European LED Market Evolution and Policy Impacts

A paper prepared for the European Commission, Member States and the Consultation Forum on the evolution of the LED market in Europe and how this affects the evidence base associated with the policy decision on Stage 6 of EC regulation No 244/2009.

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Executive Summary

The adjacent paper on European LED Market Evolution and Policy Impacts has been initiated by the Danish Energy Agency and CLASP's European Programme. The work behind the report has been performed by CLASP's European Programme and by the consultancy company Energy piano. The purpose of this work is to update some of the findings published in a Review Study of Stage 6 of European Commission (EC) regulation No 244/2009. In updating those earlier findings with new data, this paper has three objectives:

1) Provide new information on the evolution of prices of Light Emitting Diode (LED) lamps
2) Provide new energy savings estimates associated with Stage 6 scenarios
3) Evaluate the prevalence of dimmers and if it presents a barrier to Stage 6

The main conclusions in the report are given below with cross-references to the findings presented in this report:

Evolution of Price and Quality in the LED Lamp Market

LED lamps have become much more affordable than was projected in the LightingEurope forecast included in the June 2013 Review Study[1]. Current (2014) pricing of LED lamps tested by PremiumLight and national testing in Austria, Denmark and Sweden found that half of the LED lamps are achieving price points expected in 2020, 2022, 2024 and 2025 (see Section 2.1). This 10 year acceleration in affordability of LED lamps available today from major European manufacturers offer consumers payback periods of less than a 1 year in sockets used 3 hours per day (see Section 2.2). All of the LED lamps included in this report's price study have been tested by accredited lighting laboratories.

Shape, size and light quality are acceptable. Concerns about size, weight, and quality of light, including correlated colour temperature and colour rendering index, have been shown to be addressed in both a Danish study[2] and Swedish test report[3]. These studies published in 2014 have found LED lamps that meet the shape, size and light quality of the tungsten filament lamps they are replacing (see the two reports available on line).

Consumer and professional lighting companies switching: IKEA[4], a global retailer specialising in household furnishings, announced they will only sell LED lamps starting in 2016. Erco[5], a professional luminaire manufacturer, announced that from January 2015 they will only supply luminaires that use LED as the light source.

[1] "NDLS STAGE 6 REVIEW - FINAL REPORT - Review study on the Stage 6 requirements of Commission Regulation (EC) No 244/2009", by VHK (pl)/ VITO for the European Commission. Delft/Brussels, 14 June 2013
[2] Availability of non-directional LED replacement lamps, Energy piano & ÅF Lighting, 2014-02-27, for Danish Energy Agency
[3] Test Report – Clear, Non-Directional LED Lamps: 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; Swedish Energy Agency, Belgian Federal Ministry for Health, Food Chain Safety and Environment, CLASP and eceee; 19 Nov 2014
[4] IKEA announced that customers will only be able to buy LED lamps by 2016, and they intend to install large numbers of LED lamps in their stores and warehouses. Link to press release
[5] Architectural luminaire maker Erco, one of the oldest companies in the business and brand of choice for museums and galleries around the world, has gone 100% LED in all of their nearly 5,000 luminaires and light sources. Link to article

Energy Saving Scenarios Related to Stage 6

Significant energy savings for Europe: the electricity savings and carbon dioxide (CO_2) emissions reduction associated with keeping Stage 6 in 2016 are significant. Compared with the Commission's proposal for a two year delay, keeping Stage 6 in 2016 would over a ten year period from 2016 through 2026 save an additional 33 TWh of electricity – nearly equal to Denmark's total annual (2012) electricity consumption – with savings on electricity bills of approximately €6.6 billion Euro. If Stage 6 in 2016 were to be shifted to require A-class to avoid any B-class halogen lamps entering the European market, the savings would be 79 TWh more than the Commission's proposal – or nearly €15.8 billion Euro over ten years (see the scenarios in Section 3.5, and Annex A).

Risk of B-class Halogens entering the market: B-class halogens are still available for purchase in France, Germany, the Netherlands and the UK, and a non-European wholesaler has been identified offering B-class omnidirectional lamps from which lamp suppliers could outsource production. If B-class halogen lamps expand their share of the European market significantly at Stage 6, it could eliminate half of the expected energy savings between 2016 and 2026 (See Section 3.5, Scenario 2 and Scenario 5).

Dimmer Compatibility

Dimmer compatibility is not a problem for well-designed LED Lamps. The Swedish test report found that two out of the five dimmable LED Lamps tested were compatible with both trailing-edge and leading-edge dimmers, and the others dimmed on one or the other (see Section 4).

This research indicates that relative to the schedule presented in the June 2013 Review Study, which was a key input to the Commission's proposal of a two year delay, LED technology is ready for consumers from both a technological and affordability point of view. Through the use of LED lighting, significant energy savings and benefits will accrue to European households and the Union. During 2014, the LED market has started to become a mass market, and this will continue to develop between now and September 2016, the start of Stage 6 in EC No 244/2009. We encourage European policy-makers to review this new and updated evidence when taking into consideration the critical questions concerning Stage 6.

Table of Contents

List of Tables

List of Figures

Acronyms and Abbreviations

4E	Energy Efficient End-use Equipment (IEA Annex)
AEA	Austrian Energy Agency
CCT	Correlated Colour Temperature
CENELEC	European Committee for Electrotechnical Standardisation
CFL	Compact Fluorescent Lamp
CO_2	Carbon Dioxide
CRI	Colour Rendering Index
DEA	Danish Energy Agency
DOE	U.S. Department of Energy
DTU	Danish Technical University
EC	European Commission
EU	European Union
EUR	Euro (currency of the EU)
EUROSTAT	EC Statistics
GfK	Gesellschaft für Konsumforschung (International market research company)
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IEE	Intelligent Energy Europe
LED	Light Emitting Diode
lm	Lumen
NDLS	Non Directional Lighting Sources
OEM	Original Equipment Manufacturer
STEM	Swedish Energy Agency
TWh	Terawatt-hours
UK	United Kingdom
US	United States / United States of America
VITO	Flemish Institute for Technological Research NV
VHK	Van Holsteijn en Kemna BV
VAT	Value Added Tax
W	Watts

1 Introduction

In June 2013, the European Commission published an extensive technical study[6] prepared by consultants (VHK/VITO) to review the feasibility of keeping in place the Ecodesign regulatory measure EC No 244/2009 adopted in 2009 for non-directional household lamps (hereafter referred to as the "June 2013 Review Study"). On the basis of this study, and in conjunction with input from other stakeholders, the Commission proposed a two-year delay to the final stage of the European regulation on non-directional household lighting, referred to as 'Stage 6'.

The 2013 Review Study estimated the energy savings potential associated with Stage 6, based on estimates of the installed stock of incandescent and halogen lamps in Europe. In late 2014, the International Energy Agency (IEA) Energy Efficient End-use Equipment (4E) Mapping and Benchmarking Annex published an update to its non-directional, household lamp report for Europe[7], providing non-directional household lamp sales data on 7 major European Member States representing nearly half of the total EU population. This update was based on GfK sales data in these countries, and it was found that sales of mains-voltage halogen lamps were considerably higher than were predicted in the June 2013 Review Study. Thus, it became clear that in order for policy makers to make an informed decision on whether to keep, amend or delay Stage 6 of EC No 244/2009, an update to the price progression and the energy savings associated with Stage 6 would be necessary. It is hoped that this study on the evolution of LED technology across Europe will prove useful to policy makers in making a decision regarding Stage 6.

This report presents updated price information for LEDs in the European market, as well as six new scenarios for Stage 6 and associated energy savings. Dimmer compatibility of LED lamps is also addressed. The report is structured as follows:

Chapter 1. Introduction – this chapter provides the background and motivation for the study.

Chapter 2. Rapid Evolution of LED Lamp Prices – this chapter conducts a pricing survey of LED lamps. This survey is compared to the price/performance forecast in the June 2013 Review Study. The lamps included in this survey were tested by the Austrian Energy Agency, the IEE PremiumLight Programme, the Swedish Energy Agency and the Danish Technical University (DTU).

Chapter 3. Update to Energy Savings Calculations and Scenarios – this chapter establishes a new stock estimate for 2016 based on recently published GfK sales data for 7 major European countries, and provides an update to the estimate of the energy savings potential associated with Stage 6 that was originally published in the June 2013 Review Study.

Chapter 4. Light Dimmer Circuits in Europe – this chapter provides a discussion on dimmers in Europe, based on market research done previously by the Intelligent Energy Europe (IEE) PremiumLight programme.

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[6] "NDLS STAGE 6 REVIEW - FINAL REPORT - Review study on the Stage 6 requirements of Commission Regulation (EC) No 244/2009", by VHK (pl)/ VITO for the European Commission. Delft/Brussels, 14 June 2013.
[7] IEA Mapping and Benchmarking report – Domestic Lighting Update, September 2014. See: http://mappingandbenchmarking.iea-4e.org/shared_files/643/download

2 Rapid Evolution of LED Lamp Prices

2.1 LED Lamp Prices in Europe

The June 2013 Review Study provided a forecast of the LED efficacy (lm/W) and price (Euro incl. value added tax [VAT] per 500 lumen [lm] light output) for the period 2012 to 2030. The efficacy projection was adopted from a 2013 CLASP publication[8] which itself was based on US Department of Energy's Multiyear Programme Plan for Solid State Lighting, while the price projection were provided by Lighting Europe up to 2020 and extrapolated to 2030 by VHK/VITO.

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

Figure 2-1. LED Price and Performance Forecast from the June 2013 Review Study

The test report on clear, non-directional LED lamps prepared by Swedish Energy Agency, Belgian Federal Ministry for Health, Food Chain Safety and Environment, CLASP and eceee[9] found that the price and performance of approximately 50% of the mains-voltage LED lamps purchased and tested in 2014 already exceeded the projected 2016 price and performance levels in the June 2013 Review Study. One model even exceeded the anticipated 2018 level on efficacy and the 2020 level on price.

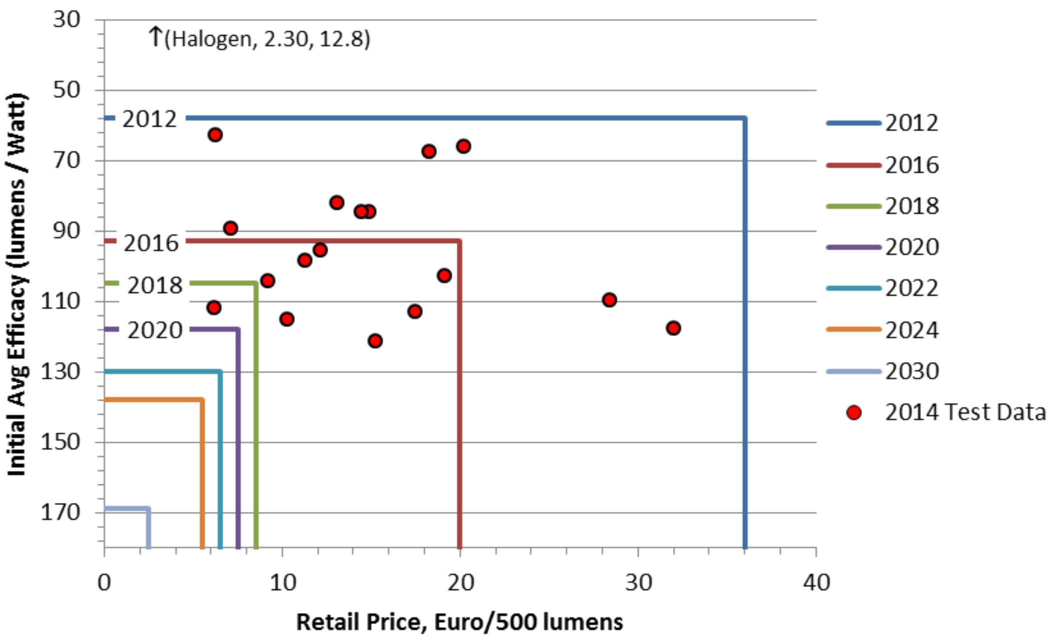

Figure 2-2. LED Price and Performance for 2014 Clear LED Lamps Plotted Against Projections from the June 2013 Review Study

[8] "European non-directional lamps market model, version 1.1 (Microsoft Excel workbook); Pernille Schiellerup, Marie Baton and Michael Scholand, CLASP Europe; 14 May 2013, Brussels."

[9] Test Report – Clear, Non-Directional LED Lamps: 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. By: Swedish Energy Agency, Belgian Federal Ministry for Health, Food Chain Safety and Environment, CLASP and eceee, 19 November 2014 Hyperlink to PDF of report

This study seeks to give an update on the price and technology evolution of LEDs in Europe. The approach was to gather current prices and performance data for 19 LED lamp products tested by lighting laboratories involved in the IEE PremiumLight project, the Austrian Energy Agency (AEA) and the Danish Technical University (DTU). For each product, a sample of 3-5 lamps was tested. The lamps ranged from 660 to 1660 lumens, which can replace 40-100 Watt incandescent lamps.

The table below presents the results with a comparison to the price projection from the June 2013 Review Study (the table shown above in Figure 2-1). For 68% of the products shown, the current price level is ahead of the progression published in the June 2013 Review Study. For half of the products, the current price level is 5-11 years ahead. It should be noted the table covers LED lamps that can replace incandescent lamp ranging from 25W to 100W.

Table 2-1. Actual Prices for LED Lamps Tested by PremiumLight, AEA and DTU Photonic

Brand	Model	Measured Lumens	Price per 500 lm	Price in 2013 Review Study	Actual price Acceleration
Posco LED	9W	715	€ 3.51	2025	11 years ahead
Osram	LED Superstar Classic A 10W	880	€ 4.77	2025	
IKEA	Ledera 13W dimmable	1032	€ 4.80	2025	
Verbatim	LED Classic 9,5W	888	€ 5.39	2024	10 years ahead
IKEA	Ledare 10 W	597	€ 5.51	2024	
IKEA	Led circular 16W dimmable	1026	€ 5.78	2024	
Osram	10W dimmable	874	€ 6.14	2022	8 years ahead
Philips	LED 13W	1076	€ 6.25	2022	
Philips	Master LEDbulb 12W	768	€ 7.16	2020	6 years ahead
Soft LED	LED Glühfaden Birne 6W	673	€ 7.39	2020	6 years ahead
Megaman	LED Classic 16.5W	1665	€ 8.33	2018	4 years ahead
GE LED	Energy Smart 10W	660	€ 8.98	2017	3 years ahead
XAVAX	LED Lampe 11W dimmable	794	€ 9.41	2016	2 years ahead
Panasonic	LDAHV10L27CGEP 10W	895	€ 13.44	2014	On time
Osram	6W dimmable	493	€ 13.62	2014	
Verbatim	4W	260	€ 12.27	2014	
Luxinia LED	SunFlux 11W dimmable	828	€ 16.00	2014	
Megaman	10W	696	€ 16.31	2014	
OSRAM	LED Star Classic B 4W	264	€ 21.63	2012	2 years behind

All lamps included in Table 2-1 were tested as mentioned above and were of good quality. The process of testing (selecting, procuring, testing and documenting) takes time, and therefore all lamps in Table 2-1 were at least one year old. **If the most recent versions of lamps had been included, the efficacy would have been higher and the price per 500 lm would have been lower.** For example, PremiumLight published test results for a Sunflux E27 7.5W LED lamp in July 2014. This lamp provided 470 lm, 63 lm/W, 2700 K, Ra 95 and 270° light distribution. A year later, this product is about to be taken off the market and is being replaced by a new product that costs less and offers a 50% improvement in efficacy. The new specification for this new lamp from SunFlux is 5W, 450 lm, 90 lm/W, 2700K, Ra>90 and 360° light distribution. Tested products that are about to be taken of the market are not included in Table 2-1.

At the Strategies in Light Europe 2013 conference, a representative of Philips Lighting[10] reported that LED technology had reached a point by the middle of 2013 where the quality, size and shape of LED retrofit lamps would be acceptable to consumers. Furthermore, Philips Lighting expected that the on-going reduction in LED lamp prices would start to enable mass market LED penetration in Europe starting at the end of 2014. The results presented in this paper, including the findings from the above table, show that Philips' forecast was correct.

In January 2015, Danish consumers were able to buy LED lamps providing 400 lumens of light for only EUR€2.90, and Philips brand LED lamps with 470 lm for EUR€6.50 and with 806 lm for EUR€13.20 (note: one year ago, the price for these same lamps was double or more). This development, coupled with market moves by companies like IKEA[11], are indicative of the fact that the LED market is becoming an affordable mass market for European consumers, with benefits for households, energy security and the environment.

Figure 2-3. LED Lamps for sale in three different large chain stores in Denmark

Similar price reduction as shown above for Denmark can be found around in EU. Figure 2-4 includes a sample of lamps for sale in seven EU countries:

- Megaman brand LED lamp with 810 lumens for EUR€8.99 for sale in Finland.
- Philips brand LED lamp with 806 lm for EUR€7.10 for sale in Czech Republic. This is the same as sold in Denmark (see Figure 2-3) but for a price much higher in Denmark at EUR€13.20. Below you can see the same lamp is even sold cheaper in Germany for EUR€6.39.
- LED lamp with 470 lm for EUR€8.20 in UK.
- Philips brand LED lamp with 1055 lm for EUR€7.90 for sale in Italy.
- OSRAM brand LED lamp with 806 lm for EUR€7.55 for sale in Spain
- Philips brand LED lamps with 1055 lm for EUR€9.95 (cheaper to buy in the Italian shop above) and with lm 470 for EUR€5.49 for sale in Latvia.
- Philips brand LED lamp with 806 lm for EUR€6.39 for sale in Germany.

[10] LED Market Transformation: Managing the Second Phase, Annetta Kelso, Senior Marketing Manager OEM Channel Europe, Philips Lighting, and the Netherlands
[11] IKEA announced that customers will only be able to buy LED lamps by 2016, and they intend to install large numbers of LED lamps in their stores and warehouses. Click here for the article.

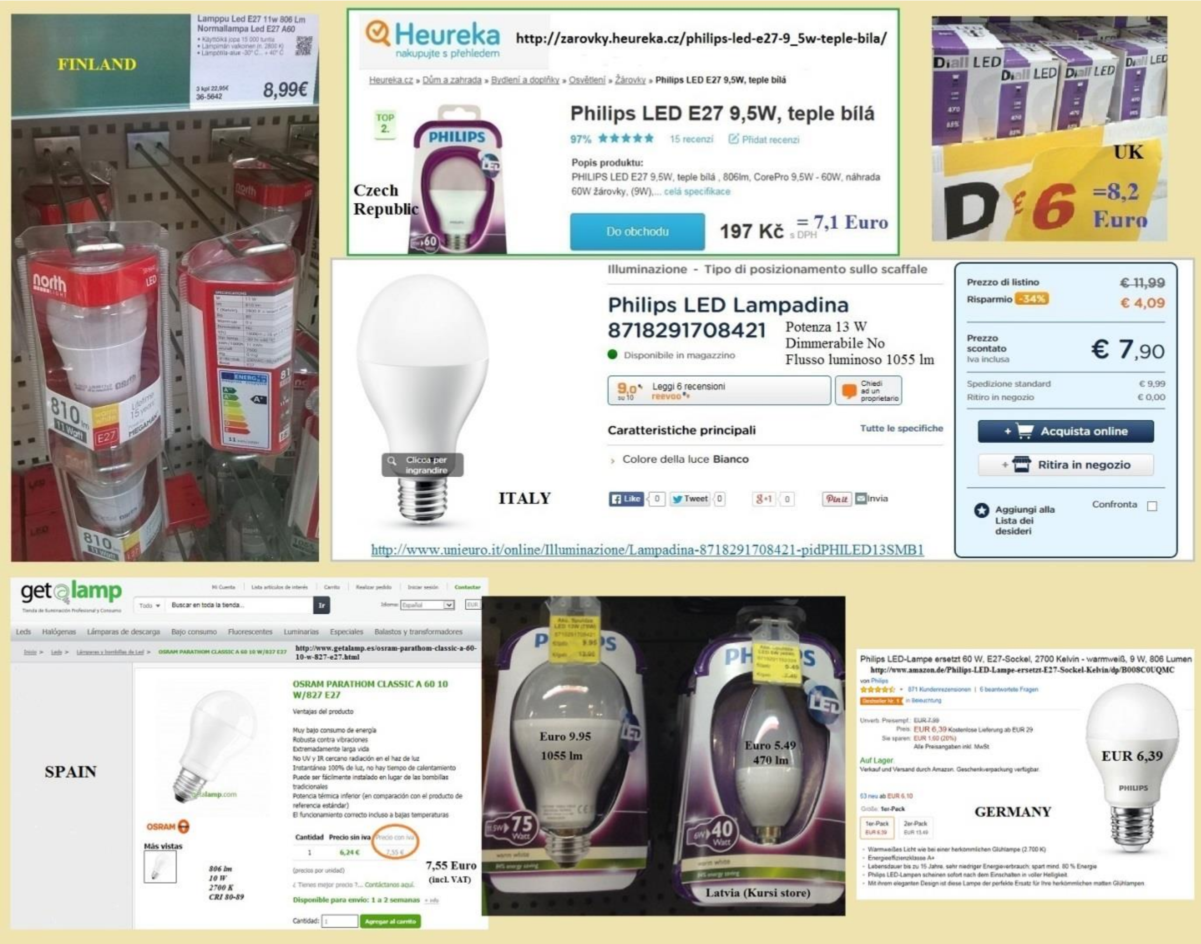

Figure 2-4. LED Lamps for sale in Czech Republic, Finland, Germany, Italy, Latvia, Spain and UK

When the perspective shifts to the market outside of Europe, it seems that Europe is actually behind the development of LED markets in both Japan and USA.

In Japan, a LED mass market appeared in 2012, where LED sales constituted 40% of sales of lighting sources[12]. In 2013, LED luminaire sales in Japan were approximately 60% of national luminaire sales[13]. Since the start of 2012, the Japan has installed 73 million LED lamps[14] nationwide, which represents 30% of all bulbs sold in Japan over that period. According to the Institute of Energy Economics in Japan, switching all of Japan's lighting to LEDs would save about 92.2 terawatt hours of electricity, 9 percent of Japan's total annual consumption. Hiroshi Amano, who shared last year's Nobel Prize for physics, stated that Japan could cut annual electric spending by as much as 1 trillion yen ($8.4 billion) within five years by using more LEDs.

In the USA, the mass market for LED retrofit lamps appeared around 2013 when CREE announced 60W and 40W equivalent dimmable quality LED lamps for retail prices around US$10.00 (EUR€8.85)

[12] Presentation by the Japanese Strategic Council on SSL at the IEA 4E SSL Annex Expert meeting in Seoul, Korea in September 2013.

[13] Presentation by the Japanese Strategic Council on SSL at the IEA 4E SSL Annex Expert meeting in Delft, The Netherlands, April 2014

[14] http://www.bloomberg.com/news/articles/2015-02-26/humble-light-bulb-helps-japan-fill-nuclear-energy-gap

– see Figure 2-5. Current prices are now US$7.00-10.00[15] (EUR€6.20-8.85), and can be found even lower when combined with an electric utility rebate scheme (e.g., US$2.97 [EUR€2.63] in Connecticut in April 2013).

Figure 2-5. Photographs of Retail Display of Cree LED Lamps in USA

Figure 2-6 shows an example of a new generation of LED lamps entering the European market. This technology has considerably higher performance than halogen, and payback times are becoming shorter. By September 2016 we will even have taken one more step in improved performance.

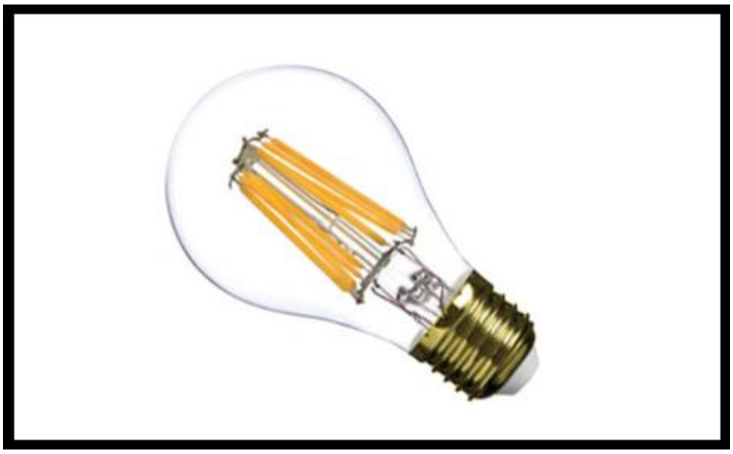

Figure 2-6. Example of the new generation LED filament lamps with very high performance

The lamp in Figure 2-6 provides:

- Shape and size like an incandescent/halogen; direct mains-voltage screw-in replacement
- 360° light distribution through clear glass envelope (i.e., sparkle effect for certain light fixtures)

[15] Current (viewed 25 January 2015) pricing of Cree LED lamps at Home Depot in the USA. To view the Home Depot ads for Cree lamps, click on this link and click on this link.

- 120 lm/W (ten times better than incandescent lamps and two times better than CFL)
- Warm-white light - 2700 K, same as incandescent/halogen lamps
- High colour rendering, CRI Ra > 90
- Long lifetime – 15,000 hours (7 times longer than halogen)

2.2 Payback Period for Consumers

Lower-priced LED lamps offer consumers shorter payback periods which will trigger higher market penetration and energy savings. Taking two LED lamps from Table 2-1 with light output levels that are comparable to a 60W incandescent / 52W halogen lamp, and one LED Lamp from the Swedish Testing study[16] with approximately the same light output, a simple payback period was calculated. These calculations are shown in the following two tables, the first for light sockets operated 3 hours per day and the second for sockets operated 1 hour per day.

LED-1: Osram, LED Superstar Classic A 60 advanced 10W Weblink
LED-2: Verbatim, LED Classic 9.5W Weblink
LED-3: Osram PARATHOM Classic A ADV 10W 827 Weblink

Table 2-2. Simple Payback Period for CFL and LED lamps compared to Halogen, 3 Hours/Day

Lamp Type	Wattage (Watts)	Daily Use (hours/day)	Efficacy (lumens/Watt)	Light Output (lumens)	Cost per Lamp (€)	Energy Use (kWh/yr)	Electricity Price (€/kWh)	Simple Payback (years)
Halogen	52	3	15	780	1.50	56.9	0.20	
CFL	15	3	55	825	3.00	16.4	0.20	0.19
LED-1	9.8	3	90	880	8.39	10.7	0.20	0.75
LED-2	9.5	3	93	888	9.27	10.4	0.20	0.83
LED-3	9.6	3	90	863	9.85	10.5	0.20	0.90

Table 2-3. Simple Payback Period for CFL and LED lamps compared to Halogen, 1 Hours/Day

Lamp Type	Wattage (Watts)	Daily Use (hours/day)	Efficacy (lumens/Watt)	Light Output (lumens)	Cost per Lamp (€)	Energy Use (kWh/yr)	Electricity Price (€/kWh)	Simple Payback (years)
Halogen	52	1	15	780	1.50	19.0	0.20	
CFL	15	1	55	825	3.00	5.5	0.20	0.56
LED-1	9.8	1	90	880	8.39	3.6	0.20	2.24
LED-2	9.5	1	93	888	9.27	3.5	0.20	2.50
LED-3	9.6	1	90	863	9.85	3.5	0.20	2.70

The payback for these three LED lamps at current prices is less than one year in sockets operated 3 hours per day, and approximately 2.5 years for sockets operated 1 hour per day. After that, consumers can enjoy many years of savings, as these same lamps claim to have operating lives of 20,000 hours, equal to approximately 20 years at 3 hours per day or 60 years at 1 hour per day.

[16] LED-3 was taken from the results of the study: "Test Report – Clear, Non-Directional LED Lamps: 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". By: Swedish Energy Agency, Belgian Federal Ministry for Health, Food Chain Safety and Environment, CLASP and eceee, 19 November 2014 Hyperlink to PDF of report

3 Update to Energy Savings Calculations and Scenarios

In the June 2013 Review Study[17], VHK/VITO prepared an estimate of the mains-voltage halogen sales and stock for the EU as well as two scenarios that depicted the savings potential, one abolishing Stage 6 and one keeping Stage 6. In this chapter, we follow the same methodology used in their calculation, but with an updated installed stock of incandescent and halogen lamps to reflect the European GfK sales data published by the IEA 4E Mapping and Benchmarking Annex. New scenarios are assessed, including a one and two year delay to Stage 6, as well as two scenarios for keeping Stage 6 in 2016: B-class as in the current regulation and an upgrade to A-class.

This chapter begins with background information about constructing the scenarios of energy for lighting.

3.1 VHK/VITO Review Study on Stage 6

As part of the review of EC 244/2009, the European Commission contracted VHK/VITO to conduct a review study on the feasibility of Stage 6. This resulted in a report issued in June 2013 (called the "June 2013 Review Study" in this report) providing the best information available at that time. That analysis included estimates of the halogen shipments and calculations of energy savings for two different scenarios:

SC1 - Abolishing Stage 6 requirements
SC2 - Keeping Stage 6 requirements

These two scenarios relied on calculating the energy consumed by the estimated installed stock of mains-voltage halogen lamps in 2016, the effective year of Stage 6. Whether the Commission kept Stage 6 in 2016, or abolished it, was calculated against that estimated installed stock of halogen lamps. The figure below is a screen-capture of the table appearing in the June 2013 Review Study[18] (called "Table 6" on page 25 of the report), where the methodology used to arrive at a stock estimate of halogens in 2016 is shown.

Table 3-1. June 2013 Review Study Methodology for Calculating Stock of Halogens in 2016

Table 6. MV-HL sales and stock EU 2009-2016, in million units

Year	ex-GLS free for MV-HL retrofit	MV-HL sales 66% EU industry	MV-HL stock	MV-HL discarded after 4 years
2009	163	163	163	-
2010	191	191	354	-
2011	162	162	516	-
2012	234	234	750	-
2013	380	543	1 130	163
2014	220	411	1 350	191
2015		162	1 350	162
2016		234	1 350	234

[17] "NDLS STAGE 6 REVIEW - FINAL REPORT - Review study on the Stage 6 requirements of Commission Regulation (EC) No 244/2009", by VHK (pl)/ VITO for the European Commission. Delft/Brussels, 14 June 2013
[18] Ibid.

This methodology was based on the assumption that CFLs would represent the main replacement for frosted incandescent lamps, limiting the sales volume of mains voltage halogen lamps. The difference between the two scenarios presented in the June 2013 Review Study was 9.4 TWh of additional savings in 2020 from SC2 (keep Stage 6 in 2016). On a cumulative basis, when compared with abolishing Stage 6, the Review Study estimated the electricity savings over 10 years from keeping Stage 6 in 2016 to be 43.2 TWh. Based on the June 2013 Review Study and other input from stakeholders, the Commission proposed a two year delay to the implementation of Stage 6.[19]

3.2 New Data – IEA 4E Mapping & Benchmarking

In September 2014, the IEA 4E Mapping and Benchmarking Annex published a report that updated all their shipment information on the European lighting market based on GfK lamp sales data.[20] This report included sales estimates for 7 major economies (i.e., Austria, Belgium, France, Germany, Great Britain, Italy and the Netherlands) and covered the following technologies, which also fall under EC 244/2009: mains-voltage incandescent, mains-voltage halogen, single-ended self-ballasted CFL and retrofit-LED lamps. The data included sales in these countries from 2007 through 2013.

The data indicate that integrally ballasted CFL sales peaked in 2010 and have been in decline ever since. Actual CFL sales in 2013 are lower than they were in 2007 for these European markets, prior to the adoption of regulation EC 244/2009. In contrast, over that time period, sales of mains voltage halogen lamps have grown by 477%. Figure 3-1 compares the GfK sales estimates to the expected shipments published in 2009[21], when the regulation was adopted. The contrast is clearly visible: the anticipated switch to CFL in 2012 after implementation of Stage 5 of 244/2009 did not occur. Instead the market has selected halogen lamps.[22] This is despite the fact that replacing frosted incandescent with CFL was deemed cost effective for most households[23]. The GfK data show that clear halogen lamp sales were 4 times larger than CFLs in 2013 and CFL sales have decreased during the period when incandescent was phased out.

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[19] 5 November 2014, Commission issued an email which stated the following: EU TBT notification concerning the Draft Commission Regulation amending Regulation (EC) No 244/2009 has now been published on the WTO website under the following reference: G/TBT/N/EU/248 (Web link to the draft regulation)

[20] IEA Mapping and Benchmarking report – Domestic Lighting Update, September 2014. (Web link to the report). The GfK data can be found on page 5 of the IEA M&B Annex Domestic Lighting Report, September 2014.

[21] Final report, Lot 19: Domestic lighting prepared by VITO for European Commission, 2009/ETE/R/069; October 2009. Annexe 8-6: Main economic and environmental data for the scenario “Option 2 Clear B Slow”.

[22] It was decided not to use the shipment estimates published in the draft Task 2 of Lot 8/9/19 report. See Annex B.

[23] Full Impact Assessment, Commission Staff Working Document, on ecodesign requirements for non-directional household lamps, 18.3.2009. Quote on page 16: “In the frosted lamps category, the analysis has shown that it is cost-effective to only allow class A level lamps (= CFLs).”

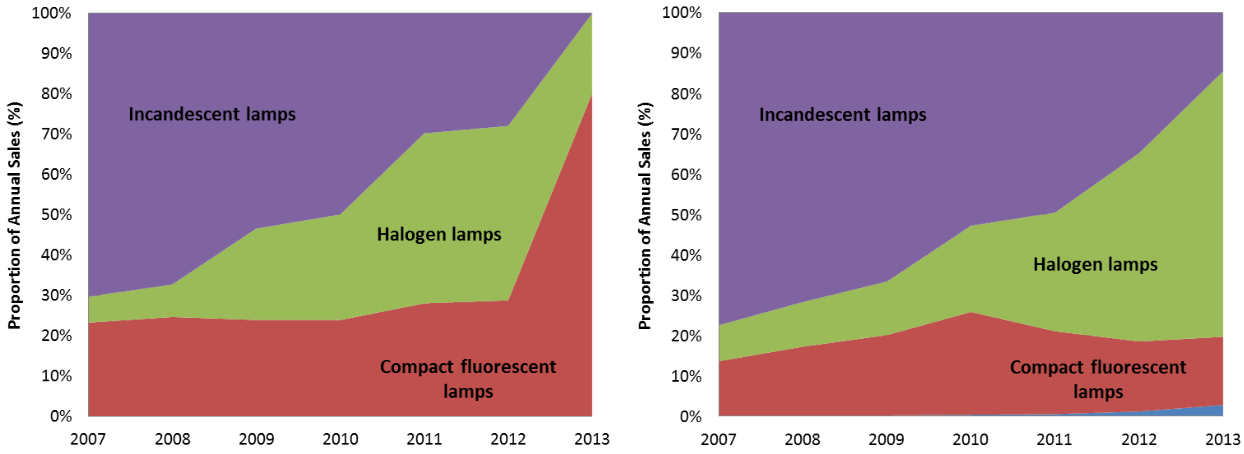

Figure 3-1. Comparison of Shipments of Non-Directional Mains-Voltage Lamps (2007-2013)

Given this substantial (and unanticipated) market shift, the energy savings estimates presented in the June 2013 Review Study needed to be revisited in the light of this new data. The GfK data show a market situation quite different from what was expected when the policy was adopted. There are still many incandescent lamps being sold and mains-voltage halogen lamps have supplanted the expected CFL sales.

3.3 Methodology for Revised EU Shipment Estimate

GfK estimates that the lamp shipment data they provided for this time period represents, on average, 70% of the overall lighting market in the seven countries covered in the years reported, including 40% in Belgium and Netherlands, 70% in Austria and Germany and 85% in France, Great Britain and Italy. The populations of these 7 countries were multiplied by each country's indicated market coverage percentages in order to calculate the total number of people – approximately 233.5 million – covered by GfK's data (2012). In order to calculate an estimate of the total proportion of the European lighting market represented in the GfK data, the total EU population of 505.6 million (2012) was used to calculate a multiplier of 2.165 (= 233.5/505.6), and this multiplier was then used to scale-up the GfK sales data to the total EU.

A second adjustment to the GfK data was made in order to ensure that the correct lamp types were used in the updated energy savings model. The GfK sales data for 'single-ended mains voltage halogen' published in the IEA 4E Mapping and Benchmarking Annex report did **not** exclusively represent non-directional household lamps. This group contained both non-directional household lamps as well as directional lamps (e.g., MR-16 lamps with a GU10 base). Therefore GfK lamp sales data of single-ended mains voltage halogen for one of the Member States were used to estimate the proportion of directional to non-directional lamps within the 'single-ended mains voltage halogen' category. It was found that the proportions were one-third directional lamps and two-thirds non-directional. This proportion was then used to reduce the EU-wide scaled GfK sales data from the IEA 4E Mapping and Benchmarking Annex report by one third to arrive at an estimate of the single-ended mains-voltage non-directional household lamps for the EU.

The figure below provides GfK's incandescent and halogen lamp shipment data, adjusted for population and directional single-ended lamps. These halogen sales are then projected forward, assuming the 2013 GfK estimate represents a near-peak in demand and that shipments soon start to decline under a business as usual scenario (i.e., how the market is expected to behave if there is no Stage 6). Shipments peak at around 480 million units in 2015 and start to decline thereafter as LED alternatives become more and more cost competitive. This graph also shows incandescent sales reported in GfK, which are presumed to decline rapidly as this technology is phased out and market surveillance authorities work to ensure compliance with the regulation.

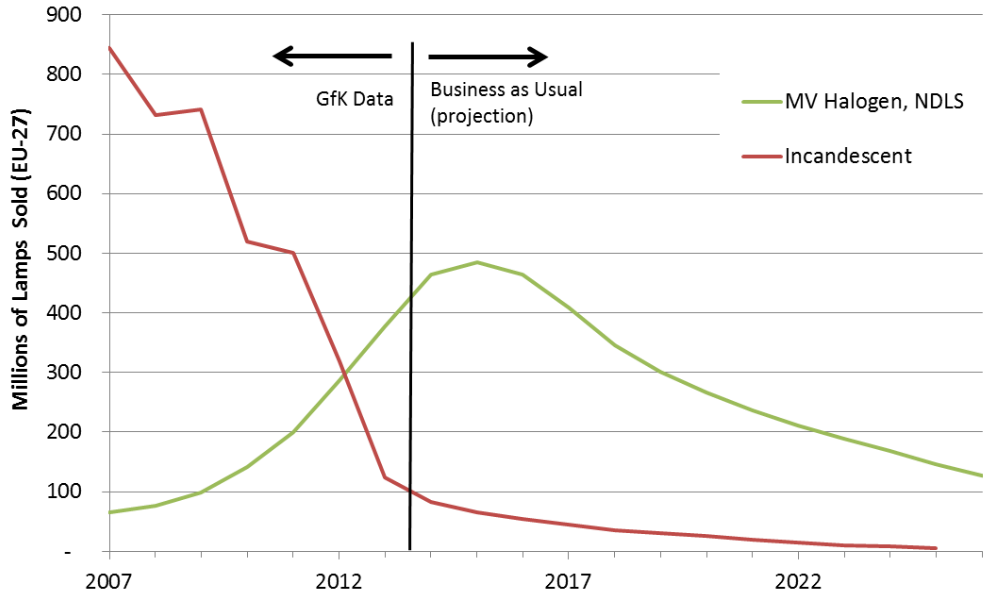

Figure 3-2. NDLS Incandescent and MV Halogen Sales Data for All EU, Business as Usual

These shipments of incandescent and MV halogen lamps are used to calculate a new installed stock of tungsten filament-based lamps in the European market in 2016. The methodology followed in preparing this stock estimate is consistent with the methodology used in the 2013 Review Study: halogen lamps have an average lifetime of 2000 hours and the average operation time is 500 hours of use per year (i.e., 1.4 hours / day). The halogen lamps thus last in the stock for an average of 4 years before being replaced. The same methodology is applied to the sales of incandescent lamps, which are assumed to have an average lifetime of 1000 hours and 333 hours of use per year (i.e., 1 hour/day), such that they last an average of 3 years in the stock model. Table 3-2 presents the new estimate of the installed stock of incandescent and halogen lamps across Europe in 2016.

Table 3-2. Denmark-CLASP Updated Stock Model (based on 2007-2013 GfK sales data)

Year	Incandescent Sales	Incandescent discarded after 3 years	Incandescent Stock	MV-Halogen Sales (NDLS)	MV-HL discarded after 4 years	MV-HL Stock
(units)	*(million lamps)*	*(million lamps)*	*(million lamps)*	*(million lamps)*	*(million lamps)*	*(million lamps)*
2009	741		741	99		99
2010	520		1,261	141		240
2011	501		1,762	199		439
2012	319	741	1,340	287		727
2013	123	520	944	376	99	1,004
2014	83	501	526	465	141	1,328
2015	65	319	271	485	199	1,613
2016	54	123	202	464	287	1,789

Table 3-2 shows that the update of the sales of mains-voltage incandescent and halogen lamps, based on 2007-2013 GfK data results in a higher estimate of the installed stock of tungsten filament-based lamps in 2016. With this new sales data, it would appear that there are approximately 2 billion incandescent and halogen sockets in Europe, whereas the June 2013 Review Study had estimated 1.3 billion. Due to this higher installed base of inefficient lighting in Europe, it should be noted that any policy-measures applied to non-directional household lamps would have an even greater impact on the resulting energy savings.

3.4 EC No 244/2009 Stage 6: B-class or A-class?

EC regulation No 244/2009 established six stages of requirements, five of which are already completed. Stage 6 is scheduled to take effect on 1 September 2016 and will phase-out mains-voltage clear halogen lamps (D-class) by requiring all clear glass non-directional household lamps to achieve B-class.[24] Although commonly referred to in the media as a 'ban' on halogen, strictly speaking, this isn't a ban on halogen lamps because low-voltage, infrared-reflective coating halogen technology can achieve B-class.

It was recently learned that B-class lamps are still offered for sale in Europe and are advertised by companies in China – see the table below and associated hyperlinks.

Table 3-3. Evidence of B-class halogens in Europe and from non-European wholesalers *

<table>
<tr><th>Retailer</th><th>Lamp</th><th>Weblink</th></tr>
<tr><td>www.energylightbulbs.co.uk</td><td>Philips Master Classic 20W ECO Boost Energy Saving GLS; B-class Halogen; £3.99</td><td>Click on this link</td></tr>
<tr><td>www.amazon.co.uk / Strictly Lamps</td><td>Philips 20w ECO Master Classic Candle Halogen Energy Saving; B-class Halogen; £3.99</td><td>Click on this link</td></tr>
<tr><td>www.confort-electrique.fr</td><td>Philips Ampoule MASTER Classic 30W E27 A55 230V; B-class Halogen; €22.69</td><td>Click on this link</td></tr>
<tr><td>www.amazon.de</td><td>Philips 18158 620 lm MasterClassic Halogen 30W E27 230V; B-class €12.99</td><td>Click on this link</td></tr>
<tr><td>www.elvvs.dk</td><td>Philips MasterClassic 30W E27 230V; B-class €16.45</td><td>Click on this link</td></tr>
<tr><td>Other wholesale Manufacturer:

Qianhui Lighting Electrical Appliance Co.</td><td>Low-voltage halogen lamp
Sparkling, crisp light
50% energy saving
Higher luminous efficacy
Voltage: 220-240V (E27 base)
Lifetime: 2000 hours
CCT: 2,800K
<table><tr><th>Standard Light Bulb (GLS)</th><th>Halogen Energy PRO Bulb (Globe-G45)</th><th>Lumen Output (LM)</th></tr><tr><td>40W</td><td>20W</td><td>360W</td></tr><tr><td>60W</td><td>30W</td><td>600W</td></tr></table></td><td>Click on this link

Note: minimum order 1000 pieces.
</td></tr>
</table>

* Note that while the validity of the claim of B-class for these wholesalers has not been tested.

[24] EC No 244/2009, Annex II, Section 1, Table 1: Clear lamps Stage 6: $Power_{max} = 0,6 * (0,88\sqrt{\Phi}+0,049\Phi)$ where Φ is the measured light output.

Thus, when Stage 6 takes effect requiring B-class, there is the possibility that the market could experience a widespread introduction of B-class halogen lamps, even though all the analysis and discussions surrounding Stage 6 to date has focused on whether LED lamps will be ready.

Lamp manufacturing in the past was often done by the major brand names, but now there has been a trend toward contract manufacturing and branding; (i.e., outsourcing the manufacturing). It is in this context that the discovery of at least one non-European wholesale manufacturer is of concern. If a retailer, importer or lamp manufacturer in Europe wants to import B-class halogen lamps, there would be little capital investment compared to commissioning their own manufacturing line, as the company could simply outsource the lamp manufacturing. Therefore a more widespread introduction of B-class halogen lamps is possible.

EC No 244/2009 split the incandescent lighting market into frosted and clear lamps with different energy-efficiency requirements for these two categories. The intention of this policy measure was that frosted incandescent lamps would be replaced by compact fluorescent lamps (CFLs, which are A-class) and clear incandescent lamps would be replaced by mains-voltage halogen lamps (D-class), with these lamps being phased out at Stage 6.

Recital 20 of the regulation (EC No 244/2009) reads: "A review of this measure should take particular note of the evolution of sales of special purpose lamp types so as to verify that they are not used for general lighting purposes, of the development of new technologies such as LEDs and of the feasibility of establishing energy efficiency requirements at the 'A' class level as defined in Commission Directive 98/11/EC of 27 January 1998 implementing Council Directive 92/75 with regard to energy labelling of household lamps (3)."

The review completed in 2014 by the Commission – and which the June 2013 Review Study was a part of – is intended to satisfy the requirements of Recital 20. Recital 20 does not contemplate a delay to Stage 6, but rather whether A-class was warranted in place of B-class. Recital 20 specifically mentions LED technology as one of the unknown variables that could be a driver behind the decision to establish A-class as the Stage 6 requirement. However, the Commission's proposal does not raise Stage 6 to an A-class, but instead delays the onset of B-class lamp technology for two years.

In the next subsection, we present some scenarios that look at the energy savings associated with Stage 6, based on the new baseline derived from the aforementioned GfK data. These scenarios consider maintaining Stage 6 with a B-class requirement, Stage 6 with an A-class requirement, and postponing Stage 6 by one or two years.

3.5 Energy Saving Scenarios

For the calculations presented in this section, the following six scenarios are considered:

Table 3-4. Description of Energy Saving Scenarios Considered in this Paper

Scenario	Short Title	Description
SC1	Abolish Stage 6	Assumes Stage 6 is abolished and no further regulatory action taken to advance the market for energy-efficient non-directional household lamps. Market evolves gradually to LED over time.
SC2	Keep Stage 6; keep B-class	Assumes Stage 6 takes effect in September 2016 and 50% of replacement sockets switch to B-class halogens. The other 50% is apportioned between CFL/alternatives (using the same proportions as in the June 2013 Review Study[25]) and LED lamps.
SC3	Keep Stage 6, move to A-class	Assumes Stage 6 takes effect in September 2016 and the minimum requirement changes to A-class. The market shifts according to the same CFL/alternatives technology mix as in the June 2013 Review Study.[26]
SC4	Delay Stage 6 to 2017; move to A-class	Assumes Stage 6 is delayed one year to September 2017 and the requirement changes to A-class; the market shifts according to the same mix technologies used in the June 2013 Review Study.
SC5*	Delay Stage 6 to 2018; keep B-class	Assumes Stage 6 takes effect in September 2018 and 40% of replacement sockets switch to B-class halogens. The other 60% is apportioned between CFL/alternatives (using the same proportions as in the June 2013 Review Study) and LED lamps.
SC6	Delay Stage 6 to 2018; move to A-class	Assumes Stage 6 takes effect in September 2018 and the requirement changes to A-class; the market shifts according to the same mix technologies used in the June 2013 Review Study.

* Scenario 5 is intended to represent the savings scenario associated with the European Commission's proposal to delay Stage 6 at B-class by 2 years.

In Annex A to this report, six tables are presented which provide the actual calculations for these scenarios. As much as possible, these calculations follow the same methodology and use the same assumptions as the tables published in the June 2013 Review Study. This includes, for example, the operating hours, wattages, lamp lifetimes, LED lamp efficacies and natural replacement rates.

Based on this analysis, Figure 3-3 presents the cumulative electricity consumption over ten years for the nearly 2 billion sockets that will be operating mains-voltage non-directional halogen and incandescent lamps in 2016. Scenario 6 represents the Commission's proposal of a two year delay at B-class.

[25] The mix of technologies includes 75% CFLs (9W); 25% G9+adapter (40W); 25% special purpose GLS (54W); weighted average of 27W

[26] It is important to note that although the June 2013 Review Study did not contemplate an increase in label class in their 'keep Stage 6 scenario', their calculation effectively assumes A-class as they did not consider any B-class lamps in their calculations. This scenario is the closest comparable scenario to that of the June 2013 Review Study.

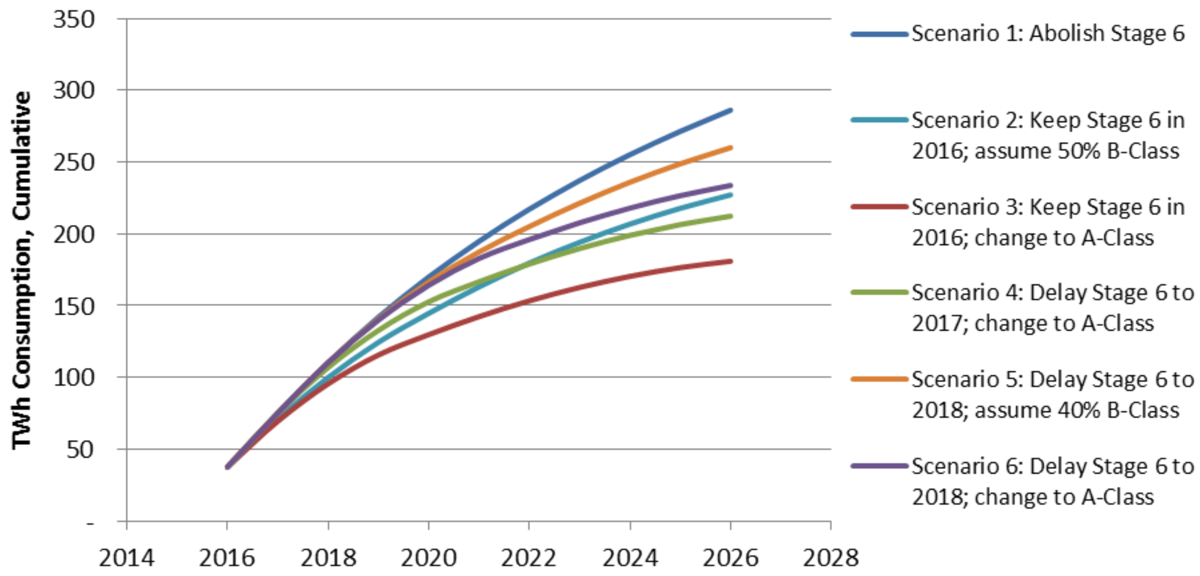

Figure 3-3. Cumulative Energy Consumption, 10 Years, Five Scenarios

The table below provides the annual electricity savings relative to Scenario 1 (i.e., abolish Stage 6). The bottom of the table sums together those annual figures, giving the cumulative electricity and CO_2 savings over the ten-year analysis period.

Table 3-5. Electricity Savings from Stage 6 Scenarios compared to Scenario 1 (SC1)

Year	SC2	SC3	SC4	SC5	SC6
	2016 & 50% B-class	**2016 & A-class**	**2017 & A-class**	**2018 & 40% B-class**	**2018 & A-class**
Units	*(TWh)*	*(TWh)*	*(TWh)*	*(TWh)*	*(TWh)*
2016	-	-	-	-	-
2017	4.2	5.7	-	-	-
2018	6.2	9.1	3.4	-	-
2019	7.1	11.5	5.8	1.2	2.0
2020	7.9	13.8	8.1	2.3	3.8
2021	6.4	12.3	10.9	3.9	6.2
2022	5.8	11.4	10.0	4.6	9.2
2023	5.5	10.7	9.3	3.8	8.3
2024	5.4	10.3	8.9	3.4	7.8
2025	5.2	10.1	8.7	3.3	7.5
2026	5.4	10.3	8.9	3.5	7.6
Total (TWh)	59.0	105.3	73.9	26.1	52.4
Total (CO_2)[27]	20.6	36.8	25.9	9.1	18.3

[27] The CO_2 emissions are presented in mega-tonnes of CO_2 savings derived from the electricity savings and using the same CO_2 intensity factor that was used in the June 2013 Review Study (i.e., 0.35 g CO_2/kWh).

Over the ten year period 2016-2026, the results of these modelling scenarios are as follows:

1. The highest level of energy consumption is SC1, which contemplates abolishing Stage 6.
2. SC2 represents a situation where B-class halogens are introduced into the European market in 2016, which roughly halves the energy savings of SC3, achieving only 59 TWh of savings.
3. The most efficient scenario is SC3 (Stage 6 in 2016 with A-class). SC3 will yield 105 TWh of electricity savings compared to SC1 over the 10 year analysis period.
4. SC4 presents the savings associated with a one year delay of Stage 6, which captures 74 TWh and thus a further 21 TWh of electricity savings compared to SC6.
5. SC5 reflects the Commission's proposal of a two year delay and B-class lamps. This is the least attractive option in terms of energy savings, with just 26 TWh, roughly half of an A-class in 2018 (SC6).
6. SC6 considers a two year delay as proposed by the Commission, however this scenario assumes shifts the market to A-class, so there are no B-class lamps in the market. Compared to SC1, this scenario results in approximately 52 TWh of electricity savings over the 10 year analysis period.

Comparing the Commission's proposal (SC5) to the regulation already in place (SC2), the two year delay at B-class will *increase* energy consumption across Europe by approximately 33 TWh over the ten-year analysis period. This represents approximately €6.6 billion Euro in higher electricity bills at an average electricity price of €0.20/kWh.

3.6 Discussion on Energy Savings Scenarios

Three of the energy saving scenarios considered in the previous section evaluate the policy option where Stage 6 is upgraded from B-class to A-class. A-class is the normal rating for CFL lamps and is the minimum class for LED lamps – most LEDs are A+ class and some are now A++.

Taken in combination with the current market information presented in section 3.4, the scenarios indicate that there is risk associated with maintaining stage 6 at a B-class level as it could result in the introduction of B-class lamps in Europe and undermine the energy savings potential of Stage 6. The following are some of the issues that policy makers may wish to consider when discussing Stage 6:

1) There is a risk of a more widespread and quick introduction of B-class halogen lamps to the European market based on sub-suppliers already capable of producing these products. B-class halogen lamps are still sold in the UK, France, Germany and elsewhere in Europe. By establishing A-class as the requirement at Stage 6, the European market will be assured of a shift toward CFL and LED technology, guaranteeing the energy savings and removing the risk to companies investing in LED products that their investments may be undermined, at least for several years.

2) Given the higher-than-expected sales of mains-voltage halogen and the persistence of incandescent lamps in the European market, the energy savings to date from the implementation of regulation EC No 244/2009 have been lower than were anticipated by the Impact Assessment. An upgrading of Stage 6 to A-class could help to off-set some of the lost energy savings experienced so far, and put Europe back on an efficient-lighting track.

3) The actual discussion in the Consultation Forum has been about whether LED lamps will be ready for Stage 6. This aspect was already evident from the material presented in the June 2013 Review Study, which focused on the readiness of LED technology. A study provided by the Danish Energy Agency in February 2014[28] showed examples of LED lamps which are available for nearly all original non-directional GLS and halogen applications. A testing study provided by the Swedish government in November 2014[29] has independently verified the quality and performance of many LED lamps available in today's European market, and life-testing is ongoing. Due to the fact that today's LED technology easily achieves A-class (most are A+ and some A++), Stage 6 would be stronger and more appropriate if it was set at A-class. It would provide more certainty to manufacturers and retailers, and eliminate the risk of a B-class product introduction. This upgrading of Stage 6 would also be consistent with Recital 20 from EC No 244/2009 which suggested that the Commission's review of the regulation in 2014 should consider "the development of new technologies such as LEDs and of the feasibility of establishing energy efficiency requirements at the 'A' class level."

4) Chapter 2 of this study shows that LED lamp prices are now decreasing to a much more affordable level, offering consumers very short payback periods followed by years of savings.

[28] Availability of non-directional LED replacement lamps, Energy piano and ÅF Lighting, 2014-02-27, Study done for Danish Energy Agency.

[29] Test Report – Clear, Non-Directional LED Lamps: 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. By: Swedish Energy Agency, Belgian Federal Ministry for Health, Food Chain Safety and Environment, CLASP and eceee, 19 November 2014 Hyperlink to PDF of report

4 Dimmer Compatibility and Consumer Acceptance in Europe

4.1 Dimmers in Europe

The idea that many dimmers and controls designed for incandescent lamps don't function for LED and CFL lamps is often mentioned as a potential barrier to greater LED market penetration in Europe. To quantify this barrier, the IEE PremiumLight project conducted a comprehensive market survey in 2012 which included detailed mapping of dimmers and controls in the different rooms of the home.[30] Twelve European countries participated, representative of 80% of the households across the EU. The survey was limited to answers from a statistical sample of 500 households in each country.

The survey found that there is a very limited use of controls in European households, as indicated by these findings:

- 55% have no dimmers and 30% have 1-2 dimmers;
- 85% use no movement sensors for automatic control and 10% have 1-2 sensors; and
- 65% use no outdoor daylight sensors for automatic control and 25% have 1-2 sensors.

Below is shown the distribution for each country on numbers of dimmers, the number of households per country, and the calculation used to determine the total distribution for all 12 countries.

Table 4-1. PremiumLight mapping of use of dimmers in 12 EU countries which together cover 80% of the households in EU

	Austria	Czech Republic	Denmark	Finland	France	Germany	Italy	Latvia	Portugal	Spain	Sweden	UK	
None	48%	73%	49%	63%	63%	48%	63%	64%	69%	64%	43%	54%	
1 - 2	39%	22%	34%	30%	27%	42%	29%	16%	24%	25%	37%	32%	
3 - 4	11%	4%	10%	5%	5%	8%	6%	4%	5%	7%	14%	12%	
5 - 6	1%	1%	3%	1%	2%	2%	1%	2%	1%	2%	4%	1%	
7 or more	1%	0%	2%	1%	2%	1%	1%	1%	1%	1%	3%	1%	
Answers	*495*	*493*	*1000*	*490*	*482*	*505*	*480*	*500*	*498*	*483*	*489*	*476*	
Household mio	3,7	4,4	2,6	2,7	33,6	40,5	28,9	0,9	3,9	17,2	5	26,5	**169,9**

Dimmers	Austria	Czech Republic	Denmark	Finland	France	Germany	Italy	Latvia	Portugal	Spain	Sweden	UK	TOTAL
1,5	2.152.727	1.459.229	1.341.813	1.198.469	13.802.490	25.262.376	12.372.813	215.600	1.397.892	6.570.186	2.776.074	12.860.294	81.409.963
3,5	1.438.889	655.984	949.025	501.429	6.343.568	11.789.109	6.532.604	117.725	657.831	4.486.957	2.433.538	10.716.912	46.623.570
5,5	246.667	196.349	473.879	181.837	4.217.427	3.969.802	1.986.875	121.115	172.289	2.154.451	1.012.270	1.837.185	16.570.146
10	224.242	89.249	430.799	275.510	5.576.763	2.405.941	3.010.417	111.668	391.566	1.068.323	1.329.243	1.670.168	16.583.891
TOTAL	4.062.525	2.400.811	3.195.517	2.157.245	29.940.249	43.427.228	23.902.708	566.108	2.619.578	14.279.917	7.551.125	27.084.559	**161.187.570**

According to Eurostat, the EU has approximately 199 million households. A simple scale-up calculation from the 170 million households represented in the PremiumLight survey (the 12 countries) to all EU gives a total use of 188 million dimmers in EU, and an average use of 0.95 dimmers per household.

Thus, it appears that the incompatibility of LED and CFL lamps with dimmers and controls designed for incandescent lamps is a limited problem, as many LED lamps are compatible with dimmers and it is only a fraction of these consumers who may have to replace their dimmer(s) with a new dimmer when they shift from using tungsten filament lamps to LED or CFL.

4.2 How large is the dimmer compatibility barrier in Europe?

This is an issue that requires further research, however it is already clear that there are LED lamps which will operate correctly on the most common types of dimmers found in Europe today. In the

[30] Assessment of the initial situation in the participating countries, PremiumLight, IEE/11/941/SI2.615944, Casper Kofod, Energy piano, 2013-06-30

Swedish testing study[31], LED lamps that were labelled as 'dimmable' were procured and tested. These LED lamps were tested on both a leading edge dimmer (ELKO 400GLI) and a trailing edge dimmer (ELKO 315GLE). Although these two dimmers do not represent all dimmers in Europe, they do represent two of the most common types found in the market. The table below presents the compatibility findings of these lamp / dimmer combinations.

Table 4-1. Dimmer Compatibility Check for Five "dimmable" LED Lamps

Lamp	Description	Leading Edge (ELKO 400GLI)	Trailing Edge (ELKO 315GLE)
#5	LED Connection "Classic LED bulb"	No	Yes
#6	IKEA "LEDARE" / 602.553.62	Yes	Yes
#13	Star Trading LED filament lampa candelabra shape	Yes	Yes
#14	Osram PARATHOM Classic A ADV 10W 827	Yes	No
#15	Philips "Clear LED bulb" - GLS 6W A60 827 Clear	Yes	No

IEC and CENELEC are both looking into standardisation for LED dimming and other controls, but members of the Committees have indicated that this could take years due to intellectual property issues associated with the various dimming approaches used in the circuits.

One solution to the compatibility issue that is being developed at this time involves the introduction of 'adaptive circuit' detection systems that enable LED lamps to determine what type of dimming circuit is installed, and to operate correctly in that application. In other words, the question of whether LED lamps are compatible with the existing dimmer stock has to do with the quality of the dimmer circuit used in the LED lamp. Manufacturers of LEDs can therefore choose to install intelligent LED drivers which can detect and adapt to an installed dimmer. Such Integrated Circuit (IC) solutions have been promoted by companies like Cirrus Logic, Marvell and iWatt since early 2012 [32,33]. These dimmable drivers were (and are) programmed to recognise the characteristics of the connected dimmer and select a compatible operating mode. It may be worth considering a requirement on manufacturers who market their products as "dimmable" to incorporate intelligent adaptive LED drivers.

4.3 US testing of Dimmer Characteristics of 14 LED A lamps and 4 dimmers

The question of LEDs being compatible on household dimmers has also been investigated in the United States, with positive findings for LED lamps. The US Department of Energy published a CALiPER report (Dec. 2014)[34] that focused on testing 14 LED A-type lamps operating on four different phase-cut dimmers.

[31] Test Report – Clear, Non-Directional LED Lamps: 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; and eceee, 19 November 2014

[32] Marvell and iWatt: http://www.ledsmagazine.com/articles/2012/02/marvell-headlines-led-driver-ic-exhibits-at-sil.html

[33] Cirrus Logic: http://www.ledsmagazine.com/articles/2012/03/cirrus-logic-enters-led-driver-ic-market-linear-tech-and-power-integration-announcements.html

[34] CALiPER Retail Study 3.1: Dimming, Flicker, and Power Quality Characteristics of LED A lamps, Dec 2014 http://energy.gov/sites/prod/files/2015/01/f19/caliper_retail-study_3-1.pdf

The DOE study discusses many of the known compatibility issues between LED lamps and phase-cut dimmers, including induced or increased flicker, but found these only present themselves in certain circumstances. The report concludes:

- The use of phase-cut dimmers will change the performance of any type of lighting system—even when the dimmer is set to full output. This variation was more significant at lower control settings than at higher settings for all four evaluated dimmers. LED lamps tended to have higher relative light output compared to the incandescent and halogen benchmarks at the same dimmer output signal.
- The choice of dimmer can make a difference. The minimum output light level achieved by a phase-cut dimmed LED lamp is a function of both the lamp's capability and its impact on the dimmer being used to control it. Consumers (and specifiers) may have a hard time distinguishing better-performing lamps from one another; at this time, physical experimentation is likely the best evaluation tool.
- Change in performance is less predictable when dimming LED lamps than when dimming incandescent lamps. The ability of LED lamps to maintain their efficacy while dimming represents their most substantial performance advantage over incandescent lamps.

Annex A. Electricity Consumption Scenarios Reported in Chapter 3

As discussed in Chapter 3, these scenarios were designed to be as similar as possible to those that were prepared by VHK/VITO in their June 2013 Review Study that was published by the Commission. Thus, these scenarios use the same assumptions for:

- Lamp lifetime
- Operating hours
- Efficacy progression of LED
- Lamp substitution technologies and proportional mix of technologies selected by consumers when replacing a halogen lamp
- CO_2 emissions factor

The table below provides a summary of the six scenarios considered.

Table A-1. Description of Energy Saving Scenarios Considered in this Paper

Scenario	Short Title	Description
SC1	Abolish Stage 6	Assumes Stage 6 is abolished and no further regulatory action taken to advance the market for energy-efficient non-directional household lamps. Market evolves gradually to LED over time.
SC2	Keep Stage 6; keep B-class	Assumes Stage 6 takes effect in September 2016 and 50% of replacement sockets switch to B-class halogens. The other 50% is apportioned between CFL/alternatives (using the same proportions as in the June 2013 Review Study[35]) and LED lamps.
SC3	Keep Stage 6, move to A-class	Assumes Stage 6 takes effect in September 2016 and the minimum requirement changes to A-class. The market shifts according to the same CFL/alternatives technology mix as in the June 2013 Review Study.[36]
SC4	Delay Stage 6 to 2017; move to A-class	Assumes Stage 6 is delayed one year to September 2017 and the requirement changes to A-class; the market shifts according to the same mix technologies used in the June 2013 Review Study.
SC5*	Delay Stage 6 to 2018; keep B-class	Assumes Stage 6 takes effect in September 2018 and 40% of replacement sockets switch to B-class halogens. The other 60% is apportioned between CFL/alternatives (using the same proportions as in the June 2013 Review Study) and LED lamps.
SC6	Delay Stage 6 to 2018; move to A-class	Assumes Stage 6 takes effect in September 2018 and the requirement changes to A-class; the market shifts according to the same mix technologies used in the June 2013 Review Study.

* Scenario 5 is intended to represent the savings scenario associated with the European Commission's proposal to delay Stage 6 at B-class by 2 years.

The following tables presents the electricity consumption from the six different Stage 6 scenarios for each of the years shown.

[35] The mix of technologies includes 75% CFLs (9W); 25% G9+adapter (40W); 25% special purpose GLS (54W); weighted average of 27W

[36] It is important to note that although the June 2013 Review Study did not contemplate an increase in label class in their 'keep Stage 6 scenario', their calculation effectively assumes A-class as they did not consider any B-class lamps in their calculations. This scenario is the closest comparable scenario to that of the June 2013 Review Study.

Table A-2. Electricity Consumption from Stage 6 Scenarios, 2016-2026

Year	SC1	SC2	SC3	SC4	SC5	SC6
	Abolish Stage 6	**2016 & 50% B-class**	**2016 & A-class**	**2017 & A-class**	**2018 & 40% B-class**	**2018 & A-class**
Units	*(TWh)*	*(TWh)*	*(TWh)*	*(TWh)*	*(TWh)*	*(TWh)*
2016	37.6	37.6	37.6	37.6	37.6	37.6
2017	37.5	33.3	31.9	37.5	37.5	37.5
2018	35.1	28.9	26.0	31.7	35.1	35.1
2019	31.7	24.6	20.1	25.9	30.4	29.7
2020	28.0	20.2	14.2	19.9	25.7	24.2
2021	24.9	18.5	12.6	14.0	21.0	18.7
2022	22.4	16.6	11.0	12.4	17.7	13.2
2023	20.0	14.5	9.4	10.8	16.3	11.7
2024	18.0	12.7	7.7	9.1	14.6	10.2
2025	16.2	11.0	6.1	7.5	12.9	8.7
2026	14.8	9.4	4.4	5.9	11.3	7.2
Total (TWh)	286.2	227.3	181.0	212.4	260.1	233.8
Total (CO_2)[37]	100.2	79.5	63.3	74.3	91.1	81.8

For a summary of the energy savings estimates comparing Scenarios 2 through 6 to Scenario 1, please see Table 3-5 in Section 3.5 of this report.

In the tables that follow, the numerical results of each of these six scenarios is presented.

Table A-3. Scenario 1. Abolish Stage 6, Allow Market to Evolve Naturally (Business as Usual)

Year	MV-HL Stock	Other retro stock	LED retro stock	LED retro sales	LED power at sales (at 500 lm)	MV-HL stock energy use (at 36W)	Other retro stock energy use (at 27W)	LED retro stock energy use	Total
	(m units)	*(m units)*	*(m units)*	*(m units)*	*W*	*TWh/yr*	*TWh/yr*	*TWh/yr*	*TWh/yr*
2016	1,991	-	-	-	-	37.6	-	-	37.6
2017	1,986	-	6	6	5.1	37.5	-	0.0	37.5
2018	1,837	-	154	149	4.7	34.7	-	0.4	35.1
2019	1,629	-	363	209	4.5	30.8	-	0.9	31.7
2020	1,411	-	580	217	4.2	26.7	-	1.4	28.0
2021	1,224	-	767	187	4.0	23.1	-	1.7	24.9
2022	1,074	-	917	150	3.9	20.3	-	2.1	22.4
2023	937	-	1,054	137	3.7	17.7	-	2.3	20.0
2024	818	-	1,173	119	3.6	15.5	-	2.5	18.0
2025	713	-	1,279	105	3.5	13.5	-	2.7	16.2
2026	629	-	1,362	84	3.4	11.9	-	2.9	14.8

[37] The CO_2 emissions are presented in mega-tonnes of CO_2 savings derived from the electricity savings and using the same CO_2 intensity factor that was used in the June 2013 Review Study (i.e., 0.35 g CO_2/kWh).

Table A-4. Scenario 2. Keep Stage 6 in 2016; Assume 50% Market Shift to B-class

Year	MV-HL Stock	HAL-B retro stock	Other retro stock	LED retro stock	LED retro sales	LED power at sales (at 500 lm)	MV-HL stock energy use (at 36W)	HAL-B retro stock energy use	Other retro stock energy use (at 27W)	LED retro stock energy use	Total
	(m units)	*(m units)*	*(m units)*	*(m units)*	*(m units)*	*W*	*TWh/yr*	*TWh/yr*	*TWh/yr*	*TWh/yr*	*TWh/yr*
2016	1,991	-	-	-	-	-	37.6	-	-	-	37.6
2017	1,494	249	100	149	149	5.1	28.2	3.3	1.4	0.4	33.3
2018	996	498	199	299	149	4.7	18.8	6.5	2.8	0.8	28.9
2019	498	747	299	448	149	4.5	9.4	9.8	4.2	1.1	24.6
2020	-	996	398	597	149	4.2	-	13.1	5.6	1.5	20.2
2021	-	919	332	741	143	4.0	-	12.1	4.7	1.8	18.5
2022	-	814	266	911	171	3.9	-	10.7	3.8	2.1	16.6
2023	-	706	199	1,086	175	3.7	-	9.3	2.8	2.4	14.5
2024	-	612	133	1,246	160	3.6	-	8.0	1.9	2.7	12.7
2025	-	537	66	1,388	141	3.5	-	7.0	0.9	3.0	11.0
2026	-	469	-	1,522	135	3.4	-	6.2	-	3.2	9.4

Table A-5. Scenario 3. Keep Stage 6 in 2016; Increase Requirement to A-class

Year	MV-HL Stock	Other retro stock	LED retro stock	LED retro sales	LED power at sales (at 500 lm)	MV-HL stock energy use (at 36W)	Other retro stock energy use (at 27W)	LED retro stock energy use	Total
	(m units)	*(m units)*	*(m units)*	*(m units)*	*W*	*TWh/yr*	*TWh/yr*	*TWh/yr*	*TWh/yr*
2016	1,991	-	-	-	-	37.6	-	-	37.6
2017	1,494	199	299	299	5.1	28.2	2.8	0.8	31.9
2018	996	398	597	299	4.7	18.8	5.6	1.5	26.0
2019	498	597	896	299	4.5	9.4	8.5	2.2	20.1
2020	-	797	1,195	299	4.2	-	11.3	2.9	14.2
2021	-	664	1,328	133	4.0	-	9.4	3.2	12.6
2022	-	531	1,460	133	3.9	-	7.5	3.5	11.0
2023	-	398	1,593	133	3.7	-	5.6	3.7	9.4
2024	-	266	1,726	133	3.6	-	3.8	4.0	7.7
2025	-	133	1,859	133	3.5	-	1.9	4.2	6.1
2026	-	-	1,991	133	3.4	-	-	4.4	4.4

Table A-6. Scenario 4. Delay Stage 6 to 2017; Increase Requirement to A-class

Year	MV-HL Stock	Other retro stock	LED retro stock	LED retro sales	LED power at sales (at 500 lm)	MV-HL stock energy use (at 36W)	Other retro stock energy use (at 27W)	LED retro stock energy use	Total
	(m units)	*(m units)*	*(m units)*	*(m units)*	*W*	*TWh/yr*	*TWh/yr*	*TWh/yr*	*TWh/yr*
2016	1,991	-	-	-	-	37.6	-	-	37.6
2017	1,986	-	6	6	5.1	37.5	-	0.0	37.5
2018	1,489	199	303	298	4.7	28.2	2.8	0.7	31.7
2019	993	397	601	298	4.5	18.8	5.6	1.5	25.9
2020	496	596	899	298	4.2	9.4	8.4	2.1	19.9
2021	-	794	1,197	298	4.0	-	11.3	2.7	14.0
2022	-	662	1,329	132	3.9	-	9.4	3.0	12.4
2023	-	530	1,462	132	3.7	-	7.5	3.3	10.8
2024	-	397	1,594	132	3.6	-	5.6	3.5	9.1
2025	-	265	1,727	132	3.5	-	3.8	3.8	7.5
2026	-	132	1,859	132	3.4	-	1.9	4.0	5.9

Table A-7. Scenario 5. Delay Stage 6 in 2018; Assume 40% Market Shift to B-class

Year	MV-HL Stock	HAL-B retro stock	Other retro stock	LED retro stock	LED retro sales	LED power at sales (at 500 lm)	MV-HL stock energy use (at 36W)	HAL-B retro stock energy use	Other retro stock energy use (at 27W)	LED retro stock energy use	Total
	(m units)	*(m units)*	*(m units)*	*(m units)*	*(m units)*	*W*	*TWh/yr*	*TWh/yr*	*TWh/yr*	*TWh/yr*	*TWh/yr*
2016	1,991	-	-	-	-	-	37.6	-	-	-	37.6
2017	1,986	-	-	6	6	5.1	37.5	-	-	0.0	37.5
2018	1,837	-	-	154	149	4.7	34.7	-	-	0.4	35.1
2019	1,339	199	119	334	179	4.5	25.3	2.6	1.7	0.8	30.4
2020	841	398	239	513	179	4.2	15.9	5.2	3.4	1.2	25.7
2021	343	597	358	692	179	4.0	6.5	7.8	5.1	1.6	21.0
2022	-	735	441	816	124	3.9	-	9.6	6.2	1.8	17.7
2023	-	678	375	939	123	3.7	-	8.9	5.3	2.1	16.3
2024	-	601	308	1,082	143	3.6	-	7.9	4.4	2.3	14.6
2025	-	521	242	1,229	147	3.5	-	6.8	3.4	2.6	12.9
2026	-	452	175	1,364	135	3.4	-	5.9	2.5	2.9	11.3

Table A-8. Scenario 6. Delay Stage 6 to 2018; Increase Requirement to A-class

Year	MV-HL Stock	Other retro stock	LED retro stock	LED retro sales	LED power at sales (at 500 lm)	MV-HL stock energy use (at 36W)	Other retro stock energy use (at 27W)	LED retro stock energy use	Total
	(m units)	*(m units)*	*(m units)*	*(m units)*	*W*	*TWh/yr*	*TWh/yr*	*TWh/yr*	*TWh/yr*
2016	1,991	-	-	-	-	37.6	-	-	37.6
2017	1,986	-	6	6	5.1	37.5	-	0.0	37.5
2018	1,837	-	154	149	4.7	34.7	-	0.4	35.1
2019	1,378	184	430	276	4.5	26.0	2.6	1.0	29.7
2020	919	367	705	276	4.2	17.4	5.2	1.6	24.2
2021	459	551	981	276	4.0	8.7	7.8	2.2	18.7
2022	-	735	1,257	276	3.9	-	10.4	2.8	13.2
2023	-	612	1,379	122	3.7	-	8.7	3.0	11.7
2024	-	490	1,502	122	3.6	-	6.9	3.3	10.2
2025	-	367	1,624	122	3.5	-	5.2	3.5	8.7
2026	-	245	1,746	122	3.4	-	3.5	3.7	7.2

Annex B. Explanation for Use of GfK Data over draft VHK Model

In Chapter 3 of this paper, a new energy savings estimate is presented which quantifies the energy savings potential of Stage 6 under a number of different scenarios. These scenarios are based on a recent IEA 4E Mapping and Benchmarking report on general illumination light sources in Europe. This IEA 4E report provides GfK sales data for 7 major European countries, with slightly less than 50% of the market captured. It was decided to use the data from the IEA report instead of that published in the draft Task 2 Preparatory Study report[38] for the following reasons:

1) The Task 2 Preparatory Study report presents draft shipment estimates which may be revised, while the IEA 4E is a Final Report and is not subject to further revision. This fact gives preference to the GfK data because it is not at risk of change. If the draft Task 2 Preparatory Study projections were to be revised, that would directly impact the estimates of energy consumption presented in this paper. For example, an initial comparison between the Task 2 Preparatory Study shipments and that of the GfK data scaled up to the full EU market found some differences for CFL and halogen lamp sales. On average, over the 7 years of sales data reported by GfK, the draft Task 2 shipment estimates over-reported integrally-ballasted CFLs by 123% while mains-voltage halogen lamps were under-reported by 6%, with highly volatile shipment estimates ranging from -58% to +42%. The table below shows the year-by-year comparison. This issue will require further discussion and understanding through the Preparatory Study review process, and thus the numbers presented in the draft Task 2 report may change over time.

Table B-1. Comparison of Shipments between GfK-based Estimates & Draft Task 2 Report

Year	VHK/VITO		GfK* (IEA 4E Report)		VHK to GfK Percent	
	CFLi	MV HAL	CFLi	MV HAL	CFLi	MV HAL
Units	*million units*	*million units*	*million units*	*million units*	*percent*	*percent*
2007	420	27	148	65	+184%	-58%
2008	467	81	175	76	+167%	+7%
2009	506	141	222	99	+128%	+42%
2010	480	172	251	141	+91%	+22%
2011	431	196	208	199	+107%	-2%
2012	345	244	159	287	+117%	-15%
2013	271	303	144	376	+88%	-19%
				Total:	+123%	-6%

*Note: GfK data presented in this table has been scaled up to represent the full European population, and the MV Halogen column has been adjusted to remove directional mains voltage halogen lamps (i.e., 33% of shipments).

2) The IEA 4E Mapping and Benchmarking report offers actual sales data spanning the 2007 to 2013 time period for a large proportion of the European Market. It also tends to represent the consumer market very well, capturing information at the point of sale in supermarkets, hardware stores, large national chains and so-on, where consumers will typically purchase lamps. For the domestic non-directional household lamp regulation, this is an advantage and ensures the data offers good representation.

[38] Preparatory Study on Light Sources for Ecodesign and/or Energy Labelling Requirements ('Lot 8/9/19'); Draft Interim Report, Task 2; Markets, Prepared by VHK, in cooperation with VITO and JeffCott Associates; 19 Nov 2014

Annex C. Information on LED Lamp Price Analysis

As discussed in Chapter 2, the LED Lamp Price Analysis is based on lamps that were tested as part of the Premium Light programme, the Austrian government or the Danish Technical University. The reason for this is to have more confidence in the calculated Euro price per 500 lumens.

Table C.1 Manufacturers, Models and Prices used in the Lamp Price Analysis

#	Manufacturer	Model	Lumen measured at lab	Price including VAT		Euro	Euro per 500 lm	Web
1	GE LED	Energy Smart	660	Euro	11.85	€ 11.85	€ 8.98	Web link
2	Luxinia LED	SunFlux 11W	828	DKR	199.00	€ 26.50	€ 16.00	Web link
3	Osram	10W	874	DKR	79.95	€ 10.74	€ 6.14	Web link
4	Osram	6W dimmable	493	DKR	99.95	€ 13.43	€ 13.62	Web link
5	Panasonic	LDAHV10L27CGEP	895	DKR	179.00	€ 24.05	€ 13.44	Web link
6	Posco LED	9W	715	£	3.75	€ 5.02	€ 3.51	Web link
7	Verbatim	4W	260	Euro	6.38	€ 6.38	€ 12.27	Web link
8	Ikea	Ledare 10 W	597	DKR	49.00	€ 6.58	€ 5.51	Web link
9	Megaman	10 W	696	DKR	169.00	€ 22.70	€ 16.31	Web link
10	Soft LED	LED Glühfaden Birne 6W	673	Euro	9.99	€ 9.99	€ 7.39	Web link
11	Megaman	LED Classic MM21048 16,5W	1665	Euro	27.75	€ 27.75	€ 8,33	Web link
12	Verbatim	LED Classic 9,5W	860	DKR	69.00	€ 9.27	€ 5.39	Web link
13	Osram	LED Superstar Classic A 60; 10W dimmable	880	Euro	8.39	€ 8.39	€ 4.77	Web link
14	Philips	LED bulb 13 W	1076	DKR	101.00	€ 13.47	€ 6.25	Web link
15	XAVAX	LED Lampe 11W dimmable	794	Euro	14.95	€ 14.95	€ 9.41	Web link
16	Philips	Master LEDbulb 12W	768	Euro	11.00	€ 11.00	€ 7.16	Web link
17	OSRAM	Osram LED Star Classic B 4W	264	DKR	85.00	€ 11.42	€ 21.63	Web link
18	IKEA	Ledare 1000 lm dimmable	1032	DKR	75.00	€ 10.00	€ 4.84	Web link
19	IKEA	LEDARE Globe dimmable	1026	DKR	89.00	€ 11.86	€ 5.78	Web link

Table C.2 Test Results of Lamps Presented in Price Analysis (1 of 4)

Manufacturer	GE	Luxinia	Osram	Osram
Product	Energy Smart 10W	SunFlux 11W	10W	6W
Socket	E27	E27	E27	E14
Measured flux [lm]	660	828	874	493
Rated flux [lm]	700	900	806	470
Measured effect [W]	9.0	11.3	10.3	6.2
Rated effect [W]	10.0	11.0	10.0	6.0
Measured efficacy [lm/W]	73	73	85	80
Rated efficacy [lm/W]	70	82	81	78
Measured colour temperature [K]	2705	2653	2713	2795
Rated colour temperature [K]	2700	2600	2700	2700
Measured colour rendering [Ra]	81	95	80	81
Rated colour rendering [Ra]	81	90	80	80
Relation between measured and rated <10%	OK	OK	OK	OK
Lifetime [hours] (rated)	25000	26000	20000	20000
Min. number of on/off cycles (rated)	25000	NA	100000	100000
Local currency	Euro	DKR	DKR	DKR
Price Jan 2015 incl. VAT	11.85	199	79.95	99.95
Price in EURO Jan 2015 incl. VAT	11.85	26.50	10.74	13.43
EURO/500 lm	9.0	16.0	6.1	13.6

Table C.3 Test Results of Lamps Presented in Price Analysis (2 of 4)

Manufacturer	Panasonic	Posco	Verbatim	IKEA	Megaman
Products	LDAHV10 L27CGEP	9W	4W	Ledare 10W	10W
Socket	E27	E27	E14	E27	E27
Measured flux [lm]	895	715	260	597	696
Rated flux [lm]	806	680	250	600	650
Measured effect [W]	10.5	9.2	3.9	10.0	10.2
Rated effect [W]	10.0	9.0	4.0	10.0	10.0
Measured efficacy [lm/W]	86	78	67	58	68
Rated efficacy [lm/W]	80	75	63	60	65
Measured colour temperature [K]	2719	3041	2768	2663	2916
Rated colour temperature [K]	2700	3000	2700	2700	2800
Measured colour rendering [Ra]	79	83	82	92	78
Rated colour rendering [Ra]	80	80	80	87	80
Relation between measured and rated <10%	OK	OK	OK	OK	OK
Lifetime [hours] (rated)	25000	40000	25000	25000	25000
Min. number of on/off cycles (rated)	100000	NA	NA	40000	1000000
Local currency	DKR	£	Euro	DKR	DKR
Price Jan 2015 incl. VAT	179	3.75	6.38	49	169
Price in EURO Jan 2015 incl. VAT	24.05	5.02	6.38	6.58	22.7
EURO/500 lm	13.4	3.5	12.3	5.5	16.3

Table C.4 Test Results of Lamps Presented in Price Analysis (3 of 4)

Manufacturer	Soft LED	Megaman	Verbatim	Osram	Philips
Product	LED Glühfaden Birne 6W	LED Classic MM21048 16,5W	LED Classic 9,5W	LED 10W Superstar Classic A 60	LED bulb 13W
Socket	E27	E27	E27	E27	E27
Equivalent GLS lamp	50	100	60	60	75
Measured colour temperature [K]	2790	2710	2977	2627	2723
Rated colour temperature [K]	2700	2800	3000	2700	2700
Measured flux [lm]	673	1665	888	880	1076
Rated flux [lm]	650	1521	860	810	1055
Measured effect [W]	6.1	16.1	9.5	9.8	13.1
Rated effect [W]	6.0	16.5	9.5	10.0	13.0
Measured efficacy [lm/W]	110	104	93	90	82
Rated efficacy [lm/W]	108	92	91	81	81
Rating: Efficacy	Very good	Very good	Very good	Very good	Very good
Measured CRI [Ra]	89	81	81	80	82
Rated CRI [Ra]	85	80	80	80	80
Rating: CRI	Good	Standard	Standard	Standard	Standard
<10% (acceptable tolerance)	OK	OK	OK	OK	OK
Effect factor	0.69	0.88	0.93	0.95	0.83
Rated lifetime [hours]	30,000	30,000	25,000	25,000	25,000
Min. number of on/off cycles (rated)	NA	50,000	50,000	1,000,000	1,000,000
Local currency	Euro	Euro	DKR	Euro	DKR
Price Jan 2015 incl. VAT	9.95	32.35	69	8.39	119
Price in Euro incl. VAT	9.95	32.35	9.27	8.39	15.99
EURO/500 lm	7.4	9.7	5.2	4.8	7.4

Table C.5 Test Results of Lamps Presented in Price Analysis (4 of 4)

Manufacturer	XAVAX	Philips	OSRAM	IKEA	IKEA
Product	LED Lampe 11W	Master LED bulb 12W	Osram LED Star Classic B 4W	LEDARE	LEDARE Circular shape
Socket	E27	E27	E14	E27	E27
Equivalent GLS lamp	60	60	25	75	75
Measured colour temperature [K]	2713	2703	2773	2676	2657
Rated colour temperature [K]	2700	2700	2700	2700	2700
Measured flux [lm]	794	768	264	1,032	1,026
Rated flux [lm]	806	806	250	1000	1000
Measured effect [W]	10.3	11.1	4.0	12.6	15.9
Rated effect [W]	11	12	4	13	16
Measured efficacy [lm/W]	77	69	66	81.7	64.7
Rated efficacy [lm/W]	73	67	63	76	63
Rating: Efficacy	Good	Good	Good	Good	Good
Measured CRI [Ra]	82	85	82	90.4	91.3
Rated CRI [Ra]	80	80	80	>87	>87
Rating: CRI	Standard	Good	Standard	Very good	Very good
<10% (acceptable tolerance)	OK	OK	OK	OK	OK
Effect factor	0.48	0.91	0.45	0.94	0.95
Rated lifetime [hours]	25,000	NA	25,000	NA	NA
Min. number of on/off cycles (rated)	1,000,000	NA	NA	NA	NA
Local currency	Euro	Euro	DKR	DKR	DKR
Price Jan 2015 incl. VAT	14.95	12.10	85	75	75
Price in Euro incl. VAT	14.95	12.10	11.42	10	10
EURO/500 lm	9.41	7.88	21.63	4.84	4.87