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10 years anniversary - phase out of incandescent lightbulbs: How has the Ecodesign lighting regulation helped consumers save money over time?

Technical report on behalf of BEUC / ANEC

Freiburg, 17.07.2019

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Table of Contents

List of Figures

List of Tables

1. Introduction

ANEC and BEUC lead a European consortium project to ensure consumer interests representation in the implementation of the Energy Labelling Directive (2010/30/EU) as well as of the Directive on Ecodesign of Energy-Related Products (2009/125/EC), aiming at improving their energy performance and reducing other adverse environmental impacts of these products. The main goal for ANEC and BEUC is to allow a simple and reliable choice for consumers when buying products which consume less energy and are better for the environment.

Under the Ecodesign Directive, inefficient incandescent light bulbs have progressively been phased out over the years, leading the way to more efficient LEDs. As the first phase out started in 2009, this year marks the 10 years anniversary of this technology change.

ANEC and BEUC wish to assess and demonstrate the financial impact of the Ecodesign lighting regulation on consumers over time.

Against this background, Oeko-Institut carried out this project and hereby submits the results.

2. Aim of the study

The aim of the study was to

- Quantify the net economic effects of this phase out for a typical European household.
- Mention and explain other advantages or disadvantages linked to the phase out for consumers (e.g. potential premature failure of LEDs).

3. Methodological approach

3.1. Definition of reference household

The calculation of the savings due to the eco-design measures on household lamps was done on the basis of a fictitious household with three persons, a couple with one child. It was assumed that this household is equipped with 45 lamps[1]. The same illustrative example was already used before in (Smith et al. 2016) to demonstrate the benefits of eco-design in general for EU households. For further background concerning the choice of this specific household type see (Smith et al. 2016).

The following data for the starting point of the scenarios - the situation just before the implementation of the first tier of the eco-design requirements for non-directional household lamps (Commission Regulation (EC) No 244/2009) on 1.9.2009 - and the reference scenario were derived from (VITO NV 2009):

- Share of different wattages of incandescent lamps in European households: 1 % 120-140 W, 7 % 100 Watt; 6 % 75 Watt; 35 % 60 Watt; 1 % 50 Watt; 40 % 40 Watt; 9 % 25 Watt, 1 % 15-20 Watt.

[1] Compared with the data on the typical equipment of European households with lamps shown in (VITO NV 2009), the assumption of 45 lamps in a 3-person household is relatively high. In (VITO NV 2009) a stock of 24,34 lighting points unidirectional lamps and 5,2 directional lamps per household in 2007

- Share of frosted versus clear lamps in European households: 71 % frosted and 29 % clear lamps.

For the operating hours it was assumed that the lamps are used averagely 450 hours per year (European Commission 2015). In contrast to scenario 1 and 2, in scenario 3 an operating time of 500 hours per year was assumed for the LED lamps in order to take into account possible rebound effects of about 10 %[2]. This assumption is in accordance with (European Commission 2015).

Against this background the 45 lamps in the reference household were defined as shown in Table 3-1. In contrast to the share of incandescent lamps shown above, 5 directional halogen lamps of 50 Watt were defined for the considered household (instead of 5 clear lamps of 60 Watt for general purpose lighting).

Table 3-1: Definition of the lamp equipment of the reference household

Wattages incandescent lamps	Number of frosted lamps	Number of clear lamps	Operation hours [hours/year]
100	2	1	450
75	2	1	450
60	11	0	450
50	1	5*	450
40	13	5	450
25	3	1	450
Total	**32**	**13**	450

Source: Own derivation on the basis of (VITO NV 2009)

*directional halogen lamps

3.2. Definition of four scenarios

Four scenarios were considered in the calculation:

- Scenario 1: No regulation
- Scenario 2: Early adopters Halogen
- Scenario 3: Early adopters LED
- Scenario 4: Halogen => LED

The following regulations were taken into account:

- COMMISSION REGULATION (EC) No 244/2009 (European Commission 18.03.2009)
- COMMISSION DELEGATED REGULATION (EU) No 874/2012 (European Commission 12.07.2012)
- COMMISSION REGULATION (EU) No 1194/2012 (European Commission 12.12.2012)

[2] The rebound effect in this case results from the tendency of consumers to increase lamp operating time when lamps are more energy efficient and to increase lamp luminosity, see e.g. Schleich, J., et al., A brighter future? Quantifying the rebound effect in energy efficient lighting. Energy Policy (2014), http://dx.doi.org/10.1016/j.enpol.2014.04.028

The timelines of the outphasing were the following:

Table 3-2: Overview of the timeline of the outphasing of incandescent lamps and halogen lamps with low efficiency (energy efficiency class D and E) differentiated by wattage

Wattage	frosted	clear
100	**01.09.2009**	**01.09.2009**
75	**01.09.2009**	**01.09.2010**
60	**01.09.2009**	**01.09.2011**
40	**01.09.2009**	**01.09.2012**
25	**01.09.2009**	**01.09.2012**

Source: Own composition based on (European Commission 18.03.2009)

Additionally from the 01.09.2018 halogen lamps of energy efficiency class C were outphased.

For directional lighting (e.g. reflector lamps) on the 01.09.2019 energy efficiency class E[3] and on the 01.09.2016 energy efficiency class C lamps were phased out.

3.2.1. Scenario 1: No regulation

In scenario 1 it is assumed that no regulation on the efficiency of lighting was ever adopted. The equipment of the reference household stayed the same between 2009 and 2019. The same is assumed for operating hours.

3.2.2. Scenario 2: Early adopters Halogen

In scenario 2 it is assumed that the reference household reacts to the regulation on efficiency of lighting in place by substituting the respective lamps immediately on the date of the prohibition for more efficient halogen lamps. Example: Substitution of 100-Watt incandescent lamps on 01.09.2009 for equally bright halogen lamps of energy efficiency class D. Equal for all the following stages.

3.2.3. Scenario 3: Early adopters LED

In scenario 3 it is assumed that the reference household reacts to the regulation on efficiency of lighting in place by substituting the respective lamps immediately on the date of the prohibition for more efficient LED lamps. Example: Substitution of 100-Watt incandescent lamps on 01.09.2009 for equally bright LED lamps. Due to the supposed lifetime of 20.000 hours[4] for LED after the purchase of the LED lamps on the due date, no substitution of LED lamps took place within the considered time period.

3 Mains-voltage filament lamps, Φ use > 450 lm

4 A lifetime of 20.000 hours was assumed for the whole considered period even though the lifetime of LED lamps might have been lower in the beginning (e.g. 2009-2011). No data were available on a probable average lifetime in these first years and the effect on the calculation was considered to be minor.

In contrast to scenario 1 and 2, in scenario 3 an operating time of 500 hours per year was assumed for the LED lamps in order to take possible rebound effects of about 10 % into account. This assumption is in accordance with (European Commission 2015).

3.2.4. Scenario 4: Halogen => LED lamps

Against the background of the fast-developing LED lamp market in the last 10 years with prices decreasing and energy efficiency increasing over time, an additional scenario was calculated. Scenario 4 considers a household that for the first 4 years behaves how described in scenario 2 and switches all lamps to LEDs in year 5 (01.09.2013). In this scenario households benefit from lower prices for LED lamps as well as from higher efficiency of LED lamps. The expectation was, that this might be the most cost-effective scenario for consumers.

In contrast to scenario 1 and 2, but equal to scenario 3, in scenario 4 an operating time of 500 hours per year was assumed – from 01.09.2013 on - for the LED lamps in order to take possible rebound effects of about 10 % into account. This assumption is in accordance with (European Commission 2015).

3.3. Calculation of Total Cost of Ownership (TCO) of the scenarios

Considered period: 10 years, from 01.09.2009 to 01.09.2019.

For each year the costs were calculated, considering eventual changes in lamp equipment due on the 01.09. of each respective year. The determined annual values were then summed up for the total value of 10 years. The following indicators were determined:

- Purchase costs [Euro] (proportional costs)
- Electricity costs [Euro] on the bases of the electricity demand [kWh]
- Total cost of ownership [Euro]

3.4. Background data

3.4.1. Lifetime of lamps

The lifetime of the different lamp types was defined as follows:

- Incandescent lamps: 1000 hours
- Halogen lamps: 2000 hours
- LED lamps: 20.000 hours[4]

For incandescent lamps and halogen lamps these are standard assumptions. The assumption for the lifetime for LED lamps refers to (European Commission 2015).

3.4.2. Wattage of considered lamps in the scenarios

The following two tables show the assumptions concerning the energy efficiency and wattage of the halogen resp. LED lamps that were considered in the scenarios 2 - 4.

Table 3-3: Overview of the efficiency and derived wattage of halogen lamps of different energy efficiency class for a luminous flux between 220 and 1400 Lumen

Wattage Incan-descent	Luminous flux [Lumen]	Halogen lamp EEK D [Watt]	Halogen lamp EEK C [Watt]	Halogen lamp EEK B* [Watt]
100	1400	93	70	64
75	1000	67	50	45
60	700	47	35	32
50	550	37	28	25
40	400	27	20	18
25	220	15	11	10
Efficiency of halogen lamps [lm/Watt]		15	20	22

Source: Own composition

* low voltage with IRC coating

Table 3-4: Overview of the efficiency and derived wattage of LED lamps in the years 2009 - 2013 for a luminous flux between 220 and 1400 Lumen. Due to the long lifetime of LED lamps the household in scenario 3 and scenario 4 purchased LED lamps not later than 2013

Wattage incandescent lamp	Luminous flux [Lumen]	Wattage LED 2009	Wattage LED 2010	Wattage LED 2011	Wattage LED 2012	Wattage LED 2013
100	1400	56,0	46,7	35,0	23,3	17,5
75	1000	40,0	33,3	25,0	16,7	12,5
60	800	32,0	26,7	20,0	13,3	10,0
50	550	22,0	18,3	13,8	9,2	6,9
40	400	16,0	13,3	10,0	6,7	5,0
25	220	8,8	7,3	5,5	3,7	2,8
Efficiency of LED lamps [lm/Watt]		25	30	40	60	80

Source: Own composition on the bases of (European Commission 2015)

3.4.3. Cost data taken into account

3.4.3.1. Purchase costs of lamps

For the prices of lamps it was referred to (European Commission 2015). In order to calculate the annual purchase costs besides the price of one lamp, the annual operating hours and lifetime were taken into account. The following prices and annual costs were considered for the calculation:

- For incandescent lamps a price of 0,60 Euro per lamp was supposed (frosted and clear). Therefore, the annual purchase costs amounted to 0,32 Euro/lamp*year (= 0,60 Euro/1000 hours*450 hours/year).
- For halogen lamps a price of 2,63 Euro was supposed (retrofit for E14 and E27). Therefore, the annual purchase costs amount to 0,59 Euro/lamp*year (= 2,63 Euro / 2000 hours *450 hours/ year)

In contrast to incandescent lamps and halogen lamps it was presumed that the prices of LED lamps decreased over time. See **Error! Reference source not found.** for an overview of the supposed prices and annual costs of LED lamps between 2009 and 2013. Due to the long lifetime of LED lamps, the household in scenario 3 and scenario 4 purchased LED lamps no later than 2013.

Table 3-5: Overview of the prices and annual costs of LED lamps in the years 2009 - 2013 for a luminous flux between 220 and 1400 Lumen.

	2009		2010		2011		2012		2013	
Lumen LED	**Price [euro/ lamp]**	**Annual costs [euro/ lamp*year]**	**Price [euro/ lamp]**	**Annual costs [euro/ lamp*year]**	**Price [euro/lamp]**	**Annual costs [euro/ lamp*year]**	**Price [euro/ lamp]**	**Annual costs [euro/ lamp*year]**	**Price [euro/ lamp]**	**Annual costs [euro/ lamp*year]**
1400	94,08	2,35	80,64	2,02	70,56	1,76	57,12	1,43	33,60	0,84
1000	67,20	1,68	57,60	1,44	50,40	1,26	40,80	1,02	24,00	0,60
800	53,76	1,34	46,08	1,15	40,32	1,01	32,64	0,82	19,20	0,48
550	36,96	0,92	31,68	0,79	27,72	0,69	22,44	0,56	13,20	0,33
400	26,88	0,67	23,04	0,58	20,16	0,50	16,32	0,41	9,60	0,24
220	14,78	0,37	12,67	0,32	11,09	0,28	8,98	0,22	5,28	0,13
Price incl. 20 % VAT [euro/ lumen]	0,0672		0,0576		0,0504		0,0408		0,024	

Source: (European Commission 2015)

3.4.3.2. Electricity costs

For the electricity costs the average electricity prices for domestic consumers in the European Union were included in the calculation (see Table 3-6).

Table 3-6: Average electricity price for domestic consumers in the European Union in 2009 – 2019 in Eurocent/kWh. *For 2018 and 2018 the price from 2017 was taken as no more current data were available.

Year	Electricity price, 2. semester of each year [Eurocent/kWh]
2009	16,38
2010	17,31
2011	18,36
2012	19,66
2013	20,34
2014	20,75
2015	21,03
2016	20,53
2017	20,48
2018*	20,48
2019*	20,48

Source: (European Commission 2018, 2017, 2013)

3.4.3.3. Other costs

No costs were assumed for installation of lamps and maintenance.

4. Results

The results of the scenario calculation are summarized in Table 4-1. For a comparison of the electricity demand see Table 4-2.

With 2.212 Euro *Scenario 1 No regulation* shows the highest total costs and the highest electricity consumption. At the same time it has the lowest purchase costs. The latter is due to very low prices (0,60 Euro/lamp resp. 0,32 euro/lamp*year) for incandescent lamps that lead to low overall purchase costs even though the lifetime of incandescent lamps is very low compared to the other alternatives. The electricity consumption is the highest of all scenarios.

In *Scenario 2 Early adopters of halogen* the household saves 745 Euro in 10 years compared to scenario 1. This represents a reduction of 34 % of total costs and a reduction of 41 % of electricity demand for lighting (see Table 4-2) and in the same time savings of 74,50 Euro on average per year.

Scenario 3 Early adopters of LED have by far the lowest electricity demand and electricity costs (see Table 4-2), 73 % less than in scenario 1. At the same time, it can be observed that the household reduces its cost by 1.260 Euro in 10 years which corresponds to a reduction of 57 % of total costs compared to scenario 1.

Scenario 4 Halogen => LED shows the lowest total costs of all scenarios with 882 Euro in 10 years for lighting. **The household saved 1.330 Euro in ten years** compared to scenario 1. This is due to electricity savings, but also relatively low purchase costs: The household first changed to halogen lamps and later – when LED lamps were more efficient and less expensive – to LED lamps. Due to this, scenario 4 has only the second lowest electricity consumption after *scenario 3 Early adopters LED*.

Table 4-1: Costs: Results of the scenarios over the whole considered period (1.1.2009 until 1.9.2019)

	Scenario 1: No regulation	Scenario 2: Early adopters halogen	Scenario 3: Early adopters LED	Scenario 4: Halo-gen =>LED
Purchase costs [Euro]	142	257	407	182
Electricity costs [Euro]	2.070	1.210	545	700
Total costs [Euro]	**2.212**	**1.467**	**953**	**882**
Total cost savings in comparison to scenario 1 [Euro]	0	-745	-1.259	-1.330
Total cost savings in comparison to scenario 1 [percent]	0%	-34%	-57%	-60%
Total cost savings per year in compar-ison to scenario 1 [Euro/year]	0	-75	-126	-133

Source: Own calculations

Table 4-2: Electricity demand: Results of the scenarios over the whole considered period (1.1.2009 until 1.9.2019)

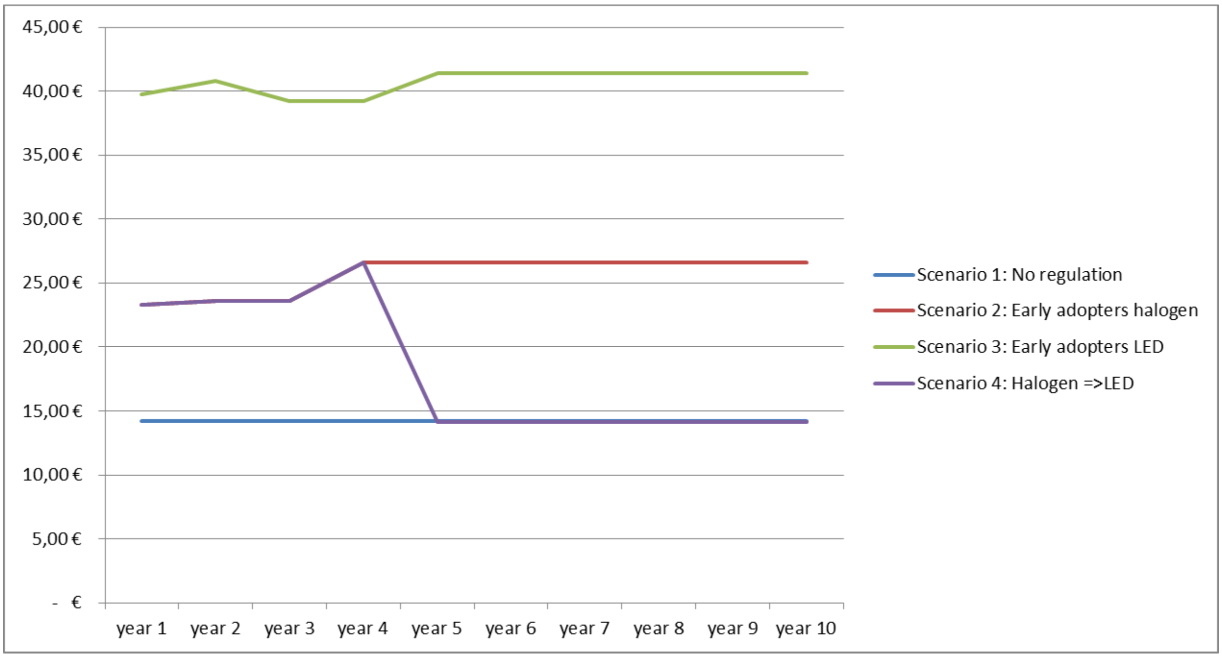
	Scenario 1: No regulation	Scenario 2: Early adopters halogen	Scenario 3: Early adopters LED	Scenario 4: Halogen =>LED
Electricity demand [kWh]	10.598	6.233	2.865	3.760
Electricity savings in comparison to scenario 1 [kWh]	0	-4.365	-7.733	-6.838
Electricity savings in comparison to scenario 1 [percent]	0%	-41%	-73%	-65%

Source: Own calculations

In the following the development of the annual costs is showed in three figures:

Figure 4-1 shows the annual purchase costs from 2009 to 2019 for the 4 scenarios. The graph reflects the different tiers of the regulations as well as the equipment of the household. In the case of LED lamps, it also reflects the decrease of purchase prices and the fact that LED lamps have a very long lifetime: Once purchased, they are not replaced within the considered time period. Early adopter households (scenario 3) that e.g. in 2009 replaced 100-Watt incandescent lamps with LED lamps payed a significantly higher price than households that bought LED lamps later (e.g. scenario 4) and did not benefit from increasing energy efficiency.

Figure 4-1: Development of the annual purchase costs from 2009 to 2019 in the 4 scenarios. Unit: Euro per year.

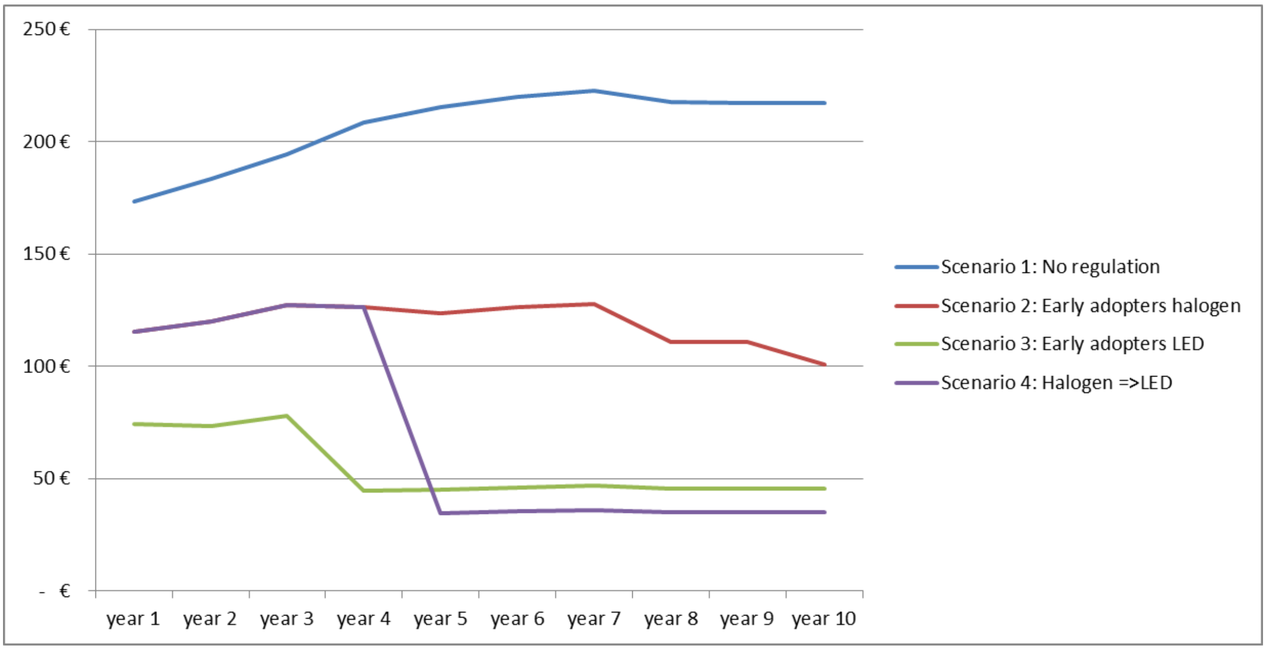


Source: Own calculation

Figure 4-2 shows the development of the annual electricity costs in the scenarios 1 to 4. The graph reflects both the different tiers of the regulation, the substitution of lamps in the different scenarios and the development of the electricity price. In scenario 1 – with no changes in lamp equipment over time – the changes of electricity prices can be detected. Whereas the other lines reflect the tiers of the regulation as well as the development of lamp prices for LED lamps (scenario 3 and 4) and the development of the electricity price.

It is striking that in scenario 4 the adoption of LED lamps at a later point in time – when LED lamps were already more efficient – leads to a lower annual electricity consumption than in scenario 3, even though the overall electricity consumption is higher (see above).

Figure 4-2: Development of the annual electricity costs from 2009 to 2019 in the 4 scenarios. Unit: Euro per year.

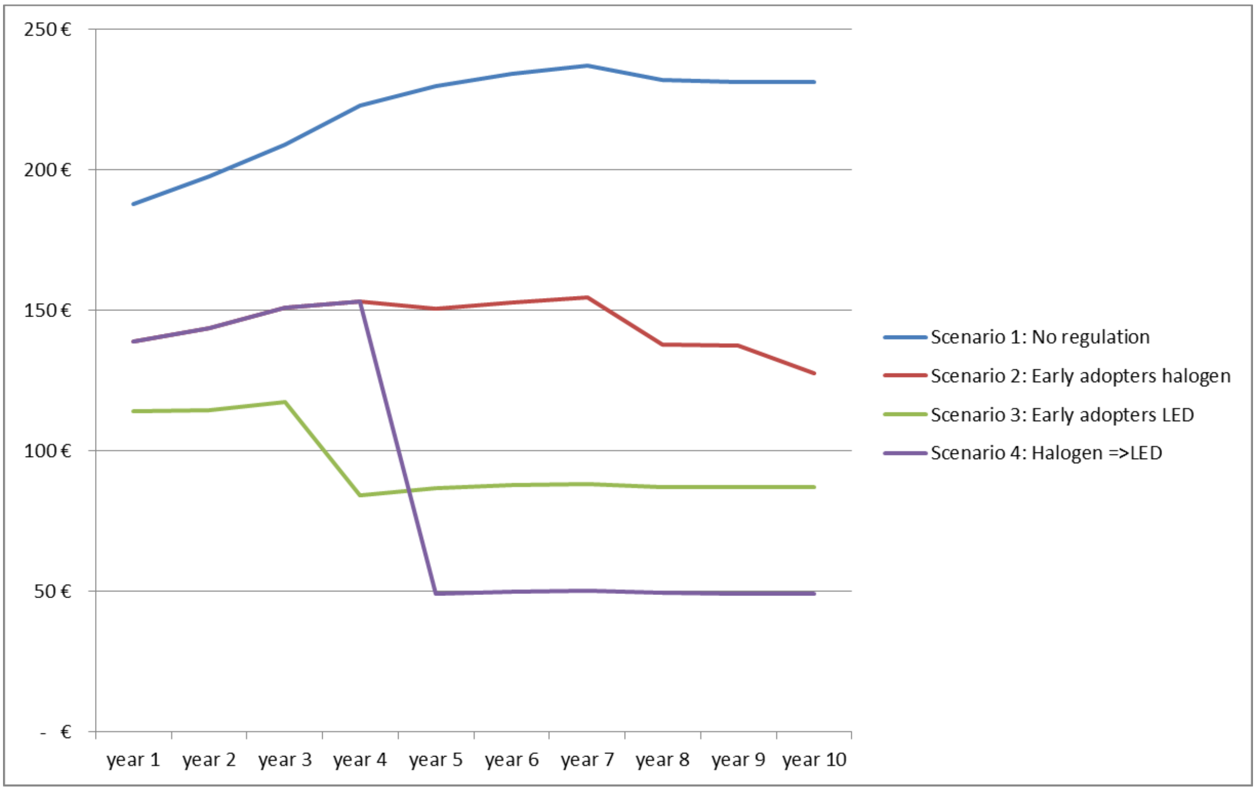


Source: Own calculation

Figure 4-3 shows the development of the annual total costs between 2009 and 2019. The graph follows strongly the antecedent figure, showing that the electricity costs dominate the overall costs. Only scenario 3 seems to be both strongly influenced by the purchase costs and the electricity costs.

The fact that in all three figures the starting year 2009 already shows rather big differences between the scenarios, is based on the requirements for frosted lamps from 01.09.2009 on. More than two thirds of lamps in households were frosted. For clear lamps, the requirements became stricter step by step.

Figure 4-3: Development of the annual total cost of ownership from 2009 to 2019 in the 4 scenarios. Unit: Euro per year.



Source: Own calculation

5. Other advantages or disadvantages linked to the phase out for consumers

With the regulation on lighting giving a clear timeline for the phasing out of other technologies and clear targets for energy efficiency etc., the development of the LED lamp market was very dynamic in the last 10 years. This concerned:

- Quality: E.g. lifetime, light colour, brightness of LED lamps improved over time[5]
- Energy efficiency increased significantly (European Commission 2015)
- Prices decreased strongly (European Commission 2015)

5 See e.g. online survey of Stiftung Warentest in June 2019: https://www.test.de/Umfrage-LED-Lampen-10-Jahre-LED-viel-Licht-aber-auch-Schatten-5475765-0/ and for lifetime (European Commission 2015)

- The lamp design diversified: Different shapes, sizes and new approaches like filament lamps occurred on the market.
- The range of application enlarged: LED lamps e.g. in furniture, handrails, bottom strips, new types of luminaires with permanently installed LED lamps etc.

Still some products show quality problems: A study from 12/2016 on filament lamps[6] – a relatively recent LED lamp type – showed strong deviations for a substantial part of the tested products of declared product features with the real performance of products in a test that was carried out on product life lime, light quality etc. Due to the long lifetime of LED lamps, unfortunately there are only few tests available.

Even though LED lamps are significantly more energy efficient than formerly used technologies, there are rebound effects that reduce the savings: One example is the increase of operating hours, which was taken into account in scenario 3 and 4 (500 instead of 450 hours per year). Another important point is that LED lamps are more and more integrated in products that did not contain lamps at all until now. Additionally, connected lamps in more and more smart homes pose new challenges with networked standby and new features, both increasing electricity consumption.

Overall, the big variety of lighting products available now make it more difficult for consumers to find the right - and preferably most efficient – lamp and luminaire type for their home.

6. Conclusions

The results of the four scenarios show clearly that the regulation led to significant savings for consumers: Between 34 % and 57 % of total costs savings were realised by early adopters of halogen lamps (scenario 2) resp. early adopters of LED lamps (scenario 3). With 60 %, the highest savings were achieved by households that started as early adopter of halogen lamps and then changed in completely to LED lamps year 5 (scenario 4).

It has to be stressed that the early adopters LED lamps play an important role for the dynamic of the market. Even though they had – and still have – disadvantages due to the early adoption: They purchased less efficient LED lamps to a significantly higher price than consumers that purchased LED lamps later on, as reflected by scenario 4.

It is clear that the reality of European households is more complex. For example, it has to be assumed that only few households indeed changed their lamps exactly on the due date. Households rather changed their lamps with some delay and realised savings later and over a longer time period. Nevertheless, the savings were (or still will be) realised due to the strong market changes and would not have occurred without the regulation.

7. Shortcomings of the study

The calculation was done for the defined household type, its lamp equipment and the above described scenarios. Referring to data from the EU eco-design preparatory studies, a kind of typical household equipment was defined, but it was not the aim to calculate the scenarios for a statistical average European household. Potential changes in the lamp equipment concerning numbers and/or luminosity of lamps over time were not considered. Although it is known in general that the lifetime of LED lamps increased between 2009 and 2019, the eventual lower lifetime of LED lamps

6 Source: https://www.topten.ch/sites/default/files/Artikel_Filament_VSE-Bulletin.pdf

at the beginning of this period was not considered in the calculation. For the whole period a lifetime of 20.000 hours was taken into account for LED lamps. This was due to a lack of data. Even if exceptions are possible (see chapter 5 for test on LED filament lamps[6]) – it seems realistic, that latest from 2012 on, LED lamps typically reach a lifetime of 20.000 hours.

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