Real-time, evidence-based policy making – critical for decisions on rapidly evolving technologies

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  - Ecodesign regulations on lighting
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- SE-BE-CLASP-eceee report in 2014/15
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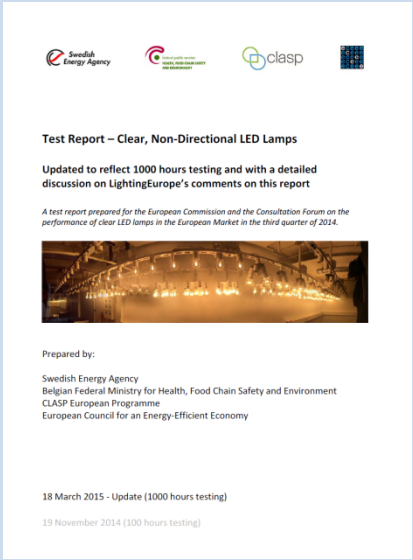
  - Purchase and *testing* of LED lamps
- The vote on stage 6: behind the scene…
- Reflections and future studies



Test Report – Clear, Non-Directional LED Lamps

Updated to reflect 1000 hours testing and with a detailed discussion on LightingEurope's comments on this report

A test report prepared for the European Commission and the Consultation Forum on the performance of clear LED lamps in the European Market in the third quarter of 2014.

Prepared by:

Swedish Energy Agency
Belgian Federal Ministry for Health, Food Chain Safety and Environment
CLASP European Programme
European Council for an Energy-Efficient Economy

18 March 2015 - Update (1000 hours testing)

19 November 2014 (100 hours testing)

The lighting regulations in EU

1. Ecodesign Regulation 244/2009 (amendment 859/2010) on non-directional lighting – *phasing out of the incadescent*
2. Ecodesign Regulation 245/2009 (amendment 347/2010) on tertiary lighting – *street and office lighting*
3. Ecodesign Regulation 1194/2012 on LED and directional lighting –*LED and directional lighting*
4. Revised and extended energy labelling 874/2012 of lamps and luminaires – *all lamps and luminaires*
5. Omnibus revision of all regulations ongoing – *possibly one single regulation, in place 2017?*

Savings: more than 100 TWh/yr from 2020 and on!


2009
Non-directional Stage 1
2010
Tertiary Stage 1
2010
Non-directional Stage 2
2011
Non-directional Stage 3
2012
Tertiary Stage 2
2012
Non-directional Stage 4
2013
Non-directional Stage 5
2013
Directional Stage 1
2014
Directional Stage 2
2015
Tertiary Stage 3
2016
Non-directional Stage 6
2017
Tertiary Stage 4
2017
Directional Stage 3
2017
Omnibus regulation
basically all applications covered
Overall timeline:

Regulation 244/2009 on non-directional lighting
+ amending regulation 859/2009

Scope: All non-directional lamps except those covered by tertiary sector lighting regulation and special lamps

In practice incandescent lamps, halogens, compact fluorescent lamps with integrated ballast, LEDs, with limits on light output (>60 lumen, <12000 lumen)

- Efficacy requirements:

2016: Stage 6

for clear lamps

Table 1

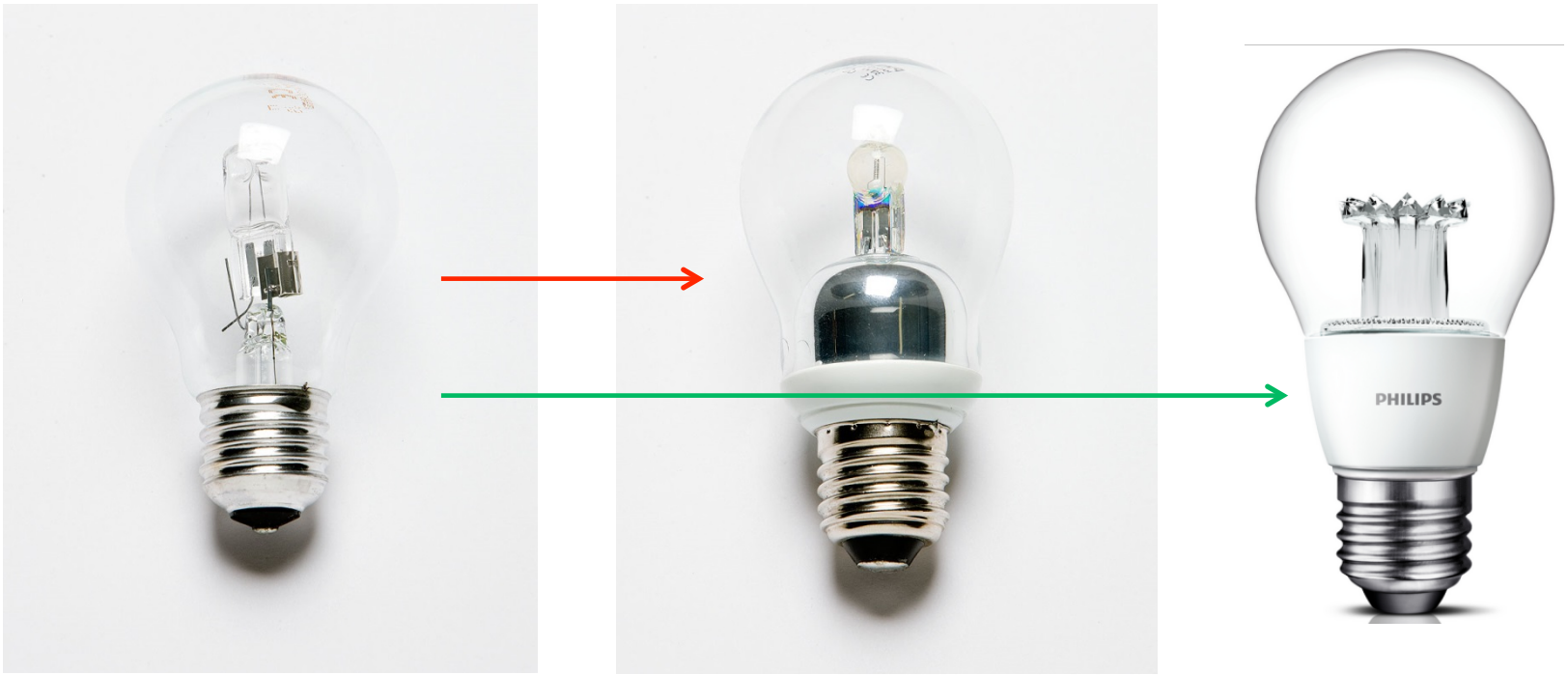
Application date	Maximum rated power (P_{max}) for a given rated luminous flux (Φ) (W)	
	Clear lamps	Non-clear lamps
Stages 1 to 5	$0,8 * (0,88\sqrt{\Phi}+0,049\Phi)$	$0,24\sqrt{\Phi}+0,0103\Phi$
Stage 6	$0,6 * (0,88\sqrt{\Phi}+0,049\Phi)$	$0,24\sqrt{\Phi}+0,0103\Phi$

Table 2

Exceptions

Scope of the exception	Maximum rated power (W)
Clear lamps $60\ lm \leq \Phi \leq 950\ lm$ in Stage 1	$P_{max} = 1,1 * (0,88\sqrt{\Phi}+0,049\Phi)$
Clear lamps $60\ lm \leq \Phi \leq 725\ lm$ in Stage 2	$P_{max} = 1,1 * (0,88\sqrt{\Phi}+0,049\Phi)$
Clear lamps $60\ lm \leq \Phi \leq 450\ lm$ in Stage 3	$P_{max} = 1,1 * (0,88\sqrt{\Phi}+0,049\Phi)$
Clear lamps with G9 or R7s cap in Stage 6	$P_{max} = 0,8 * (0,88\sqrt{\Phi}+0,049\Phi)$

Stage 6 in practice:
going from class C to class A, not B



MV Halogen with IRC: ***Class C***

Halogen with IRC and internal MV AC -> LV DC: ***Class B. But not available!***

Clear LED: ***Class A***

The stage 6 revision

1. Revision of 244/2009 and 1194/2012:
   - Close loophole on special lamps (another story)
2. In focus, the issue of stage 6 in 244/2009:
   a) Implement as planned 1 September 2016?
   b) Or delay until 1 September 2018? Or even later?
   c) No planned revision; on request by industry
3. *In short: how long do we continue with main voltage halogens until switching to clear LEDs?*

The stage 6 revision (cont)

1. COM proposal 2015: **delay** stage 6 until 1 September **2018**
   - Based on market assessments from 2012; the VHK/VITO study
2. Part of the industry, not all, preferred even further delay: 1 September 2020
3. Valid concerns that replacement lamps, i.e. LEDs, will not evolve fast enough in order to provide the same or better lighting quality for the same cost:
   - Warm colour temperatures available?
   - Sparkling appearance
   - Colour rendering
   - Dimmability
   - Life time
   - Purchase cost

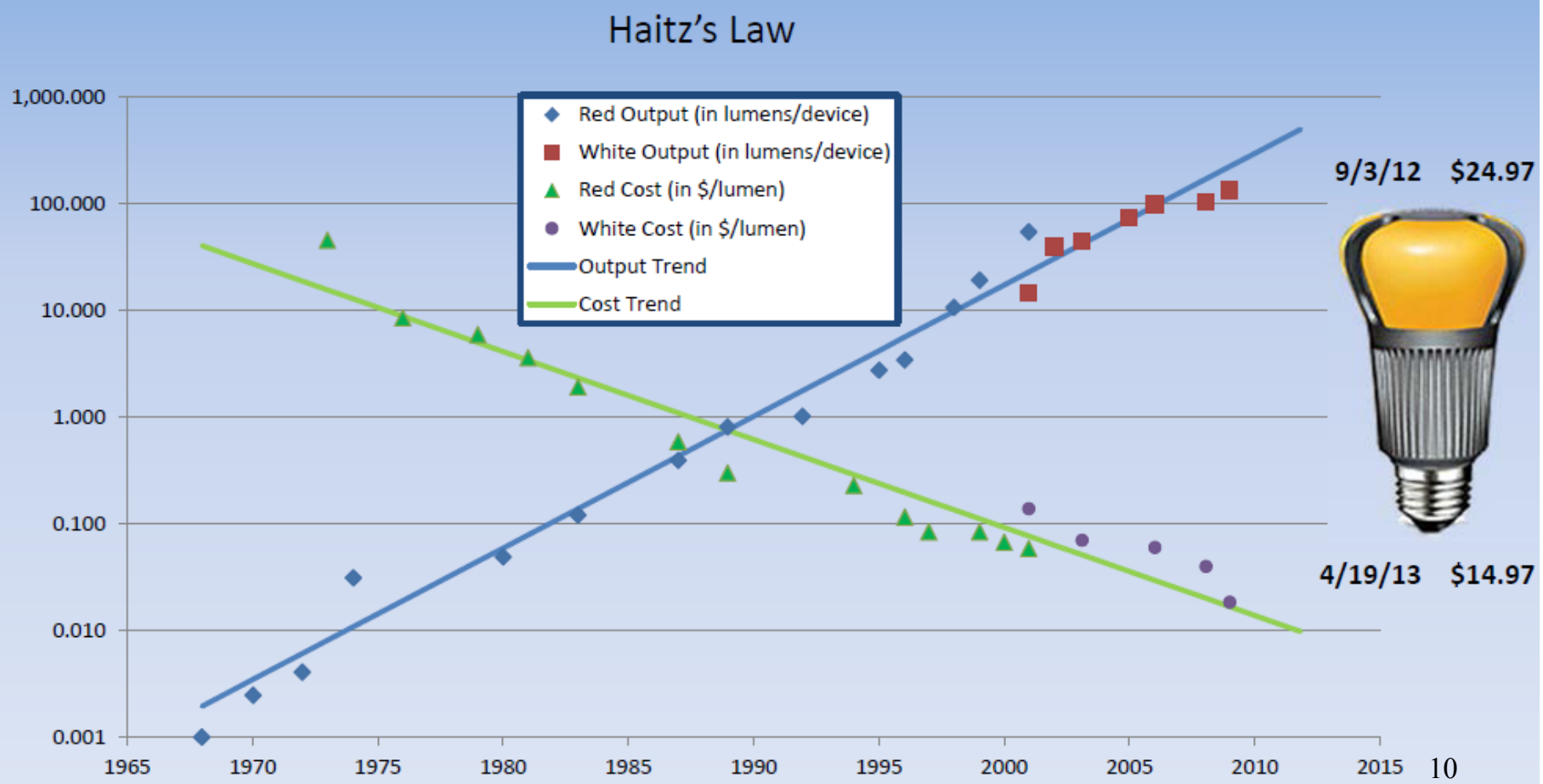
Market trends

- Some MS and NGOs: Extraordinary measures requires *extraordinary evidence*: concerns that the market assessment used is too old, because:
  - LEDs are basically *electronic devices* ->
  - *Trends follow other ”laws” than traditional light sources*
  - Many market prognoses… all show the same thing: the evolution goes *very* fast
  - We must *relate* to that when speaking about market trends the coming 2, 4, 6 years…
- *Thus, a need for an updated market assessment!*

Technology Evolution

Driven By Semi-Conductor Heritage – Rapid changes are expected

LEDs continue to follow Haitz's Law

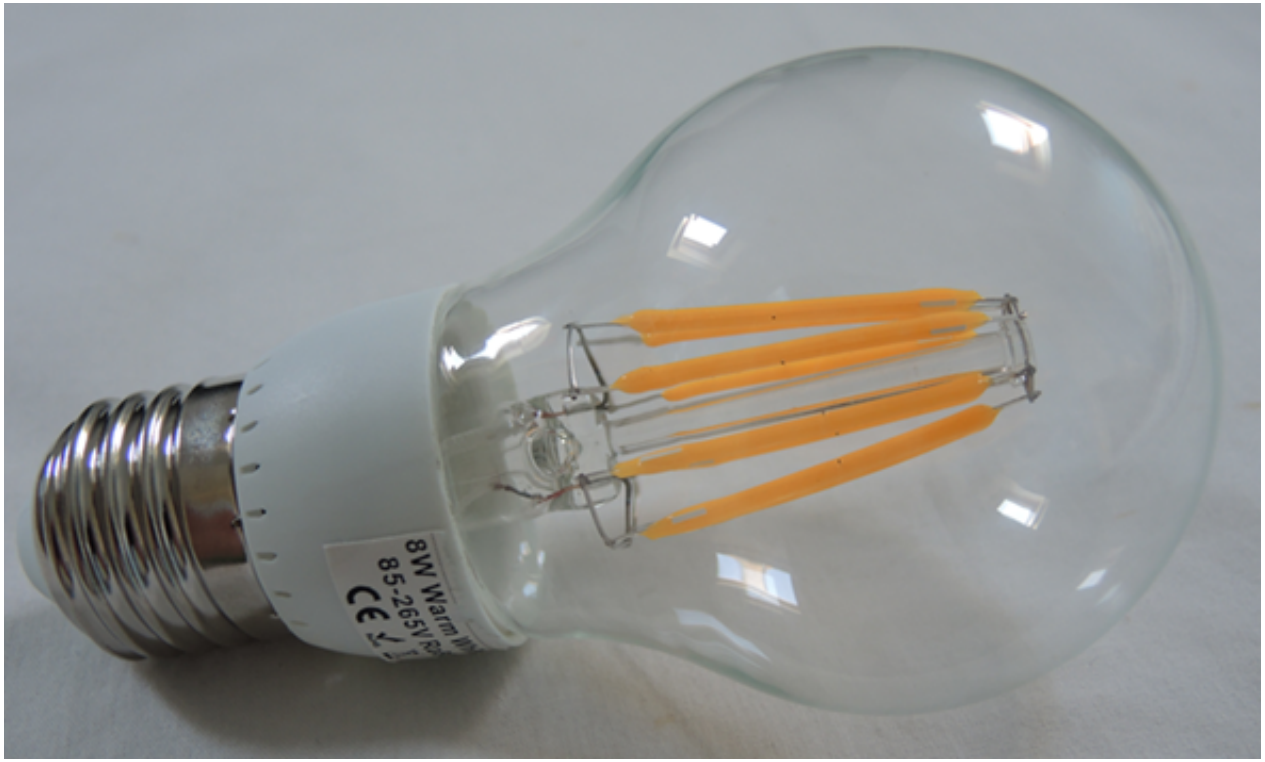


Source: Roland Haitz & Lumileds

Study by SE-BE-CLASP-eceee 2014/15: Six basic questions

1. What is the *current* cost and performance of clear LED lamps?
2. Do they give an aesthetic pleasant light?
3. Are the “dimmable” lamps compatible with leading edge and trailing edge dimmers?
4. Do these lamps meet the LED quality requirements in 1194/2012?
5. Are LED filament lamps reliable products for consumers?
6. What trends in price and performance of LED filament lamps have been observed in the last two years and what is expected in the future?

LED filament lamp



High resemblance to incandescent lamps
High efficacy, can easily be > 100 lm/W
High thermal conducting gas -> no heat sink

Methodology

1. Update the market assessments on sales and price
2. Moreover, buy and *test* LED lamps available on the European market August - September 2014
3. Limitations:
   a) Not a full market assessment, but an indicative study
   b) Testing not done as a proper market surveillance testing exercise beacuse of time constraints
4. Nevertheless, one of the most recent market assessments, in particular for the new *filament* LED lamp

Choice of lamps for testing

- 10 units of 17 LEDs models and one halogen reference lamp were purchased from on-line retailers in Belgium, France, Germany, the Netherlands, Sweden, and the United Kingdom.
- The LEDs were of three types:
  - Bare LEDs
  - Optical light guide
  - Filament LED lamp
- Dimmable or non-dimmable

Purchase price

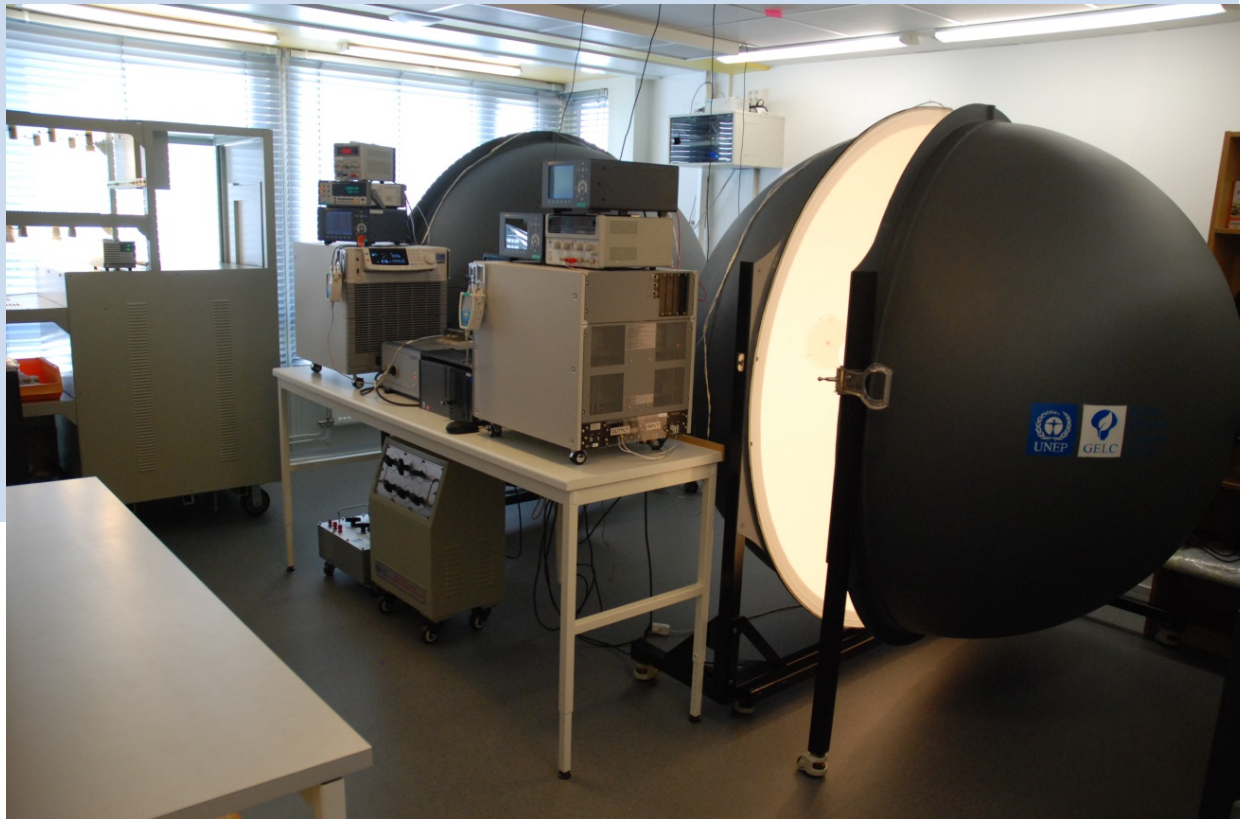
- The prices paid for all the lamps purchased, including taxes, were *normalised* to the cost in Euros per 500 lumens of light
- These normalised prices for the LED lamps ranged from €6.16 to €28.42 per 500 lumens (including VAT).
- The halogen lamps purchased had a price of €2.29 per 500 lumens.

Swedish Energy Agency lighting lab

- Main purpose: part of Sweden's MV&E program
- 2 Spheres – non-directional measurements
- 1 Near field goniophotometer – directional measurements
- Aging equipment

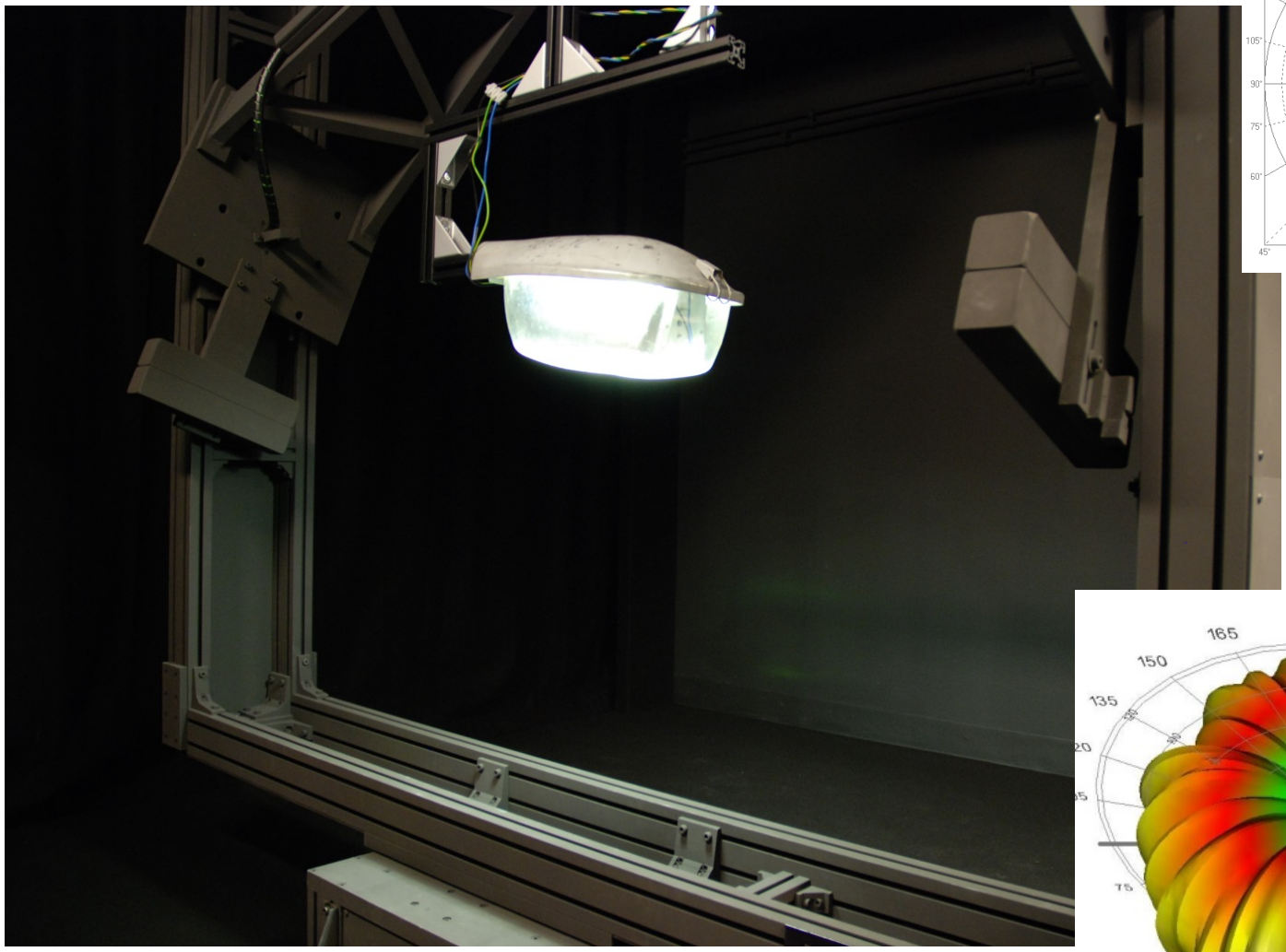
 - for life time testing

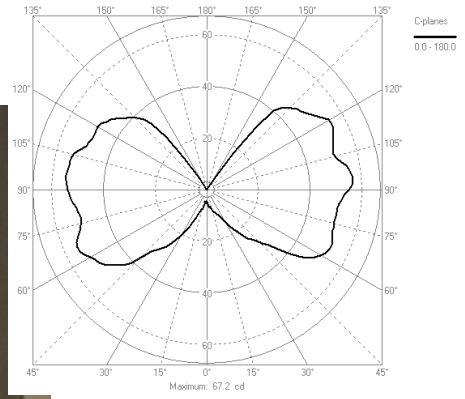
Spheres:

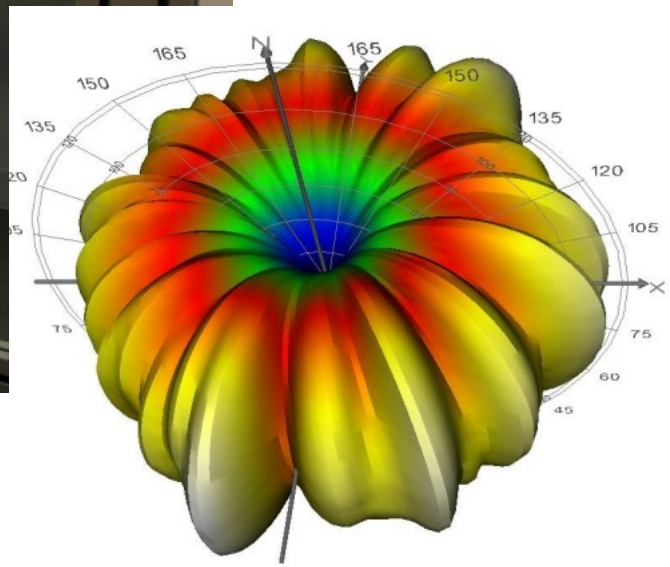


Energimyndigheten

Goniophotometer

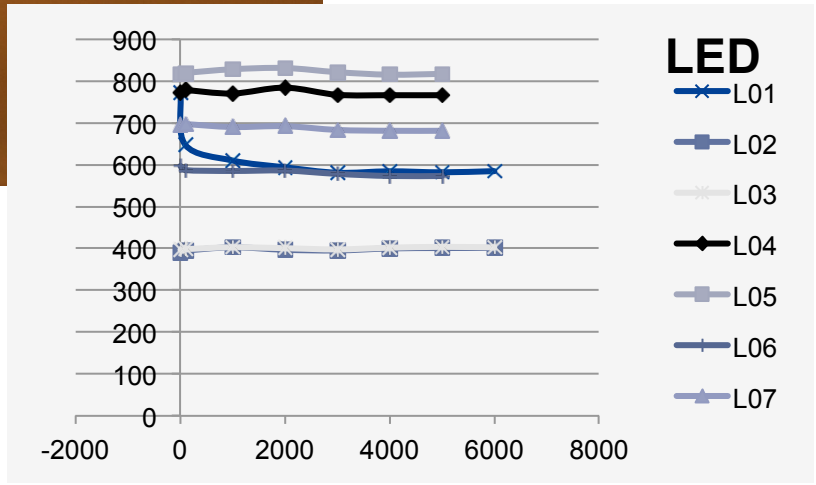






Energimyndigheten

Aging equipment - life time testing



Energimyndigheten

Measurement Parameters

- Flux (lumen)
- Power (watt)
- Efficacy (lumen/watt)
- Colour temperature (kelvin)
- Colour coordinates (x,y)
- Colour rendering (Ra, CRI)
- Power factor
- Start time (s)
- Warm up time (s)
- MacAdam ellipse
- Flicker index and percent
- Luminous intensity distribution (LID)
- Lamp surface temperature (°C)
- Size and weight
- Premature failure, 200h
- 15000 on/off 30s cycling
- Life test 1000 h
- Energy label class
- Chip count of LED filaments

Standards

Parameter	Standard
Luminous flux [lm]	CIE 84:1989
Color coordinates	CIE 15:2004
Color temperature	CIE 15:2004
Color rendering index	CIE 13.3:1995
Voltage AC and DC [V]	CIE 84:1989
Active Power [P, W]	EN 50285:1999
Frequency	SS-EN 13032-1
Harmonic distorsion (THD)	IEC 62612
Temperature	SS-EN 13032-1
Humidity	IEC 60969, IEC 62612
Air velocity	SS-EN 13032-1

Measurements

- 10 samples per product
  - 100 h aging before measurement
  - Measurements – **the data in the report in December 2014**
  - 50 % of all lamps: switching 30 s on + 30 s off
  - Additional 100 h aging to test premature failure – **also included**
  - 800 h additional aging done – in total 1000 h
  - New measurements – **the data in the updated report in April 2015**
- Sphere measurements (most parameters)
- Goniophotometer:
  - MacAdam radius
  - Light intensity distribution

VHK 2012 report: Projections 2013 -2030

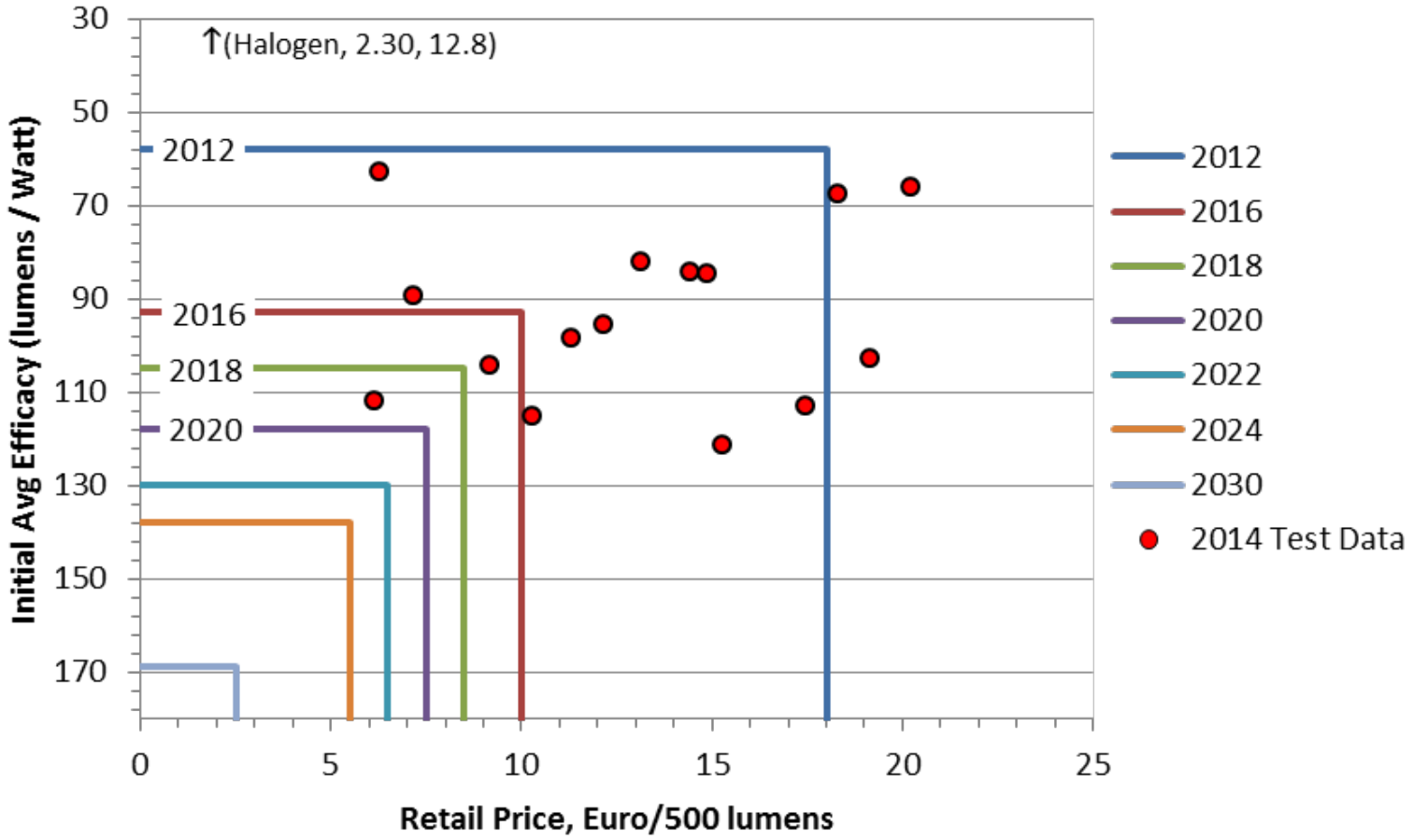
Table 2. MV LED retrofit lamp, efficacy and price projections EU 2012-2025

(sources: for efficacy CLASP 2013, based on US DoE MYPP projections; for EU lamp consumer prices incl. VAT (500 lm lamp) up to 2020 LightingEurope; 2021-2030 prices, extrapolation VHK)

Year	2012	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2030
lm/W	58	93	99	105	112	118	125	130	134	138	142	169
price in €	18.0	10.0	9.0	8.5	8.0	7.5	7.0	6.5	6.0	5.5	5.0	2.5

Projections used in the Commission proposal were based on market assessments from *2012*

Comparison old assessment and new results



Comparison old assessment and new results

- Approximately 50% of the LED lamps purchased and tested for this study already *exceed* the anticipated *2016* performance levels.
- Approximately 25% of the lamps are below the prices projected for 2016.
- One model available on the European market in 2014 already exceeds the anticipated *2018* level on *efficacy* and the *2020* level on *price*.
- The market moves *much* faster than previously expected

Q1: What is the current cost and performance of clear LED lamps?

Source of estimate	Price (Euro) per 500 lumens of light in 2014	Efficacy (lumens per watt) in 2014
VHK/VITO Report (June 2013)*	€14.00 / 500 lumen	76 lm/W
Test data average, this study	€12.52 / 500 lumen	98 lm/W
Difference, test data average in 2014 compared with VHK/VITO projected	11 percent lower	29 percent higher

The data for LED Lamps tested in this study have exceeded the expected progression of LED technology published in the VHK/VITO Report

Q2: Do they give an aesthetic pleasant light?

Subjective question of course, but:

- CCT 2700 – 2900 available, i.e. warm light
- CRI > 80 available as well; a few > 90
- Form factor for in particular filament LEDs very similar to incadescent lamps
- Anecdotic evidence for consumer satisfaction with the new LEDs as a replacement for incandescent and halogen lamps

What do consumers think? (DE)

vosLED light bulb clear 5,5W

★★★★★ (6)

- Haben bislang immer von Energiesparlampen und LED Abstand genommen. Farbtemperatur, Schaltverzögerungen und Abstrahlwinkel waren nicht akzeptabel. Die neue vosLED erfüllt alle unsere Anforderungen. Die Farbtemperatur entspricht genau der Glühlampe, die durch die neue VosLED ersetzt wurde. Hurra!!! Endlich eine Alternative.

- Dafür das die "Glühbirne nur 5,5 W hat ist die Lichtausbeute fantastisch. Es reicht eine völlig für unseren 8m Flur.

- Have so far always taken of energy saving lamps and LED distance. Color temperature, switching delays and beam angles were not acceptable. The new vosLED meets all our requirements. The color temperature corresponds exactly to the light bulb has been replaced by the new vosLED. Hurray!!! Finally an alternative.

- For having the "bulb only 5.5 W, the light yield fantastic. It goes a completely 8m for our hallway.

Translation: Google Translate

Q3: Are the “dimmable” lamps compatible with leading edge and trailing edge dimmers?

- A lot of different dimmers, but leading and trailing edge ones are two of the most common ones
- 5 lamps claimed to be dimmable
- Two of these worked with both leading and trailing; the other three only with one of them
- Will probably continue to be a problem for all LEDs and CFLs until a proper dimmer standard is agreed on

Q4: Do these lamps meet the LED quality requirements in 1194/2012?

Although not a complete test (time constraints) the preliminary result is that most of the LEDs comply with 1194/2012

- Lamp survival factor at 6000 h - tests are on-going
- Lumen maintenance at 6000 h – tests are on-going
- Number of switching cycles before failure – yes, tested for all lamps; no failures in LED, but one failure in a halogen lamp.
- Starting time – yes, all LED lamps passed
- Lamp warm-up time to 95% - yes, all LED lamps passed
- Premature failure rate at 1000 h – not complete yet; but is being tested and so far, all but one LED lamp passed the test
- Colour rendering index – yes, tested and all LED lamps met the minimum requirement with two models being within the allowable tolerance and two models in the 90's.
- Colour consistency – yes, tested and most LED lamps met the six MacAdam step requirement; two lamps exceeded this requirement.
- Lamp Power Factor – yes, tested and all lamps met the requirements with many exceeding them.

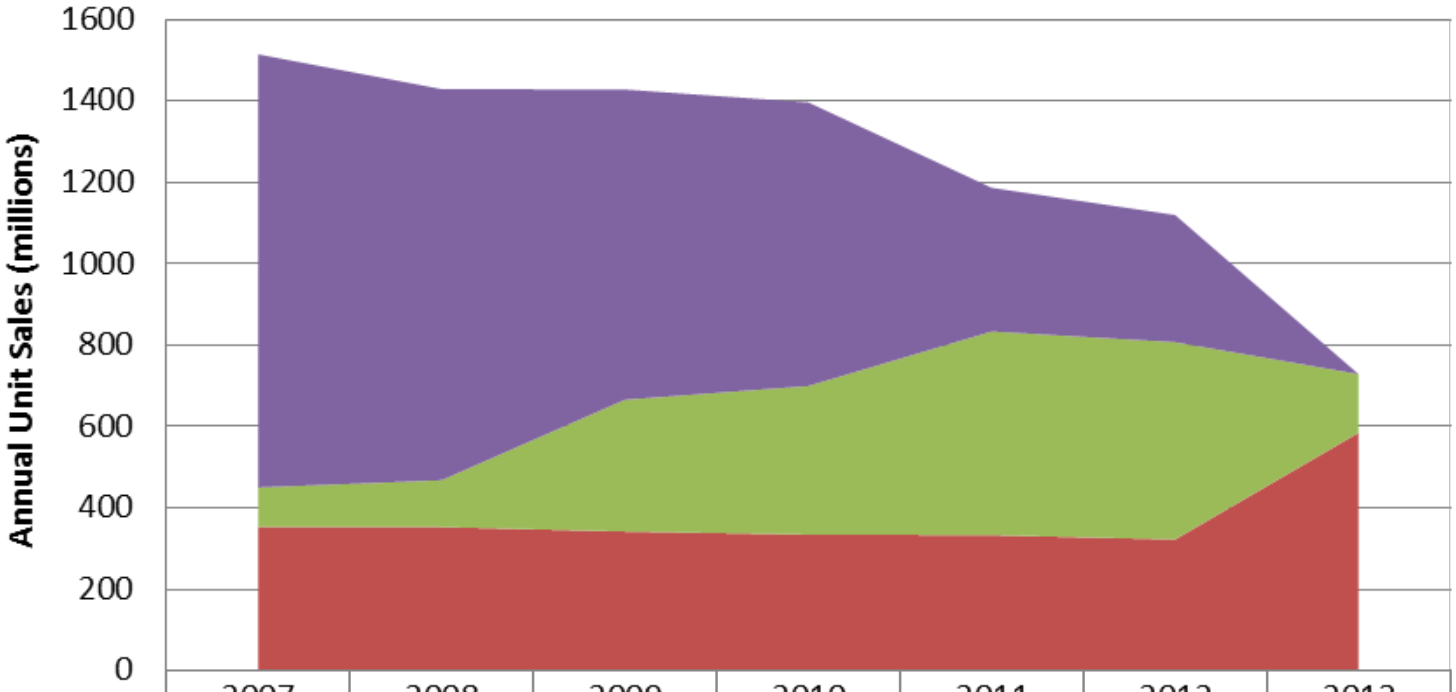
Q5: Are LED filament lamps reliable products for consumers?

- To assess reliability, the lamps were subjected to a switching-cycle test and an operational test which is on-going, but so far has completed 200 hours of testing.
- All the LED lamps finished the switching cycle test successfully (note: 5 units per model tested)
- One LED premature failed
- Ongoing, additional data after 3000 h and 6000 h

Q6: What trends in price and performance of LED filament lamps have been observed in the last two years and what is expected in the future?

- Last two years: market has moved much faster than expected
- Future… to be discussed. Expected efficacies of 200 lm/W, or more? When?
- *However, the large savings will be achieved when switching from incandescent /halogen to (CFLs and) LEDs*
  - Ex: 700 lumen per lamp:
  - Incandescent: **60 W**
  - Halogen lamp class C: **42 W**
  - LED 100 lm/W: **7 W**
  - LED 200 lm/W: **3.5 W**

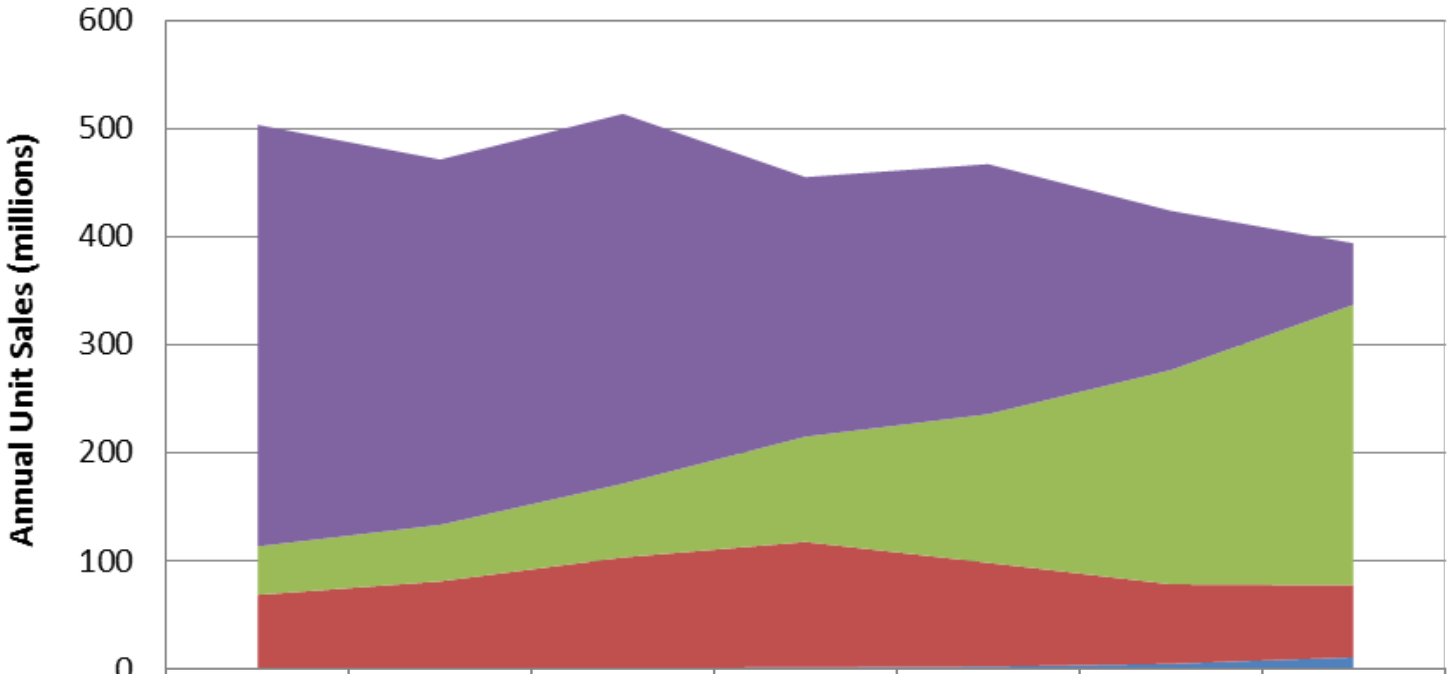
Market projection from Lot 19, 2008



	2007	2008	2009	2010	2011	2012	2013
MV Incandescents	1064.4	961	762.2	696.7	353	312.5	0
MV Halogens (single-end)	97.4	115.2	323.8	365.3	500.5	484.7	144.6
MV Self-Ballasted CFLs	353	353.1	342.3	334.6	333.2	322.7	584.6
Retrofit LED Lamps							

- CFL expected to replace the main bulk of incandescent lamps
- LEDs not visible even in 2013

Market assessment, GfK, until 2013



	2007	2008	2009	2010	2011	2012	2013
MV Incandescents	389.9	337.9	342.1	240.1	231.3	147.4	57.0
MV Halogens (single-end)	44.9	52.2	68.2	97.3	137.4	198.0	259.4
MV Self-Ballasted CFLs	68.5	80.8	102.3	116.0	96.0	73.6	66.6
Retrofit LED Lamps	0.2	0.5	1.1	1.7	2.5	5.0	11.0

- Halogen dominates completely; CFL fails to meet expected sales
- LEDs starts to show up (> 5 %)

Some observations

- Incandescent lamps dominated in 2008; halogen only a small fraction. The ”sparkling of halogens” not a big consumer preference at the time (SE: frosted lamps!)
- Switch from incandescent lamps to halogens rather than to CFLs; including a switch from frosted to clear lamps
- So, allowing class C halogens until 2016 most likely slowed down the shift to CFLs
- Need to assess whether a delay of stage 6 will lead to a parallel delay of a switch to LEDs
- But to be fair: need to consider the stock as well, due to differences in lifetime
- In all: need to readjust the projected savings; do we really deliver what has been promised in 2020?

Summary of the findings

- The proposal for stage 6 was based on old market assessments of LEDs
- New study provides new evidence on the market evolution:
  - Performance increases and cost decreases faster than previously projected
  - New filament LED lamps with a more familiar form to consumers
- Key question: when *is* the best time to phase out halogens?
- Regardless of that: does it makes sense to use old data when making the decision?

Behind the scenes:
Process of the stage 6 revision

- 2012: German lighting industry calls for a delay of stage 6, picked up by Lighting Europe. Real reason not hidden at this point: protect German (read Osram) jobs at halogen factories.
- Consultation Forum 26th April 2013: market assessment from 2012 presented by VHK indicates the LED market not mature enough to phase out the class C halogens: discusses a delay to **2018**. Data challenged by some MS and NGO´s, whereas LE was very defensive.
- Time went on… unclear when the vote would be held. Data older and older… while LED evolved faster and faster…

Process of the stage 6 revision (cont)

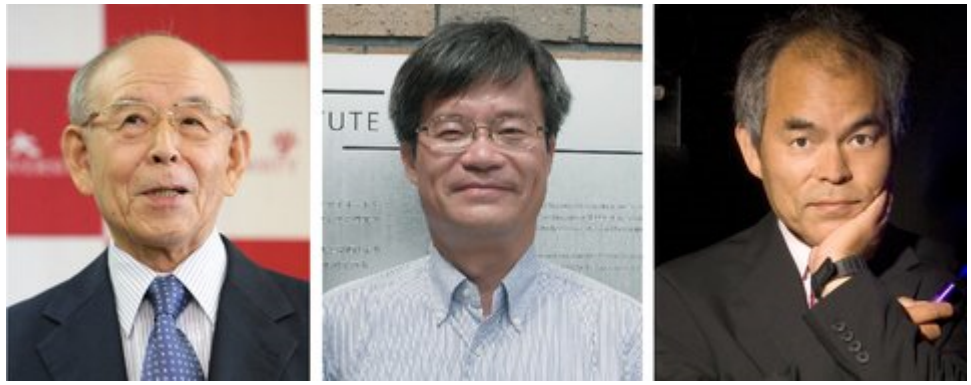
- Rumour during 2014 that a vote would take place
- SE-BE-CLASP-eceee study initiated and performed
- AOB at the CF 10th December 2014 (The Nobel day):

  SE-BE-CLASP-eceee report presented, advocating that the market already is *several years ahead* the projected development – so keep **2016**.

  LE do not agree and try to discredit the report (”flaw” report; ignore it; etc). Advocates a delay to **2020 or more**. (Kahneman: classical anchoring negotation technique)

The Nobel prize in physics 2014 for the invention of the blue LED

Isamu Akasaki and Hiroshi Amano (Japan) and Shuji Nakamura (USA)



16.30 10th December 2014 in the City hall of Stockholm!

Process of the stage 6 revision (cont)

- Regulatory Committee vote 17th April 2015:

  Before lunch: COM checks the support for a delay to 2018:

  6 MS against, 2 MS absent. According to the new system:

  20 MS pro > the required 16 MS.

  65.8 % of the population pro > the required 65.0 %.

  -> Proposal will pass! Or..?

  One MS invokes the old system (possible until 31 March 2017) :

  243 votes pro < the required 260 votes.

  -> Proposal will not pass! COM needs to withdraw it…

  Lunch: 5 MS agree to offer 2017. But the 6th MS makes a phone call…

  After lunch: the 6th MS has gotten a contra order, do now support a delay. COM proposal pass -> **stage 6 will be delayed to 2018**

Reflections

- So the updated data didn´t help… Worth the trouble despite this?
- Yes: obviously to old data at the time of the vote, so new data *was* necessary. Very close to stop the delay.
- Not only market data, but test data – expensive but much harder to argue against.
- Didn´t prevent industry to try, however… ”flaw” tests, not reliable etc – even if the main part concerned the package information!
- Industry played rough – but governments can´t:
  - Keep a decent and respectful tone, always
  - Focus on facts, and the relevant facts
  - Paul Hodsons point nr 5 is probably the key here: ”policies, police, polite…”

Future work

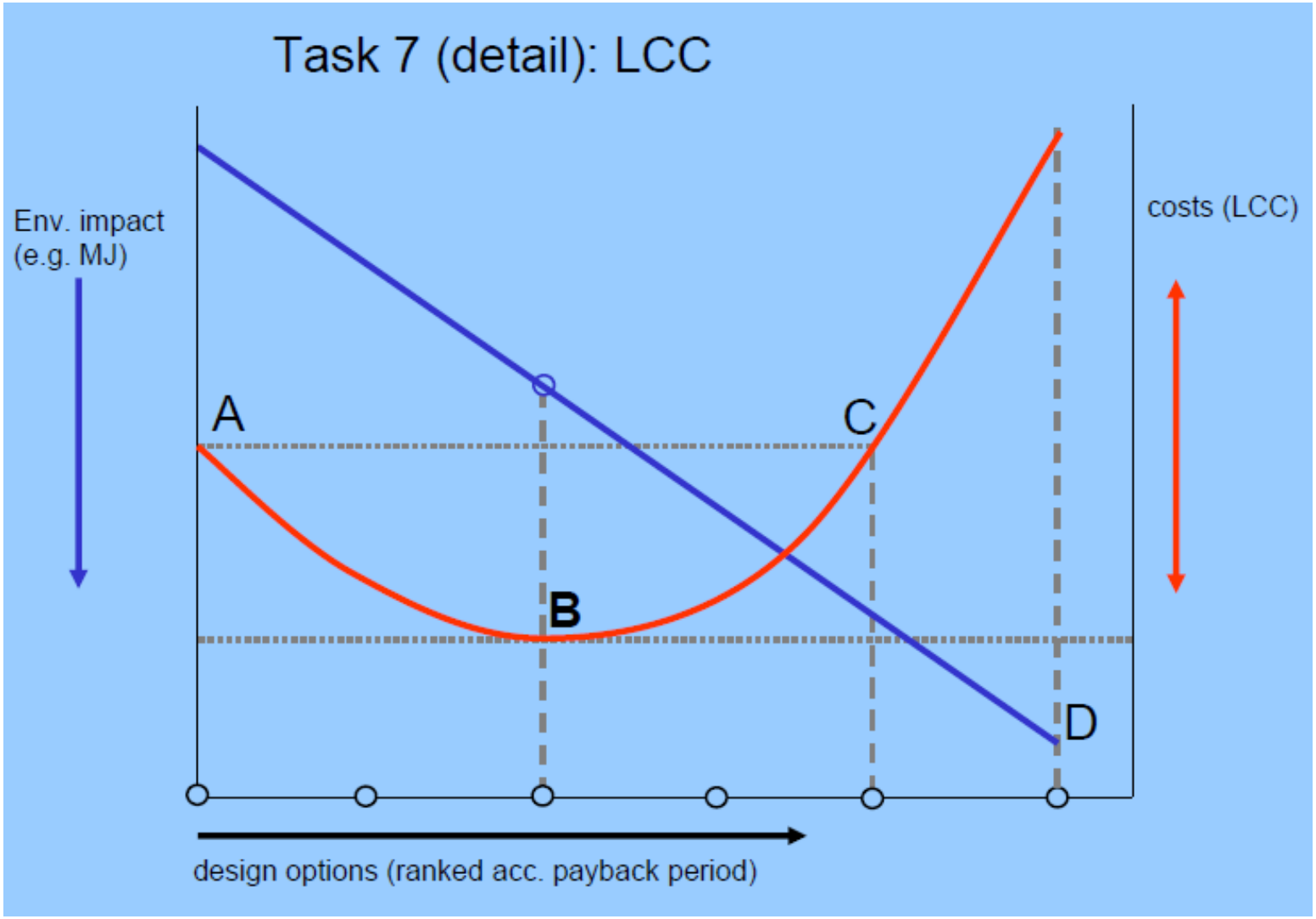
- Stage 3 in 1194/2012 (directional lamps and LEDs): planned revision finished this spring. Market assessment by COM supports MV halogens to be phased out by LED replacement lamps.
- Omnibus revision of all regulations: might lead to further requirements apart from aligning the regulations. SE et al prepared to provide new studies combining market and technical data.

Thank you!

Questions?

Prof Amano gets a Swedish X-mas decoration
from Christofer Silfvenius (SEA Light lab) Dec 2014

Life cycle cost curve



B: Least Life Cycle Cost (LLCC)