Update of the data provided by the analysis model developed in the course of the “Study to assess socio-economic impact of substitution of certain mercury-based lamps currently benefiting of RoHS 2 exemptions in Annex III”

Performed under the study request No.07.0201/2019/811056/ENV.B.3

Freiburg, 10.07.2020

Authors

Yifaat Baron
Carl-Otto Gensch

Review

Dr. Andreas Köhler

Contact
info@oeko.de
www.oeko.de

Head Office Freiburg
P. O. Box 17 71
79017 Freiburg

Street address
Merzhauser Straße 173
79100 Freiburg
Phone +49 761 45295-0

Office Berlin
Borkumstraße 2
13189 Berlin
Phone +49 30 405085-0

Office Darmstadt
Rheinstraße 95
64295 Darmstadt
Phone +49 6151 8191-0

Table of Contents

List of Tables

List of Abbreviations

BAU	Business as usual scenario
CFLni	Compact fluorescent lamps without integrated ballast
LED	light-emitting diode
LFL	Linear fluorescent lamps
MELISA	VHK (2016) Model for European LIght Sources Analysis (MELISA) VHK (2019) MELISA update for Single Lighting Regulation
Plug&Play	A lamp that can be used as a “drop-in” replacement, through its insertion into a luminaire (plugging in, screwing in), without requiring the performance of any technical changes to the luminaire aimed at establishing the compatibility of the luminaire with the replacement lamp.
SEA	Socio-economic analysis
SUB	Substitution scenario
T5	Linear fluorescent lamps with a tube diameter ≥ 9 mm and ≤ 17 mm
T8	Linear fluorescent lamps with a tube diameter > 17 mm and ≤ 28 mm
VHK	Van Holsteijn en Kemna B.V.

1 Introduction and scope of the study

In July 2019, Oeko-Institut published the final report for *the "Study to assess socio-economic impact of substitution of certain mercury based lamps currently benefiting of RoHS 2 exemptions in Annex III*" (Baron et al. 2019) (hereafter referred to as "2019 SEA study"). This study had been contracted in 2017 by the European Commission as a follow up to the "*Study to assess renewal requests for 29 RoHS 2 Annex III exemptions [no. l(a to e -lighting purpose), no. l(f - special purpose), no. 2(a), no. 2(b)(3), no. 2(b)(4), no. 3, no. 4(a), no. 4(b), no. 4(c), no. 4(e), no. 4(f), no. 5(b), no. 6(a), no. 6(b), no. 6(c), no. 7(a), no. 7(c) - I, no. 7(c) - II, no. 7(c) - IV, no. 8(b), no. 9, no. 15, no. 18b, no. 21, no. 24, no. 29, no. 32, no. 34, no. 37]*" carried out by the Oeko-Institut in 2016 which recommended inter alia a phase-out of exemptions for certain mercury-based lamps. The goal of the 2019 SEA study was to assess possible socioeconomic impacts related to the substitution of these mercury-based lamps.

The 2019 SEA study was prepared based on data from the VHK (2016) Model for European LIght Sources Analysis (MELISA), data provided by Lighting Europe in 2015 as part of its applications for exemption, as well as data provided by Lighting Europe in 2017 through direct consultation related to the study. A first version of the study was submitted to the European Commission in 2017 but underwent several technical corrections until final publication in 2019. In this sense, despite the study's relatively recent publication in 2019, the results of the assessments contained therein are based on data representing the years 2013-2017.

In particular the data for the availability of substitutes, which has a significant impact on the costs of substitution, is considered outdated. This is due to the fast development and dynamic nature of the LED market segment. The European Commission has received new evidence from stakeholders as to the share of substitutes available and has thus requested a review of the assessment results for a number of lamp types: compact fluorescent lamps with non-integrated ballast (CFLni), linear fluorescent lamps (LFL) with a tube diameter ≥ 9 mm and ≤ 17 mm (T5) and LFL with a tube diameter > 17 mm and ≤ 28 mm (T8).

This document presents the results of a review of the 2019 SEA study as regards the elements specified below, based on three different data sets described in detail in the next section.

Regarding CFLni, T5 and T8, impacts have been calculated for the period 2021-2035, as regards:

- Purchase costs of substitution of such lamps with LED alternatives (considers costs of lamps and of luminaires as well as labour costs for luminaire rewiring and for luminaire replacement, where relevant);
- Energy savings expected through substitution of such lamps with LED alternatives;
- The amount of mercury avoided on the market through substitution of such lamps with LED alternatives;
- The amount of e-waste to be generated prematurely, where substitution with LED alternatives results in replacement of lighting components (e.g., driver, dimmer) or of the luminaire in its entirety.

The following scenarios were considered:

- Business as usual scenario (BAU): current RoHS exemptions for CFLni, T5 and T8 remain valid, however, as a result of the application of the new Ecodesign Regulation on light sources, some conventional lamp types will not be allowed to be placed on the market from respective dates[1].
- Substitution scenario (SUB): RoHS exemptions for CFLni, T5 and T8 expire, resulting in a regulatory driven phase-out of such lamps as of 2021.

[1] From 1 September 2021, the Ecodesign regulations (EC) No 244/2009, (EC) No 245/2009 and (EU) No 1194/2012 will be repealed and replaced by Commission Regulation (EU) 2019/2020 of 1 October 2019 laying down ecodesign requirements for light sources and separate control gears pursuant to Directive 2009/125/EC of the European Parliament and of the Council. With the new regulation, most traditional fluorescent tube lighting T8, which are common in offices, will be phased-out from September 2023 onwards. Likewise, most CFL with integrated ballast will not be able to fulfil the requirements set by the Regulation from September 2021.

2 Data used for the current review

The current estimations have been calculated applying the 'VHK-Oeko-Institut Combined Model for RoHS'. For assessing the impacts of possible new RoHS measures for the above mentioned three lamp types, the 'VHK-Oeko Institut Combined Model for RoHS' uses as reference the sales, efficiency, power, and light source price data from the ECO-scenario of the Model for European LIght Sources Analysis (VHK 2019), which was developed by VHK for scenario analysis in the Ecodesign and Energy Labelling context. The Eco-scenario in this model integrates the differences in sales for LFL T8 lamps that are expected due to the new lighting regulations CR 2019/2020 (ecodesign) and CDR 2019/2015 (energy labelling). For LFL T5 and CFLni the sales specified in this scenario are identical to those used in the initial 2019 SEA study. Additional differences in data applied from this source are specified in Annex I.

Further input for the Combined Model comes from the 2019 SEA study. In the combined model, VHK performed the energy and cost modelling and Oeko-Institut added modelling regarding the impacts on mercury and e-waste. For assessments regarding mercury impacts, the values specified in the 2019 SEA study (Baron et al. 2019), table 15 (for CFLni) and table 34 (for T5 and T8) have been used for revised calculations. Regarding assessments made for e-waste impacts, values used for the revised calculation are based on an average of best and worst case values applied in the 2019 study (Baron et al. 2019). In both cases, the values used in the 2019 SEA study were consulted with LightingEurope in 2017.

In the 2019 SEA study, assumptions were made for each lamp type as to the following aspects:

- the share of lamps that would be substituted with Plug&Play LED alternatives,
- the share of lamps to be substituted with LED alternatives requiring a rewiring or conversion of the luminaire, and
- the share of lamps the replacement of which would require a replacement of the luminaire.

Following the market developments of the last few years, further evidence as to the current shares related to these substitution routes in the market situation of 2020 was submitted to the European Commission. For LFL, the following estimations (Table 2-1) were provided to the European Commission by CLASP (Scholand 2020), based on a study performed jointly with the Swedish Energy Agency (Bennich, P. & Scholand, M. 2020)[2] (hereafter referred to as CLASP/SwEA report), which provides an overview of the current availability of LED alternatives for the relevant lamp types. Estimations for CFLni (also under Table 2-1) were provided separately (Bass, F. & Scholand, M. 2020) for the purpose of this review and are based on the market study performed for the CLASP/SwEA report. These market share estimations shall be referred to throughout this study as the **CLASP/SwEA data set**.

The second data set used in this review is based on the market share estimates for the availability of LED alternatives for T5, T8 and CFLni initially used in the 2019 SEA study and shall be referred to throughout this study as the **2019 SEA study data set**. In the consultants' view, documents submitted to the European Commission in the period of January-May 2020 by LightingEurope

[2] For T8, CLASP also provided data based on an estimation by Seaborough, a company developing LED technologies, which represents the availability of LED alternatives as estimated by this company. This estimate was slightly higher than that of the CLASP and Swedish Energy Agency report. Due to its similarity, the Seaborough estimations were not used for a separate assessment.

indicate that the lighting industry still considers data underlying the 2019 SEA study to correctly reflect the market situation in 2020.

The consultants base this conclusion on the following assessment of documents provided by LightingEurope: In January 2020, LightingEurope submitted renewed applications for exemptions to the European Commission. The renewal of exemptions 1(a, b, c, e) (LightingEurope 2020a) and exemptions 2(a)(2), 2(a)3, and 2(b)3 (LightingEurope 2020b) was requested. The applications refer to the difficulties expected regarding the substitution of various lamp types, including CFLni, LFL T5 and LFL T8. LightingEurope also refers to the three substitution routes mentioned above.

LightingEurope (2020a) states that replacement lamps for **CFLni** are available only for a limited number of lamp bases and includes a diagram showing nineteen different lamp bases, six of which are specified to exist as LED retrofits (accounting for ca. 30%). LightingEurope states that according to the MELISA model, the penetration for LED retrofit lamps substituting CFLni lamps is estimated to be 7% in 2019 and 10% in 2021. The substitution by LED indoor luminaires is estimated at 29% in 2019 and 37% in 2021. The consultants assume that these statements represent the share of lamps replaced with Plug&Play alternatives (7-10%) and with luminaire replacements (29-37%) under a BAU scenario where new CFLni can still be purchased as replacements. In the consultants' assessment, these shares are compatible with the 2019 SEA study data set shares for the CFLni SUB-scenario, where the availability of Plug&Play replacements is between 0-20%, of rewiring replacements between 24-30% and of luminaire replacement between 56-70%, depending on the lamp power sub-category (see Table 2-1).

For LFL T8, it is explained (LightingEurope 2020b) that due to the new Ecodesign Regulation, suitable LED alternatives will be available for T8 lamps with a length of 2, 4, or 5 feet for general lighting purposes. For such lamps, "*the most common colour temperatures are not available in very cool (12000K) and warm (2700K) colours*". In the consultants' view, assuming the above numbers refer to Plug&Play availability of T8 being between 10-30%, this would be in line with the 2019 SEA study estimate of 12% Plug&Play availability.

LightingEurope (2020b) state that there is currently no substantial amount of LED based lamps available for direct LFL T5 replacement in existing applications. In the consultants' assessment, this also fits with the 2019 SEA study data set shares which assume 1% availability of Plug&Play alternatives.

The shares applied under CLASP/SwEA data set and 2019 SEA study data set are presented inTable 2-1:

Table 2-1: Lamp share estimates applied in the model

Lamp Type		CLASP/ SwEA Plug&Play*	CLASP/ SwEA: LED + Rewiring*	CLASP/ SwEA: Luminaire replacement*	2019 SEA study** Plug&Play	2019 SEA study**: LED + Rewiring	2019 SEA study**: Luminaire replacement
CFLni	P <12 W	100%	0%	0%	0%	30%	70%
	12 W ≤ P < 30 W	85%	4.5%	10.5%	20%	24%	56%
	30 W ≤ P < 50 W	75%	7.5%	17.5%	0%	30%	70%
	P ≥ 50 W	75%	7.5%	17.5%	0%	30%	70%
T5		76%	0.7%	23.3%	1%	3%	96%
T8		96%	0.45%	3.55%	12%	10%	78%

Source: *Estimations presented for P&P by CLASP at Stakeholder meeting of 12.2.2020 and confirmed per email by Michael Scholand on 25.3.2020 and by (Bass, F. & Scholand, M. 2020). Estimations for LED+Rewiring and for Luminaire replacement calculated for remainder by Oeko-Institut. **Estimations from the 2019 SEA study are reproduced from the study for all categories.
Note: The CLASP estimation for T8 is a combined estimation for EM/CGG (100% coverage representing 70% of the market share) and HF/ECC (88% coverage representing 30% of the market share);

Considerations regarding CLASP/SwEA and 2019 SEA study data sets

As an explanation for the low shares of Plug&Play availability ascertained in their documents, LightingEurope mentions various limitations and technical aspects of the discharge lamps in question. In this respect, LightingEurope (2020a) mentions the wide variety of lamps in terms of types, shapes, sizes, wattages and colours, only for a few of which one-to-one replacements are available on the market. Standards such as EN60901, EN60969, EN60968 and EN61199, for CFL compatibility are also mentioned, whereas LED standardisation is said not to exist for these aspects. Additional aspects mentioned include the light distribution of the lamp itself and within the luminaire, the often-higher weight and sometimes higher prices (higher wattages) of LED alternatives, their compatibility with existing drivers and dimmers, and possible problems with flicker. Regarding the options to replace luminaires it is mentioned that luminaires are often built into the wall or ceiling, also resulting in the need for adjustments to introduce replacement luminaires. Lamps installed in emergency lighting luminaires are also addressed where standards specify which replacement lamps they can accept, ruling out LED retrofits.

Though it can be followed that there may be various limitations to the applicability of available Plug&Play alternatives, estimating the range of these is not straightforward. However, the assumptions for the 2019 SEA study were determined at the beginning of 2017. The range of LED lamp substitutes available on the market for each of the mentioned lamp types has increased in the period between 2017 and now (2020) and is also expected to increase further due to the dynamic character of this sector. Consequently, it stands to reason that the Plug&Play coverage of such lamps has also increased beyond the numbers applied in the 2019 SEA study. The CLASP/SwEA data set represents higher shares and assumes a very high coverage of Plug&Play lamps. It is not completely clear to which degree the CLASP/SwEA Plug&Play shares take into account some of the potential problems signalled by LightingEurope, such as the share of users having an FL control gear that is listed as incompatible by the manufacturers, the share of users having an FL control gear that does not appear on the compatibility lists, the share of users potentially facing difficulties with flicker, EMC, or certification after rewiring or light distribution issues. As mentioned above, these compatibility issues are generally difficult to quantify.

Against this background, a third data set has been applied in the model calculations to check the impacts in case the shares are more moderate than the two data sets addressed in Table 2-1. This third data set is considered as a sensitivity analysis and thus titled the **Sensitivity data set**. It is based on shares applied by VHK in a calculation of impacts presented at a stakeholder meeting organised by the European Commission on 12 February 2020. The Sensitivity data set assumes an availability of Plug&Play alternatives which leads to: 50% of lamps requiring a replacement; 10% requiring rewiring; and in the rest of the cases, luminaire replacement. These shares are presented in Table 2-2.

It has been considered necessary to add the Sensitivity dataset to the report also in view of the chain of comments from LightingEurope (2020c). In its comments on the 12 February 2020 meeting, LightingEurope stated: '*In the view of LightingEurope, VHK assumed and presented a realistic share of replacement options during the stakeholder meeting*', while in later communications to the Commission they clarified that this should be interpreted as '*the VHK approach seemed to be the most realistic compared to the CLASP and Seaborough comments*'. In a subsequent presentation of calculations, LightingEurope (2020d) stated that '*About 50% of retrofit solutions are not compatible with installed luminaires*', thus suggesting that a 50% Plug&Play share, as used in the Sensitivity dataset, could at least be considered plausible. In later communications to the Commission they clarified that '*the 50% is a generalization based on a more specific breakdown by application and by product group*', but without specifying the details of this breakdown, and without supporting the 50%/10%/40% substitution shares. Taking these comments into account, the Sensitivity dataset was considered sufficiently relevant to be added to the report.

Table 2-2: Lamp share estimates applied in the model for the Sensitivity data set

Lamp type	Plug&Play	Rewiring	Luminaire replacement
All types (CFL, LFL)	50%	10%	40%

Source: Based on shares presented by VHK at expert meeting held by the European Commission on 12.2.2020

Finally, the 2019 SEA study estimated impacts for the period between 2016 and 2025. Effectively, this meant impacts to incur between 2019 and 2025, as it was assumed in the study that following a delegated act regarding the exemptions listed in Annex III of RoHS, a certain time period would be granted before discharge lamps for which an exemption would have expired would no longer be placed on the market. The current model looks at impacts over a longer period, between 2021 and 2035. 2021 was chosen in consultation with the European Commission. Although it is not clear at the time of this report when the decision on the relevant exemptions will be adopted, in practice, any amendments to the relevant exemptions are unlikely to become applicable before July 2021. The current investigation thus looks at impacts starting in 2021. A longer observation period until 2035 has been chosen to provide a more representative impact that covers most lamps to be substituted as well as a more significant share of energy savings to be obtained through the shift to LED. As setting this final date is also not straightforward, the presentation of results includes cumulative cost savings for all years, allowing readers to also see results were the observed period is set to end at an earlier date.

Detailed explanations as to how market flows and certain impacts have been calculated are specified in the 2019 SEA study report. Additional input variables used appear in Annex I. The following sections provide a summary of the results of the revision, calculated on the basis of the data sets specified above.

3 Revised estimated impacts for CFLni

Table 3-1 presents data and estimations identical for all three data sets. It includes the number of CFLni that need replacement in each year (distribution to residential and non-residential), the energy (cost) savings related to substitution with LED alternatives and the total avoided mercury on the market.

Table 3-1: Number of CFLni to be replaced, related energy (cost) savings and mercury avoided on the market

All data sets	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
CFLni projected sales, all sectors (mln)	44.8	41.9	38.1	33.5	28.6	23.5	19.1	15.0	11.3	8.3	6.5	5.1	3.9	3.0	2.2
CFLni replaced by LED, residential (mln)	13.3	13.2	12.9	12.3	10.9	9.3	7.6	5.8	4.4	3.4	2.8	2.4	2.1	1.7	1.4
CFLni replaced by LED, non-resident. (mln)	31.4	28.6	25.2	21.2	17.6	14.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total energy savings in SUB, GWh	-693	-1354	-1966	-2506	-2974	-3363	-2972	-2581	-2209	-1874	-1587	-1349	-1152	-991	-866
Total energy cost savings in SUB, M euros	**-124**	**-245**	**-359**	**-463**	**-555**	**-634**	**-569**	**-502**	**-437**	**-378**	**-323**	**-278**	**-240**	**-210**	**-186**
Total avoided mercury in SUB in kg	**134**	**126**	**114**	**101**	**86**	**71**	**57**	**45**	**34**	**25**	**20**	**15**	**12**	**9**	**7**

Source: Calculated with the VHK-Oeko-Institut Combined Model for RoHS; Note: Values are rounded; Negative values represent benefits

The first line in Table 3-1 presents the projected sales of CFLni, decreasing with the years, which would take place in the BAU scenario, where RoHS exemptions remain applicable for CFLni. Practically all these sales are replacement sales, i.e., of CFLni replacing CFLni that have reached the end-of-life. In the SUB scenario, once the RoHS exemptions are revoked, it is assumed that CFLni could no longer be sold and could no longer be used for replacement of such lamps at end-of-life. Thus, all such replacements would need to be performed with LEDs through Plug&Play replacements, through such replacements with additional rewiring work or through replacement of the luminaire. In the residential sector, where CFLni lifetime is 14 years, LED replacements take place based on these sales until 2035 (second line in table). In the non-residential sector however, where the average CFLni lifetime is 6 years, in the BAU scenario, CFLni sold in for example 2027 would replace CFLni sold in 2021. In contrast, in the SUB Scenario, CFLni replaced in 2021 by LEDs, which have a much longer lifetime, will not need to be replaced again in 2027, nor later within the observed period. Therefore, from 2027 onwards, non-residential CFLni replaced by LED are set to zero (third line in table).

Energy savings are computed as the difference between electricity consumption by LEDs replacing CFLni in the SUB scenario and electricity consumption that CFLni would otherwise have generated in the BAU scenario. The difference is multiplied by the electricity rate (€/kWh) to derive the corresponding cost savings. Energy savings (negative values in the table) increase in early years but decrease from 2027. In that year the CFLni bought in 2021 reach their end-of-life and the stock considered in the analysis starts to decrease.

In the period between 2021 and 2035, given that alternatives do not contain mercury, a total amount of 856 kg of mercury is avoided from being placed on the EU market.

The revised calculations for impacts of the regulatory driven substitution of CFLni lamps, performed on the basis of the CLASP/SwEA data set, are presented in Table 3-2.

Table 3-2: Revised estimated impacts calculated for CFLni (using CLASP/SwEA data set)

CLASP/SwEA data set	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Avoided purchase cost in SUB for CFLni, M euros	-208	-195	-179	-158	-135	-111	-91	-71	-54	-39	-31	-24	-19	-15	-11
Additional purchase cost for LED in SUB plug&play, M euros	471	403	345	285	229	186	38	28	21	16	13	11	9	8	7
Additional cost for LED+rewiring in SUB, M euros	68	62	56	48	40	33	8	6	5	4	3	3	2	2	2
Additional cost for LED+luminaire in SUB, M euros	292	274	249	219	187	153	50	38	29	22	19	16	13	11	9
Total additional purchase costs in SUB, M euros	**624**	**544**	**471**	**394**	**321**	**261**	**6**	**2**	**0**	**2**	**3**	**5**	**6**	**6**	**6**
Total additional cost in SUB, M euros (add. purchase cost minus energy cost savings)	500	299	112	-68	-234	-373	-563	-500	-437	-376	-320	-273	-234	-203	-180
Cumulative from period start in SUB, M euros	**500**	**800**	**912**	**843**	**609**	**236**	**-327**	**-828**	**-1264**	**-1640**	**-1960**	**-2232**	**-2467**	**-2670**	**-2849**
Total additional E-waste in SUB in million kg	**4,1**	**3,8**	**3,5**	**3,0**	**2,6**	**2,1**	**0,7**	**0,5**	**0,4**	**0,3**	**0,3**	**0,2**	**0,2**	**0,2**	**0,1**

Source: Calculated with the VHK-Oeko-Institut Combined Model for RoHS; Note: Values are rounded; Negative values represent benefits

The additional purchase costs are computed as the sum of (additional) costs in the SUB scenario for LED Plug&Play, LED + rewiring, and LED + luminaire replacement, minus the (avoided) purchase costs for CFLni of the BAU scenario. The additional purchase costs decrease with the years because the number of CFLni lamps substituted by LEDs decreases and because LED prices progressively decrease. From 2027, the additional costs are close to zero because only few residential CFLni are still to be replaced by LED.

Combining the additional purchase costs with the energy cost savings of Table 3-1 leads to an annual net benefit already from 2024, whereas cumulatively, the total purchase costs are set-off by total energy savings starting from 2027. The regulatory-driven substitution would result in a total net benefit of 2849 million euros for the period between 2021 and 2035. Considering a total number of 242 million CFLni substituted by LEDs, this translates into a net benefit of 11.78 euros per lamp. As the table provides cumulative results for each year, it can also be observed for example, that in the years between 2021 and 2030, benefits accumulate in an order of 1640 million euros.

The regulatory-driven phase-out results in some cases in the need to rewire existing luminaires or to replace them, which generates a total amount of 22,000 tonnes of e-waste prematurely (accelerated impact). It is noted that this calculation does not consider that fluorescent lamps or luminaires may weigh more than the LED lamps or luminaires replacing them, which in the long term could lead to a decrease in generated e-waste.

Results change significantly when applying the 2019 SEA study data set estimate on the availability of between 0 to 20% Plug&Play substitutes to the calculation model. The revised calculations for impacts, performed on the basis of the 2019 SEA study data set, are presented in Table 3-3. In total, the regulatory-driven substitution results for this data set in a total net cost of 9,044 million euros for the period between 2021 and 2035 due to the high costs of luminaire replacements. This translates into a cost of 37.39 euros per lamp. Here too, cumulative costs can be observed for each year in the table below.

In this period, a larger amount of e-waste, 180 thousand tonnes, is generated prematurely (accelerated impact) when applying the 2019 SEA study data set as a larger number of lamps replaced require rewiring (24-30%) or luminaire replacement (56-70%).

Table 3-3: Revised estimated impacts calculated for CFLni (using 2019 SEA study data set)

2019 SEA study data set	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Avoided purchase cost in SUB for CFLni, M euros	-208	-195	-179	-158	-135	-111	-91	-71	-54	-39	-31	-24	-19	-15	-11
Additional purchase cost for LED in SUB plug&play, M euros	46	39	33	28	22	18	4	3	2	2	1	1	1	1	1
Additional cost for LED+rewiring in SUB, M euros	559	509	454	391	328	268	68	51	38	30	25	21	18	15	12
Additional cost for LED+luminaire in SUB, M euros	2386	2232	2031	1785	1523	1251	406	311	234	180	151	128	110	92	76
Total additional purchase costs in SUB, M euros	**2782**	**2585**	**2340**	**2046**	**1738**	**1426**	**387**	**295**	**221**	**172**	**146**	**126**	**110**	**93**	**78**
Total additional cost in SUB, M euros (add. purchase cost minus energy cost savings)	2659	2341	1981	1583	1183	792	-182	-207	-216	-206	-177	-152	-130	-116	-108
Cumulative from period start in SUB, M euros	**2659**	**4999**	**6981**	**8563**	**9746**	**10538**	**10356**	**10149**	**9933**	**9727**	**9550**	**9399**	**9268**	**9152**	**9044**
Total additional E-waste in SUB in million kg	**33.2**	**31.1**	**28.3**	**24.9**	**21.2**	**17.4**	**5.7**	**4.3**	**3.3**	**2.5**	**2.1**	**1.8**	**1.5**	**1.3**	**1.1**

Source: Calculated with the VHK-Oeko-Institut Combined Model for RoHS; Note: Values are rounded; Negative values represent benefits

3.1 Sensitivity analysis

The 2019 SEA study dataset and the CLASP/SwEA dataset represent the upper and lower ranges of possible impacts of a phase-out of CFLni lamps to begin in 2021. To show how impacts are affected when an intermediate number of lamps is assumed to be replaced with Plug&Play substitutes, the Sensitivity data set was applied. Results for this data set are presented in Table 3-4.

Annually, the total additional costs under the Sensitivity data set assumptions lead to benefits as of 2027. However, cumulatively, the costs of the phase-out that amount to 3,404 million euros are not completely set-off within the period between 2021 and 2035. The costs of this transition amount to 14.05 euro per lamp. In total, within this period ca. 106 thousand tonnes of E-waste are generated prematurely.

Table 3-4: Revised estimated impacts calculated for CFLni (using Sensitivity data set)

Sensitivity data set	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Avoided purchase cost in SUB for CFLni, M euros	-208	-195	-179	-158	-135	-111	-91	-71	-54	-39	-31	-24	-19	-15	-11
Additional purchase cost for LED in SUB plug&play, M euros	265	227	194	161	129	105	22	16	12	9	7	6	5	4	4
Additional cost for LED+rewiring in SUB, M euros	204	186	166	143	120	98	25	19	14	11	9	8	7	5	5
Additional cost for LED+luminaire in SUB, M euros	1492	1396	1270	1116	952	782	254	195	146	113	94	80	69	58	47
Total additional purchase costs in SUB, M euros	**1753**	**1613**	**1451**	**1261**	**1066**	**874**	**210**	**158**	**118**	**93**	**80**	**70**	**62**	**53**	**45**
Total additional cost in SUB, M euros (add. purchase cost minus energy cost savings)	1629	1369	1092	799	511	239	-359	-344	-319	-285	-243	-208	-179	-157	-141
Cumulative from period start in SUB, M euros	**1629**	**2998**	**4090**	**4888**	**5399**	**5638**	**5279**	**4935**	**4617**	**4332**	**4089**	**3881**	**3702**	**3546**	**3404**
Total additional E-waste in SUB in million kg	**19.6**	**18.3**	**16.7**	**14.6**	**12.5**	**10.3**	**3.3**	**2.6**	**1.9**	**1.5**	**1.2**	**1.1**	**0.9**	**0.8**	**0.6**

Source: Calculated with the VHK-Oeko-Institut Combined Model for RoHS; Note: Values are rounded; Negative values represent benefits

4 Revised estimated impacts for LFL T5

Table 4-1 presents data and estimations identical for all three data sets. It includes the number of LFL T5 that need replacement in each year (distribution to residential and non-residential), the energy (cost) savings related to substitution with LED alternatives and the total avoided mercury on the market.

Table 4-1: Number of LFL T5 to be replaced, related energy (cost) savings and mercury avoided on the market

All data sets	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
LFL T5 projected sales, all sectors (mln)	61.2	57.3	52.7	47.7	42.7	39.3	36.1	33.0	29.9	26.8	25.0	23.1	21.1	19.0	16.9
LFL T5 replaced by LED, residential (mln)	0.4	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.3	0.4	0.6	0.7	0.8
LFL T5 replaced by LED, non-resid. (mln)	60.8	56.9	52.3	47.4	42.5	39.1	35.9	32.8	29.7	26.6	0.0	0.0	0.0	0.0	0.0
Total energy savings in SUB, GWh	-1477	-2984	-4501	-5980	-7389	-8754	-10033	-11223	-12321	-13321	-12192	-11121	-10128	-9222	-8403
Total energy cost savings in SUB, M euros	**-260**	**-531**	**-808**	**-1085**	**-1354**	**-1620**	**-1875**	**-2118**	**-2349**	**-2565**	**-2348**	**-2142**	**-1951**	**-1776**	**-1619**
Total avoided mercury in SUB, in kg	**122**	**115**	**105**	**95**	**85**	**79**	**72**	**66**	**60**	**54**	**50**	**46**	**42**	**38**	**34**

Source: Calculated with the VHK-Oeko-Institut Combined Model for RoHS; Note: Values are rounded; Negative values represent benefits

The first line in the table presents the projected sales of LFL T5, decreasing with the years, which would take place in the BAU scenario, where RoHS exemptions remain applicable for such lamps. Most of these sales are replacement sales, i.e. LFL T5 replacing LFL T5 that have reached end-of-life. In the SUB scenario, once the RoHS exemptions are revoked, it is assumed that LFL T5 could no longer be sold and could no longer be used for replacement of such lamps at end-of-life. Thus, all such replacements would need to be performed with LEDs through Plug&Play replacements, through such replacements with additional rewiring work or through replacement of the luminaire. In the residential sector, where LFL T5 lifetime is 28 years, LED replacements take place based on these sales until 2035 (second line in table). However, in the non-residential sector, where average LFL T5 lifetime is 10 years, in the BAU scenario, LFL T5 sold in for example 2031 would be replacements for LFL T5 sold in 2021. Whereas in the SUB Scenario, LFL T5s replaced by LEDs in 2021, which have a longer lifetime, no longer need to be replaced again in 2031. Therefore from 2031 onwards, non-residential LFL T5 replaced by LED are set to zero (third line in table).

Energy savings are computed as the difference between electricity consumption by LEDs substituting LFL T5 in the SUB scenario and electricity consumption that LFL T5 would otherwise have had in the BAU scenario. The difference is multiplied by the electricity rate (€/kWh) to get the corresponding cost savings. Energy savings (negative values in the table) increase in early years but decrease from 2031. In 2031 the LFL bought in 2021 reach their end-of-life and the stock considered in the analysis decreases significantly.

In the period between 2021 and 2035, a total amount of 1064 kg of mercury is avoided from being placed on the EU market.

The revised calculations for impacts of the regulatory driven substitution of LFL T5 lamps, performed on the basis of the CLASP/SwEA data set, are presented in Table 4-2.

Table 4-2: Revised estimated impacts calculated for T5 lamps (using CLASP/SwEA data set)

CLASP/SwEA data set	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Avoided purchase cost for LFLT5 in SUB, M euros	-485	-454	-418	-378	-339	-312	-286	-262	-237	-213	-199	-184	-168	-151	-135
Additional purchase cost for LED plug&play in SUB, M euros	1430	1218	1056	908	767	701	616	541	482	424	4	6	7	9	10
Additional cost for LED+rewiring in SUB, M euros	23	20	18	16	14	12	11	10	9	8	0	0	0	0	0
Additional cost for LED+luminaire in SUB, M euros	1566	1467	1348	1221	1094	1007	924	845	766	687	8	11	15	17	20
Total additional purchase costs in SUB, M euros	**2533**	**2250**	**2004**	**1767**	**1536**	**1408**	**1265**	**1134**	**1019**	**906**	**-186**	**-167**	**-146**	**-125**	**-105**
Total additional cost in SUB, M euros (add. purchase cost minus energy cost savings)	2273	1720	1196	682	182	-211	-610	-984	-1329	-1659	-2534	-2308	-2096	-1901	-1724
Cumulative from period start in SUB, M euros	**2273**	**3993**	**5189**	**5871**	**6053**	**5842**	**5232**	**4247**	**2918**	**1259**	**-1275**	**-3583**	**-5679**	**-7581**	**-9304**
Total additional E-waste in SUB, in million kg	**22.2**	**20.8**	**19.1**	**17.3**	**15.5**	**14.3**	**13.1**	**12.0**	**10.9**	**9.7**	**0.1**	**0.2**	**0.2**	**0.2**	**0.3**

Source: Calculated with the VHK-Oeko-Institut Combined Model for RoHS; Note: Values are rounded; Negative values represent benefits

The additional purchase costs are computed as the sum of (additional) costs in the SUB scenario for LED Plug&Play, LED + rewiring, and LED + luminaire replacement, minus the (avoided) purchase costs for LFL T5 of the BAU scenario. The additional purchase costs decrease with the years because the number of LFL T5 substituted by LEDs decreases and because LED prices progressively decrease. From 2031, the additional costs are even negative because the avoided costs for LFL T5 are higher than the additional costs for the few residential LFL T5 that are still to be replaced by LED.

Combining the additional purchase costs the energy cost savings of Table 4-1 leads to an annual net benefit already from 2026, whereas cumulatively the total purchase costs are set-off by the total energy cost savings starting from 2031. The regulatory-driven substitution results in a total net benefit of 9304 million euros for the period between 2021 and 2035. Considering a total of 430 million LFL T5 substituted by LEDs, this translates into a net benefit of 21.66 € per lamp.

The regulatory driven phase-out leads in some cases to the need to rewire existing luminaires or to replace them, which generates a total amount of 156,000 tonnes of e-waste prematurely (accelerated impact). It is noted that this calculation does not consider that fluorescent lamps or luminaires may weigh more than the LED lamps or luminaires replacing them, which in the long term could lead to a decrease in generated e-waste.

These results change significantly when applying the 2019 SEA study data set on the availability of 1% Plug&Play substitutes to the calculation model. The results can be viewed in Table 4-3. In total, the regulatory-driven substitution results for this data set in a total net cost of 17,426 million euros for the period between 2021 and 2035 due to the high costs of luminaire replacements. This translates into a cost of 40.57 euros per lamp. Cumulative results can be observed in the table for each year. This shows for example that 2030 is the “peak” year in terms of the cumulative costs, after which the energy cost savings are dominant and reduce the sum.

In this period a larger amount of e-waste, 643 thousand tonnes, is generated prematurely (accelerated impact) when applying the 2019 SEA study data set as a larger number of lamps replaced require rewiring (3%) or luminaire replacement (96%).

Table 4-3: Revised estimated impacts calculated for T5 lamps (using 2019 SEA study data set)

2019 SEA study data set	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Avoided purchase cost for LFLT5 in SUB, M euros	-485	-454	-418	-378	-339	-312	-286	-262	-237	-213	-199	-184	-168	-151	-135
Additional purchase cost for LED plug&play in SUB, M euros	19	16	14	12	10	9	8	7	6	6	0	0	0	0	0
Additional cost for LED+rewiring in SUB, M euros	93	82	73	64	56	51	46	41	37	33	0	0	1	1	1
Additional cost for LED+luminaire in SUB, M euros	6459	6050	5561	5037	4512	4152	3812	3485	3160	2834	34	47	61	72	83
Total additional purchase costs in SUB, M euros	6086	5694	5230	4735	4239	3901	3580	3271	2966	2659	-165	-136	-107	-79	-51
Total additional cost in SUB, M euros (add. purchase cost minus energy cost savings)	5826	5163	4422	3650	2885	2281	1705	1153	617	95	-2512	-2278	-2057	-1855	-1670
Cumulative from period start in SUB, M euros	**5826**	**10990**	**15412**	**19062**	**21947**	**24229**	**25934**	**27087**	**27704**	**27799**	**25287**	**23009**	**20951**	**19096**	**17426**
Total additional E-waste in SUB, in million kg	**91.6**	**85.8**	**78.8**	**71.4**	**64.0**	**58.9**	**54.0**	**49.4**	**44.8**	**40.2**	**0.5**	**0.7**	**0.9**	**1.0**	**1.2**

Source: Calculated with the VHK-Oeko-Institut Combined Model for RoHS; Note: Values are rounded; Negative values represent benefits

4.1 Sensitivity analysis

The 2019 SEA study dataset and the CLASP/SwEA dataset represent the upper and lower ranges of possible impacts of a phase-out of LFL T5 lamps to begin in 2021. To show how impacts are affected when an intermediate number of lamps is assumed to be replaced with Plug&Play substitutes, the Sensitivity data set was applied. Results for this data set are presented in Table 4-4.

Annually, the total additional costs under the Sensitivity data set assumptions lead to benefits as of 2027. However, cumulatively, the costs are only set off in 2034. The total cumulative benefits amount to 2,405 million euros for the period between 2021 and 2035. The benefits of this transition amount to 5.60 euro per lamp. In total, within this period ca. 279 thousand tonnes of E-waste are generated prematurely.

Table 4-4: Revised estimated impacts calculated for LFL T5 (using Sensitivity data set)

Sensitivity data set	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Avoided purchase cost in SUB for CFLni, M euros	-485	-454	-418	-378	-339	-312	-286	-262	-237	-213	-199	-184	-168	-151	-135
Additional purchase cost for LED in SUB plug&play, M euros	941	801	695	598	505	461	405	356	317	279	3	4	5	6	7
Additional cost for LED+rewiring in SUB, M euros	310	275	244	215	186	171	153	137	123	109	1	2	2	3	3
Additional cost for LED+luminaire in SUB, M euros	2691	2521	2317	2099	1880	1730	1588	1452	1317	1181	14	20	25	30	35
Total additional purchase costs in SUB, M euros	**3458**	**3142**	**2838**	**2533**	**2232**	**2051**	**1861**	**1683**	**1519**	**1356**	**-181**	**-159**	**-136**	**-113**	**-91**
Total additional cost in SUB, M euros (add. purchase cost minus energy cost savings)	3198	2612	2030	1448	879	431	-14	-435	-829	-1209	-2528	-2300	-2086	-1890	-1710
Cumulative from period start in SUB, M euros	**3198**	**5809**	**7839**	**9288**	**10166**	**10597**	**10583**	**10148**	**9319**	**8110**	**5581**	**3281**	**1195**	**-695**	**-2405**
Total additional E-waste in SUB in million kg	**39.8**	**37.3**	**34.3**	**31.0**	**27.8**	**25.6**	**23.5**	**21.5**	**19.5**	**17.5**	**0.2**	**0.3**	**0.4**	**0.4**	**0.5**

Source: Calculated with the VHK-Oeko-Institut Combined Model for RoHS; Note: Values are rounded; Negative values represent benefits

5 Revised estimated impacts for LFL T8

Table 5-1 presents data and estimations identical for all three data sets. It includes the number of LFL T8 that need replacement in each year (distribution to residential and non-residential), the energy (cost) savings related to substitution with LED alternatives and the total avoided mercury on the market.

Table 5-1: Number of LFL T8 to be replaced, related energy (cost) savings and mercury avoided on the market

All data sets	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
LFL T8 projected sales in SUB, all sectors (mln)	123.9	99.9	60.7	28.4	17.8	12.5	7.8	7.0	6.2	5.2	4.4	3.7	3.0	2.3	1.8
LFL T8 replaced by LED in SUB, residential (mln)	10.2	7.1	3.9	1.9	1.2	0.9	0.6	0.7	0.7	0.7	0.7	0.6	0.6	0.6	0.5
LFL T8 replaced by LED in SUB, non-resid. (mln)	113.7	92.8	56.8	26.5	16.5	11.5	7.2	6.3	5.4	4.5	0.0	0.0	0.0	0.0	0.0
Total energy savings in SUB, GWh	-4645	-8695	-11355	-12674	-13539	-14171	-14571	-14931	-15246	-15511	-10611	-6610	-4187	-3088	-2414
Total energy cost savings in SUB, M euros	-820	-1550	-2045	-2305	-2487	-2629	-2730	-2826	-2915	-2995	-2052	-1283	-816	-605	-475
Total avoided mercury in SUB, in kg	**310**	**250**	**152**	**71**	**44**	**31**	**20**	**18**	**15**	**13**	**11**	**9**	**7**	**6**	**4**

Source: Calculated with the VHK-Oeko-Institut Combined Model for RoHS; Note: Values are rounded; Negative values represent benefits

The first line in Table 5-1 presents the projected sales of LFL T8, decreasing with the years, which would take place in the BAU scenario, where RoHS exemptions remain valid for LFL T8. This projection reflects the Ecodesign scenario with phase-out of most LFL T8 for energy efficiency reasons starting from 2023. Most of these sales are replacement sales, i.e. LFL T8 replacing LFL T8 that have reached end-of-life. In the SUB scenario, once the RoHS exemptions are revoked, it is assumed that LFL T8 could no longer be sold and could no longer be used for replacement of such lamps at end-of-life. Thus, all such replacements would need to be performed with LEDs through Plug&Play replacements, through such replacements with additional rewiring work or through replacement of the luminaire. In the residential sector, where LFL T8 lifetime is 18 years, LED replacements take place based on these sales until 2035 (second line in table). However, in the non-residential sector, where average LFL T8 lifetime is 10 years, LFL T8 sold in for example 2031 in the BAU scenario would be replacements for LFL T8 sold in 2021. Whereas in the SUB scenario, LFL T8 replaced in 2021 by LEDs, which have a longer lifetime, will not need to be replaced again in 2031. Therefore from 2031 onwards, non-residential LFL T8 replaced by LED are set to zero (third line in table).

Energy savings are computed as the difference between electricity consumption by LEDs substituting LFL T8 in the SUB scenario and electricity consumption that LFL T8 would otherwise have had in the BAU scenario. The difference is multiplied by the electricity rate (€/kWh) to get the corresponding cost savings. Energy savings (negative values in the table) increase in early years but decrease from 2031. In that year the LFL bought in 2021 reach their end-of-life and the stock considered in the analysis starts to decrease.

In the period between 2021 and 2035, a total amount of 962 kg of mercury is avoided from being placed on the EU market.

The revised calculations for impacts of the regulatory driven substitution of LFL T8 lamps, performed on the basis of the CLASP/SwEA data set, are presented in Table 5-2.

Table 5-2: Revised estimated impacts calculated for T8 lamps (using CLASP/SwEA data set)

CLASP/SwEA data set	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Avoided purchase cost for LFLT8 in SUB, M euros	-1060	-854	-518	-242	-152	-106	-67	-60	-53	-45	-38	-32	-26	-21	-16
Additional purchase cost for LED plug&play in SUB, M euros	4509	3338	1923	855	504	351	210	180	154	127	12	11	11	10	9
Additional cost for LED+rewiring in SUB, M euros	34	26	15	7	4	3	2	2	1	1	0	0	0	0	0
Additional cost for LED+luminaire in SUB, M euros	604	487	296	138	87	61	38	34	30	25	3	3	3	3	3
Total additional purchase costs in SUB, M euros	4087	2998	1716	758	443	308	183	156	132	108	-23	-18	-12	-8	-5
Total additional cost in SUB, M euros (add. purchase cost minus energy cost savings)	3267	1448	-329	-1547	-2044	-2321	-2547	-2670	-2782	-2887	-2076	-1300	-829	-613	-480
Cumulative from period start in SUB, M euros	**3267**	**4714**	**4386**	**2838**	**794**	**-1527**	**-4074**	**-6745**	**-9527**	**-12414**	**-14490**	**-15790**	**-16619**	**-17232**	**-17712**
Total additional E-waste in SUB, in million kg	**10.6**	**8.6**	**5.2**	**2.4**	**1.5**	**1.1**	**0.7**	**0.6**	**0.5**	**0.4**	**0.1**	**0.1**	**0.1**	**0.0**	**0.0**

Source: Calculated with the VHK-Oeko-Institut Combined Model for RoHS; Note: Values are rounded; Negative values represent benefits

The additional purchase costs are computed as the sum of (additional) costs in the SUB scenario for LED Plug&Play, LED + rewiring, and LED + luminaire replacement, minus the (avoided) purchase costs for LFL T8 of the BAU scenario. The additional purchase costs decrease with the years because the number of LFL T8 substituted by LEDs decreases and because LED prices progressively decrease. From 2031, the additional costs are even slightly negative because the avoided costs for LFL T8 are higher than the additional costs for the few residential LFL T8 that are still to be replaced by LED.

Combining the additional purchase costs the energy cost savings of Table 5-1 leads to an annual net benefit already in 2023, whereas the cumulative total purchase costs are set-off by the cumulative total energy savings starting from 2026. The table shows cumulative costs for each year and as such it is observed for example that in 2030 the cumulative benefits have reached 12,414 million euro. In total, the regulatory driven substitution results in a total net benefit of over 17,721 million euros for the period between 2021 and 2035. Considering a total of 372 million LFL T8 substituted by LEDs, this translates into a net benefit per lamp of 47.56 euros.

The regulatory driven phase-out leads in some cases to the need to rewire existing luminaires or to replace them, which generates a total amount of 32,000 tonnes of e-waste prematurely (accelerated impact). It is noted that this calculation does not consider that fluorescent lamps or luminaires may weigh more than the LED lamps or luminaires replacing them, which in the long term could lead to a decrease in generated e-waste.

These results change significantly when applying the 2019 SEA study data set on the availability of 12% Plug&Play substitutes to the calculation model. In total, the regulatory-driven substitution results in a total net cost of 11,749 million euros for the period between 2021 and 2035 due to the high costs of luminaire replacements. This translates into a cost of 31.55 euros per lamp. This is despite the fact that on an annual basis, benefits can already be seen from 2025 and on. In the cumulative costs, specified in the table for each year, it is observed that total costs start to decrease here as well, however as the number of lamps to be replaced in the first years is significantly higher, though the energy savings have decreased the total costs on the cumulative basis in 2035 to less than half the amount of 2025, they are not set-off completely within the observed period.

In this period, the amount of mercury avoided on the EU market remains the same under both the CLASP/SwEA and 2019 SEA study data sets as the number of lamps to be replaced has not changed, but a larger amount of e-waste, 704 thousand tonnes, is generated prematurely (accelerated impact) applying the 2019 SEA study data set as a larger number of lamps replaced require rewiring (10%) or luminaire replacement (78%).

Table 5-3: Revised estimated impacts calculated for T8 lamps (using 2019 SEA study data set)

2019 SEA study data set	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Avoided purchase cost for LFLT8 in SUB, M euros	-1060	-854	-518	-242	-152	-106	-67	-60	-53	-45	-38	-32	-26	-21	-16
Additional purchase cost for LED plug&play in SUB, M euros	564	417	240	107	63	44	26	22	19	16	1	1	1	1	1
Additional cost for LED+rewiring in SUB, M euros	748	573	337	153	92	65	39	35	30	25	3	3	3	2	2
Additional cost for LED+luminaire in SUB, M euros	13285	10719	6515	3046	1906	1336	839	752	660	559	72	68	66	60	55
Total additional purchase costs in SUB, M euros	13537	10856	6574	3063	1909	1338	837	749	656	554	38	40	44	43	43
Total additional cost in SUB, M euros (add. purchase cost minus energy cost savings)	12717	9305	4530	758	-578	-1291	-1893	-2077	-2258	-2441	-2014	-1242	-772	-562	-433
Cumulative from period start in SUB, M euros	**12717**	**22022**	**26552**	**27310**	**26732**	**25441**	**23548**	**21471**	**19213**	**16773**	**14758**	**13516**	**12743**	**12182**	**11749**
Total additional E-waste in SUB, in million kg	**234.1**	**188.9**	**114.8**	**53.7**	**33.6**	**23.6**	**14.8**	**13.3**	**11.6**	**9.8**	**1.3**	**1.2**	**1.2**	**1.1**	**1.0**

Source: Calculated with the VHK-Oeko-Institut Combined Model for RoHS; Note: Values are rounded; Negative values represent benefits

5.1 Sensitivity analysis

The 2019 SEA study dataset and the CLASP/SwEA dataset represent the upper and lower ranges of possible impacts of a phase-out of LFL T8 lamps to begin in 2021. To show how impacts are affected when an intermediate number of lamps is assumed to be replaced with Plug&Play substitutes, the Sensitivity data set was applied. Results for this data set are presented in Table 5-4.

Annually, the total additional costs under the Sensitivity data set assumptions lead to benefits as early as 2024. However, cumulatively, the costs are only set off in 2032. The total cumulative benefits amount to 2,879 million euros for the period between 2021 and 2035. The benefits of this transition amount to 7.73 euro per lamp. In total, within this period ca. 367 thousand tonnes of E-waste are generated prematurely.

Table 5-4: Revised estimated impacts calculated for LFL T8 (using Sensitivity data set)

Sensitivity data set	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Avoided purchase cost in SUB for CFLni, M euros	-1060	-854	-518	-242	-152	-106	-67	-60	-53	-45	-38	-32	-26	-21	-16
Additional purchase cost for LED in SUB plug&play, M euros	2349	1739	1001	445	262	183	109	94	80	66	6	6	6	5	5
Additional cost for LED+rewiring in SUB, M euros	748	573	337	153	92	65	39	35	30	25	3	3	3	2	2
Additional cost for LED+luminaire in SUB, M euros	6813	5497	3341	1562	977	685	430	386	339	287	37	35	34	31	28
Total additional purchase costs in SUB, M euros	**8850**	**6955**	**4161**	**1918**	**1180**	**826**	**512**	**454**	**396**	**332**	**7**	**11**	**16**	**18**	**19**
Total additional cost in SUB, M euros (add. purchase cost minus energy cost savings)	8029	5405	2117	-387	-1307	-1803	-2219	-2372	-2519	-2663	-2045	-1271	-800	-587	-456
Cumulative from period start in SUB, M euros	**8029**	**13434**	**15551**	**15163**	**13857**	**12054**	**9835**	**7463**	**4944**	**2281**	**236**	**-1035**	**-1835**	**-2423**	**-2879**
Total additional E-waste in SUB in million kg	**122.3**	**98.7**	**60.0**	**28.0**	**17.5**	**12.3**	**7.7**	**6.9**	**6.1**	**5.1**	**0.7**	**0.6**	**0.6**	**0.6**	**0.5**

Source: Calculated with the VHK-Oeko-Institut Combined Model for RoHS; Note: Values are rounded; Negative values represent benefits

6 Conclusions

For all lamp types (CFLni, LFL T5 and LFL T8), the total costs resulting from not granting the exemption renewals requested (a “substitution scenario”) largely depend on the share of Plug&Play lamps that would be available on the market as replacements at the time from when the exemptions expire. This is related to the costs of the rewiring and, in particular, to the costs of the luminaire replacement (where no Plug&Play lamps are available) being much higher for the end-user than a simple replacement of the lamp. Where Plug&Play alternatives are available, this relatively quickly leads to benefits through related energy savings and enables an average benefit of the substitution per lamp. Where such alternatives are lacking, the costs are high, as a result of the additional labour costs for rewiring and luminaire replacement and, particularly, of the luminaire replacement costs for which relatively high unit costs have been assumed in this study (100 euro per CFLni luminaire and 250 euro per LFL luminaire).

Common to all three data sets under the substitution scenario are the calculated energy savings and mercury emission avoidance. For all lamp types concerned, in the period of 2021-2035, energy savings would cumulatively amount to 309 TWh. Accordingly, mercury avoided in lamps being placed on the market would amount to 2 882 kg (this figure does not include reductions in mercury emissions from reduced electricity generation). It is to be noted that the environmental benefits from these energy savings (e.g. in terms of climate protection) and mercury emission avoidance (e.g. in terms of pollution prevention and human health benefits) could not be considered in the 2019 SEA study or this review.

The two main data sets examined here, one using estimations from CLASP/SwEA and the other from the 2019 SEA study, differ considerably in the estimations of the share of Plug&Play lamps available, as the market availability of these lamps increased significantly in the past three years. In consequence, there are considerable differences in the expected costs and benefits between the results generated by the calculation model for these data sets. The Sensitivity data set is more moderate relative to the two main data sets, the 2019 SEA study and CLASP/SwEA respectively, and its results are placed between them. It is also noted that although the 2019 SEA study considered multiple lamps per luminaire in its sensitivity analysis, the main scenario assumed a single lamp per luminaire. In the present model, depending on the lamp type, more than one lamp is assumed to be applied per luminaire replaced (1.5, 2 and 2.5 for CFLni, LFL T8 and LFL T5 respectively) and this affects the total estimated costs where luminaire replacement is concerned.

Regarding **CFLni** lamps, applying the CLASP/SwEA data set results in a total net benefit in the order of 2 849 million euros for the period between 2021 and 2035 (benefit of 11.78 euros per lamp). The 2019 SEA study data set results in total costs in the order of 9 044 million euros (cost of 37.39 euros per lamp). The process of substitution is accompanied with a premature generation of e-waste from rewiring and lamp replacement of between 22 and 180 thousand tonnes of e-waste (CLASP/SwEA and 2019 SEA study data sets respectively), though it is possible that lower weight of LED luminaires will in the long run generate a general decrease in e-waste amounts. Both cases avoid 856 kg of mercury in lamps being placed on the EU market. Under the Sensitivity data set, the cumulative costs of the phase-out amount to 3 404 million euros for the period between 2021 and 2035 or 14.07 euro per lamp. In parallel ca. 106 000 tonnes of e-waste are generated prematurely; mercury amounts not entering the market remain the same in all data sets (856 kg).

In relation to **LFL T5** lamps, applying the CLASP/SwEA data set results in a total net benefit in the order of 9 304 million euros to be incurred between 2021 and 2035 (benefit of 21.66 euros per lamp).

The 2019 SEA study data set results in total costs in the order of 17 426 million euros (costs of 40.57 euro per lamp). The process of substitution is accompanied by a premature generation of e-waste of between 156 and 643 thousand tonnes (CLASP/SwEA and 2019 SEA study data sets respectively), possibly to be offset in the future in light of lower weight of LED luminaires and tubes which could decrease general e-waste amounts. Both cases avoid 1 064 kg of mercury in lamps being placed on the EU market. Under the Sensitivity data set, the phase-out leads to cumulative benefits in the order of 2 405 million euros for the period between 2021 and 2035 or 5.60 euro per lamp. 279 000 tonnes of e-waste are generated prematurely; mercury amounts not entering the market remain the same in all data sets (1 064 kg).

In relation to **LFL T8** lamps, the CLASP/SwEA data set results in a total net benefit in the order of 17,712 million euros between 2021 and 2035 (benefit of 47.56 euros per lamp). The 2019 SEA study data set results in total costs in the order of 11,749 million euros (costs of 31.55 euro per lamp). The substitution is accompanied with a premature generation of e-waste from rewiring and lamp replacement of between 32 and 704 thousand tonnes of e-waste (CLASP/SwEA and 2019 SEA study data sets respectively), though possibly also with a general decrease in e-waste amounts in light of lower weight of LED luminaires and tubes. Both cases avoid 962 kg of mercury in lamps being placed on the EU market. Under the Sensitivity data set, the phase-out leads to cumulative benefits in the order of 2,879 million euros for the period between 2021 and 2035 or a benefit of 7.73 euro per lamp. 368 000tonnes of e-waste are generated prematurely; mercury amounts not entering the market remain the same in all data sets (962 kg).

List of References

Baron, Y.; Blepp, M.; Gensch, C-O. (2019): Study to assess socio-economic impact of substitution of certain mercury-based lamps currently benefitting of RoHS 2 exemptions in Annex III. Under the Framework Contract led by Oeko-Institut: Assistance to the Commission on technical, socio-economic and cost-benefit assessments related to the implementation and further development of EU waste legislation. Prepared for the European Commission. Unter Mitarbeit von O. Deubzer. Hg. v. Oeko-Institut e.V.

Bass, F. & Scholand, M. (2020): Plug & Play CFLni, 11.02.2020. Email an Yifaat Baron.

Bennich, P. & Scholand, M. (2020): Assessing Annex III Fluorescent Lamp Exemptions in the Light of Scientific and Technical Progress. Report to the Committee on the Regulation of Hazardous Substances. Hg. v. Swedish Energy Agency and CLASP Europe. 24.2.2020.

LightingEurope (2020a): Request to renew Exemptions 1(a, b, c, e). under the RoHS Directive 2011/65/EU.

LightingEurope (2020b): Request to renew Exemptions 2(a)(2), 2(a)3 and 2(b)3. Under Annex III of the RoHS Directive 2011/65/EU.

LightingEurope (2020c): LightingEurope comments to the presentations in the technical meeting of the 12th of February 2020 on the 2015 RoHS mercury exemptions for lighting, Brussels, 21 February 2020

LightingEurope (2020d): LightingEurope Calculations, Potential impact of an early phase out of most fluorescent lamps subject to RoHS 2015 exemption renewal requests, 9 June 2020

Scholand, M. (2020): SEA Background document LED Linear tube compatibility table - T5 and T8 lamps - final. Hg. v. CLASP Europe.

VHK (2016): Model for European Light Sources Analysis (MELISA) v3, prepared for the European Commission, 13.07.2016.

VHK (2019): Model for European Light Sources Analysis (MELISA). Update of 7/11/2019,. prepared for the European Commision.

Annex I. Variables used in VHK-Oeko-Institut Combined Model for RoHS

Table 6-1: General input parameters

General input parameters			
Prices / costs	2015 euros		
Working hours per day	8		
Working days per year	220		
Labour cost (€/hour)	50		
VAT for residential users	20%		
	2020	2025	2030
Electricity rate, residential (2015 €/kWh) (incl. VAT)	0,21	0,22	0,23
Electricity rate, non-residential - tertiary (2015 €/kWh)	0,17	0,18	0,19
	LFL T8	LFL T5	All CFLni
N lamps per luminaire	2	2,5	1,5
Hours rewiring per luminaire	0,5	0,5	0,5
Hours installation per luminaire	0,5	0,5	0,5
FL unit price (excl. VAT, excl. install) (€)	8,42	7,92	4,39
CG unit price per light source, residential, incl. VAT (€)	10	10	10
CG unit price per light source, non-residential, excl. VAT (€)	10	10	20
LED luminaire price, residential, incl. light source and CG, incl. VAT (€)	250	250	100
LED luminaire price, non-residential, incl. light source and CG, excl. VAT (€)	250	250	100
Luminous flux, residential (lm) (FL and LED)	2400	2275	690
Luminous flux, non-residential (lm) (FL and LED)	3320	2600	1200
Annual burning hours, residential (h/a) (FL and LED)	700	700	700
Annual burning hours, non-residential (h/a) (FL and LED)	2200	2200	1600
Efficacy FL incl. CG, residential (lm/W)	72	82	55
Efficacy FL incl. CG, non-residential (lm/W)	77	85	55
Power FL incl. CG, residential (W)	33	28	12
Power FL incl. CG, non-residential (W)	43	31	22

Source: Source: Model for European LIght Sources (VHK 2019)

Table 6-2: Additional data for LEDs

LED input data	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
LED efficacy, res, lm/W [1]	110	118	126	134	142	150	152	155	157	160	160	160	160	160	160
LED efficacy, nres, lm/W [2]	132	139	148	157	166	175	179	183	186	190	190	190	190	190	190
LED price, res, euros/klm [1]	7.62	7.68	7.62	7.48	7.22	7.23	6.83	6.52	6.36	6.24	6.24	6.24	6.24	6.24	6.24
LED price, nres, euros/klm [2]	11.85	10.77	10.16	9.65	9.10	9.03	8.65	8.30	8.15	8.00	8.00	8.00	8.00	8.00	8.00
LEDs replacing LFL T8															
Power (W/unit) res	21.8	20.3	19.0	17.9	16.9	16.0	15.8	15.5	15.3	15.0	15.0	15.0	15.0	15.0	15.0
Power (W/unit) nres	25.2	23.9	22.4	21.1	20.0	19.0	18.6	18.2	17.8	17.5	17.5	17.5	17.5	17.5	17.5
LEDs replacing LFL T5															
Power (W/unit) res	20.7	19.3	18.1	17.0	16.0	15.2	15.0	14.7	14.5	14.2	14.2	14.2	14.2	14.2	14.2
Power (W/unit) nres	19.7	18.7	17.6	16.6	15.7	14.9	14.5	14.2	14.0	13.7	13.7	13.7	13.7	13.7	13.7
LEDs replacing CFLni															
Power (W/unit) res	6.3	5.8	5.5	5.1	4.9	4.6	4.5	4.5	4.4	4.3	4.3	4.3	4.3	4.3	4.3
Power (W/unit) nres	9.1	8.6	8.1	7.6	7.2	6.9	6.7	6.6	6.4	6.3	6.3	6.3	6.3	6.3	6.3

Notes:
1 – LED efficacy (incl. control gear) and price for residential, from MELISA 2019 for low-end LEDs with energy label effect (same as used in Impact Assessment accompanying 2019 single lighting regulation, SWD 2019/357 part 2, Annex 4, section 2.2)
2 – LED efficacy (incl. control gear) and price for non-residential, from MELISA 2019 for high-end LEDs with energy label effect (same as used in Impact Assessment accompanying 2019 single lighting regulation, SWD 2019/357 part 2, Annex 4, section 2.2)
Source: Model for European LIght Sources (VHK 2019)

Reference sales of fluorescent lamps

The MELISA model (VHK, 2019) projects the sales for LFL T8, and CFLni for an Ecodesign BAU scenario (without new ecodesign and energy labelling measures) and an Ecodesign ECO scenario (including also new measures). These sales are reported in Impact Assessment (IA) SWD 2019/357 Annex 4, accompanying the new lighting regulations CR 2019/2020 (ecodesign) and CDR 2019/2015 (energy labelling), but only the totals for all LFL and for all CFL are reported in the IA. The table below provides the subdivision of projected sales over LFL T8, T5 and CFLni.

For LFL T5 and CFLni, the new lighting regulations do not cause a phase-out of light sources and consequently the projected sales for BAU and ECO scenarios are the same. These sales can directly be used as fluorescent lamps to be replaced by LEDs in the RoHS SUB scenario.

For LFL T8, the new lighting regulations phase out models with 2/4/5 foot lengths. MELISA assumes that this covers ≈90% of all LFL T8 models. In the Impact Assessment the phase-out was proposed for 2021 (see sales of ECO 2021 IA in table below), but the final regulation implies a phase-out in 2023. The MELISA sales projection was adapted for the two year shift in phase-out between the IA and the final CR (see sales of ECO 2023 CR in table below).
In case of the RoHS BAU scenario (renewal of the exemptions, no forced substitution by LEDs), the ECO 2023 CR sales projection of MELISA remains valid. Hence, these ECO 2023 CR sales are the reference LFL T8 sales that would have to be substituted by LEDs in the RoHS SUB scenario.

The reference sales of MELISA are numbers of light sources. As the average FL luminaire contains more than one FL light source (see 'N lamps per luminaire' in table above), the number of luminaires to be substituted (when this substitution option is used) is lower.

In previous SEA analyses, regulation CR 2019/2020 was not finally decided yet, and thus the MELISA BAU sales were used as the reference for RoHS. As can be verified in the table below, this implied a much higher number of LFL T8 to be substituted. In addition, the previous analyses presented (maximum) purchase cost results assuming one light source per luminaire. This explains the large difference in results between the previous and the new analysis, even when the same substitution option shares are used.

Table 6-3: Sales data (mln units)

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
LFL T8																	
MELISA BAU	162	151	136	122	111	103	97	91	85	79	73	65	60	54	49	43	38
MELISA ECO 2023 CR	162	151	124	100	61	28	18	12	8	7	6	5	4	4	3	2	2
MELISA ECO 2021 IA	147	124	74	34	20	14	9	8	7	6	5	4	4	3	2	2	1
LFL T5																	
MELISA BAU	65	64	61	57	53	48	43	39	36	33	30	27	25	23	21	19	17
MELISA ECO (IA, CR)	65	64	61	57	53	48	43	39	36	33	30	27	25	23	21	19	17
CFLni																	
MELISA BAU	52	47	45	42	38	33	29	23	19	15	11	8	7	5	4	3	2
MELISA ECO (IA, CR)	52	47	45	42	38	33	29	23	19	15	11	8	7	5	4	3	2

Source: Model for European LIght Sources Analysis (VHK 2019)

Values used for calculation of mercury contents of lamps and amounts of WEEE

The calculation of the amount of mercury to be placed on the market through discharge lamps (CLFni, LFL T5 and LFL T8) is based on values from the 2019 SEA study (Baron et al. 2019), table 15 (for CFLni) and table 34 (for T5 and T8).
The following values were applied in the current calculation:

Table 6-4: Hg average amount used for calculation of Hg per lamp, in mg

T8	T5	CFLni: P <12 W	CFLni: 12 W ≤ P < 30 W	CFLni: 30 W ≤ P < 50 W	CFLni: P ≥ 50 W
2.5	2	1.5	2.5	4	14

Source: 2019 SEA Study (Baron et al. 2019)

Regarding assessments made for e-waste impacts, the 2019 study (Baron et al. 2019) calculated the waste amounts in relation to a best case and a worst case estimation. For simplicity, an average of these two cases has been assumed in the current model. Values used in the model and the basis value for calculation appear in the following table.

Table 6-5: Values used in current model for calculating E-waste generated prematurely, in kg

	LFL T8	LFL T5	CFLni
Auxiliary components (rewiring) (in kg per light source)			
Best case (2019 SEA study)	0.25	0.24	0.25
Worst case (2019 SEA study)	0.5	0.37	0.5
Average applied in current model	**0.375**	**0.305**	**0.375**
Luminaire (replacement) (in kg per luminaire)			
Best case (2019 SEA study)	2.5	2.25	1
Worst case (2019 SEA study)	7	5.5	2
Average applied in current model	**4.75**	**3.875**	**1.5**

Source: Specified in table