Ecodesign Preparatory Study
Lot 8/9/19 Light Sources

2nd Stakeholder Meeting

17 June 2015

WELCOME !

Van Holsteijn en Kemna

Vlaamse Instelling voor Technologisch Onderzoek

Agenda

1. Welcome, amendment/approval of agenda and announcements
2. Introduction
3. Task 4: Technology
4. Task 5: Environment & Economics
5. Task 6: Design Options
6. Other topics

≈13:00 h lunch break
≈17:00 h end

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INTRODUCTION

MEErP structure and state of work
Comments on Tasks 0, 1, 2, 3
Time schedule

Van Holsteijn en Kemna

Vlaamse Instelling voor Technologisch Onderzoek

MEErP structure and state of work

1st Meeting	Task 0	First product screening	Draft report – no change
	Task 1	Scope (define products, codifications, standards, legislation)	Draft report – rev. 1
	Task 2	Markets (EU production/import/export, sales, lifetimes, installed stock, market trends, basic economic data)	Draft report – rev. 1
	Task 3	Users (efficiency, usage parameters, interaction with space heating, end-of-life, infrastructure)	Draft report – rev. 1
2nd Meeting	Task 4	Technologies (existing products, BAT, BNAT, bill-of-material (BOM), packaging/distribution)	Draft report
	Task 5	Environment & Economics (base cases, environmental impact assessment, life cycle costs for consumers)	Draft report
	Task 6	Design Options (assess design improvement options, least life cycle costs (LLCC))	Draft report – rev.1
Future	Task 7	Scenarios (policy analysis, BAU and ECO scenarios, impact on industry and consumers)	Future work

Survey of comments on Tasks 0 - 3

- 7 stakeholders provided comments
- 86 points of comment in total

Published on website http://ecodesign-lightsources.eu/documents :

- Original comments
- Summary of comments, answers from study team, actions on reports
- Revised reports (revision 1) for Task 1, Task 2 – main, Task 3
  (table with changes at beginning of report)
- Unchanged reports: Task 0, Task 2 – Annexes

Comments not presented in detail here.
Following table provides a survey of the topics addressed in the comments.

Survey of comments on Tasks 0 - 3

Main topic	Detailed topics	No.
Definitions	Decorative, use standards, general review, directional light sources, power factor, lifetime, LEDs, special purpose, control gear	14
Scope	Gadgets, special purpose, appliance integrated, OLED, emergency use, luminaires, rational for exclusion	14
Testing / Verification	Parameters, flux variance, equivalence claims, LED lifetime, LED tube flux tolerance, temperature for LED test, test method for temporal light artifacts	10
Dimming	Legacy installed, 1% output limit, step dimming, number of dimmers, traditional vs. smartphone, combination of CCR and PWM, 3-wire configurations, phase-cut for CFL and LED	8
MELISA and Sales	Distribution over Member States, use EN15193 hours, new research on residential hours, special purpose sales / Annex D, ballast sales, lifetimes	8
Lifetimes	General, of LEDs, use in MELISA	8
Opinions on future regulation	DLS info, R7s, G9, A+ for LED, CRI info, R9>0, power factor, standby power	7
Health aspects	Flicker, optical safety	6
Other	Thermal lock-in, LFL T5 HO, QMH vs CMH, CLASP report, ref. for UV	5
EEI vs. lm/W	Use lm/W instead of EEI	4
Labelling (874/2012)	Method for updating, luminaire compatibility, kWh/1000h for LED	4
Environmental impacts	Oekopol information, not only use-phase, efficiency of electricity generation	2

Time schedule

Month-Year	Event
January 2014	Start contract
November 2014	Launch website
December 2014/ January 2015	Publication Draft Task Reports 0, 1, 2, 3
5 February 2015	1st Stakeholder Meeting
May 2015	Revision 1 of Draft Task Reports 0, 1, 2, 3
	Draft Task Reports 4, 5, 6
17 June 2015	**2nd stakeholder meeting**
15 July 2015	**Stakeholder comments on Draft reports 4, 5, 6**rev1 **(incl. written)**
October 2015	Final report (all tasks 0 to 7)

Any questions or remarks so far ?

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TECHNOLOGY

(Task 4 report)

Van Holsteijn en Kemna

Vlaamse Instelling voor Technologisch Onderzoek

Task 4 (Technology) - Survey

Recent lighting technologies (chapters 2-4):

LED → Timeline for efficacy and price	→ Task 6
OLED	
Laser-diode	
Smart lamps	

Classic lighting technologies, per base case (chapter 5):

Summary of current average EU-28 characteristics (BC)	→ Task 5 EcoReport
Technology description and Improvement options	→ Task 6
Best Available (classic) Technology (classic BAT)	→ Task 6
Availability of LED substitutes and characteristics (LED BAT)	→ Task 6

Production, distribution, end-of-life (chapter 6):

LED production	
Distribution and packaging	→ Task 5 EcoReport
Bill-of-Materials	→ Task 5 EcoReport
End-of-Life	→ Task 5 EcoReport

Task 4 (Technology) - Survey

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LED technology (1, types of white LEDs)

Phosphor-conversion or pc-LED:

- GaN or InGaN LED source → blue light
- Ce^{3+} YAG phosphor (cerium-doped yttrium aluminium garnet) → yellow/red light
- Most widely used type today for white LEDs
- Power conversion efficiency 55% for blue LEDs (2013), highest of all colours
- Phosphor losses: conversion efficiency 80%

Colour-mixing or cm-LED:

- Separate Red, Green and Blue (and Amber) LED sources (RGB(A)) + colour-mixing optic
- Low power conversion efficiency for red (44%), green (22%), amber (8%) (2013)
- Potentially more lumens for the same power than pc-LED.
- No phosphor losses → potentially highest efficacy for future
- Application, e.g.: lamps with user-controllable colour change ability, mood lighting

Hybrid LED:

- Combination of pc-LED and additional coloured LED sources (red, amber)
- Applications, e.g. warmer white light, user-controllable white tones, dim-to-warm

LED technology (2, efficiency of blue LEDs, 2013)

Electrical efficiency, 92%:

- voltage losses between injection point of electrons (the electrical contacts) and the active layer of the LED die

Internal Quantum Efficiency, 88%:

- ratio of the photons (light) emitted from the active layer of the LED die to the number of electrons injected into the active layer

Light Extraction Efficiency, 85%:

- due to the differences in refraction index between the semiconductor materials and the air, the emitted photons can remained trapped inside the LED die

Packaging Efficiency, 80%:

- additional losses due to the integration of the LED die into a LED package

Blue LED: 92%*88%*85%*80% → 55% power conversion efficiency (light)
→ 45% becomes heat in the LED die

Source: Solid-State Lighting Research and Development, Multi-Year Program Plan, US DoE, May 2014, http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/ssl_mypp2014_web.pdf

LED technology (3, temperature effects)

45% becomes heat in the LED die (not radiated away with light)

→ higher LED junction temperature
- → lower efficacy (temperature droop) ≈ -0.2%/˚C
- → lower useful lifetime ≈ halved for each +10˚C

→ adequate thermal design required for cooling of LEDs
- → heat sink (often Al, heavy, material resource consumption)
- → LED retrofit lamps may behave worse in existing closed luminaires
- → LED retrofit lamps not suitable for high temperature applications (ovens)

→ double advantage of efficacy improvements
- → more light for given power
- → less heat for given power
  - → lower operating temperature, or
  - → smaller heat sink or no heat sink (gas cooled LED filament lamps)

LED technology (4, current droop)

A higher operating current density (A/cm^2) reduces the efficacy (current droop).

→ Tendency to use lower current densities than would be possible

→ less light per LED die → more LED dies required for given luminous flux

→ less heat generation per die (interaction with temperature effect)

→ Causes for current droop only recently better understood

LED technology (5, wafer improvements)

- Shift to larger wafer sizes:
  2010: 59% of the wafers was 2” diameter,
  2012/2013: 53% of the wafers was 3” diameter,
  2015: 55% of the wafers will be 6” diameter.
  → more LED dies per wafer
  → cost reduction
  → production capacity increase.

- Wafer substrate materials:
  More than 80 percent of today’s LEDs are built on a sapphire substrate.
  Alternatives: e.g. silicon carbide, bulk GaN, silicon, germanium
  → opportunities for cost reduction
  → opportunities for efficacy improvement

LED technology (6, package design)

- Improvements in package design:

  2006: in-plane dimensions of 7 x 7 mm; height around 6 mm

  2015: chip-scale flip-chip package of same manufacturer

  in-plane dimensions of 1 x 1 mm; height around 0.25 mm

  → cost reduction (-80%)

  → thermal improvements

  → smaller design; more design freedom.

- Encapsulation materials:

  Protect LED die; Host for phosphors; Lens function; Light extraction function

  Standard LEDs: epoxy resin (80% market share in 2014)

  High quality LEDs: silicon-based material (20% market share in 2014)

  → opportunities for cost reduction

  → opportunities for efficacy improvement

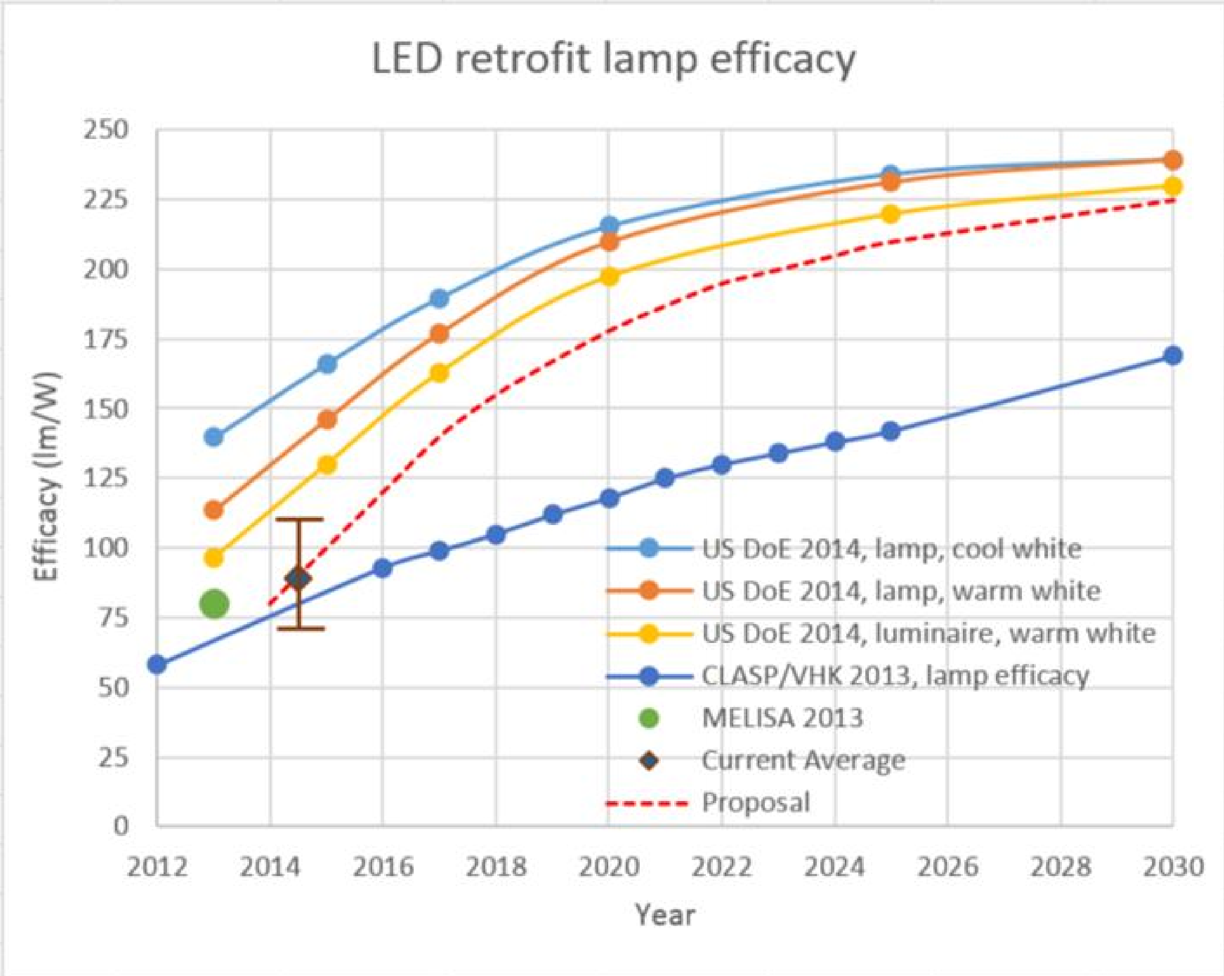
LED technology (7, conclusion)

- Huge progress has been made in recent years in LED lighting technology

- Much more can be done, and will be done, in coming years

- Examples of research topics (not exhaustive):
  - New semiconductor materials. US DoE: core technology research priority task.
  - Improve power conversion efficiency of in particular green, amber and red LEDs.
  - Reduce sensitivity to current density (i.e. current droop).
  - Reduce sensitivity to temperature (i.e. temperature droop).
  - Reduce operating temperature (i.e. thermal design).
  - Improve phosphor materials, in particular narrowing the emission bandwidth for green and red phosphors. Use of nanoparticles (‘QLED’) may play a role here.
  - Improved and cheaper encapsulation; textured surfaces improve light extraction.
  - Improved and cheaper substrate material.
  - Further optimization in package design.

LED timeline for efficacy



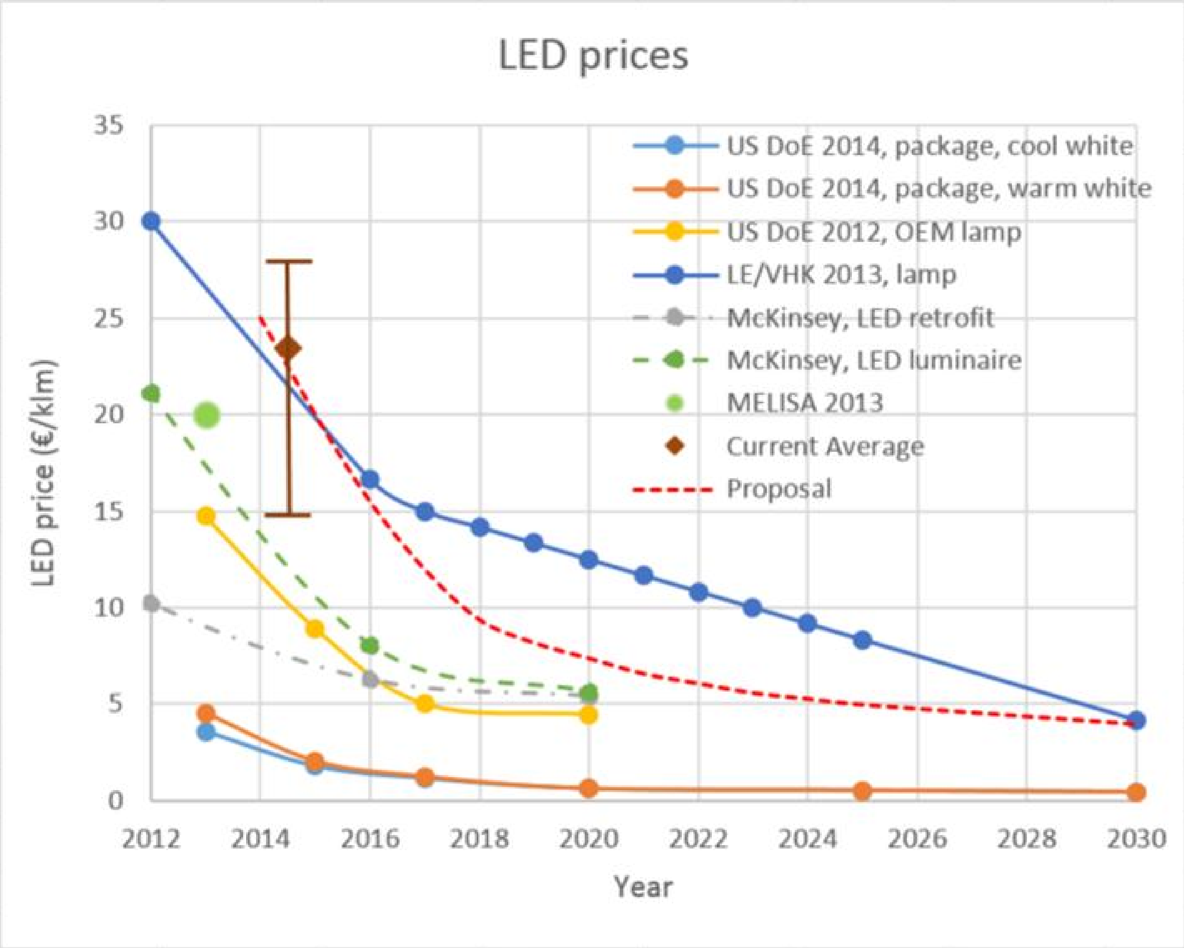
*Solid-State Lighting Research and Development, Multi-Year Program Plan, US DoE, May 2014

- US DoE* lamp: derived from package efficacy considering increased operating temperature, reduced current density, and driver losses.
- US DoE luminaire: derived from warm white lamp efficacy, considering fixture/optical efficiency.
- US DoE interpreted as best on market.

- Proposal: intended as average of new sold lamps on the market (all LED types). 2020: 175 lm/W used in Task 6

References:
- MELISA 2013: 80 lm/W
- 2014/2015 average LED: 89 lm/W
- CLASP/VHK 2013 from Stage 6 review

LED timeline for price



Assumptions:

- US DoE: 1.12 US dollar = 1 euro.
- McKinsey*: 500 lm/unit average
- VAT excluded.

- Proposal: intended as average of new sold lamps on the market (all LED types). 2020: 7.5 €/klm used in Task 6

References:

- MELISA 2013: 20 €/klm
- 2014/2015 average LED: 23.4 €/klm
- LE/VHK 2013 from Stage 6 review

* “Lighting the way: Perspectives on the global lighting market”, McKinsey & Company, second edition, August 2012.

LED technology and timeline: END

- Will current trends in LED development continue ?

- Industry needs return on LED R&D investments ?
  → efficacy improvement trend might slow down
  → industry might concentrate on cost reduction and capacity increase.

- Related to phase-out of halogen lamps (loss of revenue) ?

- Rate of improvement related to number of players on the market ?
  (e.g. some manufacturers already scaled down or abandoned LED lighting production)

Questions or Comments on LED Technology and Timeline ?

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Laser-diode

Smart lamps

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OLED technology (1)

- OLED lighting products for sale are mainly: prototypes, technology demonstrators, sample kits for designers, and premium light installations and luminaires.
  Some manufacturers recently started mass production or are preparing for it.

- Highest efficacy for commercialised panels 50 – 60 lm/W. Expected: 130 lm/W by 2018.
  US DoE target for 2020 is 150-170 lm/W. <u>OLED efficacy < LED efficacy</u>

- Main barrier to large-scale market introduction is <u>OLED price 180 euros/klm >> LED price 23 euros/klm</u>. Price reduction -90% expected (when ?) due to new production processes and to higher production volumes.

- <u>Current impact of OLED lighting on EU market negligible</u>. No significant change before 2020.
  <u>Future of OLED lighting is uncertain</u>: market researchers have widely diverging opinions.

OLED technology (2)

- OLED lighting products are NOT retrofit solutions: no OLED light bulbs, spots or tubes exist.

- OLEDs do offer new possibilities for lighting designers, in particular when flexible, transparent, colour-tuneable panels of larger size will become available on a large scale and at lower prices. Large-area diffused light is attractive for some applications, as opposed to current light sources that are point- or line-like.

- OLEDs not considered as a base case in this study. Difficult to define OLED lighting as BAT or BNAT. OLED efficacies are expected to stay behind those of LEDs, and prices are expected to remain higher than those for LEDs.

- OLEDs should be considered for future regulation:
  - avoid that early OLEDs perform poorly and cause market souring
  - consider efficacies that can be reached by OLEDs, i.e. avoid unintentional barriers

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Laser-diode technology

- Laser-diode (LD) lighting technology exists, is promising, research ongoing. Potentially, LEDs and LDs can have same power conversion efficiency. LDs do not suffer 'current droop' as LEDs do → higher current can be used → 2000 times more light per square centimetre.

- Commercial niche applications: car head lights, projection, medical.

- No existing general lighting applications. Expected in 5-10 years.

- Not clear how efficacy, costs, light quality, thermal management aspects and safety aspects will relate to those of LED lighting
  → in this moment not feasible to judge if this will be the best technology for the future.

- Laser-diode lighting will most likely not produce retrofit lamps for existing sockets, but require a new approach to lighting design, e.g. central light generation point and a light distribution system.

- No base case for laser diode lighting in this study.

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Smart lamps (1)

Definitions:

- A smart light source is a light source with some level of sensing and intelligence combined with the ability to communicate, usually wirelessly (source: Gartner)
- A smart light source is a light source containing electronics inside the housing of the lamp to provide one or more functions beyond the primary performance function, i.e. convert electricity into light (in eco-design context).

Examples of secondary functions:

- remotely 'control' the primary performance function 'light' (dimming, colour control)
  without additional electronics in the fixture/ballast; without manipulating mains voltage signature
- 'locate and configure lights' in building automation,
- 'locate users' within a building for various tasks,
- act as 'repeaters for communication signals' to extend the range,
- 'act as sensor hubs', providing e.g. sound volume, daylight, motion, presence,
- 'luminaire monitoring', e.g. on LED lumen maintenance or temperature,
- 'access points for communication signals', e.g. interface with building automation system,
- 'learn the users day-to-day routine' and adjust itself accordingly,
- provide 'audio' (integrated loudspeaker) functionality
- support the 'grid balance',
- visually 'notify' the user of certain 'events' (mail, door ringing, alert)

Smart lamps (2)

- Secondary functions, communication methods, operability, standardization, system integration, expected to be handled in:
  - Ecodesign preparatory study on smart appliances (started autumn 2014)
  - Ecodesign preparatory study on lighting systems (Lot 37)

- Colour control and dimming only digitally. Not compatible with traditional dimming.

- Secondary functions may become outdated before the lifetime of the lights → reduced useful lifetime.

- No specific sales, stock, average power, efficacy, price data available for smart lamps.

- Smart lamps are NOT a separate lamp technology; typically they are LED lamps (pc-LED, cm-LED or hybrid LED) → no specific base case in this study, part of LED base case.

- Aspects for future lighting regulation:
  - standby power (depends on communication method; auxiliary equipment)
  - exemption/inclusion of lamps with colour change ability
  - efficacy in function of (white) light colour
  - subdivision of energy consumption over functions.

OLED, Laser-diodes, Smart lamps (END)

Question or remarks on OLED, Laser-diodes, Smart lamps ?

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Classic lighting technologies (1, Base cases)

Table 3: Base cases discussed in this report

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

These are the same base cases considered in Task 2 and Task 3.

Classic lighting technologies (2, BC data)

Task 4 report, chapter 5, for each base case (BC): table summarizing average EU-28 characteristics. Used as input for EcoReports in Task 5. Example below is for LFL T8 tri-phosphor.

*Table 19: Average EU-28 characteristics for the **LFL T8t base case**, reference year 2013. (Price information is in fixed 2010 euros, inclusive 20% VAT for the residential part)*

Parameter	Residential	Non-Residential	All Sectors	Notes
Sales (mln units/yr)	15.7	229	245	
Lifetime (yr)	18.6	5.9	6.4	
Stock (mln units)	168	1208	1376	
Capacity (lm)	2400	2400	2400	
Efficacy (lm/W)	80	80	80	
Power (W)	30	30	30	Exclusive ballast power
Ballast efficiency (%)	91%	91%	91%	Electronic ballast
Burning Hours (h/a)	700	2200	2017	
Electricity rate (euros/kWh)	0.191	0.119	0.122	
Price (euros/unit)	10.10	8.42	8.52	
Installation cost (euros/unit)	0.00	6.16	5.76	143 147
Maintenance cost (euros/unit)	0.00	2.96	2.60	143

Residential and Non-residential data are the same presented in Task 2 and 3, but grouped per base case.

EcoReports use 'All Sectors' data: sum of sector data (sales, stock) or weighted average (burning hours, lifetime, economic data).

Residential: incl. VAT 20%
Non-residential: excl. VAT
All Sectors: weighted VAT

No installation and maintenance cost for Residential.

Classic lighting technologies (3, Improvement Options)

Task 4 report, chapter 5, for each base case (BC): discussion of improvement options.
Used as input for Task 6 (Design options).

Typical options considered:

BC → same BC (if still available on the market)
BC → same BC but with improved control gear, e.g. electromagnetic → electronic
BC → same classic technology but with BAT characteristics, e.g. LFL T8t BC → LFL T8t HE or XL
BC → other classic technology, e.g. HPM → HPS or MH
BC → BAT LED retrofit lamp (if available on the market)
BC → BAT LED luminaire

Aim of chapter 5: identify difficulties regarding shift in sales towards LEDs.
Shift in sales + proposed LED timeline → energy savings, environmental & economic impact in Task 7 scenario analyses.

Classic lighting technologies (4, Summary for LFL)

- LFL T12 and T8 halo-phosphor phased out, have to be substituted by another technology.

- LFL T8 tri-phosphor and LFL T5 still on the market with good efficacies, 90-110 lm/W. Large variety of models: high-efficiency, high-output, (extra) long life, etc.

- LFLs function on external ballasts. Expected that 75% of new sold ballasts is now electronic. Electro-magnetic ballasts expected to be phased from September 2017.

- Many LFLs function in luminaires that provide specific light distributions and anti-glare features. Lighting calculations performed to verify that light arriving on task areas meets standards.

- Large variety of LED retrofit tubes available with G13 cap, to substitute LFL T12 and T8.
- Less LED retrofit tubes available with G5 cap, to substitute LFL T5, only secondary brands.
- Efficacy of LED retrofit tubes 80-140 lm/W. Models with 200 lm/W in laboratory; expected to enter market soon.

Classic lighting technologies (5, Summary for LFL)

- Most LED retrofit tubes: replace or by-pass existing ballast.
  → re-wiring; qualified personnel; new safety certification of luminaires → installation cost
- Plug-and-play LED retrofit tubes: maintain existing ballast (some: replace starter)
  → higher purchase cost; lower install cost; energy losses from existing ballasts remain.

- Most LED retrofit tubes: directional light (beam angles 120 to 150˚)
  → different light distribution; new lighting calculations may be required
  → advantage of directionality: might be possible to install less lumen, might be possible to avoid luminaire losses.
  → may not be suitable for indirect lighting installations.
- LED retrofit tubes typically have lower luminous flux /unit length, but may be acceptable.

- In closed luminaires, for higher lumen lamps: assess thermal aspects of LED retrofit tube.
- Consider difference in lifetime and in lumen maintenance (in relation to temperature).

- Expected for coming years, LFL substituted by mix of LFL (T8 tri-phosphor and T5), LED retrofit tubes, and LED luminaires.

Classic lighting technologies (6, Summary for HID)

- HID-lamps:
  - Industrial and commercial lighting, street lighting, sports lighting
  - High light intensity produced in a compact space
  - Operate on external ballast
  - Light level and distribution often optimized by lighting calculations

- HPM-lamps (≈ 50 lm/W) now phased out (April 2015).
  - substitute by dedicated HPS (on same low-efficiency ballast, 84-98 lm/W),
  - substitute by BAT HPS (change ballast, colour change → install more lumens, 100-140 lm/W)
  - substitute by BAT MH (change ballast, better CRI → install less lumens, 100-120 lm/W)
  - substitute by LED retrofit or luminaire

- HPS-lamps (≈ 95 lm/W base case average)
  - yellow/orange light, low CRI → install more lumens compared to e.g. MH
  - high BAT efficacy, depending on power/lumen level and on CRI, 100-140 lm/W
  - long lifetime and good lumen maintenance (compared to MH)
  - substitute by BAT HPS, also changing electro-magnetic ballast by (dimmable) electronic
  - substitute by MH or by LED

Classic lighting technologies (7, Summary for HID)

- MH-lamps (≈ 82 lm/W base case average) :
  - Improvements in efficacy, colour rendering, and lifetime in recent years (2007-2013)
  - BAT MH-lamps 100-120 lm/W > 245/2009 Stage 3 (2017)
  - Lower lm/W, lower useful life than HPS, but better CRI, less lumen can be installed
  - Ceramic arc tube (CMH) has higher efficacy than quartz version (QMH)
  - Different light source dimensions → CMH cannot replace QMH in all applications

- LED substitutes for HID-lamps (90-120 lm/W):
  - LED retrofit lamps for HID-lamps are available on the market
  - Most are marketed by small companies (secondary brands); major lamp manufacturers offer complete LED luminaires for outdoor application (no retrofit).
  - LED retrofits often for specific HID-lamp type or for specific luminaire type.
  - Same situation as for LFL regarding ballast (plug-and-play, replace or by-pass existing ballast, safety certification issues, installation costs related to re-wiring and ballast replacement)
  - LED retrofit lamps cannot meet the high light intensities in compact space of the HID-lamps → tend to be heavier and larger, especially for high lumen.
  - Attention points: available space in luminaire, thermal management, amount and distribution of the light (e.g. new lighting calculations may be necessary), useful lifetime.

Classic lighting technologies (8, Summary for HID)

- Potential investment problem:
  - Replacements for HID-lamps are mainly bought by municipalities, sports clubs, theatres, etc.
  - Limited budget
  - Potentially made recent investments to replace HPM by HPS or MH
  - Need time to switch to LED (give time for return-on-investment)
  - Possibilities for ‘energy performance contracting’ and funding

Expected that for economic reasons the shift from HID- and FL-lamps to LED lighting will not be immediate and straightforward, and that a mix of LED and non-LED options will be used in the coming years.

Classic lighting technologies (9, Summary, Other)

- LED retrofit lamps for CFLni:
  - None offered by major lamp manufacturers
  - Available from smaller companies, secondary brands
  - Same existing ballast problem as for LFL and HID-lamps.

- LED retrofit lamps for linear halogen lamps (R7s cap):
  - Available on the market for low lumen level
  - Halogen R7s lamps up to 44,000 lm; highest capacity R7s LED only 5,200 lm. Lumen difference appears for each lamp length.
  - LED retrofit diameter is larger (55 mm (recently 20-29 mm) vs. 10-12 mm for halogen lamps) → potential geometric lock-in problem
  - Light distribution differences: LED directional 120-180˚ vs. halogen lamps 360˚ → depends on luminaire if this is a problem

Classic lighting technologies (9, Summary, Other)

- LED retrofits for MV halogen capsules (G9 cap) and LV halogen capsules (G4, GY6.35 cap):
  - Available on the market
  - Major lamp manufacturers offer only low lumen models
  - Higher lumen models are available from smaller companies, secondary brands
  - In particular higher lumen LED models are larger than halogen capsules → geometric lock-in

- LED retrofits for Other halogen lamps, non-halogen filament (GLS) lamps and CFLi's:
  - Available on the market, at least to 1000 lm.
  - Non-directional lamps: reference recent Stage 6 discussion
  - Directional lamps: reference Consultation Forum of 25 June 2015

- High-temperature applications (ovens): halogen lamps are BAT

- Details and further background information in Task 4 report, chapter 5

Summary, 2014/2015 LED retrofit efficacy and price

LED lamp type	N	Efficacy (lm/W)			euros/klm (excl. VAT)		
		min	avg	max	min	avg	max
NDLS LED filament lamps	10	96	109	121	10.33	24.80	53.33
NDLS LED other lamps	23	58	77	104	5.83	17.27	36.00
DLS LED lamps with E14/E27 cap	43	40	79	107	9.89	36.31	165.2
DLS LED lamps with GU10 cap	58	52	77	100	9.72	36.67	105.1
LED retrofits for HL LV Reflector	5	50	73	104	11.67	23.43	49.56
LED retrofits for HL LV Capsule	6	67	93	101	9.91	41.40	71.36
LED retrofits for HL MV Capsule	5	74	84	96	8.42	22.32	41.64
LED retrofits for HL MV R7s	14/11	67	96	115	4.54	26.71	57.38
LED retrofits for LFL (tubes)	14/7	80	109	148	11.31	18.21	43.95
LED retrofits for CFLni	4/2	72	91	102	23.27	28.10	32.93
LED retrofit for HID (indicative)	(3)	90		120		10	
Average, all types			**89**			**23.4**	

DLS lumens are total flux, not in cone

Question or remarks on Classic Lighting Technologies ?

Task 4 (Technology) - Survey

Recent lighting technologies (chapters 2-4):

LED → Timeline for efficacy and price → Task 6
OLED
Laser-diode
Smart lamps

Classic lighting technologies, per base case (chapter 5):

Summary of current average EU-28 characteristics (BC) → Task 5 EcoReport
Technology description and Improvement options → Task 6
Best Available (classic) Technology (classic BAT) → Task 6
Availability of LED substitutes and characteristics (LED BAT) → Task 6

Production, distribution, end-of-life (chapter 6):

LED production (no presentation, see report)
Distribution and packaging → Task 5 EcoReport
Bill-of-Materials → Task 5 EcoReport
End-of-Life → Task 5 EcoReport

Task 4 (Technology) - Survey

Recent lighting technologies (chapters 2-4):

LED → Timeline for efficacy and price → Task 6

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Classic lighting technologies, per base case (chapter 5):

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Production, distribution, end-of-life (chapter 6):

LED production

Distribution and packaging → Task 5 EcoReport

Bill-of-Materials → Task 5 EcoReport

End-of-Life → Task 5 EcoReport

Distribution and Packaging (1)

- Primary packaging: Box (paper-based material) or Blister (PET plastic + paper-based material).
- Secondary and shipment packaging: Typically corrugated fibreboard box.
- Considering all packaging levels: 90% of packaging material paper-based and 10% PET.

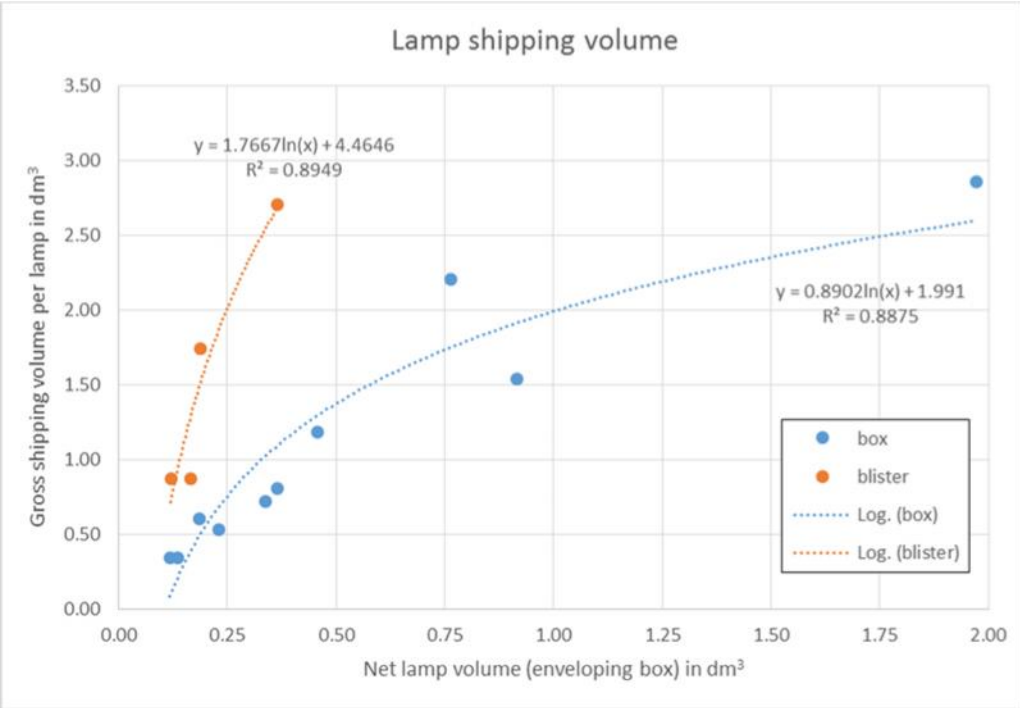
- Packaging volume (indicative for shipping volume in EcoReport):

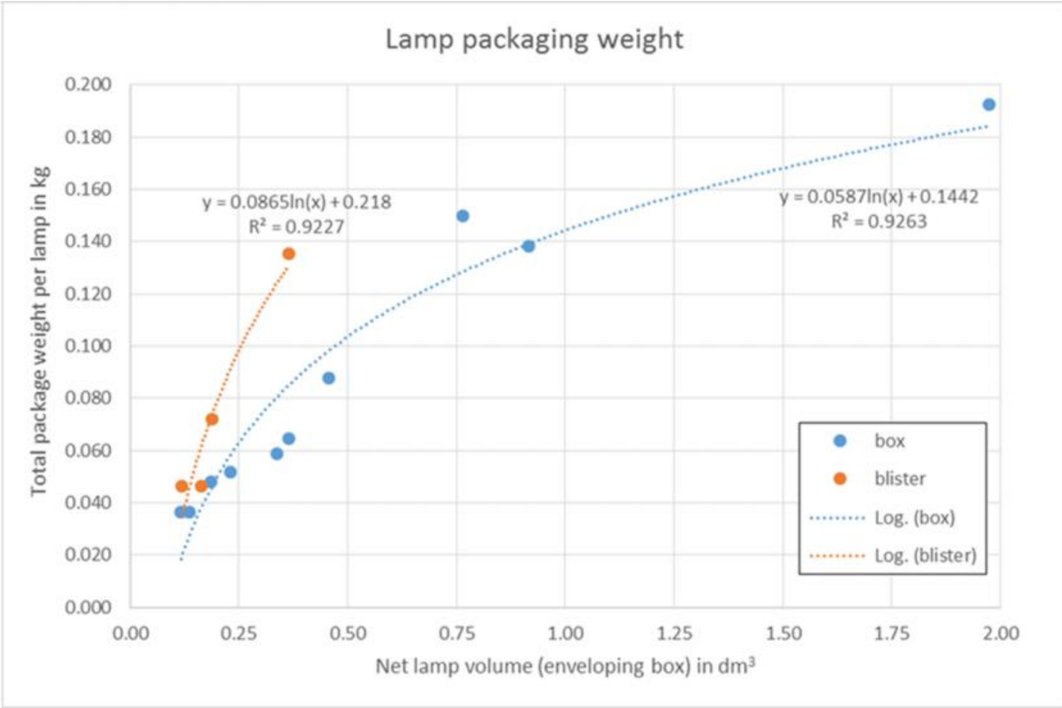
- Net enveloping volume small lamp (e.g. MR16, candle):	0.12 - 0.19 dm^3
- Net enveloping volume medium size lamp (e.g. PAR 20):	0.34 - 0.46 dm^3
- Net enveloping volume large lamp (e.g. PAR 30/38):	1 - 2 dm^3
- Gross shipping volume, small and medium lamps with primary box:	2-3 times net volume
- Gross shipping volume, large lamps with primary box:	1.5 times net volume
- Gross shipping volume, lamps with primary blister:	5-9 times net volume

- Packaging weight (indicative for packaging weight in Bill-of-Materials):

- Primary packaging weight, small lamp (e.g. MR16, candle):	12 – 23 g
- Primary packaging weight, medium lamp (e.g. PAR 20):	20 – 37 g
- Primary packaging weight, large lamp (e.g. PAR 30/38):	70 – 120 g
- Gross total packaging weight per lamp	2 – 3 times primary
- Blisters tend to be heavier than carton boxes	

Distribution and Packaging (2)





Excluded: - shipping containers and pallets (assumed to be re-used)
- enveloping plastic foils for boxes on the pallets (per-lamp contribution assumed negligible).

Assumed included: - additional packaging due to on-line ordering and associated separate shipment

Task 4 (Technology) - Survey

Recent lighting technologies (chapters 2-4):

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Production, distribution, end-of-life (chapter 6):

LED production

Distribution and packaging → Task 5 EcoReport

Bill-of-Materials → Task 5 EcoReport

End-of-Life → Task 5 EcoReport

Bill-of-Materials (1)

- Task 4 report, paragraph 6.3: bill-of-materials (BoM) for each base case.
- Total net lamp weight derived from catalogue data (as far as available)
- Material subdivision based on references from literature and/or similarity with other lamps.
- Attempt made to include special materials and critical raw materials (e.g. phosphors, tungsten)
- Packaging materials are included.
- External control gears and luminaires are excluded.
- Stakeholders are invited to verify the accuracy of these BoM's.
- Used as input for the EcoReports in Task 5.

Special case: BoM for LED. Only this BoM is presented here.

- In Tasks 6 and 7 analyses: LED lamps substitute non-LED lamps on the basis of an approximate lumen equivalence.
- Single Bill-of-materials for all LED lamps per unit of lumen, i.e. per 1000 lm (klm). This BoM is scaled, case-by-case, in function of the lumens of the lamp that is being substituted.
- First step: determine net lamp weight for such a 1000 lm LED lamp → 150 g/klm.
- Second step: subdivide weight over the various materials, using six reference BoM's from literature and own weight measurements on a LED filament lamp.

Bill-of-Materials (2)

Table 2: Bill-of-Materials for a 1000 lm LED retrofit lamp with integrated control gear.

Material	Weight (g)	EcoReport Category	EcoReport Material or process	recycling
Lens or Bulb (glass) 10%	8.592	7-Misc.	55 -Glass for lamps	
Lens or Bulb (plastic, PC)	6.397	2-TecPlastics	13 -PC	Yes
LED (filament, die, array) 2.5%	3.728	6-Electronics	49 -SMD/ LED's avg.	
Heat sink (aluminium) 43%	64.961	4-Non-ferro	28 -Al diecast	
Heat sink (local, copper)	2.896	4-Non-ferro	32 -CuZn38 cast	
Control gear (electronics, PCB) 16%	23.206	6-Electronics	50 -PWB 1/2 lay 3.75kg/m2	
Cap / Fitting / Electrical contact	6.970	4-Non-ferro	31 -Cu tube/sheet	
Housing/Base (porcelain, glass)	7.405	7-Misc.	55 -Glass for lamps	
Housing/Base (plastic, acrylic, PC) 20%	10.099	2-TecPlastics	13 -PC	Yes
Housing/Base (potting resin)	13.116	2-TecPlastics	15 -Epoxy	
Other metals (ferrous)	0.540	3-Ferro	24 -Cast iron	
Other metals (non-ferrous)	2.028	4-Non-ferro	27 -Al sheet/extrusion	
Solder paste	0.061	6-Electronics	53 -Solder SnAg4Cu0.5	
Subtotal lamp	**150.000**			
packaging cardboard/paper	36.000	7-Misc.	57 -Cardboard	
packaging plastic	4.000	1-BlkPlastics	10 -PET	Yes

Bill-of-Materials (3)

Table 69 Example of a material breakdown for a LED package: Osram Golden Dragon white LED SMD [366]. (Source for data: Ökopol 2013, table 7 [367]).

	mg	%	mg	%	mg	%	mg / klm		
Entire LED package	151.154	100.0%							
Anode/Cathode/Frame (Copper)	58.979	39.02%					786.4		
Housing, Poly Pthalamide + TiO2, glass fibre	50.000	33.08%					666.7		
Heat sink, Al2O3, AlN	24.150	15.98%					322.0		
Lens, Si-polymer	16.764	11.09%					223.5		
LED die	1.047	0.69%					14.0		
Carrier (150 micron) (Ge)			0.808	77.1%				10.8	
Phosphor (30 micron)			0.141	13.5%				1.9	
Yttrium					0.063	44.7%			0.8
Aluminium					0.032	22.7%			0.4
Oxygen					0.046	32.6%			0.6
Cerium					0.000	0.0%			0.0
Metals (3.5 micron)			0.068	6.5%				0.9	
Gold					0.056	82.1%			0.7
Silver					0.011	16.3%			0.1
Al, Ti, Ni					0.001	1.6%			0.0
Semiconductor (5 micron)			0.031	3.0%				0.4	
Gallium					0.026	83.2%			0.3
Indium					0.000	0.0%			0.0
Nitrogen					0.005	16.8%			0.1
Mg, Si					0.000	0.0%			0.0
Bonding wire (gold)	0.151	0.10%					2.0		
ESD-diode (Si)	0.063	0.04%					0.8		

Task 4 (Technology) - Survey

Recent lighting technologies (chapters 2-4):

LED → Timeline for efficacy and price → Task 6

OLED

Laser-diode

Smart lamps

Classic lighting technologies, per base case (chapter 5):

Summary of current average EU-28 characteristics (BC) → Task 5 EcoReport

Technology description and Improvement options → Task 6

Best Available (classic) Technology (classic BAT) → Task 6

Availability of LED substitutes and characteristics (LED BAT) → Task 6

Production, distribution, end-of-life (chapter 6):

LED production

Distribution and packaging → Task 5 EcoReport

Bill-of-Materials → Task 5 EcoReport

End-of-Life → Task 5 EcoReport

End-of-Life (input for EcoReports)

Incandescent lamps (GLS) and halogen lamps:
- No separate collection.
- End up in an incinerator or a landfill as mixed domestic waste (default EoL in EcoReport).

Discharge lamps (LFL, CFL, HID-lamps):
- Separate collection under WEEE-directive.
- Task 3 data used: 30% collected of which 80% recycled.
- EcoReports assume 30%*80% = 24% recycled + 76% to incinerator/landfill as mixed domestic waste (of which anyway a part is recycled, or heat recovered)

LED lamps:
- Separate collection under WEEE-directive.
- No significant amount of waste yet; no data on collection and recycling
- EcoReports assume same treatment as discharge lamps

Packaging materials:
- Eurostat 2012: 64.6% of packaging waste recycled. Percentage used in EcoReports.

End of Task 4 (Technology) Questions ?

Recent lighting technologies (chapters 2-4):

LED → Timeline for efficacy and price	→ Task 6
OLED	
Laser-diode	
Smart lamps	

Classic lighting technologies, per base case (chapter 5):

Summary of current average EU-28 characteristics (BC)	→ Task 5 EcoReport
Technology description and Improvement options	→ Task 6
Best Available (classic) Technology (classic BAT)	→ Task 6
Availability of LED substitutes and characteristics (LED BAT)	→ Task 6

Production, distribution, end-of-life (chapter 6):

LED production	
Distribution and packaging	→ Task 5 EcoReport
Bill-of-Materials	→ Task 5 EcoReport
End-of-Life	→ Task 5 EcoReport

Ecodesign Preparatory Study

Lot 8/9/19 Light Sources

2nd Stakeholder Meeting

17 June 2015

ENVIRONMENT & ECONOMICS

(Task 5 report)

Van Holsteijn en Kemna

Vlaamse Instelling voor Technologisch Onderzoek

Task 5 (1) Introduction

- Task 5: environmental impacts and life cycle costs (LCC) of all base case types of light sources
  (excluded: SPL, controls and standby, external control gear, luminaires)
- Assessments are based on the EcoReport (part of MEErP).

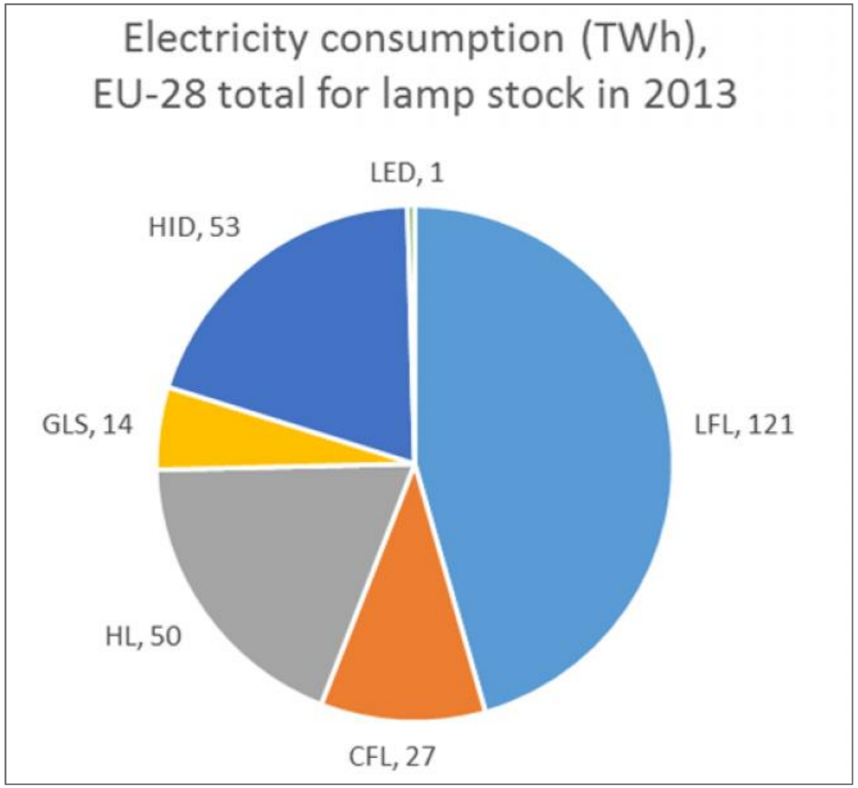
- EcoReports quantify, for reference year 2013, for 19 base case types of light sources :
  - Environmental Impacts for production, distribution, use and end-of-life stage:
    - materials use (10 categories)
    - energy & water resources as well as waste (6 parameters)
    - emissions to air (7 parameters)
    - emissions to water (2 parameters).
    - consumption of critical raw materials (EcoReport + manual elaboration)
    - mercury balance of light sources (EcoReport + manual elaboration)
  - Life Cycle Costs (LCC) and consumer expenditure for lamps
  - Inputs for EcoReports from Tasks 2, 3, 4.

Task 5 (2) Inputs for EcoReports

Input summary EcoReports EU-28 average BC characteristics (MELISA, 2013, All sectors) (from Task 2, 3, 4)	**LFL T12**	**LFL T8 halo**	**LFL T8 tri**	**LFL T5**	**LFL Other**	**CFLi**	**CFLni**	**HL LV R (MR16) (GU4, GU5.3)**	**HL LV Capsule (G4, GY6.35)**	**HL MV Capsule (G9)**	**HL MV Linear (R7s)**	**HL MV E-cap (GLS substitute)**	**HL MV Other (PAR, GU-10)**	**GLS R**	**GLS other**	**HPM**	**HPS**	**MH**	**LED (1000 lm)**
Sales (mln units)	1.2	2.2	245	76	19	271	72	164	42	67	38	303	158	36	123	2.2	14	16	57
Stock (mln units)	4.9	5.7	1376	501	160	3827	633	683	211	230	87	800	558	104	457	5.6	42	37	95
Operating hours (h/a)	1623	1398	2017	2099	1879	500	1197	450	450	450	450	450	450	450	450	4000	4000	4000	585
Useful lifetime (yr)	4.9	5.7	6.4	9.5	5.8	12	8.4	4.4	4.4	3.3	2.2	3.3	3.3	2.2	2.2	2.0	3.0	2.0	34.0
Capacity (lm)	*2450*	*2400*	*2400*	*2275*	*1032*	*523*	*633*	*490*	*490*	*420*	*3000*	*432*	*420*	*513*	*513*	*10000*	*13300*	*13120*	*1000*
Efficacy (lm/W)	*70*	*75*	*80*	*91*	*86*	*55*	*55*	*14*	*14*	*12*	*12*	*12*	*12*	*9.5*	*9.5*	*40*	*95*	*82*	*80*
Power (W)	35	32	30	25	12	9.5	12	35	35	35	250	36	35	54	54	250	140	160	12.5
Purchase price (euros/unit)	8.52	8.52	8.52	8.02	8.02	4.91	4.65	3.66	3.05	3.66	3.05	2.54	13.73	1.32	0.81	17.00	27.00	27.00	23.30
Installation cost (euros/unit)	5.75	5.77	5.76	5.77	5.77	0.74	4.32	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	9.25	9.25	9.25	1.06
Maintenance cost (euros/unit/life)	1.40	1.23	2.60	4.09	2.11	4.44	10.74	0.82	0.82	0.61	0.41	0.61	0.61	0.41	0.41	12.33	18.50	12.33	1.85
Electricity rate (euros/kWh)	0.131	0.131	0.122	0.121	0.121	0.162	0.138	0.177	0.177	0.177	0.177	0.177	0.177	0.177	0.177	0.119	0.119	0.119	0.165
BoM: Net lamp weight (g/unit)	198	131	131	80	47	60	50	30	2.4	3.6	10	24	40	30	25	160	158	110	150
BoM: Packaging weight (g/unit)	60	40	40	30	20	60	50	30	14	14	20	60	40	90	60	90	60	50	40
EoL definition	24% recycling, 76% mixed waste							100% Mixed domestic waste								24% recyc., 76% mixed			
Control gear efficiency (%)	*80%*	*80%*	*91%*	*91%*	*83%*		*91%*	*94%*	*94%*							*83%*	*83%*	*83%*	*94%*

Task 5 (3) Environmental Impacts

- Light sources consume 9.5% (265 TWh) of EU-electricity, which takes up 3.2% (2398 PJ) of EU primary energy consumption to generate and distribute.



Covers all base case types of light sources

Excluded:
- Special purpose lamps (56 TWh)
- Controls and Standby (16 TWh)
- External control gears (25 TWh)
- GLS and Tungsten stock (20 TWh)

(see Task 3: total 382 TWh)

Excluded:
- lights on means of transport

Task 5 (4) Environmental Impacts

- Light-source-related greenhouse gas emissions (103 Mt CO_2 eq.) and the emissions of acidifying agents (455 kt SO_2 eq.) are 2% of EU total. Other aggregated emissions to air take up less than 0.6% of EU totals.

- Light-source-related emissions to water and consumption of non-energy resources constitute less than 0.1% of EU-totals.

- Mercury emissions are 8% (6.3 t) of EU-total with a declining trend. Two-thirds during use phase and one-third at end-of-life.

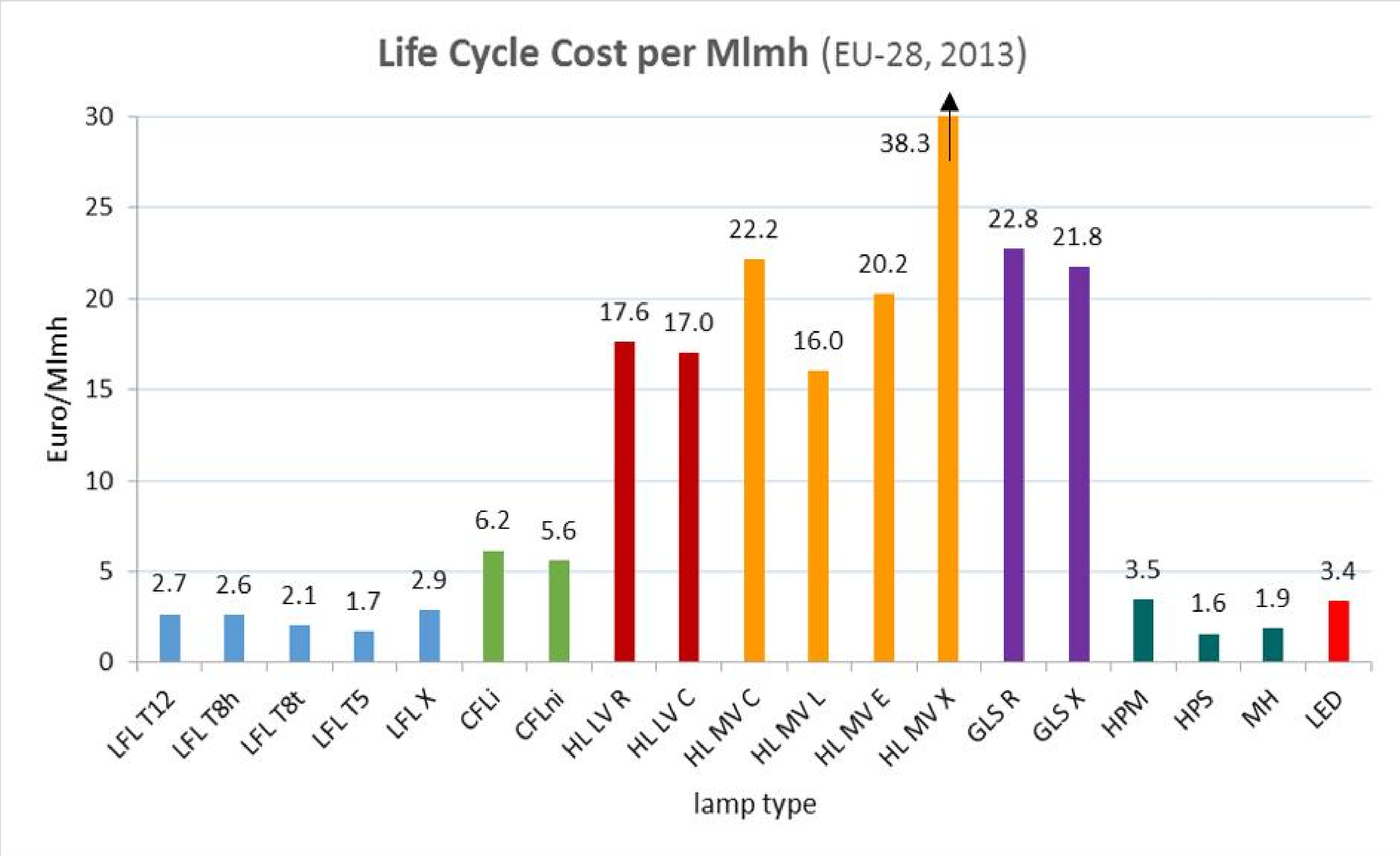
- Light sources produced for the EU market, in- and outside the EU, consume 158 tonnes Sb equivalent of critical raw materials, which equals 1.4% of EU consumption.

Task 5 (5) Environmental Impacts

- Light-source-waste is 174 kt (EU 2013), of which almost half (45 weight %) is packaging.
- End-of-life light sources, without packaging, around 1% of electric and electronic waste (WEEE).
- Light-source-waste is 15% of the solid waste from the annual electricity production needed to operate the light sources (1.2 Mt).
- The 1.4 Mt of waste related to light sources and their energy use are 0.04% of the EU-total non-hazardous and hazardous waste.

- Typically the use phase makes up 90-99% of the total impact of all parameters, with some exceptions:
  - For simple (filament) light sources with a relatively short product life such as GLS and HL, parameters relating to distribution (Polycyclic Aromatic Hydrocarbons (PAH), Particulate Matter(PM)) are significant and may constitute up to half of the total PAHs and PM emissions.
  - For energy-efficient lamps with a long product life, i.e. LEDs, the absolute impact per unit of light output (in klm) is lowest of all but --because the energy consumption during the use-phase is low-- some production parameters become relatively more significant, such as the share of hazardous waste (62% of total), the share of Persistent Organic Pollutants (POP)-emissions (36%), heavy metals emissions (12% to air, 24% to water), etc.

Task 5 (6) Life Cycle Costs per Mlmh



for light sources sold in 2013

4% escalation rate for electricity

functional unit: Mlmh = million lumen-hour output

Most uneconomic in 2013: incandescent (GLS) and halogen (HL), 16-23 (38) euros/Mlmh

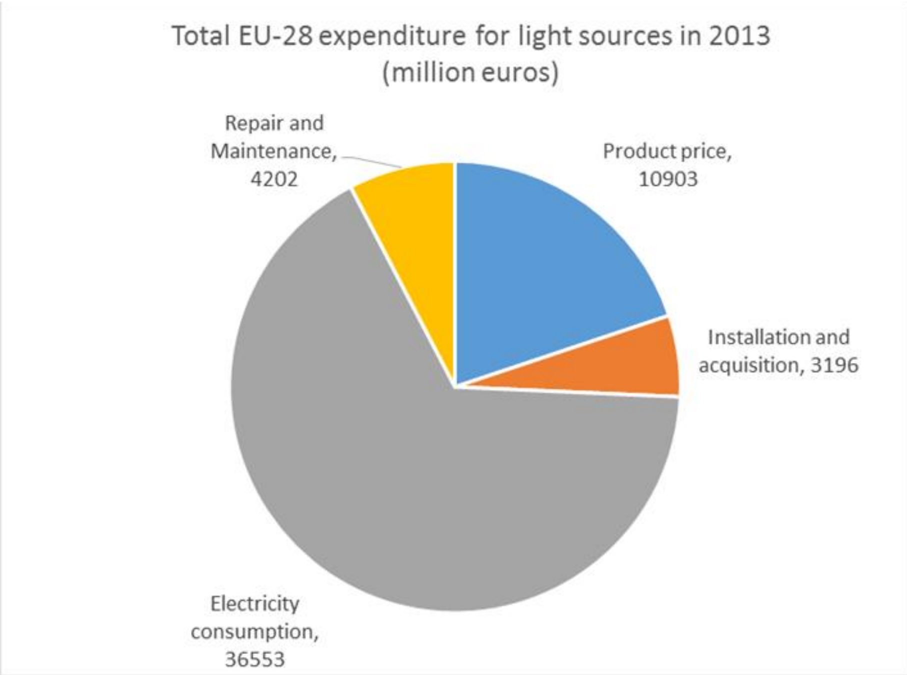
CFLs: 5.6-6.2 euros/Mlmh
LEDs: 3.4 euros/Mlmh

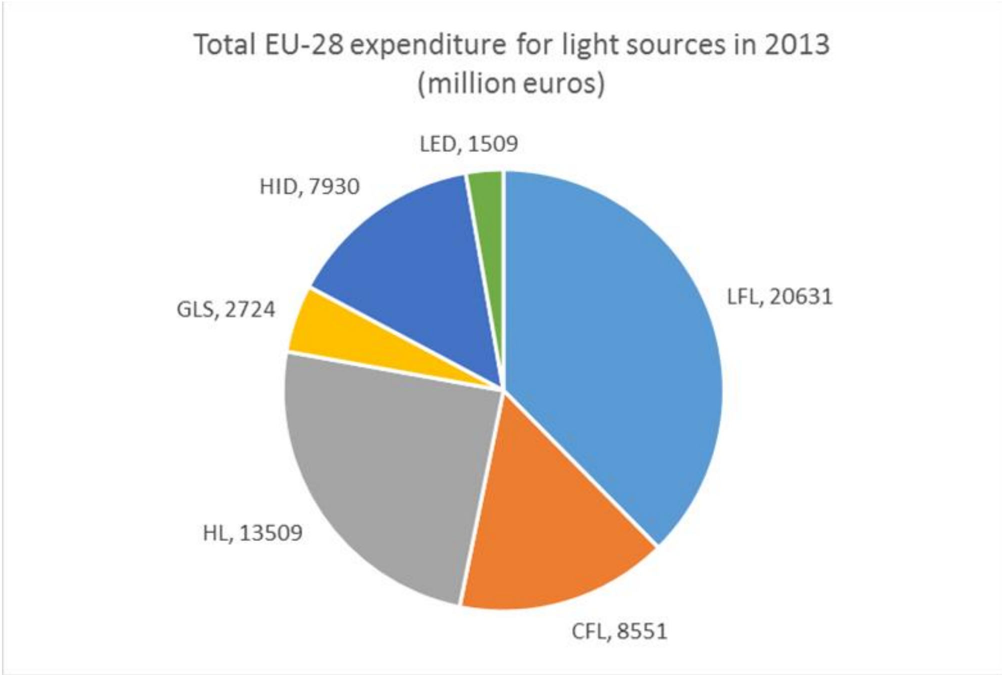
Most economic in 2013: linear fluorescent (LFL) and high intensity discharge (HID) lamps, 1.6-3.5 euros/Mlmh

This is a 2013 snapshot. LED projections: 2015 2.8 euros/Mlmh
2020 1.5 euros/Mlmh

Task 5 (7) Consumer expenditure

The total consumer expenditure for lighting in 2013 was 54.8 billion euros, of which 67% are electricity costs. LFLs account for 38% of the total expenditure (corresponds with data presented in Task 2).





Task 5 (8) Miscellaneous remarks

- EcoReport tool: no data for process water in electricity generation → zero in use phase; all process water partitioned between other phases. This is a data problem and should not be perceived as significant in the overall environmental profile of lamps.

- EcoReport tool for final assembly, distribution and retail: impact depends on shipping volumes but there are also fixed impacts per product, independent of weight or volume. Those values are representative for domestic appliances but not for lamps. For application to lamps, all fixed per-product distribution-phase values have been divided by 25.

- EcoReport tool: for some types of materials used in lamps, no impact data are available in the EcoReport. Weight of materials without associated impacts is around 1.5% of total weight.

- Critical Raw Materials (CRM): indicator for LEDs strongly influenced by presence of Germanium. Additional information from stakeholders welcome: how much Ge is actually used ? Trends ?

- The quantity of Rare Earth Elements (REE) contained in the phosphors of discharge lamps is much higher than the REE contained in LED lamps.

Questions ?

Ecodesign Preparatory Study

Lot 8/9/19 Light Sources

2nd Stakeholder Meeting

17 June 2015

DESIGN OPTIONS

(Task 6 report)

Van Holsteijn en Kemna

Vlaamse Instelling voor Technologisch Onderzoek

Task 6 (1) Introduction

- Task 6: environmental and economic impacts of design options for base case type light sources

- Design options = replacement/improvement options of Task 4 report, chapter 5
  - LED 2015 option: best currently available LED substitute (LED BAT). Lamp with highest efficacy, or most favourable combination of efficacy and price (data gathered in Task 4).
  - LED 2020 option: LED substitute that is expected to exist in 2020 according to Task 4 timeline, i.e. efficacy 175 lm/W and price 7.5 euros/klm excl. VAT (BNAT option).
  - Classic technology BAT option(s): used in particular for LFL and HID-lamps.
  - Reference: Base Case, representing average EU-28 characteristics (2013) for the type of lamp.

- Environmental impacts: only electricity consumption during use-phase presented. This is by far the most important environmental impact (Task 5). Other impacts, e.g. CO_2 emission or acidification, are proportional to this consumption in good approximation.

- Design options have different lifetimes → life cycle data difficult to compare → results have been normalized per Mega-lumen-hour (as done in Task 5): LCC/Mlmh and kWh/Mlmh .

Task 6 (2) Introduction

- Assessments based on EcoReports of Task 5, but EcoReports for design options adapted:
  - Option has same usage hours per year and same luminous flux as substituted base case lamp
    - exception: 10% rebound effect applied for CFLi and LED that substitute GLS and HL
    - exception: higher luminous flux for HPS-lamps compared to HPM and MH
  - Option has same (weighted) electricity rate as substituted base case lamp
  - Option has same (weighted) VAT % as substituted base case lamp
  - Option has same repair and maintenance cost as substituted base case lamp
  - In some cases installation costs increased to account for re-wiring and gear replacement
  - In some cases purchase price increased to account for control gear costs
  - Bill-of-Materials and CRM-use for LEDs scaled from 1000 lm to target flux
  - Energy of external control gears not included in EcoReports; added separately afterwards.
  - Luminaire costs are not included.
- Results are valid only for examined operating conditions and under the assumptions made. Not valid for every installed lamp in every situation, but indicative for average EU-28 situation.

Task 6 (3a) Results survey

Base case (BC) (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 (1.68)	LED 2015 (10.1)	may never pay back	4
LFL T5 (2275 lm, 2099 h/a)	High-efficiency T5 (1.66)	LED 2015 (10.1)	may never pay back	4
LFL T8 halo-phosphor (2400 lm, 1398 h/a)	T8 tri-phosphor (2.42)	LED 2015 (10.1)	may never pay back	3
LFL T12 (2450 lm, 1623 h/a)	T8 tri-phosphor (2.32)	LED 2015 (10.1)	may never pay back	2.5
CFLni (633 lm, 1197 h/a)	LED 2015 (5.48)	LED 2015 (11.7)	no pay back in CFLni lifetime	3.5
HPM (12000 lm, 4000 h/a) (higher lm for HPS)	HPS BAT (1.55)	HPS BAT (10.0)	5	1
HPS & MH (13200 lm, 4000 h/a) (same lm for all)	HPS BAT, MH BAT (1.73)	HPS BAT (10.6)	may never pay back	2.5
MV NDLS (GLS-X, HL-E, CFLi) (500 lm, 450 h/a)	LED 2015 (3.76)	LED 2015 (9.2)	3.5-4 (GLS, HL) >12 (CFLi)	1
MV DLS (GLS-R, HL-X) (450 lm, 450 h/a)	LED 2015 (3.85)	LED 2015 (10.0)	2	0
HL-LV-R (MR16) (490 lm, 450 h/a)	LED 2015 (4.17)	LED 2015 (12.2)	4.5	< 1
HL-LV-Capsules (490 lm, 450 h/a)	LED 2015 (3.18)	LED 2015 (10.6)	3	2
HL-MV-Capsules (420 lm, 450 h/a)	LED 2015 (3.32)	LED 2015 (10.4)	1	< 1
HL-MV-Linear (R7s) (3000 lm, 450 h/a)	LED 2015 (2.35)	LED 2015 (11.1)	1	< 1

LED 2020 always has lowest LCC/Mlmh and kWh/Mlmh (BNAT) (not in table).

For CFL, GLS, HL substitution: LED 2015 option has lowest LCC/Mlmh and kWh/Mlmh (BAT).

For LFL substitution: LED 2015 option has lowest kWh/Mlmh, but lowest LCC/Mlmh are for BAT LFL (high-efficiency or long life versions).

For HID substitution: lowest LCC/Mlmh and kWh/Mlmh obtained for BAT HPS (or BAT MH).

Investment in LED 2015 may not pay back for substitution of LFL, CFLni, HPS, MH. LED still expensive and modest efficacy advantage: evaluate carefully case-by-case.

LED 2020 payback time: 2.5-4 years for LFL, CFLni, HPS, MH. 0-2 years for CFLi, GLS, HL.

Scarce LED availability: LFL T5, CFLni, HID

Task 6 (3b) Results survey

Base case (BC) (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 (1.68)	LED 2015 (10.1)	may never pay back	4
LFL T5 (2275 lm, 2099 h/a)	High-efficiency T5 (1.66)	LED 2015 (10.1)	may never pay back	4
LFL T8 halo-phosphor (2400 lm, 1398 h/a)	T8 tri-phosphor (2.42)	LED 2015 (10.1)	may never pay back	3
LFL T12 (2450 lm, 1623 h/a)	T8 tri-phosphor (2.32)	LED 2015 (10.1)	may never pay back	2.5
CFLni (633 lm, 1197 h/a)	LED 2015 (5.48)	LED 2015 (11.7)	no pay back in CFLni lifetime	3.5
HPM (12000 lm, 4000 h/a) (higher lm for HPS)	HPS BAT (1.55)	HPS BAT (10.0)	5	1
HPS & MH (13200 lm, 4000 h/a) (same lm for all)	HPS BAT, MH BAT (1.73)	HPS BAT (10.6)	may never pay back	2.5
MV NDLS (GLS-X, HL-E, CFLi) (500 lm, 450 h/a)	LED 2015 (3.76)	LED 2015 (9.2)	3.5-4 (GLS, HL) >12 (CFLi)	1
MV DLS (GLS-R, HL-X) (450 lm, 450 h/a)	LED 2015 (3.85)	LED 2015 (10.0)	2	0
HL-LV-R (MR16) (490 lm, 450 h/a)	LED 2015 (4.17)	LED 2015 (12.2)	4.5	< 1
HL-LV-Capsules (490 lm, 450 h/a)	LED 2015 (3.18)	LED 2015 (10.6)	3	2
HL-MV-Capsules (420 lm, 450 h/a)	LED 2015 (3.32)	LED 2015 (10.4)	1	< 1
HL-MV-Linear (R7s) (3000 lm, 450 h/a)	LED 2015 (2.35)	LED 2015 (11.1)	1	< 1

LED 2020 always has lowest LCC/Mlmh and kWh/Mlmh (BNAT) (not in table).

For CFL, GLS, HL substitution: LED 2015 option has lowest LCC/Mlmh and kWh/Mlmh (BAT).

For LFL substitution: LED 2015 option has lowest kWh/Mlmh, but lowest LCC/Mlmh are for BAT LFL (high-efficiency or long life versions).

For HID substitution: lowest LCC/Mlmh and kWh/Mlmh obtained for BAT HPS (or BAT MH).

Investment in LED 2015 may not pay back for substitution of LFL, CFLni, HPS, MH. LED still expensive and modest efficacy advantage: evaluate carefully case-by-case.

LED 2020 payback time: 2.5-4 years for LFL, CFLni, HPS, MH. 0-2 years for CFLi, GLS, HL.

Scarce LED availability: LFL T5, CFLni, HID

Task 6 (3c) Results survey

Base case (BC) (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 (1.68)	LED 2015 (10.1)	may never pay back	4
LFL T5 (2275 lm, 2099 h/a)	High-efficiency T5 (1.66)	LED 2015 (10.1)	may never pay back	4
LFL T8 halo-phosphor (2400 lm, 1398 h/a)	T8 tri-phosphor (2.42)	LED 2015 (10.1)	may never pay back	3
LFL T12 (2450 lm, 1623 h/a)	T8 tri-phosphor (2.32)	LED 2015 (10.1)	may never pay back	2.5
CFLni (633 lm, 1197 h/a)	LED 2015 (5.48)	LED 2015 (11.7)	no pay back in CFLni lifetime	3.5
HPM (12000 lm, 4000 h/a) (higher lm for HPS)	HPS BAT (1.55)	HPS BAT (10.0)	5	1
HPS & MH (13200 lm, 4000 h/a) (same lm for all)	HPS BAT, MH BAT (1.73)	HPS BAT (10.6)	may never pay back	2.5
MV NDLS (GLS-X, HL-E, CFLi) (500 lm, 450 h/a)	LED 2015 (3.76)	LED 2015 (9.2)	3.5-4 (GLS, HL) >12 (CFLi)	1
MV DLS (GLS-R, HL-X) (450 lm, 450 h/a)	LED 2015 (3.85)	LED 2015 (10.0)	2	0
HL-LV-R (MR16) (490 lm, 450 h/a)	LED 2015 (4.17)	LED 2015 (12.2)	4.5	< 1
HL-LV-Capsules (490 lm, 450 h/a)	LED 2015 (3.18)	LED 2015 (10.6)	3	2
HL-MV-Capsules (420 lm, 450 h/a)	LED 2015 (3.32)	LED 2015 (10.4)	1	< 1
HL-MV-Linear (R7s) (3000 lm, 450 h/a)	LED 2015 (2.35)	LED 2015 (11.1)	1	< 1

LED 2020 always has lowest LCC/Mlmh and kWh/Mlmh (BNAT) (not in table).

For CFL, GLS, HL substitution: LED 2015 option has lowest LCC/Mlmh and kWh/Mlmh (BAT).

For LFL substitution: LED 2015 option has lowest kWh/Mlmh, but lowest LCC/Mlmh are for BAT LFL (high-efficiency or long life versions).

For HID substitution: lowest LCC/Mlmh and kWh/Mlmh obtained for BAT HPS (or BAT MH).

Investment in LED 2015 may not pay back for substitution of LFL, CFLni, HPS, MH. LED still expensive and modest efficacy advantage: evaluate carefully case-by-case.

LED 2020 payback time: 2.5-4 years for LFL, CFLni, HPS, MH. 0-2 years for CFLi, GLS, HL.

Scarce LED availability: LFL T5, CFLni, HID

Task 6 (3d) Results survey

Base case (BC) (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 (1.68)	LED 2015 (10.1)	may never pay back	4
LFL T5 (2275 lm, 2099 h/a)	High-efficiency T5 (1.66)	LED 2015 (10.1)	may never pay back	4
LFL T8 halo-phosphor (2400 lm, 1398 h/a)	T8 tri-phosphor (2.42)	LED 2015 (10.1)	may never pay back	3
LFL T12 (2450 lm, 1623 h/a)	T8 tri-phosphor (2.32)	LED 2015 (10.1)	may never pay back	2.5
CFLni (633 lm, 1197 h/a)	LED 2015 (5.48)	LED 2015 (11.7)	no pay back in CFLni lifetime	3.5
HPM (12000 lm, 4000 h/a) (higher lm for HPS)	HPS BAT (1.55)	HPS BAT (10.0)	5	1
HPS & MH (13200 lm, 4000 h/a) (same lm for all)	HPS BAT, MH BAT (1.73)	HPS BAT (10.6)	may never pay back	2.5
MV NDLS (GLS-X, HL-E, CFLi) (500 lm, 450 h/a)	LED 2015 (3.76)	LED 2015 (9.2)	3.5-4 (GLS, HL) >12 (CFLi)	1
MV DLS (GLS-R, HL-X) (450 lm, 450 h/a)	LED 2015 (3.85)	LED 2015 (10.0)	2	0
HL-LV-R (MR16) (490 lm, 450 h/a)	LED 2015 (4.17)	LED 2015 (12.2)	4.5	< 1
HL-LV-Capsules (490 lm, 450 h/a)	LED 2015 (3.18)	LED 2015 (10.6)	3	2
HL-MV-Capsules (420 lm, 450 h/a)	LED 2015 (3.32)	LED 2015 (10.4)	1	< 1
HL-MV-Linear (R7s) (3000 lm, 450 h/a)	LED 2015 (2.35)	LED 2015 (11.1)	1	< 1

LED 2020 always has lowest LCC/Mlmh and kWh/Mlmh (BNAT) (not in table).

For CFL, GLS, HL substitution: LED 2015 option has lowest LCC/Mlmh and kWh/Mlmh (BAT).

For LFL substitution: LED 2015 option has lowest kWh/Mlmh, but lowest LCC/Mlmh are for BAT LFL (high-efficiency or long life versions).

For HID substitution: lowest LCC/Mlmh and kWh/Mlmh obtained for BAT HPS (or BAT MH).

Investment in LED 2015 may not pay back for substitution of LFL, CFLni, HPS, MH. LED still expensive and modest efficacy advantage: evaluate carefully case-by-case.

LED 2020 payback time: 2.5-4 years for LFL, CFLni, HPS, MH. 0-2 years for CFLi, GLS, HL.

Scarce LED availability: LFL T5, CFLni, HID

Task 6 (3e) Results survey

Base case (BC) (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 (1.68)	LED 2015 (10.1)	may never pay back	4
LFL T5 (2275 lm, 2099 h/a)	High-efficiency T5 (1.66)	LED 2015 (10.1)	may never pay back	4
LFL T8 halo-phosphor (2400 lm, 1398 h/a)	T8 tri-phosphor (2.42)	LED 2015 (10.1)	may never pay back	3
LFL T12 (2450 lm, 1623 h/a)	T8 tri-phosphor (2.32)	LED 2015 (10.1)	may never pay back	2.5
CFLni (633 lm, 1197 h/a)	LED 2015 (5.48)	LED 2015 (11.7)	no pay back in CFLni lifetime	3.5
HPM (12000 lm, 4000 h/a) (higher lm for HPS)	HPS BAT (1.55)	HPS BAT (10.0)	5	1
HPS & MH (13200 lm, 4000 h/a) (same lm for all)	HPS BAT, MH BAT (1.73)	HPS BAT (10.6)	may never pay back	2.5
MV NDLS (GLS-X, HL-E, CFLi) (500 lm, 450 h/a)	LED 2015 (3.76)	LED 2015 (9.2)	3.5-4 (GLS, HL) >12 (CFLi)	1
MV DLS (GLS-R, HL-X) (450 lm, 450 h/a)	LED 2015 (3.85)	LED 2015 (10.0)	2	0
HL-LV-R (MR16) (490 lm, 450 h/a)	LED 2015 (4.17)	LED 2015 (12.2)	4.5	< 1
HL-LV-Capsules (490 lm, 450 h/a)	LED 2015 (3.18)	LED 2015 (10.6)	3	2
HL-MV-Capsules (420 lm, 450 h/a)	LED 2015 (3.32)	LED 2015 (10.4)	1	< 1
HL-MV-Linear (R7s) (3000 lm, 450 h/a)	LED 2015 (2.35)	LED 2015 (11.1)	1	< 1

LED 2020 always has lowest LCC/Mlmh and kWh/Mlmh (BNAT) (not in table).

For CFL, GLS, HL substitution: LED 2015 option has lowest LCC/Mlmh and kWh/Mlmh (BAT).

For LFL substitution: LED 2015 option has lowest kWh/Mlmh, but lowest LCC/Mlmh are for BAT LFL (high-efficiency or long life versions).

For HID substitution: lowest LCC/Mlmh and kWh/Mlmh obtained for BAT HPS (or BAT MH).

Investment in LED 2015 may not pay back for substitution of LFL, CFLni, HPS, MH. LED still expensive and modest efficacy advantage: evaluate carefully case-by-case.

LED 2020 payback time: 2.5-4 years for LFL, CFLni, HPS, MH. 0-2 years for CFLi, GLS, HL.

Scarce LED availability: LFL T5, CFLni, HID

Task 6 (3f) Results survey

Base case (BC) (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 (1.68)	LED 2015 (10.1)	may never pay back	4
LFL T5 (2275 lm, 2099 h/a)	High-efficiency T5 (1.66)	LED 2015 (10.1)	may never pay back	4
LFL T8 halo-phosphor (2400 lm, 1398 h/a)	T8 tri-phosphor (2.42)	LED 2015 (10.1)	may never pay back	3
LFL T12 (2450 lm, 1623 h/a)	T8 tri-phosphor (2.32)	LED 2015 (10.1)	may never pay back	2.5
CFLni (633 lm, 1197 h/a)	LED 2015 (5.48)	LED 2015 (11.7)	no pay back in CFLni lifetime	3.5
HPM (12000 lm, 4000 h/a) (higher lm for HPS)	HPS BAT (1.55)	HPS BAT (10.0)	5	1
HPS & MH (13200 lm, 4000 h/a) (same lm for all)	HPS BAT, MH BAT (1.73)	HPS BAT (10.6)	may never pay back	2.5
MV NDLS (GLS-X, HL-E, CFLi) (500 lm, 450 h/a)	LED 2015 (3.76)	LED 2015 (9.2)	3.5-4 (GLS, HL) >12 (CFLi)	1
MV DLS (GLS-R, HL-X) (450 lm, 450 h/a)	LED 2015 (3.85)	LED 2015 (10.0)	2	0
HL-LV-R (MR16) (490 lm, 450 h/a)	LED 2015 (4.17)	LED 2015 (12.2)	4.5	< 1
HL-LV-Capsules (490 lm, 450 h/a)	LED 2015 (3.18)	LED 2015 (10.6)	3	2
HL-MV-Capsules (420 lm, 450 h/a)	LED 2015 (3.32)	LED 2015 (10.4)	1	< 1
HL-MV-Linear (R7s) (3000 lm, 450 h/a)	LED 2015 (2.35)	LED 2015 (11.1)	1	< 1

LED 2020 always has lowest LCC/Mlmh and kWh/Mlmh (BNAT) (not in table).

For CFL, GLS, HL substitution: LED 2015 option has lowest LCC/Mlmh and kWh/Mlmh (BAT).

For LFL substitution: LED 2015 option has lowest kWh/Mlmh, but lowest LCC/Mlmh are for BAT LFL (high-efficiency or long life versions).

For HID substitution: lowest LCC/Mlmh and kWh/Mlmh obtained for BAT HPS (or BAT MH).

Investment in LED 2015 may not pay back for substitution of LFL, CFLni, HPS, MH. LED still expensive and modest efficacy advantage: evaluate carefully case-by-case.

LED 2020 payback time: 2.5-4 years for LFL, CFLni, HPS, MH. 0-2 years for CFLi, GLS, HL.

Scarce LED availability: LFL T5, CFLni, HID

Task 6 (3g) Results survey

Base case (BC) (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 (1.68)	LED 2015 (10.1)	may never pay back	4
LFL T5 (2275 lm, 2099 h/a)	High-efficiency T5 (1.66)	LED 2015 (10.1)	may never pay back	4
LFL T8 halo-phosphor (2400 lm, 1398 h/a)	T8 tri-phosphor (2.42)	LED 2015 (10.1)	may never pay back	3
LFL T12 (2450 lm, 1623 h/a)	T8 tri-phosphor (2.32)	LED 2015 (10.1)	may never pay back	2.5
CFLni (633 lm, 1197 h/a)	LED 2015 (5.48)	LED 2015 (11.7)	no pay back in CFLni lifetime	3.5
HPM (12000 lm, 4000 h/a) (higher lm for HPS)	HPS BAT (1.55)	HPS BAT (10.0)	5	1
HPS & MH (13200 lm, 4000 h/a) (same lm for all)	HPS BAT, MH BAT (1.73)	HPS BAT (10.6)	may never pay back	2.5
MV NDLS (GLS-X, HL-E, CFLi) (500 lm, 450 h/a)	LED 2015 (3.76)	LED 2015 (9.2)	3.5-4 (GLS, HL) >12 (CFLi)	1
MV DLS (GLS-R, HL-X) (450 lm, 450 h/a)	LED 2015 (3.85)	LED 2015 (10.0)	2	0
HL-LV-R (MR16) (490 lm, 450 h/a)	LED 2015 (4.17)	LED 2015 (12.2)	4.5	< 1
HL-LV-Capsules (490 lm, 450 h/a)	LED 2015 (3.18)	LED 2015 (10.6)	3	2
HL-MV-Capsules (420 lm, 450 h/a)	LED 2015 (3.32)	LED 2015 (10.4)	1	< 1
HL-MV-Linear (R7s) (3000 lm, 450 h/a)	LED 2015 (2.35)	LED 2015 (11.1)	1	< 1

LED 2020 always has lowest LCC/Mlmh and kWh/Mlmh (BNAT) (not in table).

For CFL, GLS, HL substitution: LED 2015 option has lowest LCC/Mlmh and kWh/Mlmh (BAT).

For LFL substitution: LED 2015 option has lowest kWh/Mlmh, but lowest LCC/Mlmh are for BAT LFL (high-efficiency or long life versions).

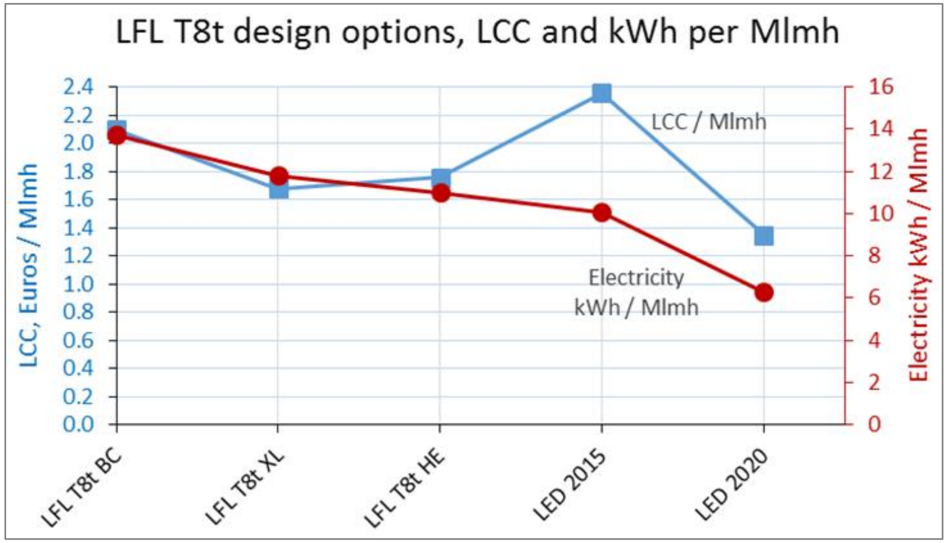
For HID substitution: lowest LCC/Mlmh and kWh/Mlmh obtained for BAT HPS (or BAT MH).

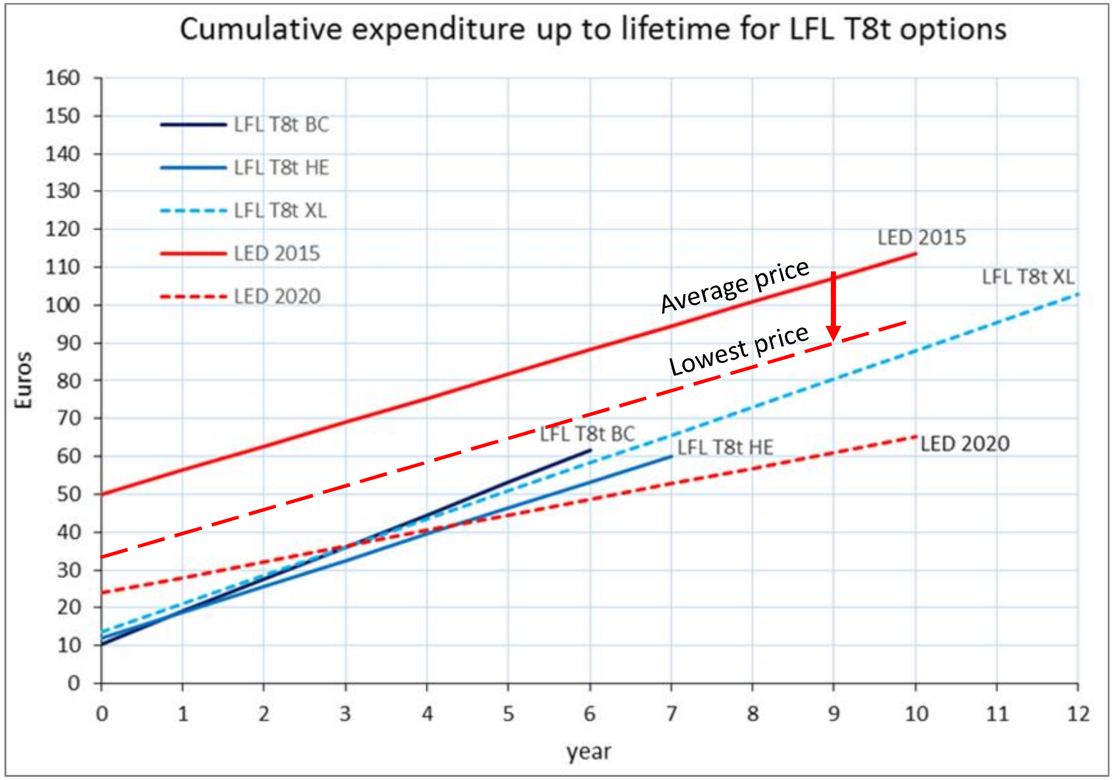
Investment in LED 2015 may not pay back for substitution of LFL, CFLni, HPS, MH. LED still expensive and modest efficacy advantage: evaluate carefully case-by-case.

LED 2020 payback time: 2.5-4 years for LFL, CFLni, HPS, MH. 0-2 years for CFLi, GLS, HL.

Scarce LED retrofit availability:
LFL T5, CFLni, HID

Task 6 (4) LFL T8 tri-phosphor

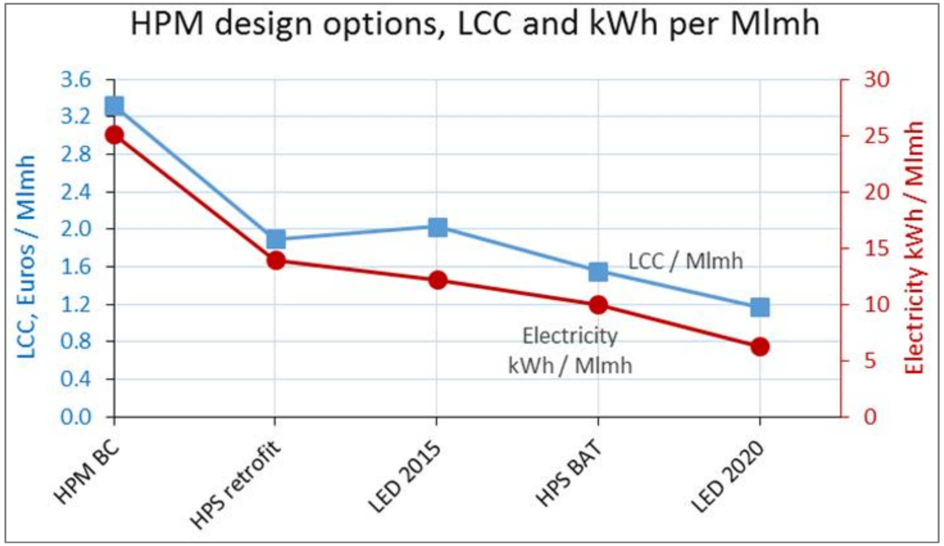


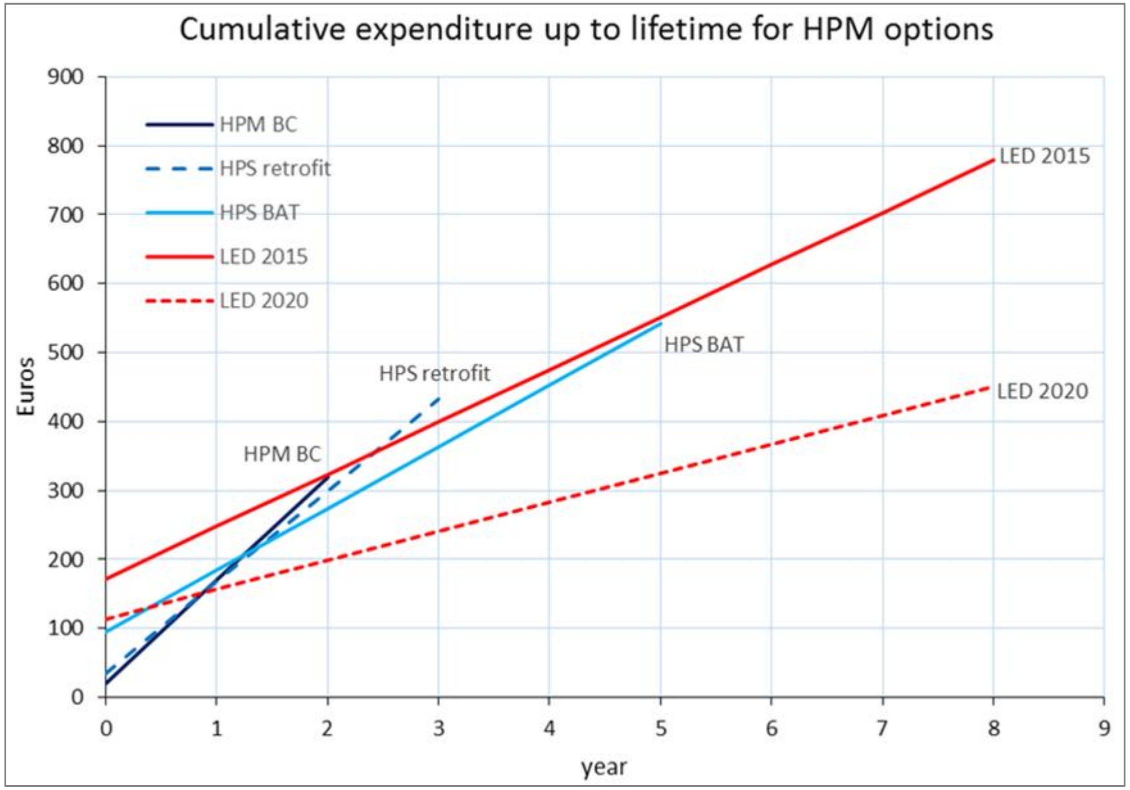


2400 lm ; 2017 h/a (all options)

LFL T8t BC:	4.8 euros,	80 lm/W,	13000 h
LFL T8t HE:	6.1 euros,	100 lm/W,	15000 h
LFL T8t XL:	7.9 euros,	93 lm/W,	40000 h
LED 2015:	44.2 euros,	109 lm/W,	20000 h
LED 2020:	18.2 euros,	175 lm/W,	20000 h

Task 6 (5) HPM-lamp substitutes

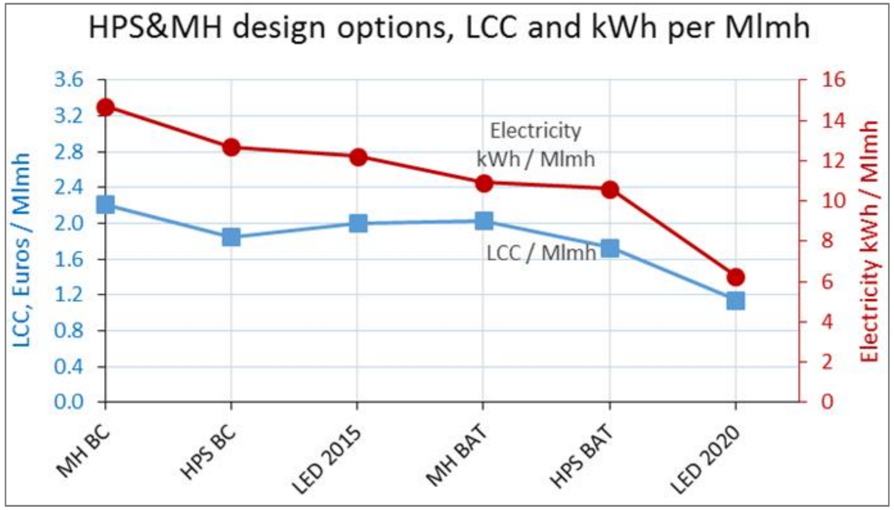


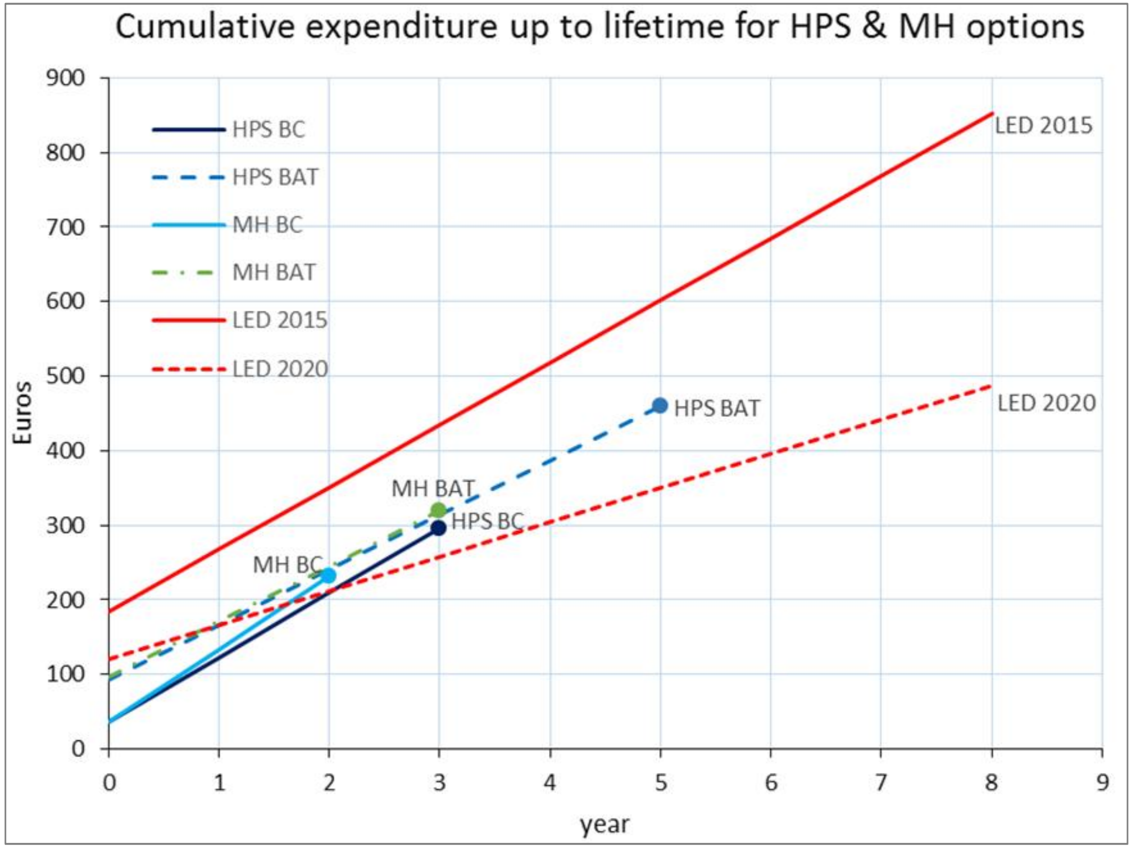


4000 h/a (all options); higher lumen for HPS !

HPM BC: 10.5 euros, 48 lm/W, 12000 lm, 8000 h
HPS retrofit: 25.6 euros, 86 lm/W, 19000 lm, 12000 h
HPS BAT: 39.2 euros, 114 lm/W, 17500 lm, 20000 h
LED 2015: 115.3 euros, 90 lm/W, 12000 lm, 32000 h
LED 2020: 57.6 euros, 175 lm/W, 12000 lm, 32000 h
(+ 47.25 euros for CG purchase and installation, last 3 options)
(+ differences in control gear efficiencies, 83%, 88%, 91%)

Task 6 (6) HPS- & MH-lamp substitutes

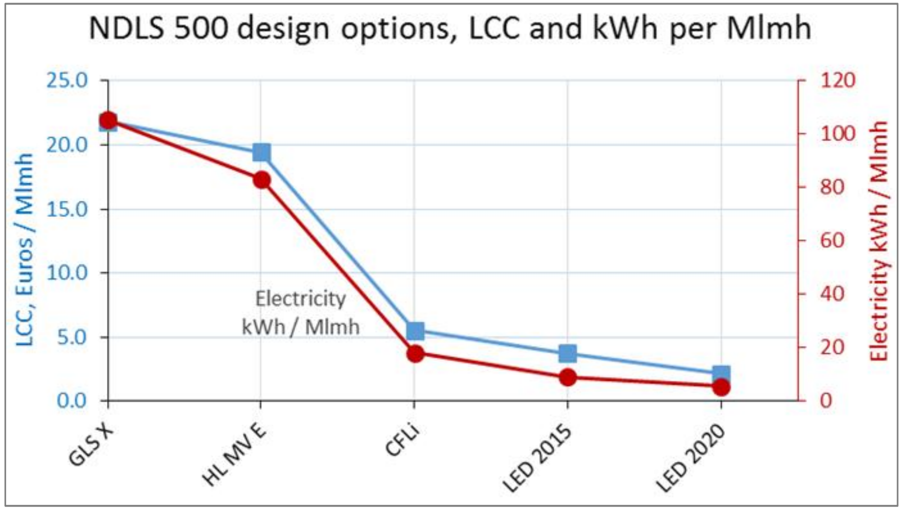


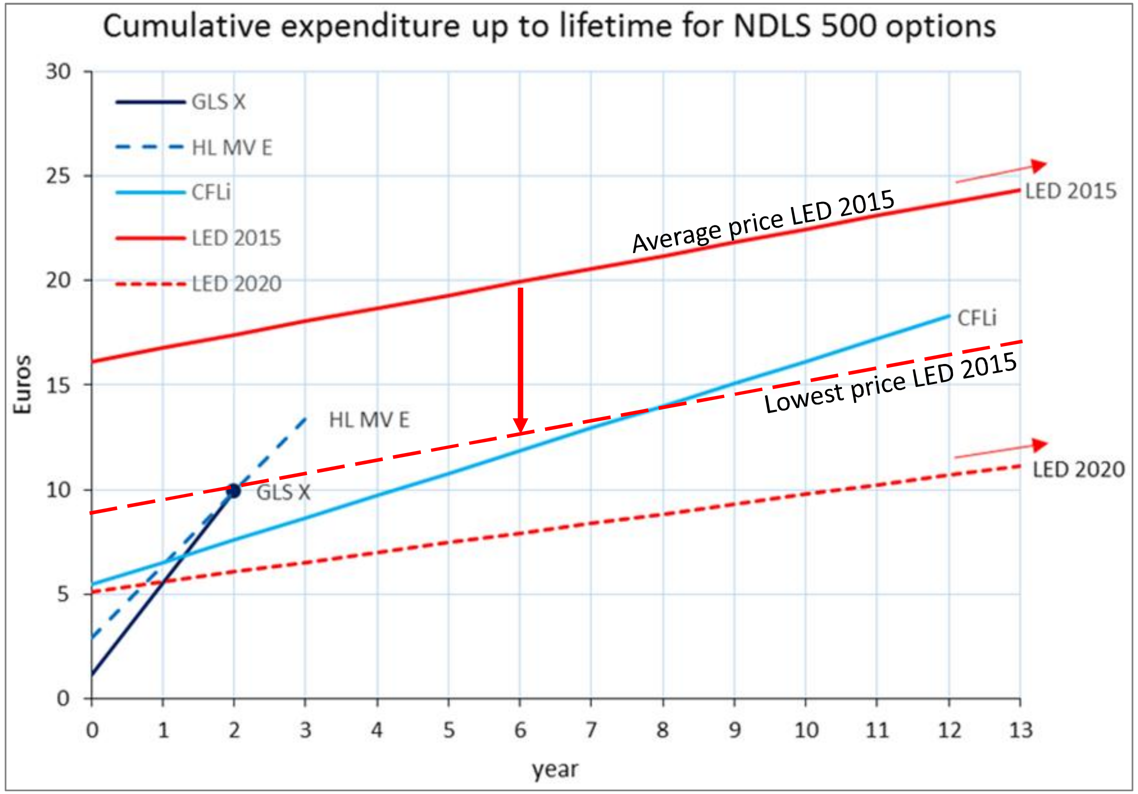


≈ 13200 lm, 4000 h/a (all options); same lumen for HPS !

HPS BC: 27.0 euros, 95 lm/W, 12000 h
HPS BAT: 37.2 euros, 107 lm/W, 20000 h
MH BC: 27.0 euros, 82 lm/W, 8000 h
MH BAT: 40.0 euros, 104 lm/W, 12000 h
LED 2015: 127.8 euros, 90 lm/W, 32000 h
LED 2020: 63.9 euros, 175 lm/W, 32000 h
(+ 47.25 euros for CG purchase and installation for BAT and LED)
(+ control gear efficiencies, 83% BC, 88% BAT, 91% LED)

Task 6 (7) NDLS 500 lm substitutes





500 lm, 450 h/a (GLS, HL); 550 lm, 500 h/a (CFL, LED)

GLS X:	0.8 euros,	9.5 lm/W,	1000 h
HL MV E:	2.5 euros,	12 lm/W,	1500 h
CFLi:	5.1 euros,	55 lm/W,	6000 h
LED 2015:	15.8 euros,	109 lm/W,	20000 h
LED 2020:	4.8 euros,	175 lm/W,	20000 h

Ecodesign Preparatory Study
Lot 8/9/19 Light Sources

2nd Stakeholder Meeting

17 June 2015

Thank you !

Any questions or remarks ?

Van Holsteijn en Kemna

Vlaamse Instelling voor Technologisch Onderzoek