Stock (year N)

EU-28 totals for the base case (Computed)

The EU-28 totals for the base case stock in a given year N are computed as follows [65]:

EU-28 total installed luminous flux (N) [Tlm] =
Stock (N) [mln units] * Stock Average luminous flux (N) [lm/unit] *1E-6

EU-28 total installed power (N) [GW] =
Stock (N) [mln units] * Stock Average power (N) [W/unit] *1E-3 [66]

EU-28 total operating hours (N) [Th/a] =
Stock (N) [mln units] * Full-power equivalent hours (N) [h/a/unit] *1E-6

EU-28 total lumen-hours (N) [Tlm.h/a] =
EU-28 total installed flux (N) [Tlm] * Full-power equivalent hours (N) [h/a/unit]

Energy-related EU-28 totals for the base case (Computed)

EU-28 total light source energy (N) [TWh/a] =
EU-28 total operating hours (N) [Th/a] * Stock average power (N) [W/unit]

EU-28 total control gear energy (N) [TWh/a] =

---

[64] Stock averages for control gear efficiency, for additional power of controls, and for standby power are weighted averages using the light source sales as a weighting factor. This is a coarse approximation because control gears and control devices typically have longer lifetimes, and less efficient / higher power devices would remain longer in the stock. The alternative would be to define the input for these 3 parameters directly as stock-averages.

[65] The totals are computed separately for the residential sector and the non-residential sector and the two contributions are then summed to obtain the All sectors total for the base case.

[66] This is for the light source alone, excluding external control gear

EU-28 total light source energy (N) [TWh/a] * (1 / Stock average control gear efficiency (N) [%] -1) [67]

EU-28 total additional energy (N) [TWh/a] =
EU-28 total operating hours (N) [Th/a] * Stock average additional power (N) [W/unit] [68]

EU-28 total standby energy (N) [TWh/a] =
Stock (N) [mln units] * Standby Hours (N) [h/a] * Stock average standby power (N) [W/unit] *1E-6

EU-28 total electric energy for base case (N) [TWh/a] =
Total light source energy (N) [TWh/a] +
Total control gear energy (N) [TWh/a] +
Total additional energy (N) [TWh/a] +
Total standby energy (N) [TWh/a]

Market-related EU-28 totals for the base case (Computed)

EU-28 total industry revenue (N) [mln euros] =
Sales (N) [mln units] * Price (N) [euros/unit] * Industry share (N) [%]

EU-28 total wholesale revenue (N) [mln euros] =
Sales (N) [mln units] * Price (N) [euros/unit] * Wholesale share (N) [%]

EU-28 total retail revenue (N) [mln euros] =
Sales (N) [mln units] * Price (N) [euros/unit] * Retail share (N) [%]

EU-28 total government revenue (N) [mln euros] =
Sales (N) [mln units] * Price (N) [euros/unit] * VAT share (N) [%] [69]

EU-28 total installation revenue (N) [mln euros] =
Sales (N) [mln units] * Installation Cost (N) [euros/unit] [70]

EU-28 total Initial consumer costs (N) [mln euros] =
EU-28 total industry revenue (N) [mln euros] +
EU-28 total wholesale revenue (N) [mln euros] +

[67] This is for external control gears; the energy consumed by control gears integrated in the light sources is counted as part of the light source energy.
[68] Additional energy from controls, sensors, dimmers, etc. for the period when light sources are emitting at least some light.
[69] This is only from light source sales, not from taxes on electricity consumption.
[70] Installation costs for the residential sector would include VAT, but these costs are now zero: installation costs are considered only for the non-residential sector and there they are considered excluding VAT. Consequently there is no VAT in the Installation costs.

EU-28 total retail revenue (N) [mln euros] +
EU-28 total government revenue (N) [mln euros] +
EU-28 total installation revenue (N) [mln euros]

Other cost-related EU-28 totals for the base case (Computed)

EU-28 total electricity cost (N) [mln euros] =
EU-28 total electric energy for base case (N) [TWh/a] * Electricity rate (N) [euros/kWh] * 1000

EU-28 total maintenance cost (N) [mln euros] =
Stock (N) [mln units] * Maintenance cost (euros/a/unit)

EU-28 total running cost (N) [mln euros] =
EU-28 total electricity cost (N) [mln euros] +
EU-28 total maintenance cost (N) [mln euros]

EU-28 total consumer expense (N) [mln euros] =
EU-28 total Initial consumer costs (N) [mln euros] +
EU-28 total running cost (N) [mln euros]

D.4 Description of the sheets for the LED base cases

The sheets for the LED base cases are similar to those for the non-LED base cases described in the previous paragraph. The main difference is that for some parameters the data source for LEDs is different (i.e. computed values instead of input).

Number of LED lamps substituting classical lamp types (Computed)

Figure 35 shows an abstract of the final part of the sheet for 'LED retrofit for LFL'. This part is identical (except for the data) for the sheet 'LED luminaire for LFL', and very similar (but with sales-shifts from different classical lamp types) for LEDs of other applications groups (HID, CFLni, DLS, NDLS).

In the example, LED retrofit lamps are substituting LFL T12 and T8, LFL T5 and LFL X. The quantity of lamps involved are copied from the sheets for the non-LED base cases.

For the lamps being substituted, their luminous flux, operating hours and standby hour are also copied here. In principle, the LED lamps will be assumed to have the same flux and hours as the lamps they are replacing, but this can be changed using a 'rebound factor', that can be separately defined for the three parameters (and separately for the residential and non-residential sectors).

The bottom part of Figure 35 shows the data for the LED lamps substituting the classic lamp types.

The LED sales for substitution of other lamp types are the sum of the contributions from the classical lamp types, in this example:

Number of LED lamps substituting other types =
number of lamps substituting LFL T12 and T8 +

number of lamps substituting LFL T5 +
number of lamps substituting LFL X

The average luminous flux, operating hours and standby hours for these LED lamps are computed as sales-weighted averages and then multiplied by the corresponding rebound factor. These data are transferred to the top part of the sheet (Figure 36).

The sales for substitution of other lamp types are added to the sales necessary to substitute LEDs reaching end-of-life (if any within the time-frame considered) and to LEDs sold for new applications. The latter two contributions are determined in the same way as for the non-LED base cases (see par. D.3). All LED lamps are assumed to have the luminous flux, the operating hours and the standby hours as computed from the substituted classical lamp types.

The luminous efficacy of the LEDs is indicated as input (cyan background fields) in Figure 36, but actually these fields are linked to the centralized LED efficacy input (for HighEnd or for LowEnd LED lamps) on the sheet 'General Input'.

The purchase prices for the LEDs are also linked to those defined on 'General Input'.

For the remaining parameters the same descriptions apply as in par. D.3.

	LED retrofit for LFL	info		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
	Sales shift data from 2014	info												
RES	Residential													
RES	Rebound factor for luminous flux			1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
RES	Rebound factor for operating hours			1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
RES	Rebound factor for standby hours			1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
RES	Substitution of LFL T12 and T8													
RES	Number of lamps	Info	mln	0.0	0.2	0.4	1.0	1.8	3.6	4.2	4.6	4.8	4.9	4.7
RES	Replaced luminous flux		lm	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400	2400
RES	Replaced fpe operating hours		h/a	700	700	700	700	700	700	700	700	700	700	700
RES	Replaced standby hours		h/a	0	0	0	0	0	0	0	0	0	0	0
RES	Substitution of LFL T5													
RES	Number of lamps		mln	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1
RES	Replaced luminous flux		lm	2275	2275	2275	2275	2275	2275	2275	2275	2275	2275	2275
RES	Replaced fpe operating hours		h/a	700	700	700	700	700	700	700	700	700	700	700
RES	Replaced standby hours		h/a	0	0	0	0	0	0	0	0	0	0	0
RES	Substitution of LFL X													
RES	Number of lamps		mln	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.3
RES	Replaced luminous flux		lm	1032	1032	1032	1032	1032	1032	1032	1032	1032	1032	1032
RES	Replaced fpe operating hours		h/a	700	700	700	700	700	700	700	700	700	700	700
RES	Replaced standby hours		h/a	0	0	0	0	0	0	0	0	0	0	0
RES	All substitutions (incl. rebound)													
RES	Number of lamps	Info	mln	0.0	0.2	0.4	1.0	1.8	3.7	4.4	4.8	5.0	5.2	5.1
RES	Replaced luminous flux	info	lm	2400	2400	2400	2400	2371	2383	2381	2370	2357	2345	2328
RES	Replaced fpe operating hours	info	h/a	700	700	700	700	700	700	700	700	700	700	700
RES	Replaced standby hours	info	h/a	0	0	0	0	0	0	0	0	0	0	0

Figure 35 Extract 1 from a sheet for a LED base case. The example is for LED retrofit for LFL and for the residential part, but the structure and the parameters are the same for LED luminaires and for the non-residential sector. On the full sheet years extend up to 2030.

	LED retrofit for LFL	Info			2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
RES	Lifetime (Lh)	info		h	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000
RES	Hour factor (Fhour)	Info	Info	%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
RES	*full power equivalent hours (tfpe)*	info	info	*h/a*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*	*700*
RES	*standby hours (tsb)*	info	info	*h/a*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
RES	*Lifetime (Ly)*	info		*yr*	*28.6*	*28.6*	*28.6*	*28.6*	*28.6*	*28.6*	*28.6*	*28.6*	*28.6*	*28.6*	*28.6*	*28.6*	*28.6*
RES	*reference luminous flux (phiref)*	*info*	*info*	*lm*	*2400*	*2400*	*2400*	*2400*	*2400*	*2400*	*2371*	*2383*	*2381*	*2370*	*2357*	*2345*	*2328*
RES	Flux factor (Fphi)	info	info	%							100%	100%	100%	100%	100%	100%	100%
RES	*installed luminous flux (phi)*	*info*	*info*	*lm*	*2400*	*2400*	*2400*	*2400*	*2400*	*2400*	*2371*	*2383*	*2381*	*2370*	*2357*	*2345*	*2328*
RES	luminous efficacy, average (LSeffavg)	info	info	lm/W	25	25	30	40	60	80	92	112	133	152	167	179	189
RES	*light source power (Pls)*	*Info*		*W*	*96*	*96*	*80*	*60*	*40*	*30*	*26*	*21*	*18*	*16*	*14*	*13*	*12*
RES	external control gear efficiency (CGef	info	info	%	85%	85%	85%	85%	85%	85%	87%	89%	91%	92%	93%	93%	94%
RES	additional power during tfpe (Padd)	info	info	W	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RES	standby power during tsb (Psb)	info	info	W	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
RES	*purchase price (2010, incl. VAT)*	*info*	*info*	*€*	*161.3*	*161.3*	*138.2*	*121.0*	*97.92*	*86.40*	*71.12*	*57.19*	*44.29*	*34.13*	*26.59*	*23.07*	*20.67*
RES	share industry			%	66%	66%	66%	66%	66%	66%	66%	66%	66%	66%	66%	66%	66%
RES	share wholesale			%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
RES	*share retail*			%	*7%*	*7%*	*7%*	*7%*	*7%*	*7%*	*7%*	*7%*	*7%*	*7%*	*7%*	*7%*	*7%*
RES	*share VAT*			%	*17%*	*17%*	*17%*	*17%*	*17%*	*17%*	*17%*	*17%*	*17%*	*17%*	*17%*	*17%*	*17%*
RES	installation costs	info		€	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RES	repair & maintenance costs	info		€/a	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RES	Sales Factor	info		%							100%	100%	100%	100%	100%	100%	100%
RES	***EU-28 Residential Sales (units)***	*info*		***mln***	***0.0***	***0.0***	***0.0***	***0.2***	***0.4***	***1.0***	***1.8***	***3.7***	***4.5***	***4.9***	***5.2***	***5.4***	***5.3***
RES	*Year in which Lamps reach EoL*	*Info*			*2036*	*2037*	*2038*	*2039*	*2040*	*2041*	*2042*	*2043*	*2044*	*2045*	*2046*	*2047*	*2048*
RES	*Reference column index for EoL*				*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*
RES	*Lamps reaching EoL*	*info*	*info*	*mln*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
RES	*Lamps for new applications*	*info*		*mln*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.1*	*0.1*	*0.2*	*0.2*	*0.2*
RES	*Lamps substituting other types*		info	*mln*	*0.0*	*0.0*	*0.0*	*0.2*	*0.4*	*1.0*	1.8	3.7	4.4	4.8	5.0	5.2	5.1

Figure 36 Extract 2 from a sheet for a LED base case. The example is for LED retrofit for LFL and for the residential part, but the structure and the parameters are the same for LED luminaires and for the non-residential sector. On the full sheet years extend up to 2030.

Annex E Basic input data and BAU-scenario

E.1 Introduction

Basic input data for the period 1990-2013, as used in MELISA v0, have been reported and discussed in the Task 2 and 3 reports and summarized per base case in chapter 5 of the Task 4 report. These data, and the outcomes to which they lead (e.g. kWh/a per household, number of lamps per household, kWh/m^2/a for non-residential sector), have been compared with those from other sources (see Tasks 2 and 3) and they were critically reviewed by the study team itself (Tasks 2, 3, 4). In only few cases comments from stakeholders have been received on the basic input data.

Although most data were found to be substantially correct or reasonable, in MELISA v1 some of the data for the 1990-2013 period have been (slightly) adapted, leading to (small) differences between the values reported in this Task 7 and values reported in earlier Task reports.

The introduction in MELISA v1 of parameter values that can be defined per year also opened the possibility to differentiate basic input data for the period 2014-2030 from those used in the preceding years.

The Business-As-Usual (BAU) scenario, is intended here as the reference scenario in which no (new) ecodesign or energy labelling measures are being introduced. This scenario is typically developed in ecodesign preparatory studies by continuing the trends observed in recent years.

However, in the case of light sources, extrapolating the 2010-2013 trends into the future would not provide a realistic scenario, for two major reasons:

- Some of the existing ecodesign regulations will have effects in the coming years: mercury lamps have been phased-out in April 2015, and many halogen lamps will be phased-out in 2016 or 2018. Consequently the increasing trend in the sales of halogen lamps cannot be expected to continue.
- The substitution of classical technology light sources by LED lighting products has started and will continue, but it would be expected to accelerate as LED prices decrease and efficacies increase.

These effects will occur even if no new policy measures are taken and therefore cannot be ignored in the BAU scenario.

This Annex addresses the basic input data used in the scenario analyses and explains the assumptions made for the BAU scenario.

E.2 Common input data for all or several base cases

E.2.1 Electricity prices

Table 15 shows the electricity prices applied in MELISA v1 for the scenario analyses. The prices are in euros/kWh, in fixed 2010 euros. For the residential sector they are inclusive VAT; for the non-residential sector exclusive VAT.

Electricity prices for the years 1990-2013 are based on Eurostat data, see also the Task 3 report, par. 2.8 [71]. For later years an escalation rate of 4% has been applied. The

[71] For residential the prices up to 2013 are based on Eurostat tariff group Dc: "annual consumption of 3500 kWh among which 1300 kWh overnight (standard dwelling of 90m²)". These tariff group definitions are according to the old (2007) methodology.

values shown in the table are not discounted (and no discounting is applied elsewhere in the model).

Table 15 Electricity prices used in the scenario analyses, in euros/kWh, fixed euros 2010. Residential values include 20% VAT; non-residential values are exclusive VAT. (Escalation rate 4% after 2013, not discounted)

Residential prices, incl. VAT									
1990	1995	2000	2005	2010	2013	2015	2020	2025	2030
0.178	0.181	0.162	0.153	0.170	0.191	0.207	0.251	0.306	0.372
Non-residential prices, excl. VAT									
1990	1995	2000	2005	2010	2013	2015	2020	2025	2030
0.119	0.103	0.084	0.087	0.106	0.119	0.129	0.157	0.191	0.232

E.2.2 General growth rates

For all base cases, the quantity of sales for new applications is computed as:

New light sources (year Y) = Stock (year Y-1) * AnnualGrowth% (year Y)

The growth percentage is taken from the definitions on the sheet 'General Input', for the residential sector or for the non-residential sector.

The annual growth for the <u>residential sector</u> is based on the growth of the number of households in EU-28 and on the growth of the number of light sources per household. Table 16 shows the number of persons in EU-28, the number of households in EU-28, and the number of light sources per household as reference information. The assumed growth rate for the residential sector is shown near the bottom of the table.

The annual growth for the <u>non-residential sector</u> is based on the Gross Domestic Product of the EU-28 and also shown in Table 16.

Values for year 2013 and before are for reference; only values for later years are actually used in the scenario analyses.

For non-residential the reference for prices up to 2013 was tariff group Ie: "annual consumption of 2000 MWh, maximum demand of 500kW and annual load of 4000 hours". These tariff group definitions are according to the old (2007) methodology.

Table 16 Number of persons in EU-28, number of households in EU-28, number of light sources per household, Gross-domestic product in EU-28, Growth rate for quantity of light sources in the residential and non-residential sectors.

Number of persons in EU-28 (millions) and annual growth rate (%) [72]									
1990	1995	2000	2005	2010	2013	2015	2020	2025	2030
			495	503	506	508	512	515	518
			0.42%	0.24%	0.22%	0.17%	0.16%	0.12%	0.12%
Number of households in EU-28 (millions) and annual growth rate (%) [73]									
1990	1995	2000	2005	2010	2013	2015	2020	2025	2030
172	182	189	195	210	214	216	220	224	228
			1.44%	0.73%	0.14%	0.38%	0.37%	0.37%	0.36%
Number of light sources per household and annual growth rate (%) [74]									
1990	1995	2000	2005	2010	2013	2015	2020	2025	2030
21	22	23	25	30.2	33	33.7	34.9	35.8	36.7
			2.97%	2.31%	2.57%	1.03%	0.50%	0.50%	0.50%
EU-28 Gross Domestic Product (billion euros) and annual growth rate (%) [75]									
1990	1995	2000	2005	2010	2013	2015	2020	2025	2030
			11502	12790	13521	14268	16143	18264	20664
			4.42%	4.44%	0.75%	2.50%	2.50%	2.50%	2.50%
Annual growth rate (%) for residential light sources									
1990	1995	2000	2005	2010	2013	2015	2020	2025	2030
			4.45%	3.06%	2.72%	1.41%	0.87%	0.87%	0.86%
Annual growth rate (%) for non-residential light sources									
1990	1995	2000	2005	2010	2013	2015	2020	2025	2030
			4.42%	4.44%	1.50%	2.50%	2.50%	2.50%	2.50%

[72] For the period 2003-2014 these data are from (accessed 20140922)
http://epp.eurostat.ec.europa.eu/tgm/table.do?tab=table&init=1&language=en&pcode=tps00001&plugin=1
The projections for 2020, 2030, 2040, 2050 are from:
http://epp.eurostat.ec.europa.eu/portal/page/portal/population/data/main_tables

[73] For the period 2005-2013 these data are from
http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=lfst_hhnhtych&lang=en accessed 20140922
These data are slightly different from those used in MELISA v0, e.g. v0 had 198.6 mln households in 2013 while latest Eurostat data give 213.8 for that year. Eurostat data are now used.
The growth rates after 2013 are the same as assumed in MELISA v0. This rate is higher than the population growth rate because the average number of persons per household is decreasing.

[74] There is a general trend for the number of lamps per household to increase.
This is a projection by the study team used to define the growth rate. Same data as in MELISA v0.
It is NOT the computed number of lamps per household that results from the current model.

[75] For the period 2003-2014 these data are from
http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=tec00001&plugin=1
accessed 20150702, Gross domestic product at market prices, at current prices, in billion euros
Current prices probably implies fixed euros 2014, but what counts here is only the inflation corrected growth rate.
The future projection is an assumption of the study team.

E.2.3 Division of LEDs over retrofit lamps and integrated luminaires

As requested by stakeholders, MELISA now distinguishes between LED retrofit lamps and integrated LED luminaires (see also par. Annex A).

The share of the light source sales shifting to LEDs that is assumed to be covered by light sources inside integrated LED luminaires differs per non-LED base case and is specified in the paragraphs dedicated to these base cases.

As reference information the following is recalled:

- Task 2, table 50, GfK data: in 2013 57% of LED sales is luminaire; 43% retrofit
- US DoE MYPP 2015, fig. 4.2: LED luminaires represent > 80% of installed Tlm-hr
- McKinsey lighting the way 2012, table 1: in 2012 210/283 = 74% of LED sales are luminaires; 26% retrofit lamps (globally); in 2020 expected 3021/3285 = 92% luminaires (globally)

Please note that the sales in MELISA are light source sales. When these sales shift from classical technology to LED, the quantity is not changed, independent from the fact if the replacement is by a LED retrofit lamp or by an integrated LED luminaire. Consequently the sales reported for the LED luminaire base cases are NOT the quantity of luminaires, but the quantity of classic technology light sources that they replace.

In addition: if not explicitly stated otherwise, the costs for the LED luminaires are taken identical to the costs of the LED retrofit lamps. The Excel sheets for LED luminaires have fields where additional costs can be specified, but this is intended for use in sensitivity analysis only.

E.2.4 Efficacy and price assumptions for LEDs

Task 4 proposal

Projections for the efficacy and prices of LEDs have been proposed in the Task 4 report, tables 1 and 2. These data are recalled below in Table 17.

The prices are in fixed 2010 euros/klm excluding VAT.

The LED efficacy in Table 17 is considered to include the control gear (driver) efficiency. The values for the latter, according to US DoE MYPP 2014, are also reported in the table. They differ from those used in MELISA v0, where 1/1.1=91% was used for all years.

Table 17 Projections for the LED efficacy (lm/W), LED price (euros/klm excl. VAT), and LED control gear efficiency (%). Sources: Task 4 report and US DoE MYPP 2014)

	2010	2013	2015	2020	2025	2030
LED efficacy (lm/W)	26	68	100	178	210	225
LED price (euros/klm, excl. VAT)	48.00	30.00	20.00	7.40	5.00	4.00
LED control gear efficiency (%)	85%	85%	89%	94%	95%	96%

LightingEurope proposal

In their comments on the Task 4 report, industry association LightingEurope (LE) has suggested to use two sets of efficacy and price data for LEDs, one for professional lamps and one for consumer lamps. Professional lamps would have higher efficacy and higher price while consumer lamps would have lower efficacy and lower price. The efficacy projections proposed by LE are shown in Figure 37.

As a rationale for these projections LE clarifies that for (non-professional) consumers the most important aspect is price reduction. They do NOT need the very long lifetimes of 15-20 kHrs (typically more than 20 years) and are not interested in saving additional 1-2 W per lamp. LE expects a mass-adoption of LED lamps in households between 2016-2020. Because of the long lifetimes, consumer LED sales will drop drastically after that. The market will then move to smart lamps with additional features, to create differentiation and to create a driver for replacement. These new features will limit the increase in driver efficiency and optical efficiency.

LE also states that the US DoE projections (best in class package efficacies: 230 lm/W in 2020; 247 lm/W ultimately) are very optimistic, reaching physical limits, that these are based on numerous improvements/innovation – still to happen – and will certainly come at high cost. The LE comment continues with details on the expected partial efficiencies, ending with the conclusion that the efficacy of consumer lamps will be only 61-64% of the best-in-class efficacy for professional lamps [76].

As regards the LED price projections, LE states that those proposed in the Task 4 report must be considered only in relation to the LE consumer efficacy projections. Prices for the higher-efficacy professional lamps are expected to be a factor 2 higher [77].

[76] From LE comments:

DOE projected LED improvement roadmap, as best in class, aims at achieving 247 lm/W ultimately and at best 230 lm/W in 2020. These assumptions are made based on numerous improvements/innovation – still to happen – and will certainly come at high cost. DOE numbers are reaching the physical limits. Industry might not focus on 95% quantum efficiency, but on further cost down by reducing the complexity of epitaxial layer and chip design. DOE show breakdown of LED efficiency, ambitious numbers, especially extraction efficiency of chip (90%, for most chip architectures expects max 86%) and package efficiency (99%, for low cost package architectures expects max 96%, in practice 92%). Yellow phosphor quantum efficiency is approaching 98%, most gain is expected in use of so-called narrow band red phosphor (reduced waist of energy in long wavelength tail with limited eye sensitivity) and on the longer term quantum dot phosphors.

Performance at Tj = 25C (junction temperature of the LED). In practice LEDs are used in consumer applications at hot conditions, Tj=115C will move to 130C in coming years (saving heatsink costs). Penalty 12-16% in Lm/W.

General considerations on system level:

Thermal: hot / cold factor: 22% (2015) to 25% (2030); bigger losses due to further over-drive of improved LEDs (for some lumen decay during life)

Driver efficacy:15% (2015) to 10% (2030); best case scenario for driver incorporated in lamp; most likely will not improve due to added features (smarter, connected, etc.)

Optical efficacy:10% (2015) to 5% (2030); assumption clear bulbs; most likely will not improve due to added features for ambiance creation

From LED to Lamp, system correction factor 61% (2015) to 64% (2030)

[77] From LE comment: When comparing the two different segments i.e. most cost efficient LED's (lm/$) versus most energy efficient LED's (lm/W), the ratio over the years is about 4.5. This ratio will remain stable. Example 2015: 2766lm/$ for low lm/W and 645 lm/$ for high lm/W -> ratio 4.3

Taking into account that the relative cost of the LED in the lamp as part of the total BOM costs will reduce in the coming years, we expect the difference in lamp costs between lm/$ and lm/W to be a factor 2.

This means that prices related to the future "professional" lm/W projections are typically a factor 2 higher than prices related to the future "consumer" lm/W projections. Your proposed price projections in task 4 are typically related to only "consumer" lm/W projections.

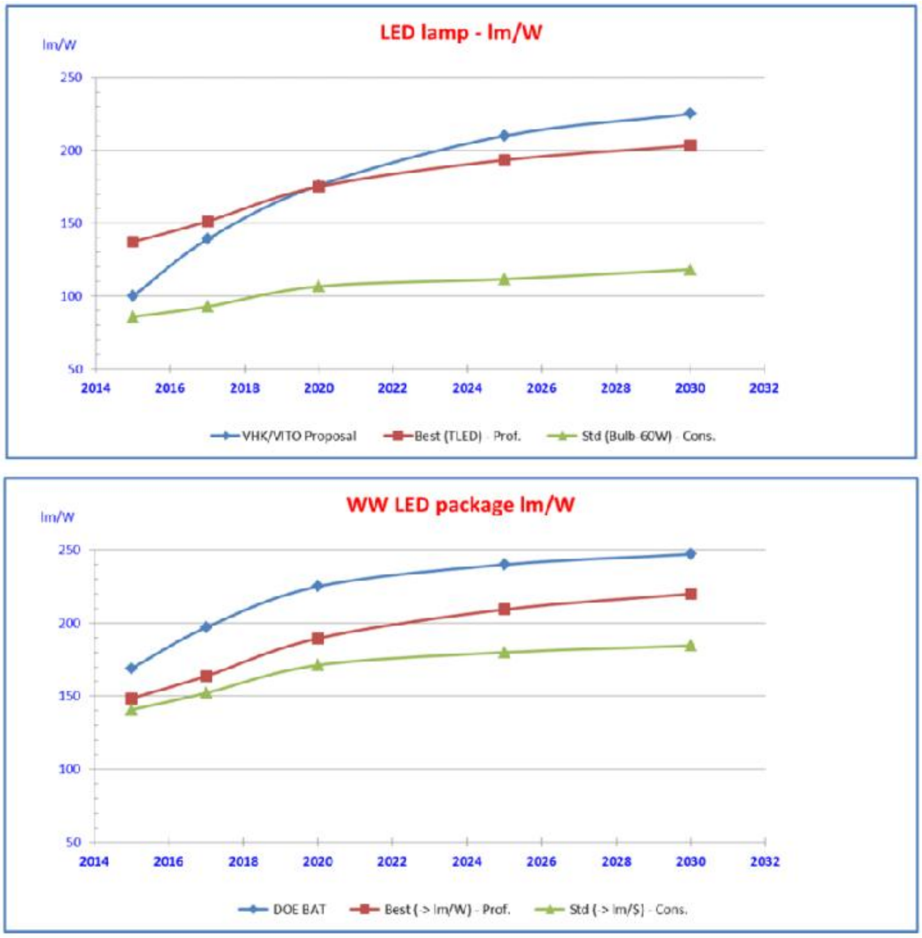


Figure 37 Efficacy projections for professional LED lamps and consumer LED lamps as proposed by LightingEurope. Top: LED lamp efficacy compared to the Task 4 proposal. Bottom: LED package efficacy compared to the US DoE package efficacy for warm white

Discussion

The LED efficacy projection proposed in Task 4 was derived by the study team starting from the US DoE MYPP 2014 projections for LED package efficacy. These values were then reduced considering the thermal, electrical and driver efficiencies reported by US DoE to obtain (retrofit) lamp efficacies. Further applying the US DoE values for fixture/optical efficiency the curve for dedicated LED luminaires was obtained. These values were interpreted as the best available on the market. As MELISA needs the average of products sold on the market, the luminaire efficacy curve was translated downwards to pass through the point that had been identified as the average efficacy of LEDs for 2014/2015. In this process, driver efficiency had already been considered, so the proposed efficacies were assumed to include control gear efficiency.

As also pointed out by CLASP during the 2nd stakeholder meeting, the US DoE projections have been drawn up by industry experts and they should be considered the best projection data available and not discarded lightly. When the Task 4 proposal was first published, the study team also received requests to better motivate why the proposed efficacy curve was so much lower than that of US DoE, suggesting that Europe should use the same curves as US DoE. In the meantime several stakeholders have declared that they agree with the projections proposed by the study team in task 4.

In the data for LED light sources that were gathered in Task 4 there is no clear evidence for the LE position. In 2014/2015 the average LED efficacy for professional lamps (substitutes for LFL, HID, CFLni) seems to be slightly higher (100-105 lm/W) than for consumer lamps (85-90 lm/W), but average euros/klm prices for professional lamps seem to be lower than those for consumer lamps [78], and not higher, certainly not a factor 2. However, the spread in efficacies and prices of lamps currently on the market is very high, and in particular data for professional lamps are relatively scarce, leading to uncertainty.

The LE efficacy curve for professional lamps is interpreted to indicate the best efficacy available on the market. This is suggested by LE, and also derives from the 2015 value (around 140 lm/W) that is representative for the current best LED retrofit tubes (LFL substitutes). The average efficacy of LED tubes in 2014/2015 has been found to be lower (around 109 lm/W). MELISA needs the average efficacy of lamps sold on the market.

The LE efficacy curve for consumer lamps is very low, reaching 120 lm/W by 2030. Although LE has provided rationale for this, the curve is in contrast with the trend in efficacy improvements in recent years and with the fact that lamps with a 120 lm/W efficacy are already on the market in 2015. In addition, if such a large difference is expected between professional lamps and consumer lamps, strange that the US DoE MYPP 2014 did not address this.

The control gear efficiencies mentioned by LE (for consumer lamps), 85% in 2015 and 90% in 2030, are considerably lower than those projected by US DoE MYPP 2014, 89% in 2015 and 96% in 2030, see Table 17. The latter are interpreted as the best possible values. For the average of sold products they would be expected to be lower.

LED efficacy and price for MELISA scenarios

Following the LightingEurope proposal, two basic LED efficacy projections with corresponding price projections have been defined (Figure 38, Figure 39, Table 18 - Table 22):

- Low-End LED curve reaching 120 lm/W and 4.0 euros/klm in 2030
- High-End LED curve reaching 208 lm/W and 7.4 euros/klm in 2030

The basic Low-End LED efficacy curve is the one proposed by LightingEurope for consumer lamps and applied in the MELISA model to GLS, Halogen lamps and CFLi sold in all sectors, and to LFL and CFLni sold in the residential sector. These lamps have low annual operating hours so that an investment in more efficient but more expensive LED light sources would have long payback times.

The corresponding Low-End LED price curve is the one proposed in Task 4 for all LED lamps, and accepted by LightingEurope for LED lamps of the Low-End efficacy curve.

[78] This is also expected to be due to the fact that professional lamps, on average, have higher luminous flux, and there seems to be a scale-effect, i.e. lamps with higher lumens seem to have lower euros/klm. This has been observed in particular for LED lamps substituting HID lamps, where the little available information indicates a price in euros/klm that is only about half of that for LEDs substituting other lamp types.

The basic High-End LED efficacy curve derives from the one proposed by LightingEurope for professional lamps [79] and applied in the MELISA model to LFL, HID-lamps and CFLni sold in the non-residential sector. These lamps have high annual operating hours so that an investment in more efficient but more expensive LED light sources has acceptable payback times.

The corresponding High-End LED price curve has been interpolated, in function of the efficacy differences, between the basic Low-End LED curve defined above (120 lm/W, 4.0 euros/klm in 2030) and the additional High-End LED curve defined below (225 lm/W, 8.0 euros/klm in 2030).

The above two curves are applied in all scenarios where no label improvements are assumed to be introduced.

In the view of the study team, some years from now, there will not be only two types of LED lamps on the market, but a more or less continuous spectrum, with efficacies and prices between the above defined Low-End and High-End products.

In addition, following the US DoE MYPP 2014 projections and the suggestions of various stakeholders, it may well be that LED products come to the market that are better than the above defined High-End products.

Therefore two additional LED efficacy projections with corresponding prices have been defined (Figure 38, Figure 39, Table 18 - Table 22):

- Low-End LED curve reaching 167 lm/W and 5.8 euros/klm in 2030
- High-End LED curve reaching 225 lm/W and 8.0 euros/klm in 2030

These two additional curves are applied in the scenarios where label improvements are assumed to be introduced.

The additional Low-End LED efficacy curve derives from the basic Low-End LED curve by assuming that a really effective energy label can lead to an increase in average efficacy corresponding to two label classes (passing from new proposed class F/E to class D/C after 2020).

The corresponding price curve has been interpolated, in function of the efficacy differences, between the basic Low-End LED curve (120 lm/W, 4.0 euros/klm in 2030) and the additional High-End LED curve (225 lm/W, 8.0 euros/klm in 2030).

In the case of improved labelling, these efficacy and price curves are applied to the same lamps with low annual operating hours as specified for the basic Low-End curve above.

The additional High-End LED efficacy curve is more or less the curve proposed by the study team in Task 4 for all LED lamps, and that was approved by several stakeholders. It derives from the US DoE MYPP 2014 best-available-efficacy projections as explained in the Task 4 report.

The corresponding price curve derives from the LightingEurope information that the price for lamps with High-End efficacies will be approximately twice the price of lamps with basic Low-End efficacies.

[79] The curve is different from the one proposed by LightingEurope because their curve indicates the best available technology, while in MELISA the average efficacy of products sold in a given year is necessary. The curve is a mix of the LE curve for later years and the curve proposed by the study team in Task 4 for earlier years.

In the case of improved labelling, these efficacy and price curves are applied to the same lamps with high annual operating hours as specified for the basic High-End curve above.

For reference, and for possible use in sensitivity analysis, a fifth curve has been defined in the model:

- BAT High-End LED curve reaching 250 lm/W and 8.9 euros/klm in 2030

This curve intends to represent the best-available technology for High-End LED lamps in the presence of an effective energy labelling. It is not used in the baseline scenario analysis.

Additional remarks on LED efficacy

The LED efficacy data presented above are assumed to be valid in standard test conditions: they are the average rated values of products sold in that year, at the start of the lifetime and typically valid at an ambient temperature of 25˚C. The values include control gear efficacies.

The decrease of efficacy during the lifetime and at higher operating temperatures should be taken into account in the model by means of the rebound factors for installed capacity (lm) (see next paragraph). E.g., when a LED lamp substitutes an LFL, its installed lumens can be chosen higher than those for the LFL it replaces, to account for differences in lumen degradation and for operating temperature effects. However, note that in some applications the directionality of the light from LED tubes might also allow to install less lumens and still obtain the same illuminance in the task area.

The same efficacy is assumed for LED retrofit lamps and for integrated LED luminaires. The reason for this is that the efficacy in MELISA represents the light source efficacy (including control gear efficiency); the optical efficacy of the luminaire is NOT included.

Additional remarks on LED price

Prices are in fixed 2010 euros, inflation corrected, not discounted, and excl. VAT. They are assumed to include additional hardware costs for components that are necessary to make a retrofit lamp work properly (e.g. new driver, new starter, additional wiring), but the labour installation costs are NOT included; these costs are defined separately.

If not stated otherwise, the same price is assumed for LED retrofit lamps and for integrated LED luminaires. The reason for this is that the LED price in MELISA represents the light source price. For luminaires, the prices are those for the light sources contained in the luminaires, not for the complete luminaires.

MELISA has the possibility to define additional costs for LED luminaires, but these are intended for use in sensitivity analysis only.

Great care has to be taken when defining additional LED luminaire costs in the model:

- If the existing classic technology luminaire anyway reached its end of life and the consumer has to choose between buying a new classic luminaire or a new LED luminaire, only the difference in cost should be counted for the new LED luminaire, because the costs of the classic luminaire are not defined in the model. This difference might also be negative, in particular in later years.
- If the consumer is forced to buy a LED luminaire because he/she can no longer find a suitable replacement or LED-retrofit lamp, the additional costs for the LED luminaire should be taken into account. In that case it should be noted

that these costs will be multiplied in the model by the original number of classic light sources that is being substituted by the LED light sources contained in the luminaire. Costs should be correctly determined to reflect this!

- In particular in future years, there may be situations in which an integrated LED luminaire costs less than LED retrofit lamps.

Lifetimes for LED lamps

In the baseline scenarios the MELISA v0 lifetime of 20,000 hours has been maintained. This was assumed to be a conservative choice.

The LightingEurope comments on Task 4 indicate that a future differentiation in lifetimes can be expected, with lower lifetimes for consumer lamps and higher lifetimes for professional lamps.

Within reasonable bounds (say down to 10,000 hours), a lower LED lifetime for Low-End lamps will hardly have any influence in the timespan considered for scenario analyses, i.e. up to 2030. Due to the relatively low annual operating hours of these lamps (around 500 h/a), lifetimes will typically be 20 years or longer anyway, so that lamps bought in 2015 will reach their average end-of-life after 2030.

For High-End lamps, the influence of different lifetimes can be examined in the sensitivity analysis.

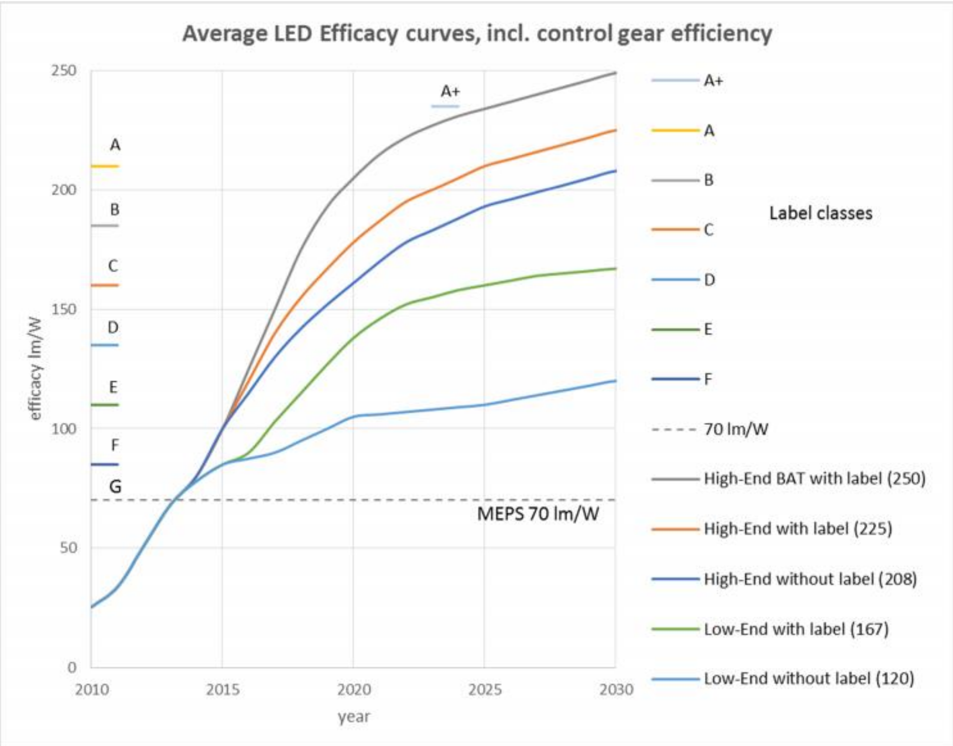


Figure 38: Curves for LED efficacy projections. Efficacies are in lm/W for the combination of light source and control gear. New proposed energy efficiency label classes for lamps are also indicated as a reference.

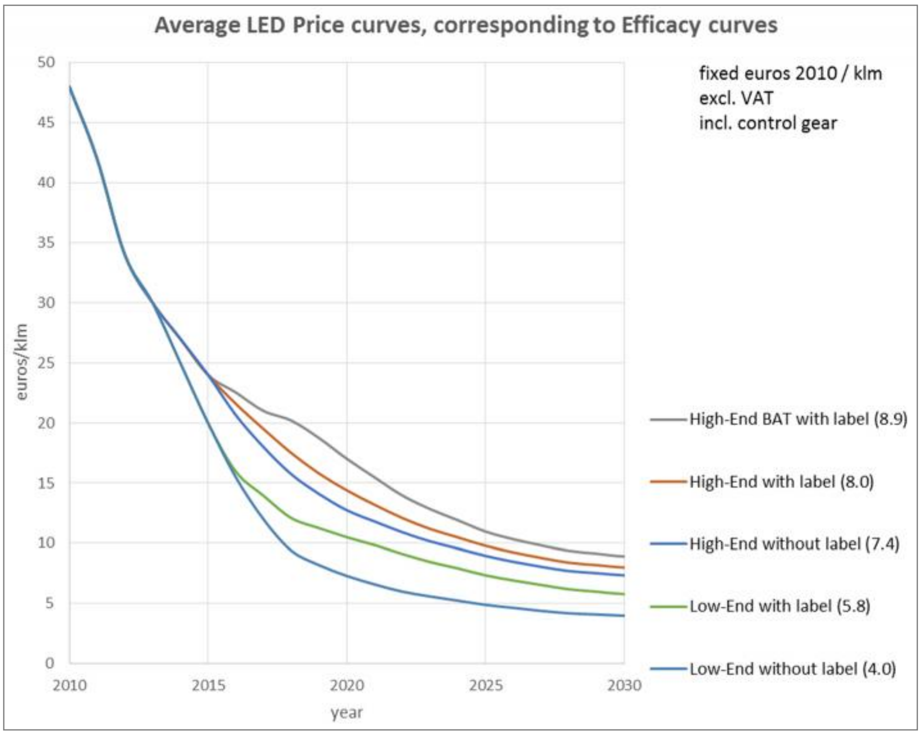


Figure 39: Curves for LED lamp price projections, corresponding to the LED efficacy projections with the same name. Prices are in euros/klm, fixed 2010 euros, excl. VAT, incl. control gears.

Table 18 Low-End LED lamps (LEDs substituting CFLi, GLS and Halogen lamps in all sectors and LFL and CFLni in the residential sector; low annual operating hours): projections for the LED efficacy (lm/W), LED price (euros/klm excl. VAT), and LED control gear efficiency (%) for use in scenarios without energy label improvements.

	2013	2015	2017	2020	2025	2030
LED efficacy (lm/W)	68	85	90	105	110	120
LED price (euros/klm, excl. VAT)	30.00	20.00	12.00	7.30	4.90	4.00
LED control gear efficiency (%)	85%	85%	86%	87.5%	90%	90%

Table 19 Low-End LED lamps (LEDs substituting CFLi, GLS and Halogen lamps in all sectors and LFL and CFLni in the residential sector; low annual operating hours): projections for the LED efficacy (lm/W), LED price (euros/klm excl. VAT), and LED control gear efficiency (%) for use in scenarios with energy label improvements.

	2013	2015	2017	2020	2025	2030
LED efficacy (lm/W)	68	85	103	138	160	167
LED price (euros/klm, excl. VAT)	30.00	20.00	13.95	10.51	7.35	5.79
LED control gear efficiency (%)	85%	86%	87%	90%	91%	92%

Table 20 High-End LED lamps (LEDs substituting LFL, HID-lamps and CFLni in the non-residential sector; high annual operating hours): projections for the LED efficacy (lm/W), LED price (euros/klm excl. VAT), and LED control gear efficiency (%) for use in scenarios without energy label improvements.

	2013	2015	2017	2020	2025	2030
LED efficacy (lm/W)	68	100	130	161	193	208
LED price (euros/klm, excl. VAT)	30.00	24.00	18.00	12.75	8.97	7.35
LED control gear efficiency (%)	85%	86.5%	88%	91%	92%	93%

Table 21 High-End LED lamps (LEDs substituting LFL, HID-lamps and CFLni in the non-residential sector; high annual operating hours): projections for the LED efficacy (lm/W), LED price (euros/klm excl. VAT), and LED control gear efficiency (%) for use in scenarios with energy label improvements.

	2013	2015	2017	2020	2025	2030
LED efficacy (lm/W)	68	100	140	178	210	225
LED price (euros/klm, excl. VAT)	30.00	24.00	19.50	14.40	9.80	8.00
LED control gear efficiency (%)	85%	87%	89%	92%	93%	94%

Table 22 BAT High-End LED lamps (LEDs substituting LFL, HID-lamps and CFLni in the non-residential sector; high annual operating hours): projections for the LED efficacy (lm/W), LED price (euros/klm excl. VAT), and LED control gear efficiency (%) for use in sensitivity analyses with energy label improvements.

	2013	2015	2017	2020	2025	2030
LED efficacy (lm/W)	68	100	150	205	234	249
LED price (euros/klm, excl. VAT)	30.00	24.00	21.00	17.03	10.98	8.91
LED control gear efficiency (%)	85%	87%	89%	92%	94.5%	96%

E.2.5 Rebound factors for LEDs

For the LED retrofit and LED luminaire base cases, MELISA allows three rebound factors to be defined, for installed luminous flux, for annual operating hours, and for standby hours. The parameter-value for LED lamps is taken as the parameter-value for the substituted non-LED lamp times the rebound factor.

There can be different reasons why luminous flux or usage hours are not identical for LED lamps and replaced classical technology lamps:

- For high-efficacy lamps such as LEDs, consumers have a general tendency to choose higher luminous flux and to let them burn longer.
- In future the share of LED lamps that will be 'smart' is assumed to increase. These 'smart' lamps will typically have longer standby hours.
- MELISA considers the initial luminous flux. Due to differences in lumen maintenance between the LED lamps and the non-LED lamps they replace, it may be necessary to install more lumens to ensure that the minimum required lumens are available also at the end-of-life.
- MELISA considers the luminous flux in standard test conditions, i.e. typically at 25°C ambient temperature. In operating conditions, LED lamps may lose more efficacy than the non-LED lamps they replace, requiring a higher initial flux in standard conditions.
- For some applications, the directionality of LED lamps, as compared to e.g. LFL and HID-lamps, may allow to install less lumens and still obtain the same illuminance or luminance in the task area. In this case the rebound factor could also be smaller than unity.

In MELISA v0 an approximate lumen equivalence was applied (rebound factor 1.0) while operating hours for LEDs were generally taken around 10% higher (rebound factor 1.1). In MELISA v1 a more detailed approach is applied.

For LEDs substituting CFLi, GLS, Halogen lamps, although there is usually no criterion for minimum maintained luminance or illuminance, the EU legislation contains information on equivalence claims.

For non-directional lamps, table 6 of Regulation 244/2009 provides the luminous fluxes for CFLi, Halogen lamps and LED lamps that may be claimed equivalent with an incandescent (GLS) lamp of a given power. Combining this with the corresponding GLS fluxes reported in table 8-1 of the VITO 2009 study for Lot19, Halogen lamps are required to have a 2-3% higher initial luminous flux than GLS lamps, CFLi's 8% higher and LEDs 17-18% higher.

In the current modelling, only replacement of GLS, Halogen lamps and CFLi's by LEDs is considered. It can be derived from the data in the Regulation that the lumen rebound factors for NDLS lamps are required to be:

LEDs substituting GLS:	1.18
LEDs substituting Halogen lamps:	1.15
LEDs substituting CFLi's:	1.09

For directional lamps Regulation 1194/2012 table 6 more or less requires the same as explained above for non-directional lamps: halogen lamps have the same flux as GLS, CFLi's have 8% more and for LED lamps the multiplication factor is 1+0,5×(1—LLMF), where LLMF is the lumen maintenance factor at the end of the nominal life. For the frequently encountered value of LLMF=0.7 for current LED lamps, this implies 15% more lumens for LEDs as compared to incandescent lamps.

As by now LEDs are substituting mainly Halogen lamps and CFLi's, an average lumen rebound factor between 1.09 and 1.15 would derive from the Regulations, both for DLS and NDLS. However, this is considerably higher than the factor found by Schleich in a 2012 research for a shift from incandescent lamps to CFLi or LED (see Task 3 report par. 3.2.5): +3.6% lumens for the average household lamp and +1.2% lumens for the main lamp in the living or dining room.

Consequently, for the scenarios a rebound factor of 1.1 for lumens has been chosen for consumer lamps, and this is assumed to cover all aspects listed at the start of this paragraph.

The report by Schleich indicated a rebound factor for operating hours of +2.4% for the average household lamp and +1.8% for the main household lamp.

Consequently, for the scenarios a rebound factor of 1.025 for (full-power equivalent) hours has been chosen for consumer lamps.

For LFL, CFLni and HID-lamps there is no reference information on equivalence in the Regulation (245/2009). However, for these lamps the lumens to be installed are often determined by lighting designers such that minimum maintained illuminance or luminance criteria are met, and they will take into account the differences (between LED and non-LED) in lumen depreciation with time, in the effects of operating temperatures on efficacy (and lifetime) and in the differences of light distribution (LED more directional, less losses in some applications).

For LFL's and CFLni's a lumen maintenance of 90% at the end of useful life is reasonable. As regards HID-lamps, the average lumen maintenance for HPS-lamps (high LLMF), HPM-lamps (low LLMF) and (C)MH lamps (low LLMF) can be assumed 85-90%.

For LED lamps, the lifetime used in the baseline model (20,000 hours) is relatively small for professional lamps, so that a lumen maintenance of at least 85% can be assumed, implying that the initial installed LED flux should be around 90/85 = 1.06 times the non-LED flux. The effects of operating temperature on efficacy could increase this to e.g. 1.1.

As indicated in the Task 4 report par. 5.4.5, there may also be justifications for installing a LED flux that is lower than the flux of the non-LED lamp it replaces, in particular when dedicated LED luminaires are applied that exploit the directionality of the LED, that have a higher optical efficacy, and that have been thermally designed for LEDs.

Consequently, for the baseline scenarios a rebound factor of 1.1 for lumens has been chosen for LED retrofit lamps substituting LFL and CFLni, and a factor 1.05 for integrated LED luminaires substituting the same lamp types, and this is assumed to cover all aspects listed at the start of this paragraph.
For LEDs substituting HID-lamps these factors have been reduced to 1.05 and 1.025 because approximately half of the LED lamps substitutes HPS-lamps that have a bad colour rendering and thus need higher installed flux.

It is not expected that operating hours will change significantly when switching from LFL/HID/CFLni to LED, these hours being related to e.g. street lighting hours or office opening hours. In addition the tendency to control them is expected to increase, leading to a decrease in full-power equivalent hours rather than an increase.
Consequently, for the scenarios a rebound factor of 1.0 for hours has been chosen for LEDs substituting LFL/HID/CFLni .

In the baseline scenarios, standby energy is not considered. Consequently the rebound factor for standby hours has been set to 1.0. Standby energy will be considered only in sensitivity analysis.

E.2.6 Additional remarks on prices and costs in MELISA

If not explicitly stated otherwise, for LED lamps the following general data apply:

Price shares (non-res):	80% industry, 10% wholesale, 10% retail, 0% VAT
Price shares (residential):	66% industry, 10% wholesale, 7% retail, 17% VAT
Installation costs:	identical to those of substituted lamps
Maintenance costs:	identical to those of substituted lamps

E.2.7 Other general parameters

Value added tax (VAT):	20% (applied only for residential sector)
Hourly Labour Costs:	37.00 euros/hour
Maximum allowable lifetime:	100 years (i.e. not used)
Jobs in industry:	20 per mln euros revenue
Jobs in wholesale:	4 per mln euros revenue
Jobs in retail:	16.7 per mln euros revenue
Jobs in installation:	10 per mln euros revenue
Jobs in maintenance:	10 per mln euros revenue
Efficiency of electricity generation and distribution:	40%
GWP for electricity:	variable with the years:
	2015: 0.395 $kgCO_2eq/kWh$
	2020: 0.380 $kgCO_2eq/kWh$
	2025: 0.360 $kgCO_2eq/kWh$
	2030: 0.340 $kgCO_2eq/kWh$
Inflation rate:	not used
Discount rate:	not used

E.3 LFL applications

E.3.1 LFL T12

Basic input data:

All input data are identical to those reported in Tasks 2, 3 and 4.

BAU assumption:

These lamps have been phased out by existing regulations and are assumed not to be for sale any longer from 2014 onwards. In the modelling all potential sales (mainly lamps reaching end-of-life) are first transferred to the LFL T8t base case and from there divided over LFL T8t, LFL T5 and LED, using the same assumptions as for other LFL T8t, see par. E.3.3.

Comments:

This base case has a minor impact. In 2013 sales are already close to zero, but there is still a small stock of LFL T12, in particular in the residential sector, where lifetimes are long (Ly=11 years).

E.3.2 LFL T8h (halophosphor)

Basic input data:

All input data are identical to those reported in Tasks 2, 3 and 4.

BAU assumption:

These lamps have been phased out by existing regulations and are assumed not to be for sale any longer from 2014 onwards. In the modelling all potential sales (mainly lamps reaching end-of-life) are first transferred to the LFL T8t base case and from there divided over LFL T8t, LFL T5 and LED, using the same assumptions as for other LFL T8t, see par. E.3.3.

Comments:

This base case has a minor impact. In 2013 sales are already close to zero, but there is still a stock of LFL T8h, in particular in the residential sector, where lifetimes are long (Ly=11 years).

E.3.3 LFL T8t (tri-phosphor)

Basic input data:

All input data are identical to those reported in Tasks 2, 3 and 4, except control gear (CG) efficiency.

In MELISA v0 this efficiency was 1/1.10=91% (single value for all years), which is rather high in particular for earlier years. If 25% is electromagnetic ballast with 80% efficiency, the average of 91% implies that the 75% electronic ballast has a very high 94.7% efficiency.

Regulation 245/2009 requires > 87-88% CG efficiency (for 30-36W lamps) from 2017, while 91% would be a class A2BAT non-dimming ballast.

In MELISA v1 the following CG efficiencies have been implemented: 80% in 1990, increasing to 86% in 2013, then to 89% in 2017, and 91% in 2020 and beyond.

BAU assumption:

Analysing the LFL and LED sales for the non-residential sector in the years 2010-2013, the conclusion is that in the year 2013 85% of LFL T8t lamps has been substituted by the same type while 14% has shifted to LFL T5 and 1% has shifted to LED. This distribution is taken as the starting point for the BAU scenario.

The analyses in Tasks 4 and 6 have shown that LED retrofit lamps for LFL T8t are widely available, that 2015 LED tubes have difficulty in competing economically with LFL T8t, but that this is expected to change by 2020. Consequently around that year an acceleration in the substitution of LFL T8 tri-phosphors by LEDs is expected.

As regards the shares of LEDs that are assumed to be LED retrofit tubes or integrated LED luminaires, in the initial years (2014,2015) 30% of the unit sales of LED light sources is assumed to be inside LED luminaires. The remainder are LED retrofit tubes. The share of light sources sold inside LED luminaires is assumed to grow gradually up to 80% in 2030, see also par. E.2.3.

Table 23 shows the assumptions made for the BAU scenario as regards the distribution of the potential LFL T8t sales over LFL T8t, LFL T5 and LED.

Table 23 Assumptions made for the BAU scenario regarding the distribution of light source sales for LFL T8 tri-phosphor applications

	2014	2015	2016	2017	2018	2019	2020	2025	2030
% sales remaining current type	85%	85%	84%	83%	82%	81%	80%	60%	40%
% sales shifting to LFL T5	13%	10%	7%	5%	3%	1%	0%	0%	0%
% sales shifting to LED retrofit	1%	4%	6%	8%	10%	11%	12%	16%	12%
% sales shifting to LED luminaire	1%	2%	3%	4%	5%	7%	8%	24%	48%
Share LED light sources in luminaires	28%	30%	32%	34%	36%	38%	40%	60%	80%

Comments:

For the residential sector the initial sales distribution is slightly different, but after some years the distribution is the same as shown in Table 23. This is not detailed here because the impact of this sector for LFLs is small.

See additional comments for LFL T5 in the next paragraph.

E.3.4 LFL T5

Basic input data:

All input data are identical to those reported in Tasks 2, 3 and 4, except control gear (CG) efficiency.

In MELISA v0 this efficiency was 1/1.10=91% (single value for all years). The minimum required ballast efficiency from 245/2009 table 17 is now (since 2010) 80-82% for 24-28W lamps. A2BAT efficiency is just below 90%. In 2017, for a 25W lamp, 245/2009 requires > 86%. -> assumed average 91% in MELISA seems high.

In MELISA v1 the following CG efficiencies have been implemented: 85% in 2002 (year of first sales), increasing to 87% in 2013, then to 89% in 2017, and 91% in 2020 and beyond (this is slightly better than the CG efficiencies assumed for LFL T8t, but reaching the same value in 2020).

BAU assumption:

Analysing the LFL and LED sales for the non-residential sector in the years 2010-2013, the conclusion is that in the year 2013 100% of LFL T5 lamps has been substituted by the same type while 0% has shifted to LED. This distribution is taken as the starting point for the BAU scenario.

The analyses in Task 4 have shown that the availability on the market of LED retrofit lamps for LFL T5 is considerably smaller than for LFL T8t. Task 6 clarified that 2015 LED tubes have difficulty in competing economically with LFL T5, but that this is expected to change by 2020. Consequently around that year an acceleration in the substitution of LFL T5 by LEDs is expected.

Considering the scarce availability of retrofit tubes with G5 cap, it is assumed that 80% of the unit sales of LED light sources is inside LED luminaires. The remaining 20% are LED retrofit tubes. These percentages are assumed to remain constant over the years.

Table 24 shows the assumptions made for the BAU scenario as regards the distribution of the potential LFL T5 sales over LFL T5 and LED. Up to 2025 the share of sales covered by LEDs is taken slightly lower than for LFL T8t.

Table 24 Assumptions made for the BAU scenario regarding the distribution of light source sales for LFL T5 applications (also used for LFL X)

	2014	2015	2016	2017	2018	2019	2020	2025	2030
% sales remaining current type	100%	100%	98%	96%	94%	92%	90%	60%	40%
% sales shifting to LED retrofit	0%	0%	0%	1%	1%	2%	2%	8%	12%
% sales shifting to LED luminaire	0%	0%	2%	3%	5%	6%	8%	32%	48%
Share LED light sources in luminaires	80%	80%	80%	80%	80%	80%	80%	80%	80%

Comments:

For the residential sector the same sales distribution is used as for the non-residential sector.

For the period 2010-2013, the sum of the LFL T5 reaching end-of-life, of the new LFL T5 applications, and of the LFL T5 substituting LFL T12 or T8 is lower than the actual sales that have been estimated for LFL T5, i.e. more LFL T5 were being sold than could be expected. The number of LFL T5 substituting T8 could be increased, but then the sales ‘mismatch’ would shift to LFL T8t.

In 2013 the sales ‘mismatch’ is 15 million on a total of 300 million (T5+T8), so around 5%. This is acceptable. For additional remarks on sales ‘mismatch’ see par. E.7.7.

E.3.5 LFL X

Basic input data:

All input data are identical to those reported in Tasks 2, 3 and 4, except control gear (CG) efficiency.

In MELISA v0 this efficiency was 1/1.20=83% (single value for all years).

In MELISA v1 the same CG efficiencies have been implemented as for LFL T8t (see also remarks there): 80% in 1990, increasing to 86% in 2013, then to 89% in 2017, and 91% in 2020 and beyond.

BAU assumption:

The starting point for the BAU scenario in 2013 has been taken as 100% LFL X and 0 % LED. See further remarks under ‘Comments’ below.

In Task 4 no specific research was performed on the availability of LED retrofit lamps for LFL X, because this base case contains a mix of various types of LFLs (it collects ‘all other’ LFLs). For the same reason, in Task 6 no LCC comparison between LFL X and LED was performed. This is acceptable considering the relatively small impact of this base case on the total of the LFLs (LFL X represent approximately 7% of the total LFL stock in 2013, and 3% of the energy consumption).

As regards the shift of sales from LFL X to LEDs for the BAU scenario, the same assumptions have been made as for LFL T5.

Comments:

Analysing the LFL X and LED sales for the non-residential sector in the years 2010-2013, a relatively large sales ‘mismatch’ appears. For example, in the year 2013, 34 million LFL X are estimated to reach their end-of-life while 2 million new applications are expected, so the potential sales would be 36 million. However, the actual sales have been separately estimated as only 18 million. A possible conclusion could be that the remaining 36-18=18 million LFL X have been replaced by LEDs, but this is not in agreement with the total sales estimated for all LEDs in 2013.

As explained in par. E.7.7 there can be many reasons for such a sales ‘mismatch’. Considering that the lack of 18 million LFL X sales is more or less compensated by the excess of 15 million sales found for LFL T5 (see previous paragraph), this mismatch has been accepted.

E.3.6 LED retrofit for LFL

Basic input data:

Lifetime:	20,000 hours
Annual operating hours:	derived from substituted lamps, rebound factor =1.0
Luminous flux:	derived from substituted lamps, rebound factor =1.1
Efficacy:	for High-End lamps in non-residential sector, see par. E.2.4 for Low-End lamps in residential sector.
Control gear efficiency:	for High-End lamps in non-residential sector, see par. E.2.4 for Low-End lamps in residential sector.
Purchase price:	for High-End lamps in non-residential sector, see par. E.2.4 for Low-End lamps in residential sector.
Price shares:	see par. E.2.6
Installation costs:	identical to those of substituted lamps
Maintenance costs:	identical to those of substituted lamps
Sales:	as resulting from sales shifts defined for LFLs

E.3.7 LED luminaire for LFL

Basic input data:

The same rules apply as for retrofit lamps in the preceding paragraph, except that the rebound factor for luminous flux is 1.05 instead of 1.1, see par. E.2.5.

E.4 HID applications

E.4.1 HPM

Basic input data:

MELISA v0 used 40 lm/W as an average efficacy, but this has now been considered too low for 10,000 lm. According to the information gathered in Task 4 it should rather be 45-50 lm/W. In MELISA v1 the value has been increased to 48 lm/W (same value as used in Task 6).

In MELISA v0 the ballast efficiency was 83% for all years. The requirements from regulation 245/2009 are: for 2012: > 85% for 222-250W lamp; from 2017: > 90%. MELISA v1 uses 80% in 1990, gradually increasing to 86% in 2013, 89% in 2017 and 90% in 2020 and later years.

Other data have not been changed from those presented in earlier Task reports, see par. 5.17.1 of the Task 4 report for a summary.

BAU assumption:

These lamps have been phased out by existing regulations from April 2015. Some sales from existing stock are still assumed up to 2018, but these quantities are very low (less than 0.6 mln lamps a year and decreasing).

Analysing the HID/HPM and LED sales for the non-residential sector in the years 2010-2013, the conclusion is that in the year 2013 77% of the (few remaining) HPM lamps has been substituted by the same type while 11% has shifted to HPS, 11% to MH and 1% to LED. This distribution is taken as the starting point for the BAU scenario.

Table 25 shows the assumptions made for the BAU scenario as regards the phase-out of HPM-lamps, and their substitution by HPS-lamps, MH-lamps and LED-lamps.

HPM sales are assumed to decrease rapidly due to the phase-out, from 77% in 2013, to 40% in 2015, reaching 0% in 2020. Sales shifting to HPS and MH are assumed to gradually decrease from 11% each in 2013 to 0 or 1% in 2020. In the same period the shift of sales to LED increases from 1% in 2013 to 99% in 2020 (of which 80% are light sources inside integrated luminaires). As quantities of HPM-lamps are low already in 2013 and the lifetime is short (2 years on average) both sales and stock are near zero by 2020 and for later years zero has been assumed (analysis stops in 2020).

Table 25 Assumptions made for the BAU scenario regarding the distribution of light source sales for HPM-applications

	2014	2015	2016	2017	2018	2019	2020	2025	2030
% sales remaining current type	65%	40%	20%	10%	5%	2%	0%		
% sales shifted to HPS	10%	9%	5%	2%	0%	0%	0%		
% sales shifted to MH	10%	9%	7%	5%	3%	2%	1%		
% sales shifting to LED retrofit	3%	8%	14%	17%	18%	19%	20%		
% sales shifting to LED luminaire	12%	34%	54%	66%	74%	77%	79%		
Share LED light sources in luminaires	80%	80%	80%	80%	80%	80%	80%		

E.4.2 HPS

Basic input data:

MELISA v0 used an efficacy of 95 lm/W for all years (up to 2013). For a 140 W lamp, from 2012, Regulation 245/2009 requires and efficacy > 110 lm/W for clear lamps and > 105 lm/W for non-clear lamps. If Ra>60, efficacies >80 (clear) or >75 (non-clear) lm/W are allowed. HPS retrofit for HPM are excluded from these requirements until April 2015.

In MELISA v1 the average 95 lm/W efficacy has been maintained up to 2010, but it then gradually increases to 110 lm/W in 2015, remaining constant afterwards.

In MELISA v0 the ballast efficiency was 83% for all years (up to 2013). The requirements from regulation 245/2009 are: for 2012: > 85% for 140W lamp; from 2017: > 90%. MELISA v1 uses 80% in 1990, gradually increasing to 86% in 2013, 90% in 2017 and later years.

Other data have not been changed from those presented in earlier Task reports, see par. 5.18.1 of the Task 4 report for a summary.

BAU assumption:

Analysing the HID/HPS and LED sales for the non-residential sector in the years 2010-2013, the conclusion is that in the year 2013 84% of the HPS lamps has been substituted by the same type while 10% has shifted to MH, and 6% to LED. This distribution is taken as the starting point for the BAU scenario.

As shown in the Task 4 report par. 5.17.3, the availability of LED retrofit lamps to substitute HPS is limited; major lamp manufacturers prefer to offer complete LED luminaires for street lighting applications. Consequently 80% of the LEDs has been assumed to be integrated luminaires.

As shown in the Task 6 report par. 3.8, the 2015 LED substitutes are not yet economically convenient. This situation is expected to change around 2020.

Table 26 shows the assumptions made for the BAU scenario as regards the distribution of the potential HPS lamp sales over HPS, MH and LED. The shift of sales towards metal-halide lamps is assumed to decrease to zero by 2020. In that year 30% of the sales shifts to LED but 70% of the potential HPS sales is still covered by the same technology. After 2020 LEDs are expected to become economically more attractive and by 2030 the sales proportions are inverted: 30% HPS and 70% LED.

Table 26 Assumptions made for the BAU scenario regarding the distribution of light source sales for HPS applications

	2014	2015	2016	2017	2018	2019	2020	2025	2030
% sales remaining current type	82%	82%	82%	82%	82%	81%	80%	60%	40%
% sales shifting to MH	14%	12%	10%	8%	6%	4%	2%	0%	0%
% sales shifting to LED retrofit	1%	1%	2%	2%	2%	3%	4%	8%	12%
% sales shifting to LED luminaire	3%	5%	6%	8%	10%	12%	14%	32%	48%
Share LED light sources in luminaires	80%	80%	80%	80%	80%	80%	80%	80%	80%

E.4.3 MH

Basic input data:

MELISA v0 used an efficacy of 82 lm/W for all years (up to 2013). MH efficacies slightly depend on power and CRI; the existing variation is from 88 to 129 lm/W.

From 2012, the 245/2009 efficacy requirement for clear MH lamps with Ra<80 is > 80 lm/W (or > 75 if non-clear)

From 2017, the 245/2009 efficacy requirement for all clear MH lamps is > 85 lm/W (or > 80 if non-clear). Existing lamps are already better than these 2017 requirements. Task 6 used 82 lm/W for MH BC and 104 lm/W for MH BAT.

For MELISA v1 the 82 lm/W has been maintained up to 2013, but efficacy then gradually increases to 90 lm/W in 2017, remaining constant in later years.

In MELISA v0 the ballast efficiency was 83% for all years (up to 2013). The requirements from regulation 245/2009 are: for 2012: > 85% for 160W lamp; from 2017: > 90%. MELISA v1 uses 80% in 1990, gradually increasing to 86% in 2013, 90% in 2017 and later years (this is the same as for HPS).

Other data have not been changed from those presented in earlier Task reports, see par. 5.19.1 of the Task 4 report for a summary.

BAU assumption:

Analysing the HID/MH and LED sales for the non-residential sector in the years 2010-2013, the conclusion is that in the year 2013 85% of the MH lamps has been substituted by the same type while 14% has shifted to LED. This distribution is taken as the starting point for the BAU scenario.

As shown in the Task 4 report par. 5.17.3, the availability of LED retrofit lamps to substitute MH is limited; major lamp manufacturers prefer to offer complete LED luminaires for street lighting applications. Consequently 80% of the LEDs has been assumed to be integrated luminaires.

As shown in the Task 6 report par. 3.8, the 2015 LED substitutes are not yet economically convenient. This situation is expected to change around 2020.

Table 27 shows the assumptions made for the BAU scenario as regards the distribution of the potential MH lamp sales over MH and LED. By 2020, 20% of the sales shifts to LED but 80% of the potential MH sales is still covered by the same technology. After 2020 LEDs are expected to become economically more attractive and by 2030 the sales proportions are inverted: 40% MH and 60% LED.

Table 27 Assumptions made for the BAU scenario regarding the distribution of light source sales for MH applications

	2014	2015	2016	2017	2018	2019	2020	2025	2030
% sales remaining current type	85%	82%	82%	82%	82%	81%	80%	60%	40%
% sales shifting to LED retrofit	3%	4%	4%	4%	4%	4%	4%	8%	12%
% sales shifting to LED luminaire	12%	14%	14%	14%	14%	15%	16%	32%	48%
Share LED light sources in luminaires	80%	80%	80%	80%	80%	80%	80%	80%	80%

Comments:

For the period 2009-2013, the MH lamp sales have been slightly adapted as compared to the MELISA v0 data presented in Task 2. In addition the quantity of non-residential LEDs has been slightly increased in the period 2011-2013. These changes have been introduced to avoid a sales 'mismatch' (see par. E.7.7) that would have led to a decreasing total stock, considered unrealistic.

E.4.4 LED retrofit for HID

Basic input data:

Lifetime:	20,000 hours
Annual operating hours:	derived from substituted lamps, rebound factor =1.0
Luminous flux:	derived from substituted lamps, rebound factor =1.05
Efficacy:	for High-End lamps in non-residential sector, see par. E.2.4
Control gear efficiency:	for High-End lamps in non-residential sector, see par. E.2.4
Purchase price:	for High-End lamps in non-residential sector, see par. E.2.4
Price shares:	see par. E.2.6
Installation costs:	identical to those of substituted lamps
Maintenance costs:	identical to those of substituted lamps
Sales:	as resulting from sales shifts defined for HID lamps

E.4.5 LED luminaire for HID

Basic input data:

The same rules apply as for retrofit lamps in the preceding paragraph, except that the rebound factor for luminous flux is 1.025 instead of 1.05, see par. E.2.5.

E.5 CFLni applications

E.5.1 CFLni

Basic input data:

MELISA v0 used 55 lm/W as an average efficacy (with the intention to increase this to 65 lm/W after 2016). There are several reasons to adapt this in MELISA v1:

- The efficacies for CFLni and CFLi were identical in MELISA v0 while the former is supposed to exclude the ballast efficiency and the latter to include it. Maintaining the CFLi efficacy on 55 lm/W; the one for CFLni should be approximately 55/91% = 60 lm/W.
- IEA/GfK sales data indicate an average efficacy of 66 lm/W for 2007, increasing to 70 lm/W in 2013.
- In the Philips catalogue efficacy values range from 48 to 82 lm/W, but values between 60 and 70 lm/W are typical.
- Required efficacies in 245/2009 (from 2010) range from 50 lm/W (only for one 5W model) to 83 lm/W (at 25˚C, excl. ballast). Although this depends on the model, a 12 W lamp should probably have ≥ 65 lm/W (all from 2010).

Consequently, in MELISA v1 the efficacy for CFLni was increased from 55 to 60 lm/W for the period 1990-2008 and then increased to 65 lm/W in 2010 and later years. For the period 1990-2008 the average power of 11.5 W was maintained, implying an increase of the average capacity from 633 to 690 lm. For later years the 690 lm were maintained so that the increase in efficacy entailed a reduction in power to 10.6 W.

In MELISA v0 the ballast efficiency was 91% for all years. The requirement from regulation 245/2009 for 2017 is > 80% for a 12W lamp; A2BAT efficiency is 91%.
Consequently the ballast efficiency has been adapted in MELISA v1, starting from 80% in 1990 and increasing to 85% in 2013, remaining constant in later years.

Other data have not been changed from those presented in earlier Task reports, see par. 5.8.1 of the Task 4 report for a summary.

BAU assumption:

Analysing the CFLni and LED sales in the years 2010-2013, the conclusion is that, in good approximation, in the year 2013 100% of the CFLni has been substituted by the same type and a negligible quantity seems to have been replaced by LED (assumed 0%).
The Task 4 research (par. 5.8.3) showed that few LED retrofit lamps are available for CFLni substitution. Consequently it has been assumed that 80% of the substitutions concerns LED light sources contained in integrated luminaires.
According to the Task 6 analysis (par. 3.6), 2015 LED substitutes for CFLni are not yet economically convenient, but this is expected to change around the year 2020. However, since 2010 the CFLni sales anyway show a downward trend.

Table 28 shows the assumptions made for the BAU scenario as regards the distribution of the potential CFLni lamp sales over CFLni and LED. By 2020, 40% of the sales shifts to LED but 60% of the potential CFLni sales is still covered by the same technology. After 2020 LEDs are expected to become economically more attractive and by 2030 the sales proportions are inverted: 20% CFLni and 80% LED.

Table 28 Assumptions made for the BAU scenario regarding the distribution of light source sales for CFLni applications

	2014	2015	2016	2017	2018	2019	2020	2025	2030
% sales remaining current type	90%	85%	80%	75%	70%	65%	60%	40%	20%
% sales shifting to LED retrofit	2%	3%	4%	5%	6%	7%	8%	12%	16%
% sales shifting to LED luminaire	8%	12%	16%	20%	24%	28%	32%	48%	64%
Share LED light sources in luminaires	80%	80%	80%	80%	80%	80%	80%	80%	80%

Comments:

For the period 2010-2012, the sum of the CFLni-lamps reaching end-of-life and of the new CFLni applications (from assumed general growth percentage) is higher than the actual sales that have been estimated for CFLni, i.e. more CFLni-lamps were being sold than could be expected. This can be due to CFLni replacing the phased-out GLS lamps. However, in 2013 the situation is inverted, CFLni sales being lower than could be expected. The difference cannot have shifted to LEDs because there is no room within the LED sales for this.

In 2013 this sales 'mismatch' is anyway less than 10% and has therefore been accepted. For additional remarks on sales 'mismatch' see par. E.7.7.

E.5.2 LED retrofit for CFLni

Basic input data:

Lifetime:	20,000 hours
Annual operating hours:	derived from substituted lamps, rebound factor =1.0
Luminous flux:	derived from substituted lamps, rebound factor =1.1
Efficacy:	for High-End lamps in non-residential sector, see par. E.2.4 for Low-End lamps in residential sector.
Control gear efficiency:	for High-End lamps in non-residential sector, see par. E.2.4 for Low-End lamps in residential sector.
Purchase price:	for High-End lamps in non-residential sector, see par. E.2.4 for Low-End lamps in residential sector.
Price shares:	see par. E.2.6
Installation costs:	identical to those of substituted lamps
Maintenance costs:	identical to those of substituted lamps
Sales:	as resulting from sales shifts defined for CFLni

E.5.3 LED luminaire for CFLni

Basic input data:

The same rules apply as for retrofit lamps in the preceding paragraph, except that the rebound factor for luminous flux is 1.05 instead of 1.1, see par. E.2.5.

E.6 DLS applications

E.6.1 HL LV R

Basic input data:

The average characteristics used in MELISA v0 were: 35W, 14 lm/W, 490 lm. This corresponds well with data from other sources and with catalogue data. Only GfK data show a slightly higher efficacy (17.5 lm/W) and a higher average flux. Task 6 used 18 lm/W for the BAT version, but costs for that version are also higher.

Regulation 1194/2012 requires EEI<0.95 from sept.2013 (for >450 lm lamps) and this is maintained in stages 2 and 3 for all lamps. EEI=Prated*1.06 / (0.88*SQRT(flux)+ 0.049*flux) gives EEI=0.85 for 35W and 490 lm, which is acceptable.

As originally intended in MELISA v0, and to align with GfK data, the efficacy is gradually increased from 14 lm/W in 2013 to 17 lm/W in 2017, maintaining the same power and thus increasing the average luminous flux (35 W, 17 lm/W, 595 lm).

In the above, the luminous flux has to be interpreted as the flux in a cone, as prescribed in Regulation 1194/2012.

In MELISA v0, 80% of HL LV R sales was assumed to be in the residential sector. Following a comparison with GfK sales data (Task 2 report, table 51), this has been reduced to 50%. Total sales over all sectors have not been changed.

Other data have not been changed from those presented in earlier Task reports, see par. 5.9.1 of the Task 4 report for a summary.

BAU assumption:

Analysing the DLS/HL LV R and LED sales in the years 2010-2013, the conclusion is that in the year 2013 89% of the HL LV R has been substituted by the same type and 11% has been substituted by LED. This distribution is taken as a starting point for the BAU scenario.

The Task 4 research (par. 5.9.3) has shown that LED retrofit lamps for HL LV R substitution are available. Consequently it has been assumed that initially the large majority of substitutions will involve retrofit lamps (80% retrofit, 20% luminaires in 2014). The share of LED light sources inside integrated LED luminaires is assumed to grow gradually (40% retrofit, 60% luminaires in 2030).

According to the Task 6 analysis (par. 3.11), 2015 LED substitutes for HL LV R are already economically convenient (payback time 4 years), and this is expected to further improve towards 2020 (payback time 0.5 years).

Table 29 shows the assumptions made for the BAU scenario as regards the distribution of the potential HL LV R lamp sales over HL LV R and LED. By 2020, 30% of the sales has shifted to LED. After 2020 LEDs are expected to become economically even more attractive and by 2030 the sales proportions are: 25% HL LV R and 75% LED.

Table 29 Assumptions made for the BAU scenario regarding the distribution of light source sales for HL LV R applications

	2014	2015	2016	2017	2018	2019	2020	2025	2030
% sales remaining current type	85%	85%	82%	79%	76%	73%	70%	50%	25%
% sales shifting to LED retrofit	12%	12%	14%	16%	18%	19%	21%	30%	30%
% sales shifting to LED luminaire	3%	3%	4%	5%	6%	8%	9%	20%	45%
Share LED light sources in luminaires	20%	20%	22%	24%	26%	28%	30%	40%	60%

E.6.2 HL MV X (DLS)

Basic input data, efficacy, power and flux:

The average characteristics used in MELISA v0 were: 35W, 12 lm/W, 420 lm. The lumens were interpreted as the total flux, not the flux in a cone.

Data from other sources (CLASP, VITO 2009, IEA/GfK) are somewhat confusing but generally indicate a higher average power, between 40 and 52 W.

The following data can be derived from the MV DLS market overview as average for halogen lamps:

GU10-cap: 48.3 W ; 382 lm(total) ; 318 lm(cone) ; 7.9 lm(total)/W ; 6.6 lm(cone)/W.
E-cap: 59.3 W ; 570 lm(total) ; 475 lm(cone) ; 9.6 lm(total)/W ; 8.0 lm(cone)/W.
Any cap: 52.7 W ; 454 lm(total) ; 378 lm(cone) ; 8.6 lm(total)/W ; 7.2 lm(cone)/W.

These data generally indicate a higher power than used in MELISA v0 and a lower efficacy, but they are based on quantities of models, not on sales.

Regulation 1194/2012, from Sept. 2014, requires: $EEI=P/(0{,}88\sqrt{\Phi}+0{,}049\Phi)<1.75$. This is for a luminous flux in a 90° or 120° cone.

For 300 lm(cone) this gives: 52.4 W max, 5.7 lm(cone)/W min
For 432 lm(cone) this gives: 69.1 W max, 6.3 lm(cone)/W min
For 500 lm(cone) this gives: 77.3 W max, 6.5 lm(cone)/W min
For 800 lm(cone) this gives: 112.2 W max, 7.1 lm(cone)/W min

Regulation 1194/2012, from Sept. 2016 (stage 3), requires: EEI<0.95
For 432 lm this gives: 37.5 W max, 11.5 lm(cone)/W min
MV HL cannot meet this and will be phased-out.

Considering the data above it has been decided to use the following data in MELISA v1: 50W, 7.2 lm/W, 360 lm (for lumens in a cone).

Basic input data, price:

The problem with this base case is that it contains many small and cheap GU10 lamps, but also some large and much more expensive PAR lamps.

The MELISA v0 price was 11.84 euros/lamp excl. VAT. This gave a high LCC/Mlmh peak in Task 5 fig.7 and there were remarks from stakeholders on this.

From the MV DLS market overview, an average price of approximately 5 euros/lamp excl. VAT can be estimated. This has been taken as the new price in MELISA v1.

Basic input data, sales and BC definition:

The subdivision of directional halogen lamps over the base cases HL MV E (GLS substitutes with E-cap, including reflector) and HL MV X (PAR lamps and lamps with GU10 cap) is not completely clear. It is assumed in MELISA v1 that all directional lamps are in HL MV X and all non-directional lamps in HL MV E. Sales quantities (from MELISA v0, as presented in the Task 2 report) have not been changed for this. This may imply that the quantity of DLS is slightly underestimated (some reflector lamps with E-cap could be missing) and the quantity of NDLS slightly overestimated, but considering that the total quantity should anyway be correct, the overall effects on the scenario analyses are judged acceptable.

Other data have not been changed from those presented in earlier Task reports, see par. 5.14.1 of the Task 4 report for a summary.

BAU assumption:

Analysing the DLS/HL MV X and LED sales in the years 2010-2013, the conclusion is that in the year 2013 90% of the HL MV X has been substituted by the same type and 10% has been substituted by LED. This distribution is taken as a starting point for the BAU scenario.

The MV DLS market overview has shown that LED retrofit lamps for HL MV X substitution are widely available and that they are already economically convenient. Consequently it has been assumed that initially the large majority of substitutions will involve retrofit lamps (80% retrofit, 20% luminaires in 2014). The share of LED light sources inside integrated LED luminaires is assumed to grow gradually (40% retrofit, 60% luminaires in 2030).

Considering Regulation 1194/2012 stage 3 and the related MV DLS market assessment of August/September 2015, directional mains-voltage halogen lamps will be phased out starting September 2016.

Table 30 shows the assumptions made for the BAU scenario as regards the phase-out of HL MV X (DLS) lamp. By 2016, 40% of the sales has shifted to LED and due to the regulations HL MV X sales drop to 0% by 2020 (all HL MV X assumed replaced by LED).

Table 30 Assumptions made for the BAU scenario regarding the distribution of light source sales for HL MV X (DLS) applications

	2014	2015	2016	2017	2018	2019	2020	2025	2030
% sales remaining current type	80%	70%	60%	20%	10%	5%	0%	0%	0%
% sales shifting to LED retrofit	16%	24%	31%	61%	67%	68%	70%	60%	40%
% sales shifting to LED luminaire	4%	6%	9%	19%	23%	27%	30%	40%	60%
Share LED light sources in luminaires	20%	20%	22%	24%	26%	28%	30%	40%	60%

E.6.3 GLS R (DLS)

Basic input data:

The average characteristics used in MELISA v0 were: 54W, 9.5 lm/W, 513 lm. The lumens were interpreted as the total flux, not the flux in a cone.

The power of 54 W corresponds well with the average found in the MV DLS market overview (55 W) and the average used in other sources (VITO 2009 54 W, CLASP 60 W). Only recent IEA/GfK data give lower values: ≈48W in 2007 and ≈40-45W in 2013, but these are not specific for DLS.

As regards efficacy, the MV DLS market overview and data for GLS still present in manufacturer catalogues indicate 4-6 lm/W with peaks up to 8 lm/W for some higher power PAR38. This is for lumens measured in a cone.

Comparable halogen lamps (see HL MV X (DLS)) now use 7.2 lm(cone)/W, and GLS efficacy has to be lower than that.

Regulation 1194/2012, from Sept. 2014, requires: $EEI=P/(0{,}88\sqrt{\Phi}+0{,}049\Phi)<1.75$. This is for a luminous flux in a 90° or 120° cone (since September 2013 same rule, but applicable only for > 450 lm lamps)

For 300 lm this gives: 52.4 W max, 5.7 lm(cone)/W min

For 432 lm this gives: 69.1 W max, 6.3 lm(cone)/W min

For 500 lm this gives: 77.3 W max, 6.5 lm(cone)/W min

For 800 lm this gives: 112.2 W max, 7.1 lm(cone)/W min

Some higher power PAR lamps meet this, but in general GLS are intended to be phased out, which implies that efficacy cannot be higher than 5-6 lm(cone)/W.

Considering the data above it has been decided to use the following data in MELISA v1: <u>54 W, 6.0 lm/W, 324 lm (for lumens in a cone)</u>.

Other data have not been changed from those presented in earlier Task reports, see par. 5.15.1 of the Task 4 report for a summary.

BAU assumption:

Sales for this base case have been decreasing significantly for several years already, mainly shifting to halogen lamps and in recent years to LED. The impact of this base case in the scenario analyses is therefore low. The BAU scenario assumes that this trend will continue and that sales will drop to zero by 2020.

Table 31 shows the assumptions made for the BAU scenario as regards the phase-out of GLS R (DLS) lamp. In 2015, 30% of the sales has shifted to LED and due to the regulations GLS R sales drop to 0% by 2020 (all GLS R assumed replaced by LED).

Table 31 Assumptions made for the BAU scenario regarding the distribution of light source sales for GLS R (DLS) applications

	2014	2015	2016	2017	2018	2019	2020	2025	2030
% sales remaining current type	80%	70%	60%	20%	10%	5%	0%	0%	0%
% sales shifting to LED retrofit	16%	24%	31%	61%	67%	68%	70%	60%	40%
% sales shifting to LED luminaire	4%	6%	9%	19%	23%	27%	30%	40%	60%
Share LED light sources in luminaires	20%	20%	22%	24%	26%	28%	30%	40%	60%

E.6.4 LED retrofit for DLS

Basic input data:

Lifetime:	20,000 hours
Annual operating hours:	derived from substituted lamps, rebound factor =1.025
Luminous flux:	derived from substituted lamps, rebound factor =1.1
Efficacy:	for Low-End lamps in all sectors, see par. E.2.4
Control gear efficiency:	for Low-End lamps in all sectors, see par. E.2.4
Purchase price:	for Low-End lamps in all sectors, see par. E.2.4
Price shares:	see par. E.2.6
Installation costs:	identical to those of substituted lamps
Maintenance costs:	identical to those of substituted lamps
Sales:	as resulting from sales shifts defined for DLS lamps

E.6.5 LED luminaire for DLS

Basic input data:

The same rules apply as for retrofit lamps in the preceding paragraph.

E.7 NDLS applications

E.7.1 CFLi

Basic input data:

The average characteristics used in MELISA v0 were: 9.5 W, 55 lm/W, 523 lm.

Comments have been received from stakeholders that the average power of 9.5 W is too low, and a value of 11 W was suggested. That the assumed power of 9.5 W is low was also signalled by the study team itself when comparing with other sources in the Task 3 report. IEA/GfK data indicated 13 W (2007) -14 W (2013).

The average efficacy of 55 lm/W is compatible with the choice for CFLni, compares well to data from other sources, and satisfies the requirements of Regulation 244/2009 for non-clear lamps (from maximum 8.9 W and minimum 44.8 lm/W at 400 lm to maximum 15 W and minimum 53.2 lm/W at 800 lm).

As a consequence, in MELISA v1 the average power has been gradually increased from 9.5 W in the year 2000 to 11 W in the year 2013. The efficacy has been maintained at 55 lm/W and consequently the luminous flux increases from 523 lm to 605 lm.

Other data have not been changed from those presented in earlier Task reports, see par. 5.7.1 of the Task 4 report for a summary.

BAU assumption:

Analysing the NDLS/CFLi and LED sales in the years 2010-2013, the conclusion is that in the year 2013 95% of the CFLi has been substituted by the same type and 5% has been substituted by LED. This distribution is taken as a starting point for the BAU scenario.

The Task 4 research (par. 5.13.3) has shown that LED retrofit lamps for CFLi substitution are available. Consequently it has been assumed that initially the large majority of substitutions will involve retrofit lamps (80% retrofit, 20% luminaires in 2014). The share of LED light sources inside integrated LED luminaires is assumed to grow gradually (40% retrofit, 60% luminaires in 2030).

According to the Task 6 analysis (par. 3.9), 2015 LED substitutes for CFLi are not economically convenient yet, but this is expected to change by 2019-2020. Anyway the trend in CFLi sales is downwards since 2009 and this is expected to continue and accelerate.

Table 32 shows the assumptions made for the BAU scenario as regards the distribution of the potential CFLi lamp sales over CFLi and LED. By 2020, 80% of the sales has shifted to LED. By 2030 this is expected to be 90%.

Table 32 Assumptions made for the BAU scenario regarding the distribution of light source sales for CFLi applications

	2014	2015	2016	2017	2018	2019	2020	2025	2030
% sales remaining current type	80%	75%	60%	50%	40%	30%	20%	10%	10%
% sales shifting to LED retrofit	16%	20%	31%	38%	44%	50%	56%	54%	36%
% sales shifting to LED luminaire	4%	5%	9%	12%	16%	20%	24%	36%	54%
Share LED light sources in luminaires	20%	20%	22%	24%	26%	28%	30%	40%	60%

E.7.2 HL MV E (NDLS)

Basic input data, efficacy, power and flux:

The average characteristics used in MELISA v0 were: 36 W, 12 lm/W, 432 lm, with the intention to increase to 15 lm/W and 540 lm after 2016.

Other sources generally indicate a higher average power (CLASP 52 W, VITO 2009 40 W, IEA/GfK ≈47W in 2007, ≈40W in 2013, for all MV halogens except linear), higher flux (VITO 480 lm; GfK: ≈690 lm (2007) and ≈580 lm (2013), and identical or slightly higher efficacy (VITO 12 lm/W; GfK 14.5->14.2 lm/W).

Regulation 244/2009, from 2009, requires $P_{max} = 1,1 * (0,88\sqrt{\Phi}+0,049\Phi)$ (gradually more lamps have to satisfy 2012 requirement).

For 432 lm this gives: 43.4 W max, 10.0 lm/W min

Regulation 244/2009, from 2012 to 2018 (stage 6 recently postponed from 2016 to 2018, see regulation 2015/1428), requires $P_{max} = 0,8 * (0,88\sqrt{\Phi}+0,049\Phi)$

For 300 lm this gives: 24.0 W max, 12.5 lm/W min

For 432 lm this gives: 31.6 W max, 13.7 lm/W min

For 500 lm this gives: 35.3 W max, 14.1 lm/W min

For 800 lm this gives: 51.3 W max, 15.6 lm/W min

Regulation 244/2009, after September 2018 (new stage 6 date), requires: $P_{max} = 0,6 * (0,88\sqrt{\Phi}+0,049\Phi)$

For 432 lm this gives: 23.7 W max, 18.2 lm/W min

MV HL cannot meet this and will be phased-out.

The MELISA v0 average lamp characteristics do not meet the 2012 requirements from Regulation 244/2009 and have therefore been adapted in MELISA v1. The original characteristics are maintained over the period 1990-2011, but then the efficacy is increased to 14 lm/W in 2013. The power of 36 W is maintained, consequently increasing the luminous flux to 504 lm.

Other data have not been changed from those presented in earlier Task reports, see par. 5.13.1 of the Task 4 report for a summary.

Basic input data, sales and BC definition:

The subdivision of directional halogen lamps over the base cases HL MV E (GLS substitutes with E-cap, including reflector) and HL MV X (PAR lamps and lamps with GU10 cap) is not completely clear. It is assumed in MELISA v1 that all directional lamps are in HL MV X and all non-directional lamps in HL MV E. Sales quantities (from MELISA v0, as presented in the Task 2 report) have not been changed for this. This may imply that the quantity of DLS is slightly underestimated (some reflector lamps with E-cap could be missing) and the quantity of NDLS slightly overestimated, but considering that the total quantity should anyway be correct, the overall effects on the scenario analyses are judged acceptable.

BAU assumption:

Analysing the NDLS/HL MV E and LED sales in the years 2010-2013, the conclusion is that in the year 2013 95% of the HL MV E has been substituted by the same type and 5% has been substituted by LED. This distribution is taken as a starting point for the BAU scenario.

The Task 4 research (par. 5.13.3) has shown that LED retrofit lamps for HL MV E substitution are available. Consequently it has been assumed that initially the large majority of substitutions will involve retrofit lamps (80% retrofit, 20% luminaires in 2014). The share of LED light sources inside integrated LED luminaires is assumed to grow gradually (40% retrofit, 60% luminaires in 2030).

According to the Task 6 analysis (par. 3.9), 2015 LED substitutes for HL MV X are already economically convenient but still have relatively long payback times (3-4 years). This situation is expected to further improve rapidly in the coming years.

As outlined also above, HL MV E lamps are phased-out by the effects of Regulation 244/2009 stage 6 (as amended) from September 2018.

Table 33 shows the assumptions made for the BAU scenario as regards the distribution of the potential HL MV E (NDLS) lamp sales over HL MV E and LED. By 2018 (phase-out year), 50% of the sales has shifted to LED. By 2020 this is expected to be 90% and in 2023 and later 100%.

Table 33 Assumptions made for the BAU scenario regarding the distribution of light source sales for HL MV E (NDLS) applications

	2014	2015	2016	2017	2018	2019	2020	2025	2030
% sales remaining current type	90%	85%	80%	75%	50%	20%	10%	0%	0%
% sales shifting to LED retrofit	8%	12%	16%	19%	37%	58%	63%	60%	40%
% sales shifting to LED luminaire	2%	3%	4%	6%	13%	22%	27%	40%	60%
Share LED light sources in luminaires	20%	20%	22%	24%	26%	28%	30%	40%	60%

E.7.3 GLS X (NDLS)

Basic input data, efficacy, power and flux:

The average characteristics used in MELISA v0 were: 54 W, 9.5 lm/W, 513 lm.

A comparison with IEA/GfK sales data (≈48W in 2007 and ≈40-45W in 2013, see Task 3 report) suggests that the 54 W average power is high. The phase-out of incandescent lamps started in September 2009 with the higher powers and then gradually included also lower powers, including all lamps with more than 60 lm from 2012, so that it is reasonable to assume that the average power of sold GLS lamps decreases over the period 2009-2012.

A comparison with other data sources also suggests that the 9.5 lm/W efficacy is low for a 513 lm lamp. VITO 2009 and IEA/GfK indicate 11 lm/W, and this compares well with data for a standard GLS bulb that can still be found in a manufacturer catalogue (25W, 220lm -> 8.8 lm/W; 40W, 415 lm -> 10.4 lm/W, 60W, 715 lm -> 11.9 lm/W, 100W 1340 lm -> 13.4 lm/W).

Considering the above data, the MELISA v0 values were maintained in MELISA v1 up to year 2009, but they then gradually change until reaching 45 W, 11 lm/W, 495 lm by 2012.

Other data have not been changed from those presented in earlier Task reports, see par. 5.16.1 of the Task 4 report for a summary.

BAU assumption:

Sales for this base case have been decreasing significantly for several years already, mainly shifting to halogen lamps, CFLi, and in recent years to LED. The impact of this base case in the scenario analyses is therefore low. The BAU scenario assumes that this trend will continue and that sales will drop to zero by 2020 (Table 34).

Table 34 Assumptions made for the BAU scenario regarding the distribution of light source sales for GLS X (NDLS) applications

	2014	2015	2016	2017	2018	2019	2020	2025	2030
% sales remaining current type	90%	70%	50%	30%	10%	5%	0%	0%	0%
% sales shifting to LED retrofit	8%	24%	39%	53%	67%	68%	70%	60%	40%
% sales shifting to LED luminaire	2%	6%	11%	17%	23%	27%	30%	40%	60%
Share LED light sources in luminaires	20%	20%	22%	24%	26%	28%	30%	40%	60%

E.7.4 HL LV C

Basic input data:

The average characteristics used in MELISA v0 were: 35 W, 14 lm/W, 490 lm.

Regulation 244/2009, from 2012 up to 2018 (amended, was 2016): Pmax = 0,8 * (0,88√Φ+0,049Φ) /1.06, after sept. 2018: Pmax = 0,6 * (0,88√Φ+0,049Φ) /1.06

For 2012, for 490 lm, this gives 32.8 W max, 14.9 lm/W min.

For 2018, for 490 lm, this gives 24.6 W max, 19.9 lm/W min

For 2012, for 540 lm, this gives 35.4 W max, 15.3 lm/W min.

For 2018, for 540 lm, this gives 26.6 W max, 20.3 lm/W min

There are HL LV C lamps on the market that meet the 2018 requirements, but some of the less-performing models may be phased-out.

The average MELISA v0 characteristics do not meet the requirements. Consequently, in MELISA v1 the characteristics 35 W, 14 lm/W, 490 lm are maintained up to 2012, but then gradually changed to 27 W, 20 lm/W, 540 lm in 2019.

In MELISA v0, 80% of HL LV R sales was assumed to be in the residential sector. Following a comparison with GfK sales data (Task 2 report, table 51), this has been reduced to 50%. Total sales over all sectors have not been changed.

Other data have not been changed from those presented in earlier Task reports, see par. 5.10.1 of the Task 4 report for a summary.

BAU assumption:

Analysing the NDLS/HL LV C and LED sales in the years 2010-2013, the conclusion is that in the year 2013 95% of the HL LV C has been substituted by the same type and 5% has been substituted by LED. This distribution is taken as a starting point for the BAU scenario.

The Task 4 research (par. 5.10.3) has shown that LED retrofit lamps for HL LV C substitution are available, but it might be difficult to find high-lumen models, and in some cases LED dimensions might be too large to fit in existing luminaires. Consequently it has been assumed that initially the majority of substitutions will involve retrofit lamps (70% retrofit, 30% luminaires in 2014). The share of LED light sources inside integrated LED luminaires is assumed to grow gradually (30% retrofit, 70% luminaires in 2030).

According to the Task 6 analysis (par. 3.12), 2015 LED substitutes for HL LV C are already economically convenient and this will further improve towards 2020.

Table 35 shows the assumptions made for the BAU scenario as regards the distribution of the potential HL LV C lamp sales over HL LV C and LED. By 2020, 50% of the sales has shifted to LED. After 2020 LEDs are expected to become economically even more attractive and by 2030 the sales proportions are: 10% HL LV C and 90% LED.

Table 35 Assumptions made for the BAU scenario regarding the distribution of light source sales for HL LV C applications

	2014	2015	2016	2017	2018	2019	2020	2025	2030
% sales remaining current type	95%	90%	85%	80%	70%	60%	50%	30%	10%
% sales shifting to LED retrofit	4%	7%	10%	13%	19%	25%	30%	35%	27%
% sales shifting to LED luminaire	2%	3%	5%	7%	11%	15%	20%	35%	63%
Share LED light sources in luminaires	30%	30%	32%	34%	36%	38%	40%	50%	70%

E.7.5 HL MV C

Basic input data:

MELISA v0 uses 35W, 12 lm/W, 420 lm, life 1500 h. MELISA foresaw 15 lm/W with 525 lm after 2016.

Other sources: CLASP 52W, VITO 40W, GfK ≈47W in 2007, ≈40W in 2013 (for all MV halogens except linear)

Flux: VITO 480 lm; GfK: ≈690 lm (2007) and ≈580 lm (2013)

Efficacy: VITO 12 lm/W; GfK 14.5->14.2 lm/W

Philips Ecohalo clickline (G9): 18-53W, 204-850 lm, 11.1-16 lm/W. Other series have lower efficacies.

Regulation 244/2009, from 2012 onwards (G9 cap exempted from stage 6): $P_{max} = 0{,}8 * (0{,}88\sqrt{\Phi}+0{,}049\Phi)$

For 420 lm this gives: 30.9 W max, 13.6 lm/W min

For 525 lm this gives: 36.7 W max, 14.3 lm/W min

The average MELISA v0 characteristics do not meet the requirements. Consequently, in MELISA v1 the characteristics 35 W, 12 lm/W, 420 lm are maintained up to 2012, but then gradually changed to 36.7 W, 14.3 lm/W, 525 lm in 2014.

Other data have not been changed from those presented in earlier Task reports, see par. 5.11.1 of the Task 4 report for a summary.

BAU assumption:

Analysing the NDLS/HL MV C and LED sales in the years 2010-2013, the conclusion is that in the year 2013 95% of the HL MV C has been substituted by the same type and 5% has been substituted by LED. This distribution is taken as a starting point for the BAU scenario.

The Task 4 research (par. 5.11.3) has shown that LED retrofit lamps for HL MV C substitution are available, but it might be difficult to find high-lumen models, and in some cases LED dimensions might be too large to fit in existing luminaires. Consequently it has been assumed that initially the majority of substitutions will involve retrofit lamps (70% retrofit, 30% luminaires in 2014). The share of LED light sources inside integrated LED luminaires is assumed to grow gradually (30% retrofit, 70% luminaires in 2030).

According to the Task 6 analysis (par. 3.13), 2015 LED substitutes for HL MV C are already economically convenient and this will further improve towards 2020.

Table 36 shows the assumptions made for the BAU scenario as regards the distribution of the potential HL MV C lamp sales over HL MV C and LED. By 2020, 50% of the sales has shifted to LED. After 2020 LEDs are expected to become economically even more attractive and by 2030 the sales proportions are: 10% HL MV C and 90% LED.

Table 36 Assumptions made for the BAU scenario regarding the distribution of light source sales for HL MV C applications

	2014	2015	2016	2017	2018	2019	2020	2025	2030
% sales remaining current type	95%	90%	85%	80%	70%	60%	50%	30%	10%
% sales shifting to LED retrofit	4%	7%	10%	13%	19%	25%	30%	35%	27%
% sales shifting to LED luminaire	2%	3%	5%	7%	11%	15%	20%	35%	63%
Share LED light sources in luminaires	30%	30%	32%	34%	36%	38%	40%	50%	70%

E.7.6 HL MV L

Basic input data:

The average characteristics used in MELISA v0 were: 250 W, 12 lm/W, 3000 lm.

The IEA/GfK data reported in Task 3 showed ≈300 W with 5000-6600 lm in 2007 and 200-240 W with 3700-5100 lm in 2013. Both VITO 2009 and IEA/GfK indicated higher efficacies, between 17 and 19 lm/W. The BAT option analysed in Task 6 considered 19.4 lm/W.

Regulation 244/2009, from 2009 onwards (R7s cap exempted from stage 6), requires: $Pmax = 0{,}8 * (0{,}88\sqrt{\Phi}+0{,}049\Phi)$

For 3000 lm this gives: 156 W max, 19.2 lm/W min

For 4000 lm this gives: 201 W max, 19.9 lm/W min

These data correspond well with lamps sold by some major suppliers.

The average MELISA v0 characteristics do not meet the requirements. Consequently, in MELISA v1 the characteristics 250 W, 12 lm/W, 3000 lm are maintained up to 2009, but then gradually changed to 200 W, 19 lm/W, 3800 lm in 2012.

Other data have not been changed from those presented in earlier Task reports, see par. 5.12.1 of the Task 4 report for a summary.

BAU assumption:

Analysing the NDLS/HL MV L and LED sales in the years 2010-2013, the conclusion is that in the year 2013 95% of the HL MV L has been substituted by the same type and 5% has been substituted by LED. This distribution is taken as a starting point for the BAU scenario.

The Task 4 research (par. 5.12.3) has shown that LED retrofit lamps for HL MV L substitution are available, but it might be difficult to find high-lumen models, light distribution characteristics may not always be adequate, and in some cases LED dimensions might be too large to fit in existing luminaires. Consequently it has been assumed that initially the majority of substitutions will involve retrofit lamps (70% retrofit, 30% luminaires in 2014). The share of LED light sources inside integrated LED luminaires is assumed to grow gradually (30% retrofit, 70% luminaires in 2030).

According to the Task 6 analysis (par. 3.14), 2015 LED substitutes for HL MV L are already economically convenient and this will further improve towards 2020.

Table 37 shows the assumptions made for the BAU scenario as regards the distribution of the potential HL MV L lamp sales over HL MV L and LED. By 2020, 50% of the sales has shifted to LED. After 2020 LEDs are expected to become economically even more attractive and by 2030 the sales proportions are: 10% HL MV C and 90% LED.

Table 37 Assumptions made for the BAU scenario regarding the distribution of light source sales for HL MV L applications

	2014	2015	2016	2017	2018	2019	2020	2025	2030
% sales remaining current type	95%	90%	85%	80%	70%	60%	50%	30%	10%
% sales shifting to LED retrofit	4%	7%	10%	13%	19%	25%	30%	35%	27%
% sales shifting to LED luminaire	2%	3%	5%	7%	11%	15%	20%	35%	63%
Share LED light sources in luminaires	30%	30%	32%	34%	36%	38%	40%	50%	70%

E.7.7 GLS and HL storage; sales mismatch

In MELISA v1 the potential sales for a base case are computed as the sum of:

- Lamps reaching end-of-life (derived from lifetime and annual operating hours)
- Lamps for new applications (derived from general growth percentages)
- Lamps substituting other lamp types

These potential sales are then subdivided using scenario assumptions:

- Lamps being substituted by the same base case type
- Lamps being substituted by LED (retrofit or luminaire)
- Lamps being substituted by other non-LED lamp types.

For the period up to 2013 the actual sales data are known (with an uncertainty margin) and can be compared with the potential sales. In several cases there is a sales 'mismatch' (= actual sales - potential sales), which can be caused by e.g.:

- Lamps are being bought that are not immediately installed,
- Lamps are being installed from storage (not bought in the year considered),
- The real useful lifetime might be different or the spread in lifetime should be considered,
- The assumed general growth percentage is not adequate for the base case,
- There is an exchange of lamp types that is not considered in the modelling, e.g. substitution of CFLni by HID, HID by LFL, DLS by NDLS, etc.
- Uncertainty in the actual sales (at least +/-10% is likely, maybe even higher in the non-residential sector).

For most application areas (LFL, HID, CFLni, DLS) the sales mismatch is small and can be neglected. An exception are the NDLS lamps, in particular in the residential sector.

For the base cases of the NDLS application, the shifts of sales between CFLi, Halogen lamps and GLS are not explicitly modelled; only the shifts from these base cases to LED are explicitly addressed.

Consequently, for the GLS X (NDLS) base case a high negative sales mismatch is found: potential sales are much higher than the actual sales, implying that GLS are being substituted by other types (e.g. CFLi, HL).

In compensation, the CFLi and HL base cases show a high positive sales mismatch: potential sales are much lower than the actual sales, implying that the CFLi or HL are substituting other types (e.g. GLS).

The sum of all sales mismatches over the NDLS base cases should be small (ideally zero), but for the years 2009-2013 a relatively large negative gap remains (around 10% of total NDLS sales), implying that there are GLS lamps that are not being replaced by the GLS, HL, CFLi or LED lamps sold in those years.

The assumption in MELISA is that this residential NDLS sales gap is filled by GLS and Halogen lamps that come from household storages [80], i.e. consumers bought more lamps than needed in preceding years and are using them only now.

This is handled in two separate base cases 'GLS Storage' and 'HL Storage', where the quantity of lamps needed to (approximately) resolve the mismatch is entered as sales without associated initial costs. The 'GLS Storage' lamps have the same characteristics

[80] In MELISA v0 this was presented as 'GLS stock' and 'Tungsten stock', but in MELISA v1 the indication 'from storage' has been preferred.

as the GLS X (NDLS) base case; the 'HL Storage' lamps the same as the HL MV E (NDLS) base case. For the remainder these 'Storage' base cases are treated in the same way as the other base cases.

E.7.8 LED retrofit for NDLS

Basic input data:

Lifetime:	20,000 hours
Annual operating hours:	derived from substituted lamps, rebound factor =1.025
Luminous flux:	derived from substituted lamps, rebound factor =1.1
Efficacy:	for Low-End lamps in all sectors, see par. E.2.4
Control gear efficiency:	for Low-End lamps in all sectors, see par. E.2.4
Purchase price:	for Low-End lamps in all sectors, see par. E.2.4
Price shares:	see par. E.2.6
Installation costs:	identical to those of substituted lamps
Maintenance costs:	identical to those of substituted lamps
Sales:	as resulting from sales shifts defined for NDLS lamps

E.7.9 LED luminaire for NDLS

Basic input data:

The same rules apply as for retrofit lamps in the preceding paragraph.

Annex F Input data for ECO-scenarios

F.1 Introduction

There are two main differences between the ECO-scenarios and the BAU-scenario:

- Different shift in sales from classic technology light sources to LED products,
- Different assumption regarding LED efficacy and price projections

For the remainder, all input data for the ECO-scenarios are identical to those for the BAU-scenario explained in the previous Annex.

Sales shift differences

It is recalled that the ECO70 scenario introduces a maximum power requirement for lighting products (when emitting rated luminous flux of Φ) of:

$P_{on} \leq (2+\Phi/70)*((CRI+240)/320)$ W, assumed to enter into force in 2020

In the ECO80+120 scenario the maximum allowed power is decreased using similar formulations:

$P_{on} \leq (2+\Phi/80)*((CRI+240)/320)$ W, assumed to enter into force in 2020
$P_{on} \leq (2+\Phi/120)*((CRI+240)/320)$ W, assumed to enter into force in 2024

In the ECO120 scenario the same criterion as above is introduced earlier:

$P_{on} \leq (2+\Phi/120)*((CRI+240)/320)$ W, assumed to enter into force in 2020

For details and scope of application, see par. 1.3.2, 1.3.5 and 1.3.7 of the main text.

The ECO70 requirement is assumed to phase-out, by 2020, all GLS, HL, CFLi and CFLni that were still allowed on the market by existing regulations (exception: by 2025 for light sources with G9 and R7s caps).
The effect of the ECO70 requirement on LFL and HID-lamps is more complex and has been investigated in detail. The phase-out is partial and regards only the light sources with lowest efficacy (and lowest CRI). The effect on these lamps is reported more in detail in par. F.2.

The effect of the ECO80 requirement is similar to the one of the ECO70 requirement, but a larger part of LFL and HID-lamps is phased out, see par. F.2.

The effect of the ECO120 requirement (as second stage of the 80+120 scenario) is assumed to lead to an LED-only situation, all other lamp technology types being phased out around 2024.
The effect of the ECO120 requirement (as separate single stage scenario in 2020) is assumed to lead to an LED-only situation, all other lamp technology types being phased out around 2020.

As a general rule, in the case of a complete phase-out of a base case, the share of potential sales remaining in the same base case in the ECO scenario, i.e. not shifting to LED, is assumed to be:

- 2 years before the ecodesign measure: 90% of the BAU-value
- 1 year before the ecodesign measure: 80% of the BAU-value
- in the year of the ecodesign measure: 50% of the BAU-value
- 1 year after the ecodesign measure: 20% of the BAU-value
- 2 years after the ecodesign measure: 10% of the BAU-value
- 3 years after the ecodesign measure: 5% of the BAU-value
- 4 years after the ecodesign measure: 0% of the BAU-value

If the phase-out is partial these percentages are proportionally increased.

If the phase-out is partial, there will be a positive effect on the average efficacy of the non-phased out models, and there might also be an effect on average luminous flux and power (and operating hours), but this is currently not modelled. This is a conservative approach: savings resulting from the measures might be slightly underestimated.

LED projection differences

The ECO70, ECO80+120 and ECO120 scenarios differ from the BAU only in sales shift towards LED products. The efficacies and prices of these LED products are assumed to remain the same as in the BAU scenario (if the scenarios are without label improvement).

In contrast, the effect of improved labelling is assumed to have no influence on the sales shift, but to lead only to a higher LED efficacy curve, with corresponding higher prices.

See par. 1.3.5.1 and Annex E.2.4 for detailed information on the LED efficacy and price curves.

F.2 Sales shift assumptions per base case

This paragraph reports per base case the assumed sales shifts from classical technology products to LED products in the ECO70 and ECO80+120 scenarios. For reference, the sales shifts of the BAU scenario are also repeated.

F.2.1 LFL T12

See par. E.3.1. All potential sales are transferred first to LFL T8t and are redistributed from there over LFL T8t, LFL T5 and LED. This is the same in all scenarios.

F.2.2 LFL T8 halophosphor

See par. E.3.2. All potential sales are transferred first to LFL T8t and are redistributed from there over LFL T8t, LFL T5 and LED. This is the same in all scenarios.

F.2.3 LFL T8 triphosphor

See par. E.3.3 for the assumptions leading to the BAU scenario.

In the ECO70 scenario it is estimated that 15% of the existing LFL T8t models would be phased-out if an 85% control gear efficiency is assumed. This regards mainly models with power ≤ 15 W, 18 W models with a CCT=6500 K, 50% of the models with CRI≥90 and all models with CRI<80 (expected to be T8 halo-phosphor). A CRI-correction factor of 1.2 would be required to maintain all CRI≥90 lamps except 15 W.

In the ECO80 scenario it is estimated that 75% of the existing LFL T8t models would be phased-out if an 85% control gear efficiency is assumed. Only models with 36 W and some models with 58 W would remain. Assuming 90% control gear efficiency, 55% of the models would be phased out (models of 36 W and higher would remain). All models with CRI≥90 and all models with CRI < 80 (expected to be T8 halo-phosphor) would be phased out. A CRI-correction factor of 1.35 would be required to maintain all CRI≥90 lamps except 15 W.

In the ECO120 scenario it is assumed that all LFL T8 lamps will be phased out.

These conclusions are based on an analysis of catalogue data for 110 LFL T8 models. As additional reference, analysis data from UBA (Christoph Mordziol) and graphs derived from efficacy limits in current regulations have been used.

Table 38 shows the sales shift assumptions for the three scenarios.

Table 38 Assumptions made regarding the distribution of light source sales for LFL T8 tri-phosphor applications, for the BAU, ECO70, ECO80+120 and ECO120 scenarios.

BAU	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2030
% current type	85%	84%	83%	82%	81%	80%	76%	72%	68%	64%	60%	40%
% to LFL T5	10%	7%	5%	3%	1%	0%	0%	0%	0%	0%	0%	0%
% to LED retrofit	4%	6%	8%	10%	11%	12%	13%	15%	15%	16%	16%	12%
% to LED luminaire	2%	3%	4%	5%	7%	8%	11%	13%	17%	20%	24%	48%
ECO70						ECO 70						
% current type	85%	84%	83%	81%	79%	74%	67%	62%	58%	54%	51%	34%
% to LFL T5	10%	7%	5%	3%	1%	0%	0%	0%	0%	0%	0%	0%
% to LED retrofit	4%	6%	8%	10%	13%	16%	19%	20%	20%	20%	20%	13%
% to LED luminaire	2%	3%	4%	6%	8%	10%	15%	18%	22%	26%	29%	53%
ECO80+120						ECO 80				ECO 120		
% current type	85%	84%	83%	76%	69%	50%	30%	23%	20%	13%	6%	0%
% to LFL T5	10%	7%	5%	3%	1%	0%	0%	0%	0%	0%	0%	0%
% to LED retrofit	4%	6%	8%	14%	19%	30%	39%	40%	38%	38%	38%	20%
% to LED luminaire	2%	3%	4%	8%	11%	20%	31%	37%	41%	49%	56%	80%
ECO120						ECO 120						
% current type	85%	84%	83%	74%	65%	40%	15%	7%	0%	0%	0%	0%
% to LFL T5	10%	7%	5%	3%	1%	0%	0%	0%	0%	0%	0%	0%
% to LED retrofit	4%	6%	8%	15%	21%	36%	47%	48%	48%	44%	40%	20%
% to LED luminaire	2%	3%	4%	8%	13%	24%	37%	45%	52%	56%	60%	80%

F.2.4 LFL T5

See par. E.3.4 for the assumptions leading to the BAU scenario.

In the ECO70 scenario it is assumed that all T5 models will remain on the market. This implies that the ECO70 scenario is identical to the BAU scenario for this lamp type. There are some HO-models and some high-CRI models that are close to the limit, but this has been neglected for the purpose of scenario analysis.

In the ECO80 scenario it is estimated that 25% of the existing LFL T5 models would be phased-out if an 88% control gear efficiency is assumed. In general, all HE-models would remain on the market while 50% of the HO models is at risk of being phased out. With the currently proposed CRI correction, all high-CRI models would be phased-out if they have 88% control gear efficiency or less.

In the ECO120 scenario it is assumed that all LFL T5 lamps will be phased out.

These conclusions are based on an analysis of catalogue data for 91 linear T5 High-Efficiency (HE) models with CRI between 80 and 89, 116 linear T5 High-Output (HO) models with CRI between 80 and 89, 15 T5 models with CRI≥90 and 35 T5 circular or miniature models (part of which falling in the LFL X base case). A control gear efficiency of 88% was assumed and characteristics at 25°C ambient temperature have been used. As additional reference, analysis data from UBA (Christoph Mordziol) and graphs derived from efficacy limits in current regulations have been used.

Table 39 shows the sales shift assumptions for the three scenarios.

Table 39 Assumptions made regarding the distribution of light source sales for LFL T5 applications, for the BAU, ECO70 and ECO80+120 scenarios

BAU	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2030
% current type	100%	98%	96%	94%	92%	90%	84%	78%	72%	66%	60%	40%
% to LED retrofit	0%	0%	1%	1%	2%	2%	3%	4%	6%	7%	8%	12%
% to LED luminaire	0%	2%	3%	5%	6%	8%	13%	18%	22%	27%	32%	48%
ECO70 = BAU						ECO 70						
% current type	100%	98%	96%	94%	92%	90%	84%	78%	72%	66%	60%	40%
% to LED retrofit	0%	0%	1%	1%	2%	2%	3%	4%	6%	7%	8%	12%
% to LED luminaire	0%	2%	3%	5%	6%	8%	13%	18%	22%	27%	32%	48%
ECO80+120						ECO 80				ECO 120		
% current type	100%	98%	96%	92%	87%	79%	67%	60%	36%	13%	6%	0%
% to LED retrofit	0%	0%	1%	2%	3%	4%	7%	8%	13%	17%	19%	20%
% to LED luminaire	0%	2%	3%	7%	10%	17%	26%	32%	51%	69%	75%	80%
ECO120						ECO 120						
% current type	100%	98%	96%	85%	74%	45%	17%	8%	4%	0%	0%	0%
% to LED retrofit	0%	0%	1%	3%	5%	11%	17%	18%	19%	20%	20%	20%
% to LED luminaire	0%	2%	3%	12%	21%	44%	67%	74%	77%	80%	80%	80%

F.2.5 LFL X

See par. E.3.5 for the assumptions leading to the BAU scenario.

This base case has a very small impact on the scenario analyses outcomes and consequently has not been investigated in detail.

In the ECO70 scenario it is estimated that 50 % of the existing LFL X models would be phased-out.

In the ECO80 scenario it is estimated that 75 % of the existing LFL X models would be phased-out.

In the ECO120 scenario it is assumed that all LFL X lamps will be phased out.

Table 40 shows the sales shift assumptions for the three scenarios.

Table 40 Assumptions made regarding the distribution of light source sales for LFL X applications, for the BAU, ECO70 and ECO80+120 scenarios

BAU	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2030
% current type	100%	98%	96%	94%	92%	90%	84%	78%	72%	66%	60%	40%
% to LED retrofit	0%	1%	2%	3%	3%	4%	6%	8%	10%	11%	12%	12%
% to LED luminaire	0%	1%	2%	3%	5%	6%	10%	14%	18%	23%	28%	48%
ECO70						ECO 70						
% current type	100%	98%	96%	89%	83%	68%	50%	43%	38%	33%	30%	20%
% to LED retrofit	0%	1%	2%	5%	7%	13%	19%	21%	21%	21%	21%	16%
% to LED luminaire	0%	1%	2%	6%	10%	20%	31%	37%	41%	46%	49%	64%
ECO80+120						ECO 80				ECO 120		
% current type	100%	98%	96%	87%	78%	56%	34%	25%	21%	13%	6%	0%
% to LED retrofit	0%	1%	2%	6%	9%	18%	25%	27%	22%	28%	28%	20%
% to LED luminaire	0%	1%	2%	7%	13%	26%	41%	48%	42%	59%	66%	80%
ECO120						ECO 120						
% current type	100%	98%	96%	85%	74%	45%	17%	8%	4%	0%	0%	0%
% to LED retrofit	0%	1%	2%	7%	11%	22%	32%	33%	33%	32%	30%	20%
% to LED luminaire	0%	1%	2%	9%	15%	33%	52%	59%	64%	68%	70%	80%

F.2.6 HPM

See par. E.4.1 for the assumptions leading to the BAU scenario.

These lamps are already phased-out by current regulations in 2015, which is considered in the BAU scenario. Consequently the ECO measures have no additional effect.

F.2.7 HPS

See par. E.4.2 for the assumptions leading to the BAU scenario.

In the ECO70 scenario it is assumed that 30% of the existing HPS models would be phased-out. In good approximation this regards the powers smaller than 100 W. This phase-out is mainly due to the low CRI for these models (typically 25). If the CRI influence in the correction factor would be doubled, i.e. using (CRI+80)/160 instead of (CRI/2+120)/160, approximately 70% of the models would be phased-out, approximately corresponding to powers of 250 W and smaller.

In the ECO80 scenario it is assumed that 50% of the existing HPS models would be phased-out. This regards in particular the powers of 150-250 W and smaller. If the CRI influence in the correction factor would be doubled, i.e. using (CRI+80)/160 instead of (CRI/2+120)/160, nearly all models would be phased-out.

In the ECO120 scenario all HPS-models are assumed to be phased-out.

These conclusions are based on an analysis of catalogue data for 49 HPS models. A control gear efficiency of 86% was assumed. As additional reference, analysis data from UBA (Christoph Mordziol) and graphs derived from efficacy limits in current regulations have been used.

Table 41 shows the sales shift assumptions for the three scenarios.

Table 41 Assumptions made regarding the distribution of light source sales for HPS applications, for the BAU, ECO70 and ECO80+120 scenarios

BAU	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2030
% current type	82%	82%	82%	82%	81%	80%	76%	72%	68%	64%	60%	40%
% to MH	12%	10%	8%	6%	4%	2%	1%	0%	0%	0%	0%	0%
% to LED retrofit	1%	2%	2%	2%	3%	4%	5%	6%	6%	7%	8%	12%
% to LED luminaire	5%	6%	8%	10%	12%	14%	18%	22%	26%	29%	32%	48%
ECO70						ECO 70						
% current type	82%	82%	82%	80%	76%	68%	58%	53%	49%	45%	42%	28%
% to MH	12%	10%	8%	6%	4%	2%	1%	0%	0%	0%	0%	0%
% to LED retrofit	1%	2%	2%	3%	4%	6%	8%	9%	10%	11%	12%	14%
% to LED luminaire	5%	6%	8%	12%	16%	24%	33%	38%	41%	44%	46%	58%
ECO80+120						ECO 80				ECO 120		
% current type	82%	82%	82%	78%	73%	60%	46%	36%	29%	16%	6%	0%
% to MH	12%	10%	8%	6%	4%	2%	1%	0%	0%	0%	0%	0%
% to LED retrofit	1%	2%	2%	3%	5%	8%	11%	13%	14%	17%	19%	20%
% to LED luminaire	5%	6%	8%	13%	18%	30%	43%	51%	57%	67%	75%	80%
ECO120						ECO 120						
% current type	82%	82%	82%	74%	65%	40%	15%	6%	3%	0%	0%	0%
% to MH	12%	10%	8%	6%	4%	2%	1%	0%	0%	0%	0%	0%
% to LED retrofit	1%	2%	2%	4%	6%	12%	17%	19%	19%	20%	20%	20%
% to LED luminaire	5%	6%	8%	16%	25%	46%	67%	75%	78%	80%	80%	80%

F.2.8 MH

See par. E.4.3 for the assumptions leading to the BAU scenario.

In the ECO70 scenario it is assumed that 15% of the existing MH models would be phased-out. None of the Ceramic models is phased out, while around 50% of the Quartz MH models is phased out. It could be estimated that Quartz MH sales are 25-30% of the total MH sales. Note that it is possible that many of the quartz models would anyway be phased out by existing regulation in 2017.

In the ECO70 scenario it is assumed that 27% of the existing MH models would be phased-out. None of the Ceramic models is phased out, while around 90% of the Quartz MH models is phased out.

In the ECO120 scenario it is assumed that all MH lamps will be phased out.

These conclusions are based on an analysis of catalogue data for 50 Ceramic MH models and 41 Quartz MH models. A control gear efficiency of 86% was assumed. As additional reference, analysis data from UBA (Christoph Mordziol) and graphs derived from efficacy limits in current regulations have been used.

Table 42 shows the sales shift assumptions for the three scenarios.

Table 42 Assumptions made regarding the distribution of light source sales for MH applications, for the BAU, ECO70 and ECO80+120 scenarios

BAU	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2030
% current type	82%	82%	82%	82%	81%	80%	76%	72%	68%	64%	60%	40%
% to LED retrofit	4%	4%	4%	4%	4%	4%	5%	6%	6%	7%	8%	12%
% to LED luminaire	14%	14%	14%	14%	15%	16%	19%	22%	26%	29%	32%	48%
ECO70						ECO 70						
% current type	82%	82%	82%	81%	79%	74%	67%	62%	58%	54%	51%	34%
% to LED retrofit	4%	4%	4%	4%	4%	5%	7%	8%	8%	9%	10%	13%
% to LED luminaire	14%	14%	14%	15%	17%	21%	26%	30%	33%	36%	39%	53%
ECO80+120						ECO 80				ECO 120		
% current type	82%	82%	82%	80%	77%	69%	60%	55%	51%	32%	12%	0%
% to LED retrofit	4%	4%	4%	4%	5%	6%	8%	9%	10%	14%	18%	20%
% to LED luminaire	14%	14%	14%	16%	19%	25%	32%	36%	40%	54%	70%	80%
ECO120						ECO 120						
% current type	82%	82%	82%	74%	65%	40%	15%	7%	3%	0%	0%	0%
% to LED retrofit	4%	4%	4%	5%	7%	12%	17%	19%	19%	20%	20%	20%
% to LED luminaire	14%	14%	14%	21%	28%	48%	68%	74%	77%	80%	80%	80%

F.2.9 CFLni

See par. E.5.1 for the assumptions leading to the BAU scenario.

In the ECO70 scenario it is assumed that ALL of the existing CFLni models would be phased-out.

Consequently, the same is true in the ECO80 and ECO120 cases and the ECO80+120 and ECO120 scenarios are identical to the ECO70 scenario for this lamp type.

Table 43 shows the sales shift assumptions for the three scenarios.

Table 43 Assumptions made regarding the distribution of light source sales for CFLni applications, for the BAU, ECO70 and ECO80+120 scenarios

BAU	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2030
% current type	85%	80%	75%	70%	65%	60%	56%	52%	48%	44%	40%	20%
% to LED retrofit	3%	4%	5%	6%	7%	8%	9%	10%	10%	11%	12%	16%
% to LED luminaire	12%	16%	20%	24%	28%	32%	35%	38%	42%	45%	48%	64%
ECO70						ECO 70						
% current type	85%	80%	75%	70%	60%	50%	25%	10%	5%	2%	0%	0%
% to LED retrofit	3%	4%	5%	6%	8%	10%	15%	18%	19%	20%	20%	20%
% to LED luminaire	12%	16%	20%	24%	32%	40%	60%	72%	76%	78%	80%	80%
ECO80+120 =ECO70						ECO 80				ECO 120		
% current type	85%	80%	75%	70%	60%	50%	25%	10%	5%	2%	0%	0%
% to LED retrofit	3%	4%	5%	6%	8%	10%	15%	18%	19%	20%	20%	20%
% to LED luminaire	12%	16%	20%	24%	32%	40%	60%	72%	76%	78%	80%	80%

F.2.10 HL LV R (DLS)

See par. E.6.1 for the assumptions leading to the BAU scenario.

In the ECO70 scenario it is assumed that ALL of the existing HL LV R models would be phased-out.

Consequently, the same is true in the ECO80 and ECO120 cases and the ECO80+120 and ECO120 scenarios are identical to the ECO70 scenario for this lamp type.

Table 44 shows the sales shift assumptions for the three scenarios.

Table 44 Assumptions made regarding the distribution of light source sales for HL LV R (DLS) applications, for the BAU, ECO70 and ECO80+120 scenarios

BAU	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2030
% current type	85%	82%	79%	76%	73%	70%	66%	62%	58%	54%	50%	25%
% to LED retrofit	12%	14%	16%	18%	19%	21%	23%	25%	27%	29%	30%	30%
% to LED luminaire	3%	4%	5%	6%	8%	9%	11%	13%	15%	17%	20%	45%
ECO70						ECO 70						
% current type	85%	82%	79%	70%	60%	35%	15%	5%	2%	0%	0%	0%
% to LED retrofit	12%	14%	16%	22%	29%	46%	58%	63%	63%	62%	60%	40%
% to LED luminaire	3%	4%	5%	8%	11%	20%	27%	32%	35%	38%	40%	60%
ECO80+120 =ECO70						ECO 80				ECO 120		
% current type	85%	82%	79%	70%	60%	35%	15%	5%	2%	0%	0%	0%
% to LED retrofit	12%	14%	16%	22%	29%	46%	58%	63%	63%	62%	60%	40%
% to LED luminaire	3%	4%	5%	8%	11%	20%	27%	32%	35%	38%	40%	60%

F.2.11 HL MV X (DLS)

See par. E.6.2 for the assumptions leading to the BAU scenario.

These lamps are already phased-out by current regulations in 2016, which is considered in the BAU scenario. Consequently the ECO measures have no additional effect.

F.2.12 GLS R (DLS)

See par. E.6.3 for the assumptions leading to the BAU scenario.

These lamps are already phased-out by current regulations in 2016, which is considered in the BAU scenario. Consequently the ECO measures have no additional effect.

F.2.13 CFLi (NDLS)

See par. E.7.1 for the assumptions leading to the BAU scenario.

In the ECO70 scenario it is assumed that ALL of the existing CFLi models would be phased-out.

Consequently, the same is true in the ECO80 and ECO120 cases and the ECO80+120 and ECO120 scenarios are identical to the ECO70 scenario for this lamp type.

Table 45 shows the sales shift assumptions for the three scenarios.

Table 45 Assumptions made regarding the distribution of light source sales for CFLi (NDLS) applications, for the BAU, ECO70 and ECO80+120 scenarios

BAU	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2030
% current type	75%	60%	50%	40%	30%	20%	18%	16%	14%	12%	10%	10%
% to LED retrofit	20%	31%	38%	44%	50%	56%	56%	55%	55%	55%	54%	36%
% to LED luminaire	5%	9%	12%	16%	20%	24%	26%	29%	31%	33%	36%	54%
ECO70						ECO 70						
% current type	75%	60%	50%	35%	22%	10%	5%	2%	0%	0%	0%	0%
% to LED retrofit	20%	31%	38%	48%	56%	63%	65%	65%	64%	62%	60%	40%
% to LED luminaire	5%	9%	12%	17%	22%	27%	30%	33%	36%	38%	40%	60%
ECO80+120 =ECO70						ECO 80				ECO 120		
% current type	75%	60%	50%	35%	22%	10%	5%	2%	0%	0%	0%	0%
% to LED retrofit	20%	31%	38%	48%	56%	63%	65%	65%	64%	62%	60%	40%
% to LED luminaire	5%	9%	12%	17%	22%	27%	30%	33%	36%	38%	40%	60%

F.2.14 HL MV E (NDLS)

See par. E.7.2 for the assumptions leading to the BAU scenario.

These lamps are already phased-out by current regulations in 2018, which is considered in the BAU scenario. Consequently the ECO measures have no additional effect.

F.2.15 GLS X (NDLS)

See par. E.7.3 for the assumptions leading to the BAU scenario.

These lamps are already phased-out by current regulations, which is considered in the BAU scenario. Consequently the ECO measures have no additional effect.

F.2.16 HL LV C (NDLS)

See par. E.7.4 for the assumptions leading to the BAU scenario.

In the ECO70 scenario it is assumed that ALL of the existing HL LV C models would be phased-out.

Consequently, the same is true in the ECO80 and ECO120 cases and the ECO80+120 and ECO120 scenarios are identical to the ECO70 scenario for this lamp type.

Table 46 shows the sales shift assumptions for the three scenarios.

Table 46 Assumptions made regarding the distribution of light source sales for HL LV C (NDLS) applications, for the BAU, ECO70 and ECO80+120 scenarios

BAU	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2030
% current type	90%	85%	80%	70%	60%	50%	46%	42%	38%	34%	30%	10%
% to LED retrofit	7%	10%	13%	19%	25%	30%	31%	32%	33%	34%	35%	27%
% to LED luminaire	3%	5%	7%	11%	15%	20%	23%	26%	29%	32%	35%	63%
ECO70						ECO 70						
% current type	90%	85%	75%	62%	48%	25%	10%	5%	2%	0%	0%	0%
% to LED retrofit	7%	10%	17%	24%	32%	45%	52%	53%	53%	52%	50%	30%
% to LED luminaire	3%	5%	9%	14%	20%	30%	38%	42%	45%	48%	50%	70%
ECO80+120 =ECO70						ECO 80				ECO 120		
% current type	90%	85%	75%	62%	48%	25%	10%	5%	2%	0%	0%	0%
% to LED retrofit	7%	10%	17%	24%	32%	45%	52%	53%	53%	52%	50%	30%
% to LED luminaire	3%	5%	9%	14%	20%	30%	38%	42%	45%	48%	50%	70%

F.2.17 HL MV C (NDLS; G9 cap)

See par. E.7.5 for the assumptions leading to the BAU scenario.

In the ECO70 scenario it is assumed that ALL of the existing HL MV C models would be phased-out. However, for these lamps an exemption has been made until 2025.

Consequently, the same is true in the ECO80 and ECO120 cases and the ECO80+120 and ECO120 scenarios are identical to the ECO70 scenario for this lamp type.

Table 47 shows the sales shift assumptions for the three scenarios.

Table 47 Assumptions made regarding the distribution of light source sales for HL MV C (NDLS; G9 cap) applications, for the BAU, ECO70 and ECO80+120 scenarios

BAU	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2030
% current type	90%	85%	80%	70%	60%	50%	46%	42%	38%	34%	30%	10%
% to LED retrofit	7%	10%	13%	19%	25%	30%	31%	32%	33%	34%	35%	27%
% to LED luminaire	3%	5%	7%	11%	15%	20%	23%	26%	29%	32%	35%	63%
ECO70											ECO 70	
% current type	90%	85%	80%	70%	60%	50%	46%	40%	34%	28%	15%	0%
% to LED retrofit	7%	10%	13%	19%	25%	30%	31%	34%	36%	37%	43%	30%
% to LED luminaire	3%	5%	7%	11%	15%	20%	23%	26%	30%	35%	43%	70%
ECO80+120 =ECO70											ECO 120	
% current type	90%	85%	80%	70%	60%	50%	46%	40%	34%	28%	15%	0%
% to LED retrofit	7%	10%	13%	19%	25%	30%	31%	34%	36%	37%	43%	30%
% to LED luminaire	3%	5%	7%	11%	15%	20%	23%	26%	30%	35%	43%	70%

F.2.18 HL MV L (NDLS; R7s cap)

See par. E.7.6 for the assumptions leading to the BAU scenario.

In the ECO70 scenario it is assumed that ALL of the existing HL MV L models would be phased-out. However, for these lamps an exemption has been made until 2025. Consequently, the same is true in the ECO80 and ECO120 cases and the ECO80+120 and ECO120 scenarios are identical to the ECO70 scenario for this lamp type.

Table 48 shows the sales shift assumptions for the three scenarios (identical to those for HL MV C).

Table 48 Assumptions made regarding the distribution of light source sales for HL MV L (NDLS; R7s cap) applications, for the BAU, ECO70 and ECO80+120 scenarios

BAU	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2030
% current type	90%	85%	80%	70%	60%	50%	46%	42%	38%	34%	30%	10%
% to LED retrofit	7%	10%	13%	19%	25%	30%	31%	32%	33%	34%	35%	27%
% to LED luminaire	3%	5%	7%	11%	15%	20%	23%	26%	29%	32%	35%	63%
ECO70											ECO 70	
% current type	90%	85%	80%	70%	60%	50%	46%	40%	34%	28%	15%	0%
% to LED retrofit	7%	10%	13%	19%	25%	30%	31%	34%	36%	37%	43%	30%
% to LED luminaire	3%	5%	7%	11%	15%	20%	23%	26%	30%	35%	43%	70%
ECO80+120 =ECO70											ECO 120	
% current type	90%	85%	80%	70%	60%	50%	46%	40%	34%	28%	15%	0%
% to LED retrofit	7%	10%	13%	19%	25%	30%	31%	34%	36%	37%	43%	30%
% to LED luminaire	3%	5%	7%	11%	15%	20%	23%	26%	30%	35%	43%	70%

Annex G Results details

This Annex groups selected results details. It is intended for those that want to study more in-depth the backgrounds of the conclusions reported in the main text. Most data are provided without further comment.

The first part of the Annex presents additional graphs for the electric energy consumption, the total expense for lighting, the acquisition costs and the running costs, for all scenarios (BAU, ECO70+LBL, ECO80+120, ECO80+120+LBL and ECO120+LBL), separately for the residential sector, the non-residential sector, and the sum of both sectors. This provides further insight in the difference in effect of the scenarios in the two sectors.

The second part of the Annex contains a detailed data table:

- Data for more parameters than reported in the main text
- Stock averages for many parameters
- Subdivision of EU-28 total data over the residential and non-residential sector.

G.1 Subdivision of savings over the Residential and Non-Residential sectors

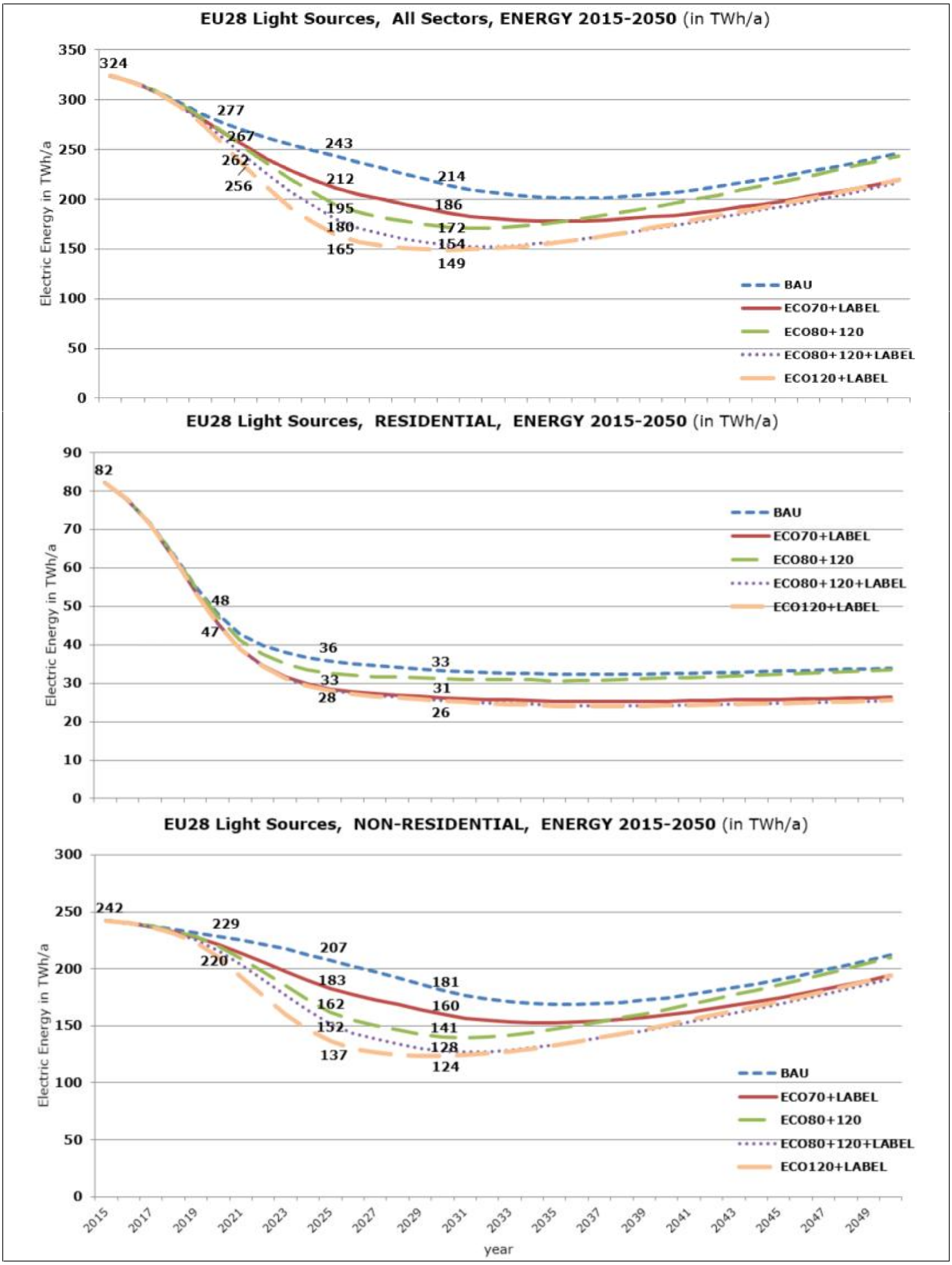


Figure 40: Electric energy consumption in TWh/a for the non-residential sector (bottom), for the residential sector (centre), and for both sectors together (top), for all scenarios.

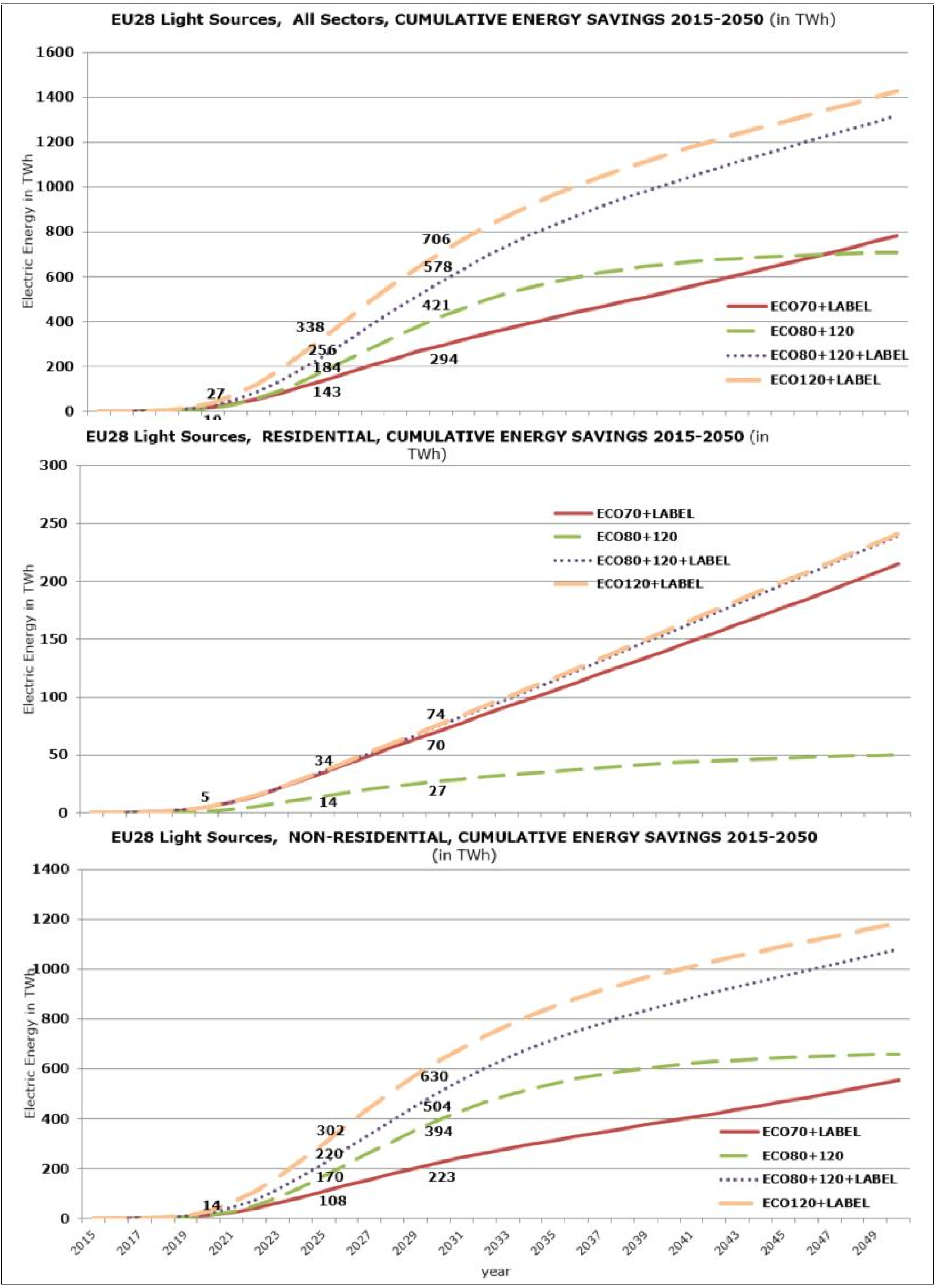


Figure 41: Cumulative electric energy savings in TWh for the non-residential sector (bottom), for the residential sector (centre), and for both sectors together (top), for the ECO scenarios with respect to the BAU.

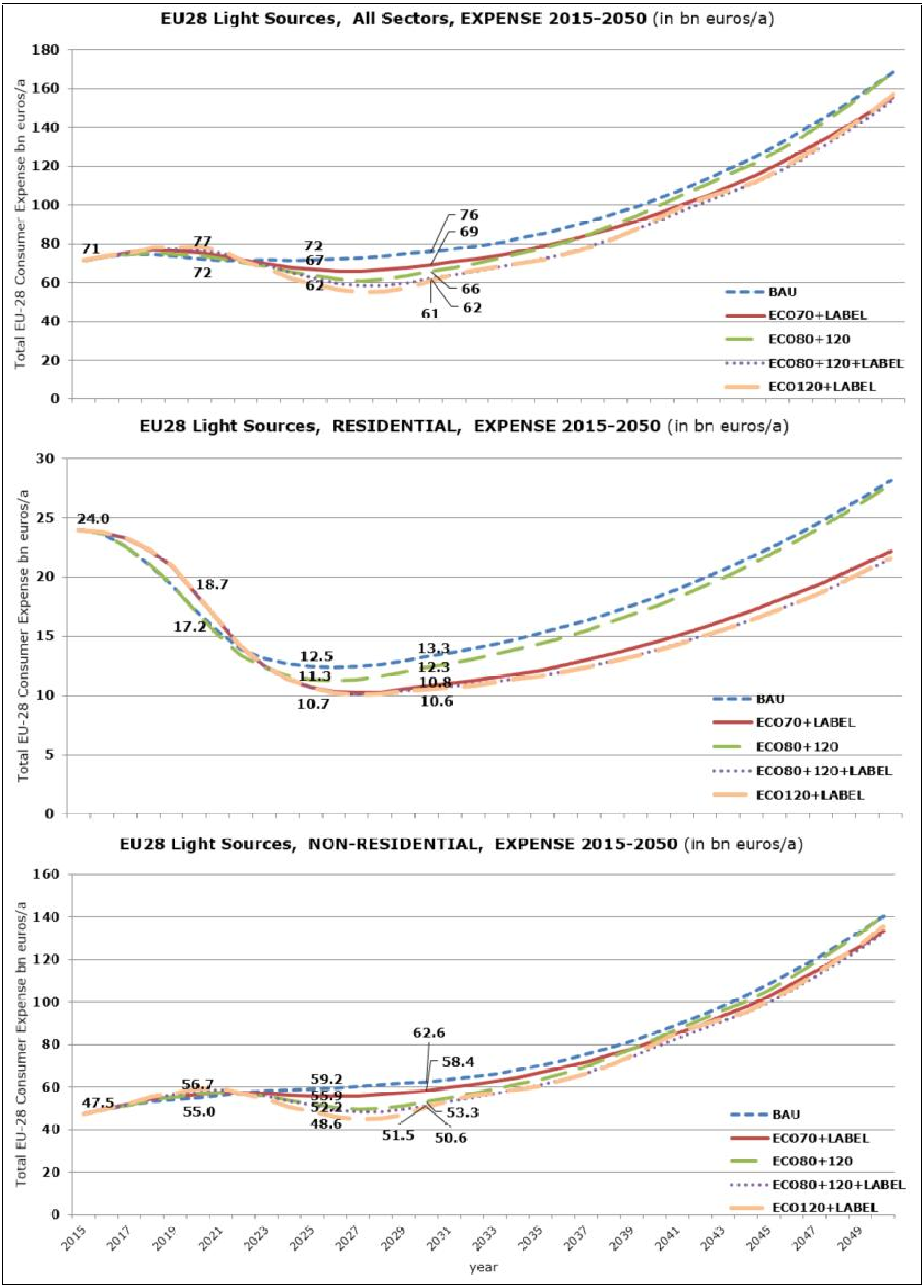


Figure 42: Total expense for lighting in bn euros/a for the non-residential sector (bottom), for the residential sector (centre), and for both sectors together (top), for all scenarios.

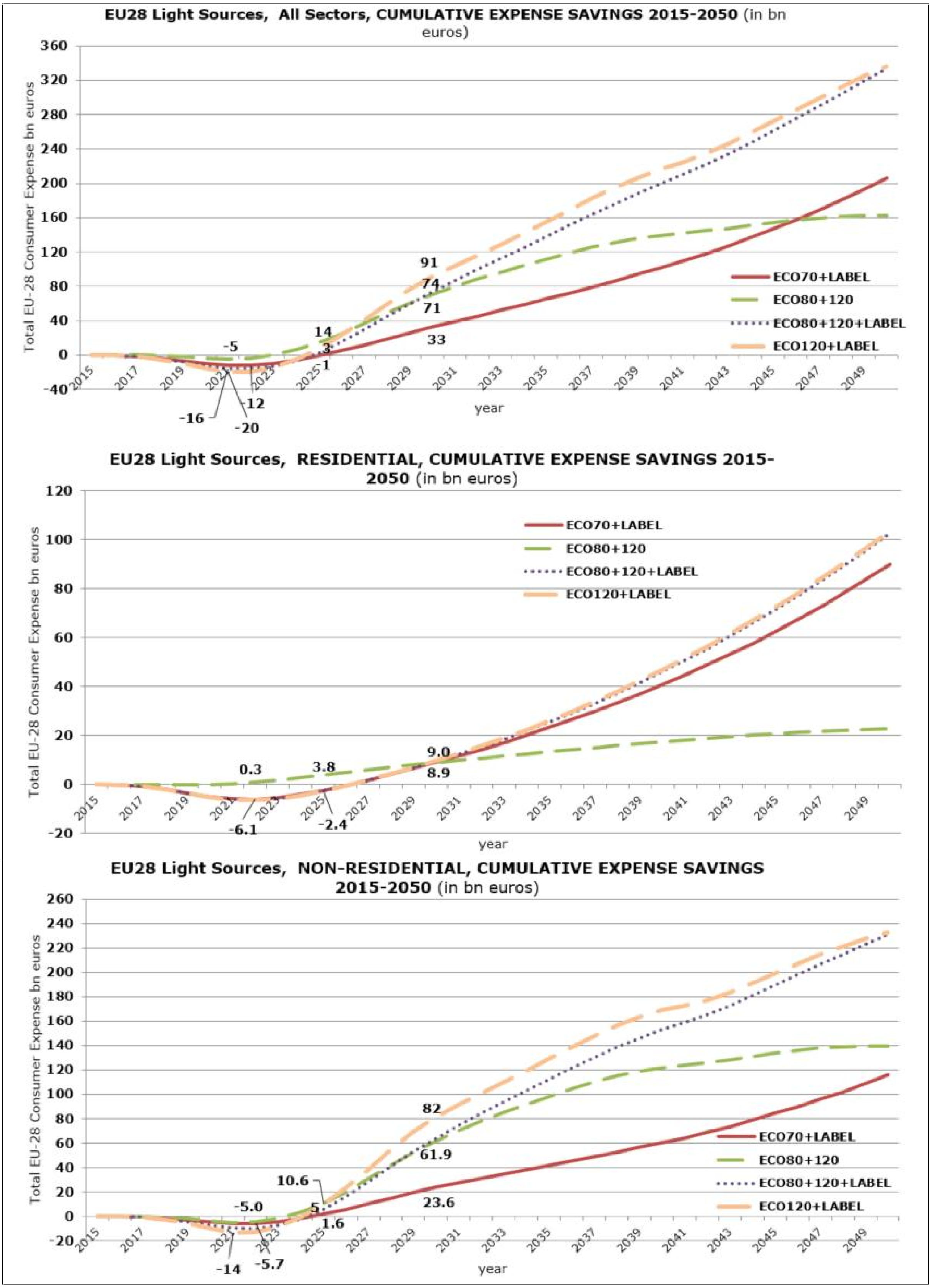
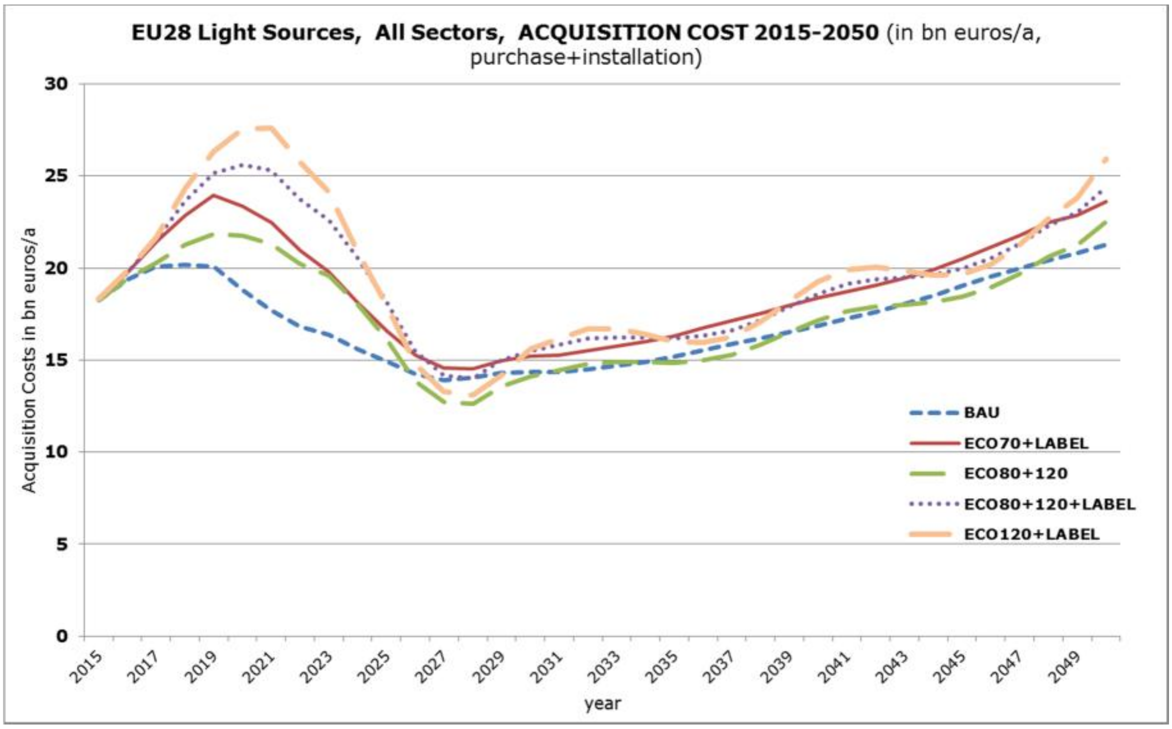


Figure 43: Cumulative expense savings in bn euros for the non-residential sector (bottom), for the residential sector (centre), and for both sectors together (top), for the ECO scenarios with respect to the BAU.



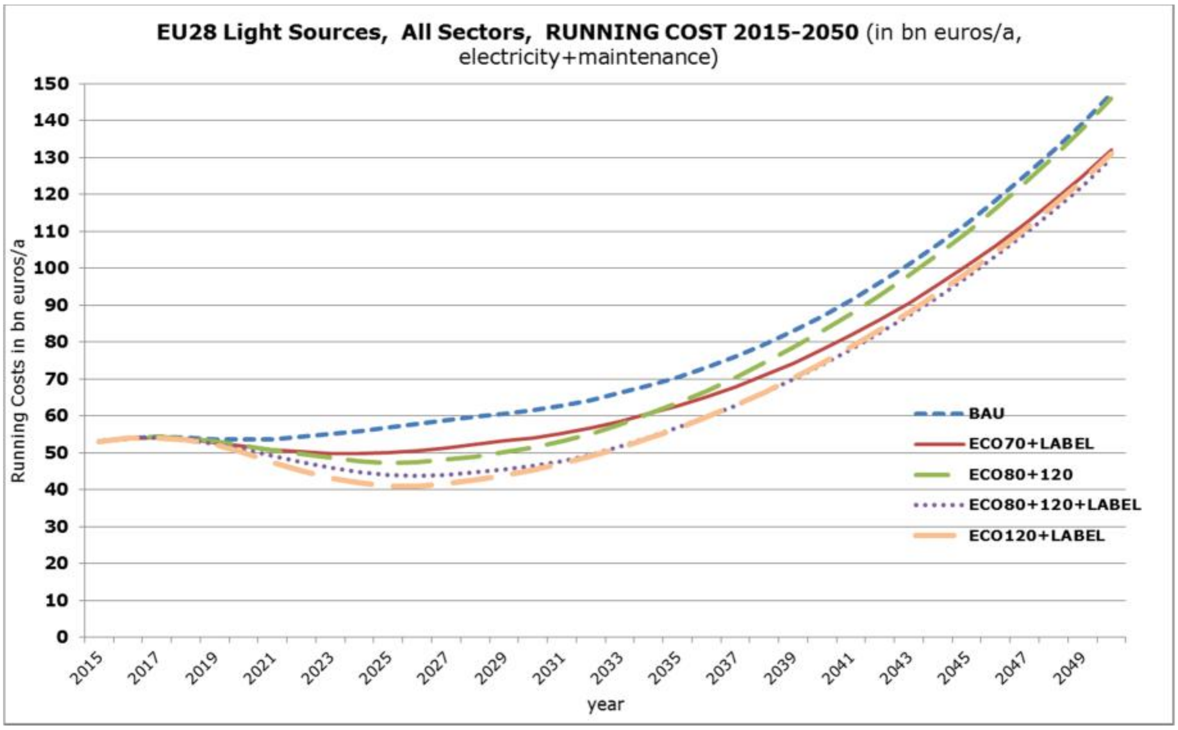


Figure 44: Acquisition costs (purchase and installation; top) and Running Costs (electricity and maintenance; bottom), in bn euros/a, EU-28 totals, for ALL SECTORS, for all scenarios. Note: different scales for the two figures.

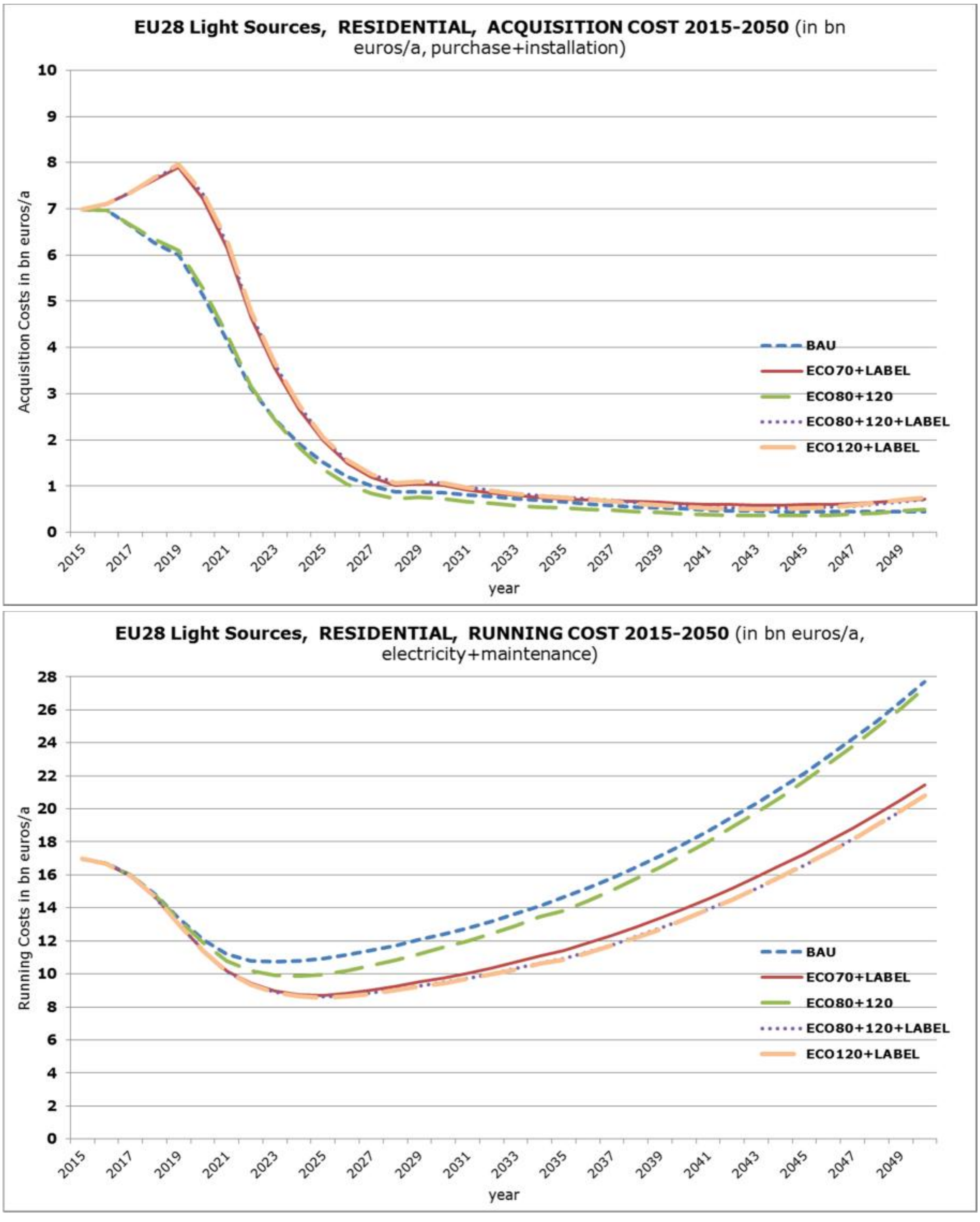
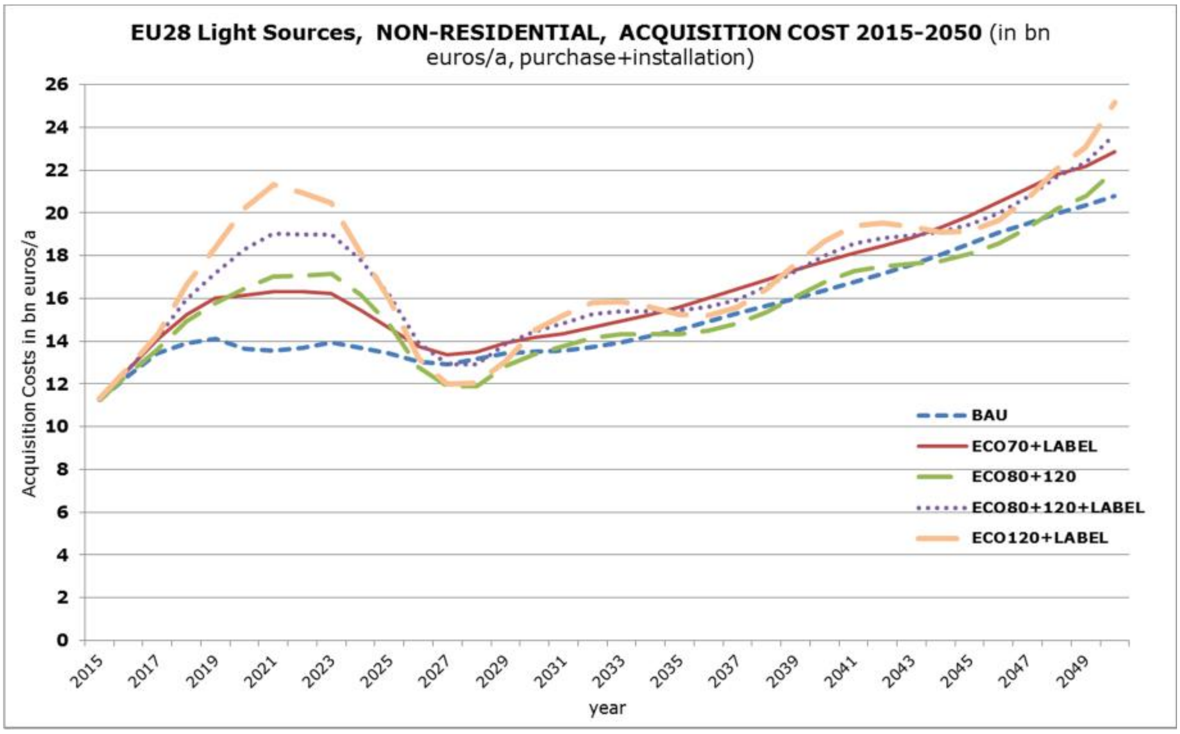


Figure 45: Acquisition costs (purchase and installation; top) and Running Costs (electricity and maintenance; bottom), in bn euros/a, EU-28 totals, for the RESIDENTIAL SECTOR, for all scenarios. Note: different scales for the two figures.



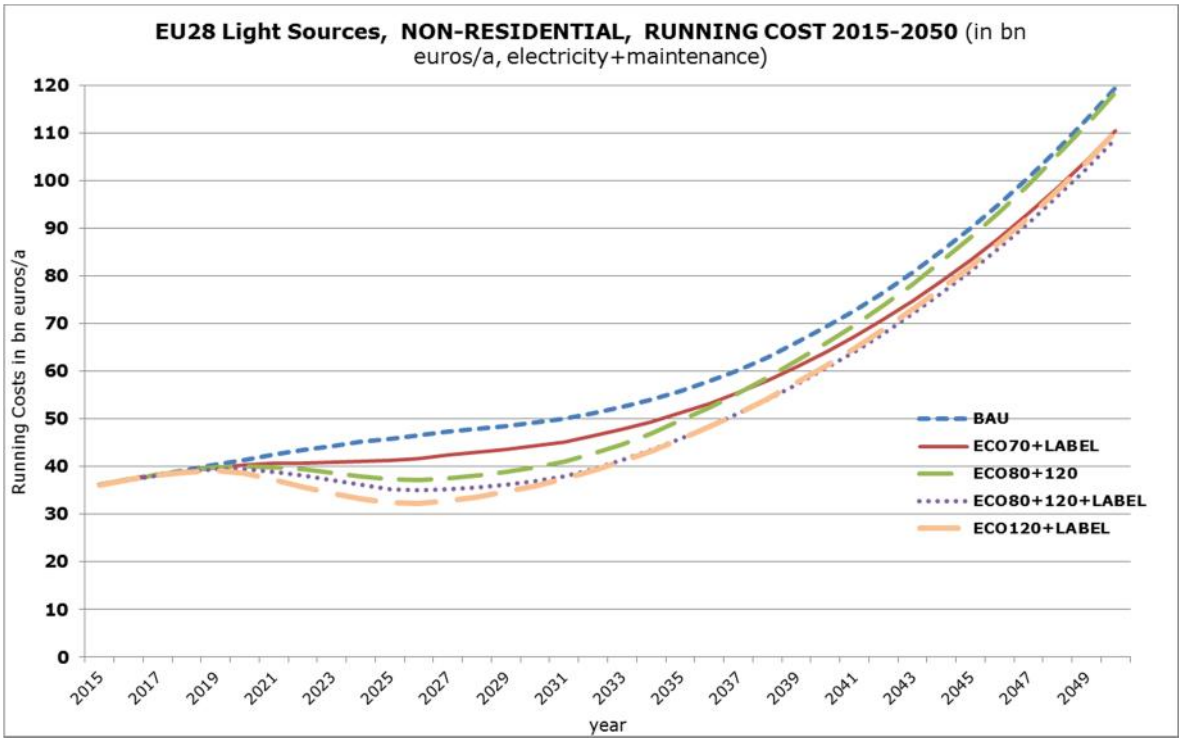


Figure 46: Acquisition costs (purchase and installation; top) and Running Costs (electricity and maintenance; bottom), in bn euros/a, EU-28 totals, for the NON-RESIDENTIAL SECTOR, for all scenarios. Note: different scales for the two figures.

G.2 Detailed data table

Scenario comparison, EU-28 Totals, Absolute values RES=Residential NRES=Non-Residential ALL= RES + NRES			1990	2010	2015	2020					2025					2030				
				BAU		BAU	ECO70+LBL	ECO80+120	ECO80+120+ LBL	ECO120+ LBL (2020)	BAU	ECO70+LBL	ECO80+120	ECO80+120+ LBL	ECO120+ LBL (2020)	BAU	ECO70+LBL	ECO80+120	ECO80+120+ LBL	ECO120+ LBL (2020)
Sales	ALL	mln units	2112	2353	1717	1828	1828	1827	1827	1826	1057	961	929	929	914	873	769	743	743	751
Sales	RES	mln units	1439	1363	989	938	938	938	938	938	340	302	302	302	302	209	172	172	172	172
Sales	NRES	mln units	673	990	728	890	890	889	889	888	717	658	626	626	612	664	597	570	570	579
Sales	Share RES / ALL	%	68%	58%	58%	51%	51%	51%	51%	51%	32%	31%	33%	33%	33%	24%	22%	23%	23%	23%
Sales	Share LED in ALL	%	0%	0%	22%	63%	71%	75%	75%	79%	67%	81%	98%	98%	100%	82%	88%	100%	100%	100%
Sales	Share LED in RES	%	0%	1%	28%	78%	85%	85%	85%	85%	80%	97%	99%	99%	99%	87%	96%	100%	100%	100%
Sales	Share LED in NRES	%	0%	0%	13%	48%	57%	65%	65%	72%	62%	74%	97%	97%	100%	80%	86%	100%	100%	100%
Stock	ALL	mln units	5579	10078	11427	12534	12534	12534	12534	12534	13577	13577	13577	13577	13577	14731	14731	14731	14731	14731
Stock	RES	mln units	3471	5626	6454	6896	6896	6896	6896	6896	7198	7198	7198	7198	7198	7514	7514	7514	7514	7514
Stock	NRES	mln units	2108	4452	4972	5638	5638	5638	5638	5638	6379	6379	6379	6379	6379	7217	7217	7217	7217	7217
Stock	Share RES / ALL	%	62%	56%	56%	55%	55%	55%	55%	55%	53%	53%	53%	53%	53%	51%	51%	51%	51%	51%
Stock	Share LED in ALL	%	0%	0%	7%	42%	44%	45%	45%	46%	70%	78%	83%	83%	86%	84%	90%	96%	96%	97%
Stock	Share LED in RES	%	0%	0%	9%	52%	54%	54%	54%	54%	79%	86%	86%	86%	86%	88%	94%	95%	95%	95%
Stock	Share LED in NRES	%	0%	0%	4%	29%	31%	34%	34%	35%	59%	69%	80%	80%	86%	79%	86%	97%	97%	99%
Average lifetime	ALL	years	3	4	7	7	7	7	7	7	13	14	15	15	15	17	19	20	20	20
Average lifetime	RES	years	2	4	5	7	7	7	7	7.3	21	24	24	24	24	36	44	44	44	44
Average lifetime	NRES	years	3	4	7	6	6	6	6	6	9	10	10	10	10	11	12	13	13	13

Scenario comparison, EU-28 Totals, Absolute values RES=Residential NRES=Non-Residential ALL= RES + NRES		1990	2010	2015	2020					2025					2030				
		BAU	BAU	BAU	BAU	ECO70+LBL	ECO80+120	ECO80+120+ LBL	ECO120+ LBL (2020)	BAU	ECO70+LBL	ECO80+120	ECO80+120+ LBL	ECO120+ LBL (2020)	BAU	ECO70+LBL	ECO80+120	ECO80+120+ LBL	ECO120+ LBL (2020)
Installed Capacity ALL	Tlm	5.5	10.2	11.9	13.6	13.6	13.6	13.6	13.7	15.3	15.4	15.6	15.6	15.6	17.1	17.2	17.4	17.4	17.3
Installed Capacity RES	Tlm	2.1	3.6	4.2	4.8	4.8	4.8	4.8	4.8	5.1	5.2	5.2	5.2	5.2	5.4	5.4	5.5	5.5	5.5
Installed Capacity NRES	Tlm	3.4	6.6	7.6	8.8	8.8	8.9	8.9	8.9	10.2	10.3	10.4	10.4	10.4	11.7	11.8	11.9	11.9	11.9
Inst. Cap. Share RES in ALL	%	39%	35%	36%	35%	35%	35%	35%	35%	34%	34%	33%	33%	33%	32%	32%	31%	31%	32%
Average unit capacity ALL	lm	991	1015	1038	1084	1086	1088	1088	1090	1129	1136	1146	1146	1150	1161	1169	1178	1178	1177
Avg. unit capacity RES	lm	619	645	658	693	694	694	694	694	714	718	719	719	719	722	725	726	726	727
Avg. unit capacity NRES	lm	1605	1484	1532	1563	1566	1570	1570	1573	1598	1607	1627	1627	1636	1618	1631	1648	1648	1645
Installed Power (excl. CG) ALL	GW	263	326	292	202	193	195	191	189	158	129	129	116	110	140	115	117	101	99
Installed Power (excl. CG) RES	GW	177	197	167	89	85	87	85	85	60	47	53	46	46	54	42	50	41	41
Installed Power (excl. CG) NRES	GW	86	129	125	113	108	108	106	104	98	82	76	70	64	86	73	67	60	58
Inst. Power Share RES in ALL	%	67%	60%	57%	44%	44%	45%	44%	45%	38%	36%	41%	40%	42%	39%	37%	43%	41%	41%
Average unit power ALL	W	47	32	26	16	15	16	15	15	11.6	9.5	9.5	8.6	8.1	9.5	7.8	8.0	6.9	6.7
Average unit power RES	W	51	35	26	13	12	13	12	12	8.3	6.5	7.4	6.4	6.4	7.2	5.6	6.6	5.5	5.5
Average unit power NRES	W	41	29	25	20	19	19	19	19	15.4	12.9	11.9	11.0	10.1	11.9	10.1	9.3	8.3	8.0

Scenario comparison, EU-28 Totals, Absolute values RES=Residential NRES=Non-Residential ALL= RES + NRES		1990	2010	2015	2020					2025					2030				
		BAU	BAU	BAU	BAU	ECO70+LBL	ECO80+120	ECO80+120+ LBL	ECO120+ LBL (2020)	BAU	ECO70+LBL	ECO80+120	ECO80+120+ LBL	ECO120+ LBL (2020)	BAU	ECO70+LBL	ECO80+120	ECO80+120+ LBL	ECO120+ LBL (2020)
Installed Capacity/Power ALL	lm/W	21	31	41	67	71	70	71	72	97	119	120	134	142	122	150	148	172	175
Installed Capacity/Power RES	lm/W	12	18	25	54	57	55	57	57	86	111	98	112	113	100	129	109	132	133
Installed Capacity/Power NRES	lm/W	40	51	61	78	82	82	83	85	104	124	136	148	163	136	162	176	199	204
Load/Light Source Energy ALL	lm/W	43	56	65	87	90	90	92	94	113	129	143	154	168	144	166	183	202	207
Load/Light Source Energy RES	lm/W	13	21	28	56	59	57	59	59	87	109	97	111	111	100	127	109	131	131
Load/Light Source Energy NRES	lm/W	63	72	79	93	96	97	99	102	117	132	152	161	180	152	172	199	216	222
Operating Hours (fpe) ALL	Th/a	4.6	8.6	9.7	10.8	10.8	10.8	10.8	10.8	12.1	12.1	12.1	12.1	12.1	13.4	13.4	13.4	13.4	13.4
Operating Hours (fpe) RES	Th/a	1.6	2.8	3.2	3.5	3.5	3.5	3.5	3.5	3.7	3.7	3.7	3.7	3.7	3.9	3.9	3.9	3.9	3.9
Operating Hours (fpe) NRES	Th/a	3.0	5.8	6.5	7.4	7.4	7.4	7.4	7.4	8.4	8.4	8.4	8.4	8.4	9.5	9.5	9.5	9.5	9.5
Oper. Hours Share RES in ALL	%	35%	32%	33%	32%	32%	32%	32%	32%	31%	31%	31%	31%	31%	29%	29%	29%	29%	29%
Average unit hours ALL	h/a	829	851	852	864	864	864	864	864	891	892	892	892	892	910	911	911	911	911
Average unit hours RES	h/a	470	491	494	501	501	501	501	501	517	518	518	518	518	521	523	523	523	523
Average unit hours NRES	h/a	1420	1305	1316	1308	1308	1308	1308	1308	1313	1314	1314	1314	1314	1315	1316	1316	1316	1316
Electric Energy ALL	TWh/a	225	328	324	277	267	267	262	256	243	212	195	180	165	214	186	172	154	149
Electric Energy RES	TWh/a	83	95	82	48	46	47	46	45	36	28	33	28	28	33	26	31	26	25
Electric Energy NRES	TWh/a	142	234	242	229	221	220	216	210	207	183	162	152	137	181	160	141	128	124
Energy Share RES in ALL	%	37%	29%	25%	17%	17%	18%	17%	18%	15%	13%	17%	16%	17%	16%	14%	18%	17%	17%
Energy Share LED in ALL	%	0%	0%	6%	18%	18%	22%	20%	23%	36%	42%	65%	63%	75%	58%	64%	92%	91%	96%
Energy Share LED in RES	%	0%	0%	3%	24%	23%	26%	23%	23%	54%	58%	66%	60%	61%	69%	73%	82%	78%	79%
Energy Share LED in NRES	%	0%	0%	7%	16%	17%	21%	20%	23%	33%	40%	65%	63%	78%	56%	62%	94%	94%	99%

Scenario comparison, EU-28 Totals, Absolute values RES=Residential NRES=Non-Residential ALL= RES + NRES		1990	2010	2015	2020					2025					2030				
			BAU		BAU	ECO70+LBL	ECO80+120	ECO80+120+ LBL	ECO120+ LBL (2020)	BAU	ECO70+LBL	ECO80+120	ECO80+120+ LBL	ECO120+ LBL (2020)	BAU	ECO70+LBL	ECO80+120	ECO80+120+ LBL	ECO120+ LBL (2020)
GHG Emissions ALL	MtCO2eq	113	135	128	105	101	102	99	97	87	76	70	65	59	73	63	58	52	51
GHG Emissions RES	MtCO2eq	41	39	32	18	17	18	17	17	13	10	12	10	10	11	9	11	9	9
GHG Emissions NRES	MtCO2eq	71	96	96	87	84	84	82	80	75	66	58	55	49	62	54	48	44	42
Total Expense ALL	bn euros	41	60	71	72	75	74	77	78	72	67	64	62	59	76	69	66	62	51
Total Expense RES	bn euros	16	21	24	17	19	17	19	19	12	11	11	11	11	13	11	12	11	11
Total Expense NRES	bn euros	24	39	47	55	57	57	58	59	59	56	52	52	49	63	58	53	51	51
Total Expense Share RES in ALL	%	40%	34%	34%	24%	25%	23%	24%	24%	17%	16%	18%	17%	18%	17%	16%	19%	17%	17%
Purchase Cost ALL	bn euros	4.6	10.4	15.1	15.1	19.7	18.1	22.0	23.9	11.5	13.4	13.1	15.2	15.1	11.0	12.1	11.1	12.5	12.6
Purchase Cost RES	bn euros	1.7	4.5	7.0	5.1	7.2	5.3	7.3	7.4	1.5	2.0	1.4	2.1	2.1	0.9	1.0	0.7	1.1	1.1
Purchase Cost NRES	bn euros	3.0	5.9	8.1	10.0	12.5	12.8	14.7	16.6	10.0	11.4	11.8	13.1	13.0	10.1	11.1	10.4	11.5	11.5
Purchase Cost Share RES in ALL	%	36%	43%	46%	34%	37%	29%	33%	31%	13%	15%	10%	13%	14%	8%	8%	7%	8%	8%
Average unit price ALL	euros	2.2	4.4	8.8	8.3	10.8	9.9	12.0	13.1	10.9	13.9	14.2	16.4	16.5	12.6	15.7	15.0	16.9	16.7
Average unit price RES	euros	1.2	3.3	7.1	5.5	7.7	5.6	7.8	7.8	4.5	6.6	4.5	6.8	6.8	4.1	5.9	4.3	6.2	6.2
Average unit price NRES	euros	4.4	6.0	11.2	11.2	14.0	14.4	16.5	21.2	13.9	17.3	18.8	21.0	19.9	15.2	18.5	18.3	20.1	13.1
Energy Cost ALL	bn euros	32	41	48	48	46	46	45	44	50	44	41	37	35	54	47	44	39	38
Energy Cost RES	bn euros	15	16	17	12	11	12	11	11	11	9	10	9	9	12	10	12	9	9
Energy Cost NRES	bn euros	17	25	31	36	35	34	34	33	39	35	31	29	26	42	37	33	30	29
Energy Cost Share RES in ALL	%	47%	39%	35%	25%	25%	26%	25%	26%	22%	20%	24%	23%	25%	23%	21%	26%	24%	25%

Scenario comparison, EU-28 Totals, Absolute values			1990	2010	2015	2020					2025					2030				
RES=Residential NRES=Non-Residential ALL= RES + NRES			BAU			BAU	ECO70+LBL	ECO80+120	ECO80+120+ LBL	ECO120+ LBL (2020)	BAU	ECO70+LBL	ECO80+120	ECO80+120+ LBL	ECO120+ LBL (2020)	BAU	ECO70+LBL	ECO80+120	ECO80+120+ LBL	ECO120+ LBL (2020)
Install Cost	ALL=NRES	mln euros	2524	3975	3127	3673	3665	3660	3660	3642	3429	3232	3024	3024	2922	3406	3140	2967	2967	3017
Maintenance	ALL=NRES	mln euros	1852	4528	5020	5656	5656	5656	5656	5656	6399	6399	6399	6399	6399	7240	7240	7240	7240	7240
Industry Revenue	ALL	bn euros	2.9	6.0	9.9	10.9	14.5	13.4	16.3	17.8	8.8	10.4	10.3	11.9	11.7	8.6	9.5	8.8	9.9	9.9
Industry Revenue	RES	bn euros	0.7	1.8	3.8	3.2	4.6	3.3	4.7	4.7	0.9	1.3	0.9	1.4	1.4	0.5	0.7	0.5	0.7	0.7
Industry Revenue	NRES	bn euros	2.2	4.1	6.1	7.8	9.9	10.1	11.6	13.1	7.9	9.1	9.4	10.5	10.4	8.1	8.8	8.3	9.2	9.2
Ind. Rev. Share RES in ALL		%	24%	31%	38%	29%	32%	25%	29%	26%	10%	13%	9%	11%	12%	6%	7%	6%	7%	7%
Wholesale Revenue	ALL	bn euros	0.8	1.9	2.1	1.7	2.1	1.9	2.3	2.5	1.2	1.3	1.3	1.5	1.5	1.1	1.2	1.1	1.3	1.3
Wholesale Revenue	RES	bn euros	0.4	1.0	1.1	0.6	0.8	0.6	0.8	0.8	0.2	0.2	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.1
Wholesale Revenue	NRES	bn euros	0.4	1.0	1.0	1.1	1.3	1.4	1.5	1.7	1.0	1.1	1.2	1.3	1.3	1.0	1.1	1.0	1.1	1.2
Whl. Rev. Share RES in ALL		%	48%	50%	51%	36%	37%	31%	34%	32%	15%	15%	11%	14%	14%	9%	8%	7%	8%	8%
Retail Revenue	ALL	bn euros	0.7	1.8	1.9	1.6	1.9	1.8	2.1	2.3	1.2	1.3	1.3	1.5	1.5	1.1	1.2	1.1	1.2	1.2
Retail Revenue	RES	bn euros	0.3	0.9	0.9	0.5	0.6	0.5	0.6	0.6	0.2	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.1
Retail Revenue	NRES	bn euros	0.4	0.8	1.0	1.1	1.3	1.3	1.5	1.7	1.0	1.1	1.2	1.3	1.3	1.0	1.1	1.0	1.1	1.2
Ret. Rev. Share RES in ALL		%	49%	52%	49%	32%	32%	26%	29%	27%	13%	11%	8%	10%	10%	7%	6%	5%	6%	6%
Taxes (VAT)	ALL=RES	bn euros	0.28	0.74	1.16	0.85	1.20	0.88	1.22	1.22	0.25	0.33	0.23	0.34	0.34	0.14	0.17	0.12	0.18	0.18

Scenario comparison, EU-28 Totals, Absolute values RES=Residential NRES=Non-Residential ALL= RES + NRES		1990 BAU	2010 BAU	2015 BAU	2020 BAU	2020 ECO70+LBL	2020 ECO80+120	2020 ECO80+120+ LBL	2020 ECO120+ LBL (2020)	2025 BAU	2025 ECO70+LBL	2025 ECO80+120	2025 ECO80+120+ LBL	2025 ECO120+ LBL (2020)	2030 BAU	2030 ECO70+LBL	2030 ECO80+120	2030 ECO80+120+ LBL	2030 ECO120+ LBL (2020)
Total Jobs ALL	thousands	116	241	321	345	423	400	464	499	300	332	327	362	359	301	319	301	325	326
o/w Industry	thousands	58	119	199	219	290	269	325	357	177	208	206	237	235	172	190	176	198	198
o/w Wholesale	thousands	3	8	8	7	8	8	9	10	5	5	5	6	6	4	5	4	5	5
o/w Retail	thousands	12	30	32	26	32	30	36	39	20	21	21	24	24	18	20	18	20	20
o/w Install	thousands	25	40	31	37	37	37	37	36	34	32	30	30	29	34	31	30	30	30
o/w Maintenance	thousands	19	45	50	57	57	57	57	57	64	64	64	64	64	72	72	72	72	72
Quantities per Household																			
Sales (incl. from storage)	units	8.4	7.4	6.0	4.3	4.3	4.3	4.3	4.3	1.5	1.4	1.4	1.4	1.4	0.9	0.8	0.8	0.8	0.8
Stock	units	20	27	30	31	31	31	31	31	32	32	32	32	32	33	33	33	33	33
Installed Capacity	klm	13	17	20	22	22	22	22	22	23	23	23	23	23	24	24	24	24	24
Installed Power	W	1034	936	776	406	385	398	385	385	267	208	237	206	206	237	185	219	181	180
Operating Hours	h/a	9504	13160	14802	15729	15744	15744	15744	15744	16641	16673	16673	16673	16673	17196	17256	17256	17256	17256
Load	klmh	6374	9052	10332	11461	11487	11491	11491	11493	12423	12509	12527	12527	12534	12958	13057	13089	13089	13096
Electric Energy	kWh/a	483	450	381	219	208	215	207	207	160	127	146	126	125	146	115	137	112	112
Total Consumer Expense	euros	96	98	111	78	85	78	85	86	56	48	51	48	48	58	47	54	46	46
o/w Purchase Cost	euros	9.7	21.2	32.4	23.4	32.9	24.0	33.3	33.5	6.8	8.9	6.1	9.2	9.2	3.8	4.5	3.2	4.7	4.7
o/w Industry Revenue	euros	4.0	8.7	17.7	14.4	21.0	15.2	21.3	21.4	4.1	5.9	4.0	6.0	6.1	2.4	2.9	2.1	3.1	3.1
o/w Wholesale Revenue	euros	2.1	4.6	5.0	2.8	3.6	2.7	3.6	3.7	0.8	0.9	0.6	0.9	0.9	0.4	0.4	0.3	0.5	0.5
o/w Retail Revenue	euros	2.0	4.4	4.4	2.3	2.8	2.1	2.8	2.8	0.7	0.7	0.5	0.7	0.7	0.3	0.3	0.2	0.3	0.3
o/w Taxes (VAT)	euros	1.6	3.5	5.4	3.9	5.5	4.0	5.6	5.6	1.1	1.5	1.0	1.5	1.5	0.6	0.7	0.5	0.8	0.8
o/w Installation Cost	euros	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
o/w Energy Cost	euros	86.0	76.5	78.7	55.0	52.2	54.1	52.1	52.1	48.9	39.0	44.5	38.5	38.3	54.4	42.9	50.9	41.7	41.5
o/w Maintenance	euros	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Annex H Statement of contractor on right to delivered result

I, Dirk Fransaer, representing the “Consortium of VITO NV, VHK BV, Viegand & MaagØe ApS, Wuppertal Institute for Climate, Environment and Energy GmbH, and ARMINES”, party to the contract ‘Preparatory Study on Lighting Systems for Ecodesign and/or Energy Labelling Requirements (‘Lot 8/9/19’), specific contract No. ENER/C3/2012-418 LOT1/07/SI2.668526 implementing framework contract No. ENER/C3/2012-418-Lot 1’, warrant that the Contractor holds full right to the delivered Task 7 report of the ‘Preparatory Study on Lighting Systems for Ecodesign and/or Energy Labelling Requirements (‘Lot 8/9/19’)’, which is free of any claims, including claim of the creators who transferred all their rights and will be paid as agreed within 30 days from the receipt of confirmation of acceptance of work.

Mol, Belgium,
Date:
Signature:

Dirk Fransaer
Managing Director VITO NV