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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, 08.05.2020

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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)
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.
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 study was prepared based on data from the VHK (2016) Model for European LIght Sources Analysis (MELISA), data provided by Lighting Europe in 2015, submitted 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 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.

Particularly 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 new evidence as provided by the Commission.

Related to 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 luminaires as well as labour costs for luminaire rewiring and for luminaire replacement);
- Energy savings expected through substitution of such lamps with LED;
- The amount of mercury avoided on the market through substitution with LED;
- The amount of e-waste to be generated prematurely through substitution with LED.

The following scenarios were considered:

- Business as usual scenario (BAU): current RoHS exemptions for CFLni, T5 and T8 remain valid, however it will no longer be possible to place some conventional lamp types on the market as a result of the application of the new Ecodesign Regulation on light sources[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.

Finally, for each lamp type, the data on market availability of substitutes used in the 2019 SEA study were entered into the revised model for comparison.

[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. Additional 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, values specified in the 2019 SEA study(Baronetal.É, table 15 (for CFLni) and table 34 (for T5 and T8) as estimated average values 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, these values were at the time consulted with Lighting Europe.

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, evidence as to the current shares related to these substitution routes in the market situation of 2020 was submitted to the European Commission. The following estimations (Table 2-1) for LFL 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), providing 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 share estimations shall be referred to throughout this study as the CLASP/SwEA data set.

For comparison, the share estimates for the availability of LED alternatives for T5, T8 and CFLni initially used in the 2019 SEA study were also applied to the model and shall be referred to throughout this study as the 2019 SEA study data set. The shares applied therein are also specified in Table 2-1 below.

[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.

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);

Detailed explanations as to how market flows and certain impacts have been calculated are specified in the 2019 SEA 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.Revised estimated impacts for CFLni

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 2-2.

The first line in the table 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).

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.

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 later start to decrease (2027) and values even become positive (indicating additional expense) in the last years of the analysis period. Within the analysis, the different lifetimes for CFLni and LED and the decrease in sales year-by-year (lamps to be replaced) will lead to a LED stock (and energy) that is higher than the CFLni stock (and energy) in later years. This leads to the decrease in the energy saving costs from 2027 onwards.

Combining the additional purchase costs with the costs regarding saved energy 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 1033 million euros for the period between 2021 and 2035. Considering a total number of 243 million CFLni substituted by LEDs, this translates into a net benefit of 4.27 euros per lamp.

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. On the other side, the regulatory-driven phase-out in some cases would result 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.

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

	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	-2712	-2068	-1459	-912	-443	-56	266	530	734
Total energy cost savings in SUB, M euros	**-124**	**-245**	**-359**	**-463**	**-555**	**-634**	**-521**	**-405**	**-294**	**-192**	**-103**	**-29**	**33**	**83**	**122**
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	500	299	112	-68	-234	-373	-515	-404	-294	-191	-99	-24	39	89	128
Cumulative from period start in SUB, M euros	**500**	**800**	**912**	**843**	**609**	**236**	**-279**	**-682**	**-976**	**-1167**	**-1266**	**-1290**	**-1251**	**-1162**	**-1033**
Total avoided mercury in SUB in kg	**134**	**126**	**114**	**101**	**86**	**71**	**57**	**45**	**34**	**25**	**20**	**15**	**12**	**9**	**7**
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

These 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. In total, the regulatory-driven substitution results for this data set in a total net cost of over 10,860 million euros for the period between 2021 and 2035 due to the high costs of luminaire replacements. This translates into a cost of 44.89 euros per lamp.

In this period, the amount of mercury avoided on the EU market remains the same under both CLASP/SwEA and 2019 SEA data sets as the number of lamps to be replaced has not changed, but a larger amount of e-waste, 180 thousand tonnes, is generated prematurely (accelerated impact) when applying the 2019 SEA data set as a larger number of lamps replaced require rewiring (24-30%) or luminaire replacement (56-70%).

3 Revised estimated impacts for LFL T5

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 3-1.

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).

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.

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 later start to decrease. The different lifetimes for LFL T5 and LED and the decrease in sales from year to year (lamps to be replaced) lead to a LED stock (and energy) that is higher than the LFL T5 stock (and energy) in later years. This leads to the decrease in the energy saving costs from 2031 onwards.

Combining the additional purchase costs with the saved energy costs leads to an annual net benefit already from 2026, whereas cumulatively the total purchase costs are set-off by the total energy savings starting from 2031. The regulatory-driven substitution results in a total net benefit of 5836 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 13.59 € per lamp.

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

Table 3-1: Revised estimated impacts calculated for T5 lamps (using CLASP/SwEA data set)

	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	-10885	-8572	-6427	-4467	-2694
Total energy cost savings in SUB, M euros	**-260**	**-531**	**-808**	**-1085**	**-1354**	**-1620**	**-1875**	**-2118**	**-2349**	**-2565**	**-2096**	**-1651**	**-1238**	**-861**	**-520**
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	2273	1720	1196	682	182	-211	-610	-984	-1329	-1659	-2282	-1818	-1384	-986	-625
Cumulative from period start in SUB, M euros	**2273**	**3993**	**5189**	**5871**	**6053**	**5842**	**5232**	**4247**	**2918**	**1259**	**-1023**	**-2841**	**-4225**	**-5211**	**-5836**
Total avoided mercury in SUB, in kg	**122**	**115**	**105**	**95**	**85**	**79**	**72**	**66**	**60**	**54**	**50**	**46**	**42**	**38**	**34**
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

These results change significantly when applying the 2019 SEA study data set on the availability of 1% Plug & Play substitutes to the calculation model. In total, the regulatory-driven substitution results for this data set in a total net cost of over 20,895 million euros for the period between 2021 and 2035 due to the high costs of luminaire replacements. This translates into a cost of 48.65 euros per lamp.

In this period, the amount of mercury avoided on the EU market remains the same under both the CLASP/SwEA and 2019 SEA data sets as the number of lamps to be replaced has not changed, but a larger amount of e-waste, 643 thousand tonnes, is generated prematurely (accelerated impact) when applying the 2019 SEA data set as a larger number of lamps replaced require rewiring (3%) or luminaire replacement (96%).

4 Revised estimated impacts for LFL T8

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 4-1.

The first line in the table 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).

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.

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 later start to decrease and values even become positive (indicating additional expense) in the last years of the analysis period. The different lifetimes for LFL T8 and LED and the decrease in sales from year to year (lamps to be replaced) lead to a LED stock (and energy) that is higher than the LFL T8 stock (and energy) in later years.

Combining the additional purchase costs with the saved energy costs 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. As of 2032, the annual net benefit for energy savings is negative (i.e. costs occur), however, this is due to the number of LFL to be replaced in these years having significantly decreased. Thus, in the comparison of energy consumption, the total consumption of LEDs operating in this period is larger than that of still operating LFL, resulting in energy costs rather than savings. Nonetheless, the total cumulative costs show a net benefit until the end of the observed period. In total, the regulatory driven substitution results in a total net benefit of over 6593 million euros for the period between 2021 and 2023. Considering a total of 372 million LFL T8 substituted by LEDs, this translates into a net benefit per lamp of 17.70 euros.

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

Table 4-1: Revised estimated impacts calculated for T8 lamps (using CLASP/SwEA data set)

	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	-5026	3537	8727	11084	12534
Total energy cost savings in SUB, M euros	-820	-1550	-2045	-2305	-2487	-2629	-2730	-2826	-2915	-2995	-977	671	1669	2123	2402
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	3267	1448	-329	-1547	-2044	-2321	-2547	-2670	-2782	-2887	-1001	653	1657	2115	2397
Cumulative from period start in SUB, M euros	**3267**	**4714**	**4386**	**2838**	**794**	**-1527**	**-4074**	**-6745**	**-9527**	**-12414**	**-13415**	**-12762**	**-11105**	**-8990**	**-6593**
Total avoided mercury in SUB, in kg	**310**	**250**	**152**	**71**	**44**	**31**	**20**	**18**	**15**	**13**	**11**	**9**	**7**	**6**	**4**
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

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 over 22,868 million euros for the period between 2021 and 2035 due to the high costs of luminaire replacements. This translates into a cost of 61.41 euros per lamp.

In this period, the amount of mercury avoided on the EU market remains the same under both the CLASP/SwEA and 2019 SEA data sets as the number of lamps to be replaced has not changed, but a larger amount of e-waste, 703 thousand tonnes, is generated prematurely (accelerated impact) applying the 2019 SEA data set as a larger number of lamps replaced require rewiring (10%) or luminaire replacement (78%).

5 Conclusions

For all lamp types (CFLni, LFL T5 and LFL T8), the total costs of not granting the exemption renewals requested (a substitution scenario) largely depend on the share of plug & play lamps available as replacements on the market at the time from when the exemptions expire. This is related to the costs of the rewiring and, in particular, the luminaire replacement routes 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 driven 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).

Both data sets examined here, one using estimations from CLAP/SwEA and the other from the 2019 SEA study, differ considerably in the estimations of the share of available plug & play lamps, 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 of these data sets.

In relation to **CFLni** lamps, applying the CLASP/SwEA data set results in a total net benefit in the order of 1033 million euros for the period between 2021 and 2035 (benefit of 4.27 euros per lamp). The 2019 SEA study data set results in total costs in the order of 10,860 million euros (cost of 44.89 euro 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 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 being placed on the EU market.

In relation to **LFL T5** lamps, applying the CLASP/SwEA data set results in a total net benefit in the order of 5836 million euros to be incurred between 2021 and 2035 (benefit of 13.59 euros per lamp). The 2019 SEA study data set results in total costs in the order of 20,895 million euros (costs of 48.65 euro per lamp). The process of substitution is accompanied with a premature generation of e-waste of between 156 and 643 thousand tonnes (CLASP/SwEA and 2019 SEA study respectively), possibly to be set-off in the future in light of lower weight of LED luminaires and tubes which could decrease general e-waste amounts. Both cases avoid 1064 kg of mercury being placed on the EU market.

In relation to **LFL T8** lamps, the CLASP/SwEA data set results in a total net benefit in the order of 6593 million euros between 2021 and 2035 (benefit of 17.70 euros per lamp). The 2019 SEA study data set results in total costs in the order of 22,868 million euros (costs of 61.41 euro per lamp). The substitution is accompanied with a premature generation of e-waste from rewiring and lamp replacement of between 32 and 703 thousand tonnes of e-waste (CLASP/SwEA and 2019 SEA study 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 being placed on the EU market.

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

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 (exemplary), 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	CFLni
			all
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
LED light source unit price (excl. VAT, excl. install) (€)	Varies with year		
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

General input parameters			
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
Efficacy LED incl. CG, residential (lm/W)	varies with year		
Efficacy LED incl. CG, non-residential (lm/W)	varies with year		
Power LED incl. CG, residential (W)	varies with year		
Power LED incl. CG, non-residential (W)	varies with year		