

Evidence of the availability of mercury-free alternative products to certain fluorescent lamps

Report to the Committee on the Regulation of Hazardous Substances

Preface

Europe is considering whether to extend the exemptions granted to certain products listed in Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances (RoHS) in electrical and electronic equipment.¹ The Swedish Energy Agency and CLASP worked together to develop this report in response to Article 6 of Directive 2011/65/EU on the restriction of the use of certain hazardous substances (RoHS) in electrical and electronic equipment which addresses the review and amendment of the list of restricted substances exempted under RoHS. This report addresses linear fluorescent lamps of diameters T8 and T5, and compact fluorescent lamps which are not integrally ballasted (CFLni). The report does not address T12 linear fluorescent lamps or integrally ballasted compact fluorescent lamps (CFLi) as both are phased out on 1 September 2021 under Commission Regulation EU 2019/2020²

There are substitute technologies that can replace these mercury-containing fluorescent lamps currently exempted in Annex III. We conducted a technical and economic feasibility analysis into mercury-free light-emitting diode (LED) products that are drop-in direct replacements and found strong justification for removing the exemptions from RoHS for fluorescent lighting. This report presents the findings of that analysis, including summarising the technological feasibility and economic justification of the mercury-free alternatives to fluorescent lamps. Based on this analysis, the report discusses specific RoHS exemption categories that can be considered for retirement.

This report was originally released on 30 October 2019 to key stakeholders and decision-makers in Europe. This revised edition (v.2) contains the same estimated benefits and impacts, but is a slightly revised draft, addressing formatting and editorial issues and improving the presentation of the results. This revised version also responds to some criticisms that were received from LightingEurope, an industry association who represents some of the lighting manufacturers in Europe, including all the major companies who supply fluorescent lamps. We have provided a response to LightingEurope's comments in Annex C of this report.

The authors welcome any additional comments or suggestions on the analysis presented in this report.

¹ Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (recast) (Text with EEA relevance)Text with EEA relevance: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:02011L0065-20190722>

² 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 and repealing Commission Regulations (EC) No 244/2009, (EC) No 245/2009 and (EU) No 1194/2012 (Text with EEA relevance.) https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2019.315.01.0209.01.ENG&toc=OJ:L:2019:315:TOC

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Table of Contents

Summary	6
1 Methodology	10
2 Are there alternative mercury-free replacements for fluorescent lamps?	13
3 Will removing the exemption result in a reduction in mercury in the environment?	20
4 Is it cost-effective for LED lamps to replace linear fluorescent lamps?	27
5 Are the societal benefits in terms of energy, CO₂ and cost savings significant?	31
5.1 Benefits from Phase-Out of T8 Fluorescent Lamps.....	31
5.2 Benefits from Phase-Out of T5 Fluorescent Lamps.....	32
5.3 Benefits from Phase-Out of CFLni Fluorescent Lamps.....	33
5.4 Cumulative Savings Potential	35
Annex A. Images of Mercury-Containing Lighting and LED Replacement	36
Annex B. WEEE Glossary of Key Terms	38
Annex C. LightingEurope Letter of 8 November 2019	40
C.1 Availability of Mercury-Free LED Substitutes	40
C.2 Collection of waste lamps	50
C.3 Conclusion.....	52
Annex D. Letter from Seaborough B.V. to DG Environment at the European Commission	54

List of Figures

Figure 1. EU-28 shipment forecast T8, T5 and CFLni fluorescent lamps, assuming RoHS phase-out in 2021 (VHK MELISA model)	12
Figure 2. Picture and description of T5 and T8 fluorescent lamps and pin-based CFLs	13
Figure 3. Examples of LED replacements for fluorescent lamps	14
Figure 4. GE/Tungsham offers direct retrofit pin-based LED replacements for CFLs with a 4x longer life	15
Figure 5. Sylvania offers products that are ideal for upgrading fluorescent fixtures to LED	16
Figure 6. OSRAM notes that LED tubes “outperform conventional T8, T5 and T8 fluorescent lamps”	17
Figure 7. Philips offers “InstantFit” LED tubes that avoid any need to change the driver or rewire	18
Figure 8. OSRAM offers T5 lamps with integrated drivers that are “plug and play” replacements	18
Figure 9. Tungsham advertisement noting the “quick and easy installation” of its LED retrofit lamps	19

Figure 10. Life-cycle flow diagram of fluorescent lamps in Europe 23

Figure 11. Philips Lighting/Signify highlighting the mercury-free alternative to fluorescent lighting 24

Figure 12. OSRAM/LEDvance Literature Highlighting Benefits of LED Tubular Retrofit Lamps..... 27

List of Tables

Table 1. Proposals for Consideration on the Exemptions for Certain Fluorescent Lamps..... 6

Table 2. Four Key Questions and Summaries of our Findings..... 7

Table 3. Summary of the Benefits from a Scenario where RoHS exemptions for T8, T5 and CFLni Lamps are Limited to 1 September 2021 9

Table 4. Collection Rates in 2019 for the Two Scenarios Analysed, Lamps are Cat 3 21

Table 5. Survey of Danish Households on Bulb Disposal (2016 Study in Denmark) 22

Table 6. Shipment Forecast for T8, T5 and CFLni Lamps in Europe; RoHS phase-out in 2021 25

Table 7. Life-Cycle Economic Analysis of T8 Lamp Replacement in Europe 28

Table 8. Life-Cycle Cost Economic Analysis of T5 Lamp Replacement in Europe 29

Table 9. Life-Cycle Cost Economic Analysis of CFLni Lamp Replacement in Europe 30

Table 10. Electricity and Cost Savings from the Phase-Out of T8 fluorescent lamps in Europe 32

Table 11. Energy and Financial Savings from Phase-Out of T5 fluorescent lamps in Europe 33

Table 12. Energy and Financial Savings from Phase-Out of CFLni fluorescent lamps in Europe 34

Table 13. Net Benefits from Phase-Out of T8, T5 and CFLni Lamps in September 2021..... 35

Summary

The Swedish Energy Agency and CLASP conducted a review of several categories of fluorescent lighting products which are exempted in Annex III of the restriction of the use of certain hazardous substances (RoHS) in electrical and electronic equipment.³ This review found that there are mercury-free alternative products which can replace these fluorescent lamps, enabling these on-going exemptions from RoHS to be retired.

Through continued investment and on-going breakthroughs in light emitting diode (LED) light sources and drivers alike, the market now enjoys LED retrofit lamps that can be installed directly into existing luminaires without the need for rewiring. These lamps can operate on the existing fluorescent ballast, whether it is magnetic (line frequency) or high frequency. Pictures of examples of some of these lamps can be found in Annex A of this report.

The table below summarises our proposals for consideration based on our findings of the existence of alternative LED replacements for the exempted fluorescent lighting in Annex III of the RoHS Directive. These alternative products are cost-effective and can be installed directly into the fluorescent sockets without the need for rewiring.

Table 1. Proposals for Consideration on the Exemptions for Certain Fluorescent Lamps

RoHS Annex Exemption	Proposals for consideration
Mercury in single capped (compact) fluorescent lamps not exceeding (per burner):	
1(a) For general lighting purposes < 30 W: 2,5 mg shall be used per burner after 31 December 2012;	Consider setting the exemption to expire on 1 September 2021
1(b) For general lighting purposes ≥ 30 W and < 50 W: 3,5 mg may be used per burner after 31 December 2011;	
1(c) For general lighting purposes ≥ 50 W and < 150 W: 5 mg;	
1(d) For general lighting purposes ≥ 150 W: 15 mg;	
2(a) Mercury in double-capped linear fluorescent lamps for general lighting purposes not exceeding (per lamp):	
2(a)(2) Tri-band phosphor with normal lifetime and a tube diameter ≥ 9 mm and ≤ 17 mm (e.g. T5): 3 mg may be used per lamp after 31 December 2011	Consider setting the exemption to expire on 1 September 2021
2(a)(3) Tri-band phosphor with normal lifetime and a tube diameter > 17 mm and ≤ 28 mm (e.g. T8): 3,5 mg may be used per lamp after 31 December 2011	
2(a)(4) Tri-band phosphor with normal lifetime and a tube diameter > 28 mm (e.g. T12): 3,5 mg may be used per lamp after 31 December 2012	
2(a)(5) Tri-band phosphor with long lifetime (≥ 25 000 h): 5 mg may be used per lamp after 31 December 2011	
2(b) Mercury in other fluorescent lamps not exceeding (per lamp):	
2(b)(3) Non-linear tri-band phosphor lamps with tube diameter > 17 mm (e.g. T9): 15 mg may be used per lamp after 31 December 2011	Consider setting the exemption to expire on 1 September 2021

³ DIRECTIVE 2011/65/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (recast) (Text with EEA relevance) <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:02011L0065-20190722>

The analysis is based on four key questions which explore the technical and economic feasibility of the alternatives to mercury lighting. These four questions and abbreviated answers are shown in the table below. More detail and information underpinning these answers is provided in the body of this report.

Table 2. Four Key Questions and Summaries of our Findings

Key Question	Summary of Findings
<p>Are there alternative mercury-free replacements for fluorescent lamps?</p>	<p>Yes. There are thousands of mercury-free LED replacement lamps available today to replace fluorescent lamps – different sizes, lengths, ballast types (i.e., magnetic/starter and high frequency electronic), colour temperatures, and regular, high output and ultra-high light output levels. Lamps are also available which are “universal” and can operate on a variety of input power configurations. Many of these LED products are designed as direct retrofits into existing fluorescent fixtures to avoid the need to rewire. For example, Philips/Signify states⁴ that there is “No need to change drivers or rewire”, noting that they offer a “plug and play solution that works straight out of the box”. OSRAM/LEDvance state⁵ that their “SubstiTUBE” product is a “Quick, simple and safe lamp replacement without rewiring.” Sylvania lighting advertises that their SubstiTUBE product is “engineered to operate on existing instant start and select programmed rapid start electronic T8 ballasts, these lamps minimise labour and recycling costs.”⁶ Tungsram reports that in addition to “the 2.5-3x longer life (compared to T8 fluorescent lamps operated on electro-magnetic gear) and lower wattages, Tungsram LED T8 tubes provide lower system loss while existing fixtures remain intact.”⁷</p>
<p>Will removing the exemption result in a reduction in mercury in the environment?</p>	<p>Yes. Each fluorescent lamp contains several milligrams of mercury and our research has found that more than half of the fluorescent lamps sold in Europe are never recovered and instead end up being discarded with regular municipal waste, contaminating landfill sites and run-off. A 2014 European Commission study on collection rates found that the collection rate was only 12% in 2010 for all lamps under the WEEE Directive.⁸ The WEEE Directive sets a target of 80% recycling, however some studies show that the actual rate of separate collection at the end-of-life is less than 50%, thus while reported recycling rates are high, these percentages are not based on total lamps removed from service, but are instead only considering those lamps that are delivered to the correct waste treatment facility. The Minamata Convention encourages the sharing of information around mercury-free alternative products and calls for periodic reviews of the exemptions list. In Europe, by not renewing the exemptions for many of these fluorescent lamps for which there are cost-effective, mercury-free, direct replacement alternatives, RoHS would be aligning with the objective of the Convention and removing 2.6 metric tonnes of mercury from our homes and offices across Europe.</p>

⁴ <https://www.lighting.philips.com/main/support/support/tools/ledtube-selectortool>

⁵ <https://www.ledvance.com/professional/products/product-stories/led-tubes-online-special/index.jsp>

⁶ <https://assets2.sylvania.com/media/bin/asset-1377974/asset-1377974>

⁷ <https://tungsram.com/en/products/led-retrofit/led-tubes>

⁸ https://ec.europa.eu/environment/waste/weee/pdf/Final_Report_Art7_publication.pdf

Key Question	Summary of Findings
<p>Is it cost-effective for LED lamps to replace linear fluorescent lamps?</p>	<p>Yes. Economic calculations are presented in section 3 for the most popular lamps. The payback period for replacing a 36W T8 linear fluorescent lamp with an LED retrofit lamp in Europe today is between 5 and 11 months, and the service life of these lamps is 1.5 to 2.5 times longer than fluorescent, saving on replacement costs. LED replacements for T5 fluorescent lamps have longer payback periods of approximately 3 to 3.5 years, however they will operate for approximately 16 years and represent the best option for the end-user, with a net present value life-cycle cost savings of between €55 and €67 for each T5 fluorescent lamp replaced. LED replacements for compact fluorescent lamps not integrally ballasted (CFLni) offer very attractive payback periods of between 1.3 and 3.0 years and will last 2-3 times longer than the fluorescent lamp. For European businesses and households, there is a very strong value proposition in switching to LED, and lighting manufacturers' websites highlight the cost-effectiveness and energy savings potential of LED alternatives to fluorescent lamps.</p>
<p>Are the societal benefits in terms of energy, CO₂ and cost savings significant?</p>	<p>Yes. The consultants who prepared the one-lighting regulation review study and impact assessment for the European Commission conducted some new runs of the MELISA market model for this study to help quantify the benefits of phasing out certain fluorescent lamps in 2021. The cumulative benefit through the year 2030 for these specific lamp types are reported as follows:</p> <ul style="list-style-type: none"> • T8 phase-out: Saves 64 TWh electricity, avoids 18.9 MMT CO₂ and has a net saving of €5.0 billion in electricity bills and lamps • T5 phase-out: Saves 60 TWh electricity, avoids 17.8 MMT CO₂ and has a net saving of €4.7 billion in electricity bills and lamps • CFLni phase-out: Saves 14 TWh electricity, avoids 4.2 MMT CO₂ and has a net saving of €2.8 billion in electricity bills and lamps <p>Taken together, phasing out these three lamp types offers significant societal benefit. In addition, the total electricity savings of 138.3 TWh also avoids the release of mercury from the power stations which burn coal. Using the Commission's estimate of 0.016 mg Hg/kWh of electricity generated in Europe, a further 2.2 metric tonnes of mercury emissions from European power stations would be eliminated.</p>

Results Summary

If the RoHS exemptions for T8, T5 and CFLni lamps were limited to 1 September 2021, this would move both of those markets to LED earlier than in the business as usual case, accruing the following benefits across Europe:

Table 3. Summary of the Benefits from a Scenario where RoHS exemptions for T8, T5 and CFLni Lamps are Limited to 1 September 2021

Metric for T5 and T8 compared to Business as Usual*	Savings from limiting RoHS exemption to 1 September 2021 (cumulative through 2030)
Hg Reduction: Avoided quantity of mercury put into the lighting supply chain, with the risk of breakage or improper disposal (2.6 metric tonnes) and avoided mercury emitted from power stations due to electricity savings (2.2 metric tonnes).	4.8 metric tonnes Hg
Energy Bill Savings: Billions of Euros saved by businesses and consumers on their lighting bills through the use of more energy-efficient LED lamps	€12.5 billion
Energy Reduction: TWh of cumulative energy reduction	138.3 TWh electricity
CO₂ Reduction: Metric tonnes of CO ₂ reduction from the avoided generation of electricity for lighting	40.9 million metric tonnes CO ₂

*Business as Usual is calculated on the basis of the one-lighting ecodesign regulation adopted by the European Commission on 1 October 2019 becoming law and taking effect. The one-lighting regulation will phase-out T8 fluorescent lamps in September 2023, however it was found to be cost-effective to phase-out T8 fluorescent lamps faster than this, thus this analysis considers a scenario phase-out date of September 2021 for T8 (an acceleration of 2 years). T5 and CFLni do not have a phase-out date in the one-lighting ecodesign regulation, however they are also considered for phase-out in September 2021 through the end of their exemptions in the RoHS Directive.

The balance of this report provides the data, evidence and analysis to support the summary of findings on the key questions presented in this section.

1 Methodology

The Swedish Energy Agency and CLASP worked together to develop a report considering mercury-free alternatives to some of the lighting products exempted in Annex III of the restriction of the use of certain hazardous substances (RoHS). Due to time and resource constraints, we chose to focus on specific lamp types listed under fluorescent lighting (i.e. Group 1, Group 2a and Group 2b) because these are the most popular mercury-based lamps with the highest volume of sales in Europe, and therefore are responsible for the largest releases of mercury into the environment. We did not consider the lamps in Group 3 (cold cathode fluorescent lamps) or Group 4 (mercury vapour, high pressure sodium, metal halide), however mercury-free alternatives for these products also exist and may be a topic for future study.

Thus, for this analysis, we started from the list of exempted fluorescent lamps in Annex III of the RoHS Directive:

- Mercury in single capped (compact) fluorescent lamps not exceeding (per burner):
 - 1(a) For general lighting purposes < 30 W
 - 1(b) For general lighting purposes ≥ 30 W and < 50 W
 - 1(c) For general lighting purposes ≥ 50 W and < 150 W
 - 1(d) For general lighting purposes ≥ 150 W
- 2(a) Mercury in double-capped linear fluorescent lamps for general lighting purposes not exceeding (per lamp):
 - 2(a)(2) Tri-band phosphor with normal lifetime and a tube diameter ≥ 9 mm and ≤ 17 mm (e.g. T5)
 - 2(a)(3) Tri-band phosphor with normal lifetime and a tube diameter > 17 mm and ≤ 28 mm (e.g. T8)
 - 2(a)(4) Tri-band phosphor with normal lifetime and a tube diameter > 28 mm (e.g. T12)
 - 2(a)(5) Tri-band phosphor with long lifetime ($\geq 25\,000$ h)
- 2(b) Mercury in other fluorescent lamps not exceeding (per lamp):
 - 2(b)(3) Non-linear tri-band phosphor lamps with tube diameter > 17 mm (e.g. T9)

Our objective with this work was to prepare a current (October 2019) market and technology assessment that reflects recent innovations in driver technology used in LED lighting and enables (mercury-free) LED lamps to be installed into existing fluorescent luminaires, avoiding the need to rewire and replace luminaires.

We then looked at the market to identify whether mercury-free LED replacements existed for these fluorescent lamps, to determine whether the LED replacements were widely available from multiple retailers in different countries. We found that LED replacements do exist and are widely available in the European Market, and since LED lamps are now roughly twice as

efficient as fluorescent lighting and last 2-3 times longer than fluorescent lamps, LED replacement lamps save end-users money while also eliminating mercury.

The authors gathered information on products available on the European market – both fluorescent lamps and LED alternatives to those lamps – and conducted an economic assessment including looking at payback period, life-cycle cost and internal rate of return. We also calculated environmental benefits, such as energy savings and reduction in CO₂ emissions.

To understand the magnitude of the savings potential if these exemptions were retired across Europe, the authors contacted Van Holsteijn en Kemna (VHK), the Netherlands-based private consultancy firm that conducted the regulatory analysis for the Commission on the ecodesign one-lighting regulation which was adopted by the Commission on 1 October 2019. VHK built and maintains a European lighting market model called “MELISA” (Model for European Light Sources Analysis) on behalf of the European Commission. We asked VHK to provide us with shipment estimates of the T5 and T8 lamps that would be avoided if certain RoHS exemptions were retired on 1 September 2021. VHK responded that they would conduct these runs as a one-time courtesy, on a strictly personal title and not assuming any liability for the data or its use.

As noted above, on 1 October 2019 the European Commission adopted the one-lighting regulation, which scheduled the phase-out of 90% of the T8 lamps in September 2023⁹. VHK calculated the benefits from accelerating the phase-out of T8 lamps by two years (going from 2023 to 2021) and for phasing-out T5 lamps in 2021 (note: the new ecodesign lighting regulation does not have a phase-out date for T5 fluorescent). In addition, VHK conducted a run that evaluated the phase-out of non-integrally ballasted compact fluorescent lamps (CFLni) which also do not have a phase-out date in the new ecodesign lighting regulation.

VHK provided¹⁰ shipment forecasts in terms of unit sales for T5, T8 and CFLni lamps, as illustrated in the figure below. In the forecasts for T5 and CFLni lamps they mirrored the assumption used by the Commission that adopting a phase-out for a future year triggers a small part of the market (10 to 15%) to move earlier to the mercury-free alternatives. The dark blue line depicts the anticipated shipments of T8 fluorescent lamps under the business as usual scenario, including the new EU lighting regulation (adopted 1 October 2019). The green line depicts shipments of T8 fluorescent lamps if there is a two-year acceleration of the phase-out, with the RoHS exemption for T8 advanced to September 2021 from September 2023. The red line shows projected sales of T5 fluorescent lamps, which have no phase-out date in the new EU ecodesign regulation for lighting. The yellow line depicts shipments if the T5 RoHS exemption is retired in September 2021. The black line projects shipments of CFLni lamps under business as usual with no phase-out date in the new lighting regulation, and the bright blue line shows CFLni lamp shipments if the RoHS exemption is retired in September 2021.

⁹ On 1 October 2019, the European Commission adopted a package of regulations, including new requirements on lighting which will phase out 2 foot, 4 foot and 5 foot lengths of T8 linear fluorescent lamps in September 2023. See: 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 and repealing Commission Regulations (EC) No 244/2009, (EC) No 245/2009 and (EU) No 1194/2012 (Text with EEA relevance.) https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2019.315.01.0209.01.ENG&toc=OJ:L:2019:315:TOC

¹⁰ Personal communication and analysis conducted by VHK using the MELISA lighting market model (which was also used for the Impact Assessment for the Ecodesign one-lighting regulation) --as a one-time courtesy, on a strictly personal title and not assuming any liability for the data or its use-- to provide estimates of the savings potential of various scenarios. Communication on 16 October 2019.”

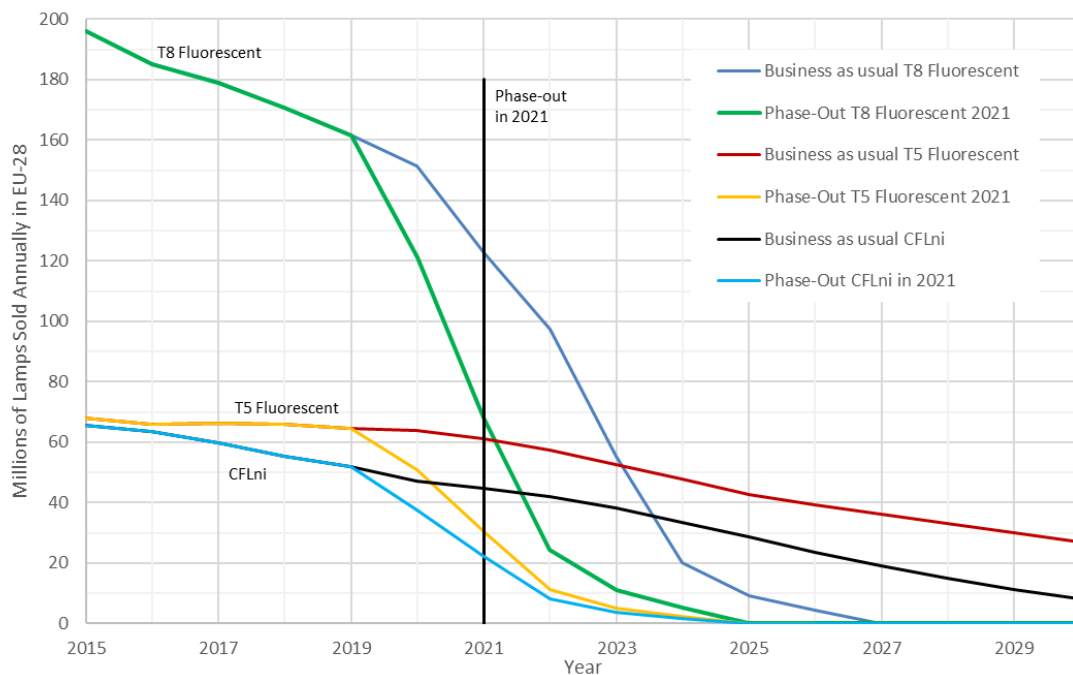


Figure 1. EU-28 shipment forecast T8, T5 and CFLni fluorescent lamps, assuming RoHS phase-out in 2021 (VHK MELISA model)

The authors then conducted literature surveys on the disposal of mercury-containing lamps and on the substitution of products covered by the WEEE Directive¹¹, and arrived at four key questions:

- Are there alternative mercury-free replacements for fluorescent lamps?
- Will removing the exemption result in a reduction in mercury in the environment?
- Is it cost-effective for LED lamps to replace linear fluorescent lamps?
- Are the societal benefits in terms of energy, CO2 and cost savings significant?

The balance of this report presents our responses to each of these key questions, including the evidence we found and the analysis we conducted to answer them.

¹¹ https://ec.europa.eu/environment/waste/weee/index_en.htm

2 Are there alternative mercury-free replacements for fluorescent lamps?

Yes. According to the Design Lights Consortium Quality Products List in the US, there are literally thousands of different models of linear LED replacement lamps for T5 and T8 installations¹², and over eight hundred different models of pin-based compact fluorescent lamps (i.e., not integrally ballasted) CFLni products. Although we don't have access to a similar database for the EU, sampling on the EU market shows a similar range of products.

The product groups we are focusing on in this analysis are linear fluorescent lamps and pin-based CFLs.

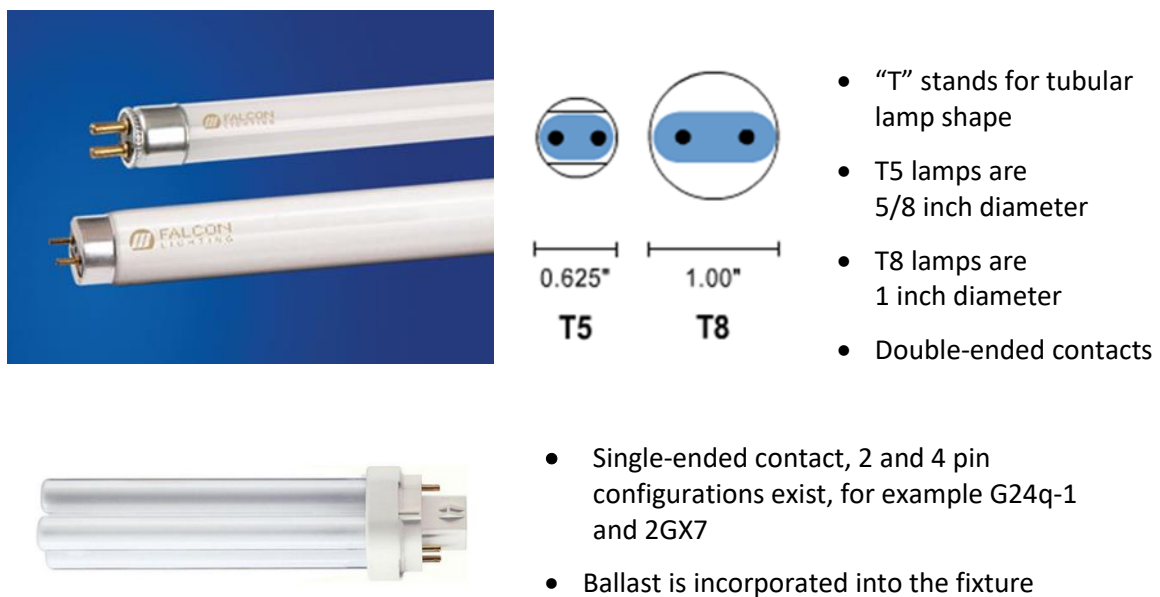


Figure 2. Picture and description of T5 and T8 fluorescent lamps and pin-based CFLs

These mercury-containing fluorescent lamps are rapidly being replaced in Europe with alternative products based on light emitting diode (LED) technology, which does not contain mercury.

¹² The Design Lights Consortium (DLC) in the United States maintains a [qualified products list database](#) that represents a large percentage of the LED lamps and luminaires offered on the market in North America. In the categories of T5 and T8 LED replacement lamps, the DLC database contains 26,224 models. While it is recognised that the DLC database does not cover Europe, it is presumed that the European market will have a similarly large sample of models for sale.



Figure 3. Examples of LED replacements for fluorescent lamps

As seen in Figure 2 above, manufacturers including Philips, Sylvania and Osram offer LED retrofit lamps. These and other companies describe the products as offering numerous advantages over fluorescent lamps including that they are easy to install, offer broad compatibility with existing fluorescent fixtures, allow retrofitting without costly rewiring, provide high-quality light, and reduce energy use and cost during operation.

LED retrofit lamps are designed to fit into existing fluorescent fixtures to minimise inconvenience and avoid the need for rewiring. The types of LED retrofit tubes available now include lamps that can be installed directly into fixtures with the following configurations:

- ✓ Using a magnetic ballast and starter
- ✓ Using a high-frequency electronic ballast
- ✓ Where the old ballast is bypassed and mains-voltage is wired directly to the G5 (T5) or G13 (T8) sockets
- ✓ Where an LED driver has been retrofitted into an existing fluorescent luminaire

Manufacturers also offer “universal” lamp replacements, which can operate on several of these combinations of power supplies. As OSRAM¹³ states in a description of one of its “universal” T8 lamps:

OSRAM SUBSTITUBE T8 UNIVERSAL: ONE FOR ALL

With OSRAM SubstiTUBE T8 Universal, you no longer need to give any thought to the driver technology being used. The innovative all-in-one LED tube can be operated with ECG, CCG and AC mains. It not only makes it much easier for users to operate, but also eliminates the need to keep a double amount of lamps on hand. SubstiTube T8 Universal is suitable for a range of different applications thanks to a selection of three different types: Advanced Ultra Output, Advanced and Value. With a long lifetime up to 60,000 hours and a lumen output up to 3,700 lm, the Advanced Ultra Output and the Advanced models are especially suitable for supermarkets, offices, industrial and public buildings, as well as the illumination of production areas.

Philips/Signify makes similar claims on its website¹⁴ about the universal suitability of its LED lamps:

¹³ <https://www.ledvance.com/professional/products/product-stories/led-tubes-online-special/osram-substitube-t8-universal/index.jsp>

¹⁴ <https://www.lighting.philips.co.uk/products/led-tube>

Philips Lighting

The perfect tube for every application with MASTER LEDtubes. From offices to retail stores, car parks to industry, every customer has their own unique lighting requirements. Now you can find the right LEDtube every time with the Philips MASTER LEDtubes portfolio. From optimized energy efficiency to the highest light output for the most demanding applications. A simple switch, our LEDtubes come in a choice of lengths and color temperatures, with the option of rotating end caps. We've repositioned the way that our lamps are labelled into three new categories of light output – Standard, High and Ultra output. So with Philips, you have the right LEDtube every time.

In Figure 4, GE/Tungshram highlights the wide range of pin-based LED retrofit products it offers, enabling the end-user to “replace inefficient CFL lighting without the need for tools or a costly upgrade.”¹⁵ On the same webpage, GE/Tungshram notes that its LED plug-in 2Pin range is designed with a universal base (G24d) to replace G24d-1, G24d-2, G24d-3 CFL plug-in base types, and that it “easily plugs into existing relevant CFL plug-in sockets.” In this way, existing CFL pin-base luminaires can be used while the light source is upgraded to LED, avoiding mercury-containing products.

LED Plug-in & LED 2D

The new LED Plug-In and LED 2D replacement lamps from GE enable you to replace inefficient CFL lighting without the need for tools or a costly upgrade. GE's LED retrofit lamps provide up to 4x the life of an average CFL and use less than half the energy, delivering a more targeted light that requires less lumens and reduces waste. The result is a dramatic reduction in operating cost, coupled with equally impressive improvements in the quality of light.

The current range includes LED replacement lamps for following CFL Plug In lamps:

- 26/32W CFL 4Pin Plug In with G24-q3 or GX24q-3 base
- 16W 2D 2Pin with GR8 base
- 28W 2D 4Pin with GR10q base
- 18W CFL 4Pin Plug-In with G24q-2 or GX24q-2 base
- 13/18/26W CFL 2Pin Plug In with G24d-1, 2, 3 base types



Figure 4. GE/Tungshram offers direct retrofit pin-based LED replacements for CFLs with a 4x longer life

Figure 5 presents marketing material from Sylvania, which offers a T8 retrofit solution¹⁶ it describes as “ideal for upgrading fluorescent fixtures to LED.” That product operates “with a

¹⁵ <https://tungshram.com/en/products/led-retrofit/led-plug-in>

¹⁶ <https://assets2.sylvania.com/media/bin/asset-7401814/asset-7401814>

ballast or directly on line voltage” for a high degree of flexibility, making these lamps ideal for upgrading fluorescent installations to LED.

SYLVANIA Lamps

DUALescent™ T8 Universal Lamp

UL Type A+B

Application

Product is ideal for upgrading fluorescent fixtures to LED, which provides energy savings. DUALescent provides flexibility for the distributor and contractor with one lamp to satisfy either operation with a ballast or directly on line voltage.

Benefits and Features

- Utilizes either fluorescent ballast or operates directly on line voltage providing flexibility in installation
- Lamps operate on shunted and non-shunted lampholders thereby reducing installation costs.
- DLC listed allows for rebates in areas where applicable, saving on overall project cost
- No polarity; can be installed in either direction, saving time (costs) in installation
- Low wattage lamp providing for maximum energy savings

Figure 5. Sylvania offers products that are ideal for upgrading fluorescent fixtures to LED

Philips Lighting also highlights a product whose output perfectly matches the fluorescent lamps being replaced, noting that end-users will not be able to distinguish the LED lamps from fluorescent ones:

MASTER LEDtube EM/Mains - The Philips MASTER LEDtube integrates a LED light source into a traditional fluorescent form factor. Its unique design creates a perfectly uniform visual appearance which cannot be distinguished from traditional fluorescent. This product is the ideal solution for up lighting in general lighting applications.

The figure below from LEDvance/OSRAM highlights reasons how its mercury-free SubstiTUBE LED tubes “outperform conventional T8, T5 and T9 fluorescent lamps.” It describes them as: simple to replace without rewiring, lasting up to 3 times longer, reducing energy bills by 50%, immediately reaching full brightness, flicker-free, and paying for themselves in as little as four months.

OSRAM SUBSTITUBE: OUR TOP BENEFITS FOR YOUR LIGHTING PROJECTS

Radiant illumination, singular technology: The new OSRAM SubstiTUBE LED tubes outperform conventional T8, T5 and T9 fluorescent lamps in many ways.



Figure 6. OSRAM notes that LED tubes “outperform conventional T8, T5 and T8 fluorescent lamps”

While the final report¹⁷ of the “Study to assess socio-economic impact of substitution of certain mercury-based lamps currently benefitting of RoHS 2 exemptions in Annex III” cites high rewiring costs associated with the retrofit of LED linear tubes, it would appear that this information may be out of date because it fails to capture information about multiple products on the market in 2019. The findings of the exemption review study may have been valid in 2016 when the research appears to have been conducted, but the lighting industry and its suppliers have invested substantially in improving the driver electronics used with retrofit LED lamps. Ultimately, the industry has been pursuing a “plug and play” retrofit solution, and those products are now available in the market.

Following are some screen captures from LightingEurope members that specifically refer to the convenience of installation, that there is no need for rewiring, and that the new LED Lamps being offered represent a “plug and play” solution into existing fluorescent fixtures across the market. According to Philips Lighting¹⁸ there is “No need to change drivers or rewire” because its products offer a “plug and play solution that works straight out of the box.”

¹⁷ <https://op.europa.eu/en/publication-detail/-/publication/9f8f7878-b72a-11e9-9d01-01aa75ed71a1/language-en/format-PDF>

¹⁸ <https://www.lighting.philips.com/main/support/support/tools/ledtube-selectortool>

The luminaire works on HF ballast

- Choose MASTER LEDtube T5 InstantFit
- No need to change drivers or rewire
- It's a plug and play solution that works straight out of the box
- Quick and easy installation

Check if your ballast is compatible with MASTER LEDtube Value InstantFit >

Next

Philips InstantFit
Means plug and play installation, truly hassle free.

Watch the MASTER LEDtube T5 InstantFit video

Figure 7. Philips offers “InstantFit” LED tubes that avoid any need to change the driver or rewire

According to OSRAM¹⁹, customers can easily upgrade fluorescent luminaires to LED “without doing the least bit of rewiring.” It notes that with “their integrated ECG, the innovative LED tubes with a diameter of 16 mm are true plug-&-play replacements for conventional T5 fluorescent lamps with 49 W and 80 W.”

OSRAM SUBSTITUBE T5 PLUG & PLAY REPLACEMENT OF FL T5 TUBES



T5 luminaires can now be easily upgraded to the latest energy-saving LED technology without doing the least bit of rewiring – thanks to OSRAM SubstiTUBE Advanced T5. With their integrated ECG, the innovative LED tubes with a diameter of 16 mm are true plug-&-play replacements for conventional T5 fluorescent lamps with 49 W and 80 W. The splinter protection makes them ideal for use in particularly sensitive production areas.

Figure 8. OSRAM offers T5 lamps with integrated drivers that are “plug and play” replacements

¹⁹ <https://www.ledvance.com/professional/products/product-stories/led-tubes-online-special/osram-substitube-t5/index.jsp>

In Figure 9, Tungsram advertises²⁰ that its products operate on “both magnetic and electric gear” and can offer lower system loss while “existing fixtures remain intact.” Their website notes that these lamps are energy efficient (e.g., >60% energy saving), contain no lead or mercury, and fit directly into standard T8 linear fluorescent G13 sockets.

Convert your existing linear fluorescent fixture to LED lighting with a simple switch. LED T8 tubes from Tungsram offer safe, reliable and affordable energy saving alternatives to standard fluorescent T8 lamps both on magnetic and electronic gear. Besides the 2.5-3x longer life (compared to T8 fluorescent lamps operated on electro-magnetic gear) and lower wattages, Tungsram LED T8 tubes provide lower system loss while existing fixtures remain intact.

Savings through decreased energy costs

Low power consumption of 9-27 watts offer even >60% energy saving versus 18-58W LFL tubes.

Low maintenance costs

L70 50000hours long life results in 1-2 less maintenance cycles vs standard T8 fluorescent tubes.

Environmentally Conscious

These lamps are energy efficient, contain no lead or mercury, and are compliant with material restriction requirements of RoHS.

Reliable quality light

Instant on, with CRI 80+.

Quick, and easy installation

Fits directly into standard T8 linear fluorescent G13 sockets.

Figure 9. Tungsram advertisement noting the “quick and easy installation” of its LED retrofit lamps

Lighting manufacturers around the world have worked hard to develop “plug and play” solutions which enable rapid and easy retrofit of LED lighting into existing linear fluorescent lamps. These alternative products are mercury free and offer easy installation, thereby improving lighting performance, removing mercury, and avoiding energy and CO₂ emissions.

²⁰ <https://tungsram.com/en/products/led-retrofit/led-tubes>

3 Will removing the exemption result in a reduction in mercury in the environment?

Yes. The installation of mercury-free alternatives for mercury-containing products will reduce the presence of mercury in our living spaces and landfills. At the end of its useful life there is always a risk that fluorescent lamps will not be recovered and recycled, but instead will simply be discarded into the general waste stream where they go on to contaminate landfills, soil, streams, rivers and ultimately the oceans with mercury. Our research has indicated that **half** of the mercury content of T5 and T8 lamps is not collected properly.

The Waste Electrical and Electronic Equipment (WEEE) Directive²¹ sets a target for countries across Europe of 80% recycling for gas-discharge lamps. This target is far from sufficient to protect against leaks from lamps into the environment. Indeed, the Directive sets the minimum annual collection rate at “65% of the average weight of EEE placed on the market in the three preceding years in the Member State concerned, or alternatively 85% of WEEE generated on the territory of that Member State” but does not set specific collection targets for individual categories. Based on a 2016 study of the collection rates of WEEE²², the Commission concluded that it is not appropriate to set individual collection targets in the WEEE Directive at this stage²³, while recognising that the generic collection target of 85% will likely “be reached mostly by increasing the collection of heavy and easily accessible WEEE that has a positive economic value and is less expensive (or more profitable) to treat.” Lamps are not heavy compared to other equipment covered under WEEE.

A 2014 European Commission study²⁴ on WEEE collection found that the collection rate for lamps covered under the WEEE Directive was only 12% in 2010 (see Table 4, where lamps are listed under “Cat 3”). This study projected that the collection rate for lamps would reach 16% in 2019 in the absence of a specific collection target for this category. Collection targets were set by Directive 2012/19/EU and are expected to increase the overall collection rate of WEEE, however the impact on the collection of lamps is expected to be limited. Indeed, their light weight and the fact that they are relatively difficult to collect and transport makes them largely irrelevant for Member States to reach their national collection targets. Furthermore, the small size of lamps makes them easier to dispose of in the general waste than other types of WEEE covered products.

²¹ [Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment \(WEEE\) \(recast\) \(Text with EEA relevance\) https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1571396988961&uri=CELEX:02012L0019-20180704](https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1571396988961&uri=CELEX:02012L0019-20180704)

²² https://www.researchgate.net/profile/Jaco_Huisman/publication/297453161_Study_on_Collection_Rates_of_Waste_Electrical_and_Electronic_Equipment_WEEE_possible_measures_to_be_initiated_by_the_Commission_as_required_by_Article_74_75_76_and_77_of_Directive_201219EU_on_Waste_EI/links/56df1cf408aee77a15f2c5/Study-on-Collection-Rates-of-Waste-Electrical-and-Electronic-Equipment-WEEE-possible-measures-to-be-initiated-by-the-Commission-as-required-by-Article-74-75-76-and-77-of-Directive-2012-19-EU-on-Was.pdf

²³ <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52017DC0171>

²⁴ https://ec.europa.eu/environment/waste/weee/pdf/Final_Report_Art7_publication.pdf

Table 4. Collection Rates in 2019 for the Two Scenarios Analysed²⁵, Lamps are Cat 3

Categories	Current collection rate	Collection rates to be achieved for the considered general collection target in scenario 1	Collection rates to be achieved for the considered individual targets in scenario 2
Cat 1	38%	95%	85%
Cat 2	47%	95%	85%
Cat 3	12%	16%	85%
Cat 4 exc. PV	38%	95%	85%
Cat 5	26%	70%	85%
Cat 6	49%	70%	85%
PV Panels	3%	85%	85%
Total	37%	85%	85%

Table 13: Collection rates in 2019 for the two scenarios analysed.

A large share of uncollected gas-discharge lamps may be compact fluorescent lamps, which are more common in residential use than T5 and T8 lamps. However, according to the MELISA model developed by VHK for the EC, the share of linear fluorescent lamps in the lamps covered by the WEEE Directive was 38% in 2009.²⁶ Considering a case in which 16% of those lamps are collected (the projected 2019 collection rate in the 2014 study), then 22% of these 38% would not be collected, which corresponds to 58% of the linear fluorescent lamps not collected. Extractions from Eurostat²⁷ show that although the situation seems to have improved since 2010, the collection rate of gas-discharge lamps is estimated to be only a third to a half of all gas-discharge lamps reaching their end of life. Thus, it is understood that **at least half** of these mercury-containing lamps (and possibly more) are simply discarded in the general waste stream.

A 2016 Study to assess renewal requests for 29 RoHS 2 Annex III exemptions²⁸ includes reports from Member States that confirm those concerns. In particular, Belgium and Denmark report that a significant share of mercury-containing lamps are not handled correctly. The following is an extract from the contribution of the Belgian Federal Public Services for Health, Food Chain Safety and Environment²⁹:

²⁵ Source: Study on collection rates of waste electrical and electronic equipment (WEEE) - Possible measures to be initiated by the commission as required by article 7(4), 7(5), 7(6) and 7(7) of Directive 2012/19/EU on waste electrical and electronic equipment (WEEE) Cat 3 represents lamps and scenario 1 represent the actual current situation with no individual target per category. Scenario 2 represents a 85% target for each category.

²⁶ We selected 2009 because according to the MELISA model it represents the lowest share of T5 and T8 amongst the lamps covered by the WEEE Directive, as we had to use the share of sales as a proxy for the share of waste. Therefore, by considering that all properly collected lamps in 2009 were T5 and T8, we calculated the most optimistic scenario in terms of properly collected and recycled T5 and T8 lamps.

²⁷ <https://ec.europa.eu/eurostat/web/waste/key-waste-streams/weee>

²⁸ https://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/RoHS-Pack_9_Part_LAMPS_06-2016.pdf

²⁹ https://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Contribution_Exemption_1-4/Ex_1-4_FPS_Health_Food_chain_safety_and_Environment_Be_position_Hg_lamps_20151016.pdf

In reference to the obligation in the WEEE Directive 2012/19/EU to collect and recycle lamps, including CFL, we note the following in relation to the collection phase of the process: No specific obligation exist to achieve a total (100%) collect ratio of the CFL, therefore we think that the actual ratio of collect achieved by the European operators should be identified to evaluate the level of efficacy of the system in place. Indeed - even if significant efforts have been implemented by the operators - indications that below 50% of CFL lamps was achieved in 2014 in Belgium. We recommend thus a thorough evaluation of these rates around EU to evaluate the mercury lost (i.e. potentially emitted to the environment) and ensuing consequences.

In Denmark, the Danish Environment Protection Agency reported on a survey of Danish household disposal of light bulbs. The table below is an extract from that report.

Table 5. Survey of Danish Households on Bulb Disposal (2016 Study in Denmark)

Table 4-4: Survey of Danish households on bulb disposal

Responses of Danish households to the question "Think of the last time you had to discard one of the following worn out bulbs. How did you discard the bulb?"	Energy saving bulb (i.e. CFLs)	LED bulb	Fluorescent tube	Special bulb (halogens or incandescent bulbs)
I delivered it at the recycling station	38%	26%	39%	31%
I delivered it as bulky waste	4%	3%	4%	3%
I put it into the bin for domestic waste	18%	10%	8%	19%
I delivered it as hazardous waste	11%	6%	9%	8%
I delivered it as small electronic waste	9%	7%	7%	8%
I delivered it as glass	3%	2%	3%	4%
Other	2%	2%	2%	2%
I never put a bulb like that to waste	5%	36%	15%	7%
I do not remember/I do not know	10%	17%	15%	17%
Correct disposal behavior total	38%	33%	39%	
Incorrect disposal behavior total	30%	10%	16%	

Source: Provided by DEPA (2016a), referencing data from the EPINION 2014 survey.

And while these collection rates are low – 38% for CFLs and 39% for fluorescent lamps – the following extract from the report indicates that the estimated rate of collection of lamps in Denmark is significantly higher than the European average reported in the Commission’s 2014 study on collection rate:

“In Denmark DPA-system administers the mandatory producer responsibility system. According to the **2014 statistics of the DPA-system** 1547 tons of bulbs (the various types of bulbs are not specified) were put on the market for consumers and 199 tons for professionals, for a total of 1746 tons of bulbs³⁵. Concerning collection 765 tons of bulbs were collected from consumers and 12 tons from professionals, amounting to 777 tons and corresponding to a collection percentage of 45%.³⁶ According to **statistical data from the DPA system for 2006**, in 2006 Denmark achieved an overall collection rate of 36%³⁷. Data from 2010 shows an overall collection rate of 43%.

All of these data seem to contradict the fact that the majority of Member States report having met the target of 80% for the re-use/recycling of gas-discharge lamps³⁰, sometimes reporting recycling rates greater than 100%. The reason for these very high reported recovery rates has to do with what is defined as the “recycling rate” in the regulation, which only reflects the share of lamps that are properly handled after being delivered to a recycling centre or similarly specialized facility. Thus, the high recycling rate by definition excludes lamps which are

³⁰ Cf. pp.189 and 2010-211 of the [Implementation report for Directives 2002/96/EC and 2012/19/EU on WEEE- Period 2013-2015](#) (published in September 2018)

disposed of in the general waste stream. Unfortunately, the majority of fluorescent lamps in Europe are not disposed of correctly and thus the mercury in those lamps ends up not being properly treated, polluting the environment and posing a health risk.

Figure 10 depicts our best estimate of the flow of fluorescent lamps in Europe based on the data sources indicated in this footnote.³¹ We estimate that less than half the fluorescent lamps which are installed in Europe are recovered and recycled at the end of life.

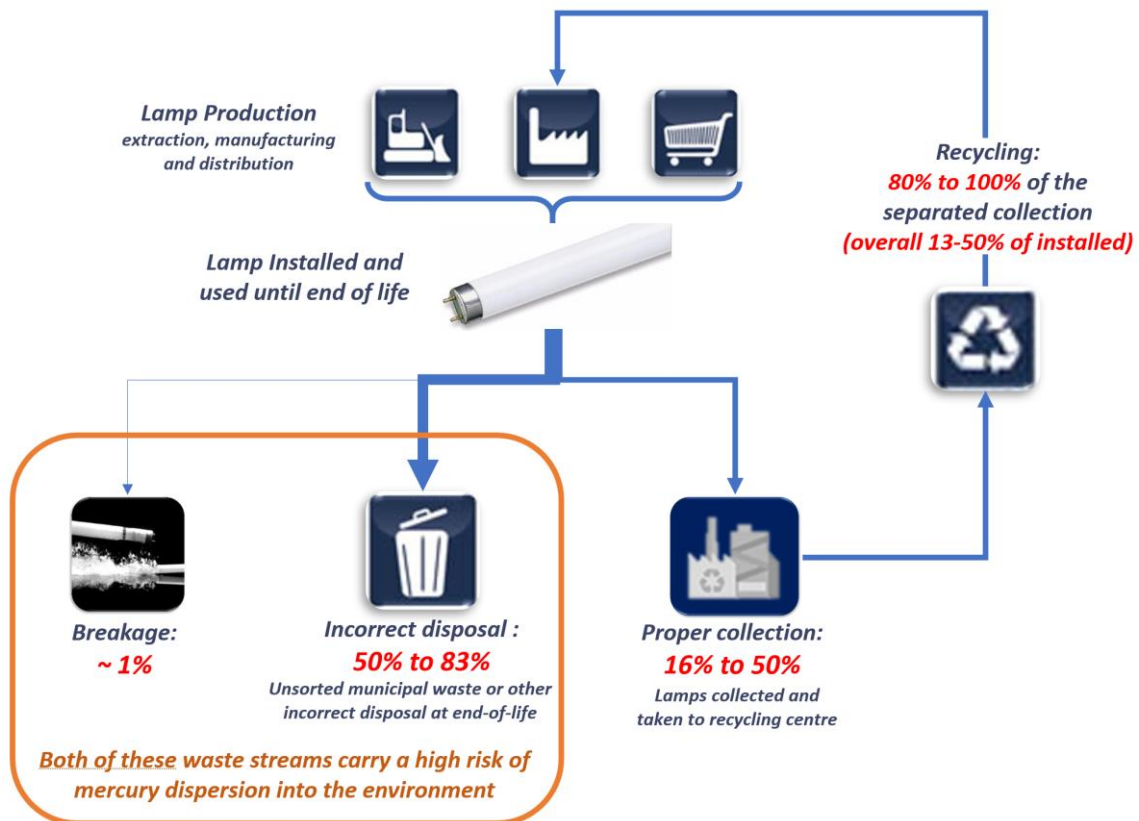


Figure 10. Life-cycle flow diagram of fluorescent lamps in Europe

Following our review of the above-mentioned sources we are concerned that **about half of the total mercury content of T5 and T8 fluorescent lamps seems to not be appropriately treated.**

³¹ Sources: * Danish Ministry of the Environment, Environmental Protection Agency, Survey of Chemical Substances in Consumer Products, No. 104 2010 - *Survey and health assessment of mercury in compact fluorescent lamps and straight fluorescent lamps*, quoting Defra, 2009. Department for Environment, Food and Rural Affairs.

<http://www.defra.gov.uk/environment/business/products/roadmaps/lightbulbs.htm>

** Study on collection rates of waste electrical and electronic equipment (WEEE) - Possible measures to be initiated by the commission as required by article 7(4), 7(5), 7(6) and 7(7) of Directive 2012/19/EU on waste electrical and electronic equipment (WEEE), 2014-

https://ec.europa.eu/environment/waste/weee/pdf/Final_Report_Art7_publication.pdf; Eurostat -

<https://ec.europa.eu/eurostat/web/waste/key-waste-streams/weee>; Belgian estimate reported in Assistance to the Commission on Technological Socio-Economic and Cost-Benefit Assessment Related to Exemptions from the Substance Restrictions in Electrical and Electronic Equipment: Study to assess renewal requests for 29 RoHS 2 Annex III exemptions, 2016 - https://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/RoHS-Pack_9_Part_LAMPS_06-2016.pdf

*** Final Implementation Report for Directives 2002/96/EC and 2012/19/EU on Waste Electrical and Electronic Equipment (WEEE): 2013 – 2015 -

https://ec.europa.eu/environment/archives/waste/reporting/pdf/Final_Implementation_Report_2013_2015_WEEE.pdf

Today, these mercury-containing fluorescent lamps are rapidly being replaced across Europe with alternative products based on light emitting diode (LED) technology which is mercury-free, cost-effective, longer-lasting and provides the same or better lighting service compared to fluorescent. Figure 11 is from Philips Lighting/Signify³² who market LED lighting to businesses as “A green choice”, noting that “LED tubes are a mercury-free alternative to traditional fluorescent tubes, a responsible choice that can also contribute towards your green credentials.”

The right tube, right now

Our portfolio of LED tubes is now available with a range of options in High and Ultra Output.

Save on energy costs

LED tubes are up to 65% more efficient than TL-D lamps, so you can save on energy costs without compromising on light quality.

Long-lasting and reliable

With a lifetime of 50,000 hours they outshine TL-D lamps by 25,000 hours for lower maintenance and operation costs.

High quality of light

Our LED tubes won't flicker or cause glare. The 100% instant light has a high colour consistency and uniform visual appearance in a choice of colour temperatures.

NEW Ultra output, ultra efficient

Choose Ultra Output for ultra efficiency of 148 lm/W and exceptional light quality. Philips has a long history of ground-breaking innovation in lighting technologies. Our Ultra Output LED tubes are specially designed for demanding applications that require a high light output to comply with ergonomic norms. In fact they raise the bar in lighting efficiency and comfort by meeting all office, supermarket and healthcare standards.

A green choice

LED tubes are a mercury-free alternative to traditional fluorescent tubes, a responsible choice that can also contribute towards your green credentials.

100% safe installation

LED tubes are the fastest and easiest way to upgrade existing luminaires to LED technology. Installation is 100% safe and 0% hassle with a simple lamp-for-lamp replacement.



Figure 11. Philips Lighting/Signify highlighting the mercury-free alternative to fluorescent lighting

As discussed in Chapter 1 (Methodology), the authors contacted VHK and asked them to conduct some model runs of various phase-out scenarios for T8, T5 and CFLni lamps. VHK performed that analysis and provided the associated shipment forecasts and energy and financial savings. Table 6 presents the cumulative total number of fluorescent lamps that are not sold, and total mercury avoided from the European market in various scenarios. It is expected that these values represent minimum levels of avoided mercury, as the increased market demand for LED lamps driven by the retirement of RoHS exemptions would likely further accelerate global investment in and development of LED products. Please note that the analysis presented here does not reflect avoided mercury outside of Europe that could result from accelerated LED lamp technology and market development elsewhere in the world.

Table 6. Shipment Forecast for T8, T5 and CFLni Lamps in Europe; RoHS phase-out in 2021

Year	T8 LFL Sales			T5 LFL Sales			CFLni Sales		
	BAU, phase-out in 2023*	RoHS phase-out in 2021	Avoided T8 lamps	BAU, no phase-out*	RoHS phase-out in 2021	Avoided T5 lamps	BAU, no phase-out*	RoHS phase-out in 2021	Avoided CFLni lamps
	(millions)	(millions)	(millions)	(millions)	(millions)	(millions)	(millions)	(millions)	(millions)
2015	196	196	-	68	68	-	66	66	0
2016	185	185	-	66	66	-	64	64	0
2017	179	179	-	66	66	-	60	60	0
2018	171	171	-	66	66	-	55	55	0
2019	162	162	-	65	65	-	52	52	0
2020	151	121	30	64	51	13	47	38	9
2021	123	68	54	61	30	31	45	22	22
2022	97	24	73	57	11	46	42	8	34
2023	55	11	44	53	5	48	38	4	34
2024	20	5	15	48	2	45	33	2	32
2025	9	-	9	43	-	43	29	0	29
2026	4	-	4	39	-	39	23	0	23
2027	-	-	-	36	-	36	19	0	19
2028	-	-	-	33	-	33	15	0	15
2029	-	-	-	30	-	30	11	0	11
2030	-	-	-	27	-	27	8	0	8
Total			231			391			237

* Under the new ecodesign one-lighting regulation which was adopted by the Commission on 1 October 2019, T8 fluorescent lamps are phased-out in September 2021. T5 fluorescent lamps and CFLni lamps do not have a phase-out date, thus shipments continue through 2030 (the last year of shipment forecasts in the MELISA model).

To calculate an estimate of the total mercury avoided through the retirement of the RoHS exemptions for these three popular lamp types, the RoHS limits were multiplied by the volume of lamps: T8 lamps contain 3.5 mg of mercury, the T5 lamps contain 3.0 mg of mercury and the CFLni lamps contain 2.5 mg of mercury.

$$(231 \text{ million T8 lamps}) \times (3.5 \text{ mg Hg}) + (391 \text{ million T5 lamps}) \times (3.0 \text{ mg Hg}) +$$

$$(237 \text{ million CFLni lamps}) \times (2.5 \text{ mg Hg}) = \mathbf{2574 \text{ kilograms Hg}}$$

Thus approximately 2.6 metric tonnes of mercury could be avoided in Europe if the RoHS Committee determines that technologically feasible, economically justified non-mercury containing alternatives to T8, T5 and CFLni fluorescent lamps exist and sets the exemptions to expire on 1 September 2021.

Retiring those exemptions would align with the objectives of the Minamata Convention and the RoHS Directive as follows:

Minamata Convention, Article 1: Objective:

The objective of this Convention is to protect the human health and the environment from anthropogenic emissions and releases of mercury and mercury compounds.

Minamata Convention, Article 4: Mercury Added Products, paragraphs (4) and (7):

4. The Secretariat shall, on the basis of information provided by Parties, collect and maintain information on mercury-added products and their alternatives, and shall make such information publicly available. The Secretariat shall also make publicly available any other relevant information submitted by Parties.

7. Any Party may submit a proposal to the Secretariat for listing a mercury-added product in Annex A, which shall include information related to the availability, technical and economic feasibility and environmental and health risks and benefits of the non-mercury alternatives to the product, taking into account information pursuant to paragraph 4.

Limiting the extension for CFLni, T5 and T8 linear fluorescent lamps is also consistent with protecting human health and the environment, as stated in the objective of the RoHS Directive:

Article 1: Subject matter

This Directive lays down rules on the restriction of the use of hazardous substances in electrical and electronic equipment (EEE) with a view to contributing to the protection of human health and the environment, including the environmentally sound recovery and disposal of waste EEE.

4 Is it cost-effective for LED lamps to replace linear fluorescent lamps?

Yes. The phase-out of linear fluorescent lamps is cost-effective today, in many cases with a payback period shorter than one year. The following screen capture from the OSRAM/LEDVANCE website³³ points to the fact that payback periods can be as short as four months. This is due to the long operating hours for these installations and the fact that direct-replacement LED retrofit tubes are now more than twice as efficient as some mercury-containing fluorescent lamps.

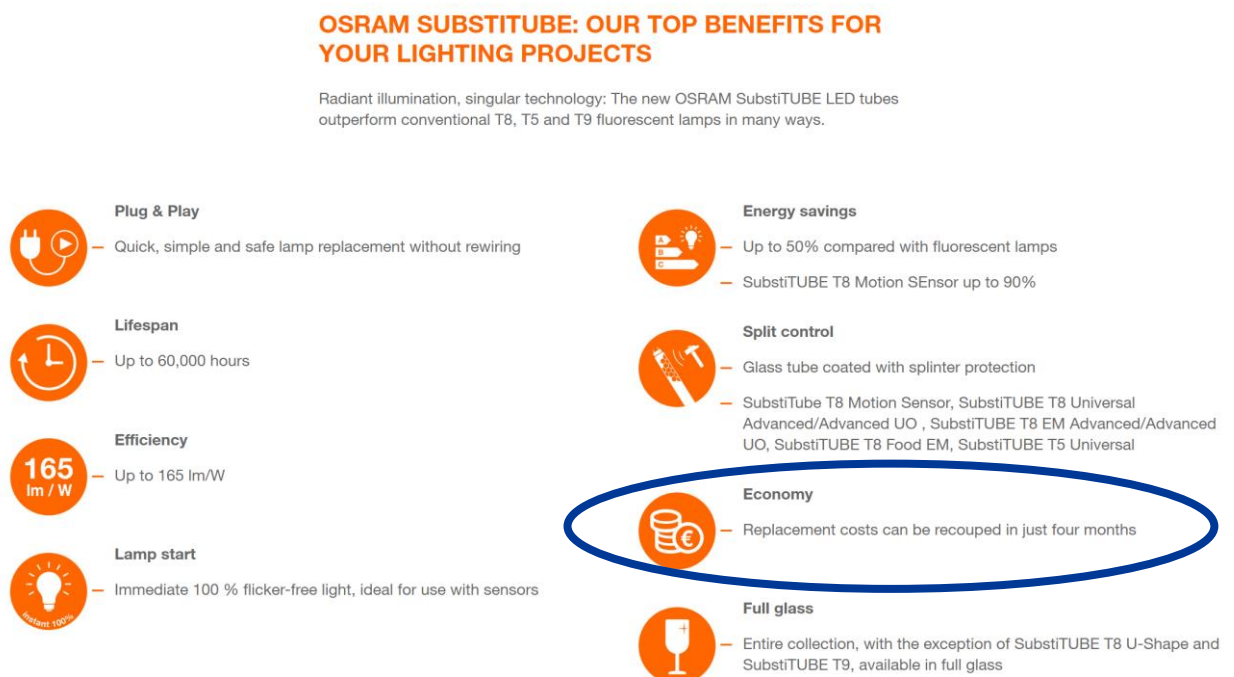



Figure 12. OSRAM/LEDvance Literature Highlighting Benefits of LED Tubular Retrofit Lamps

The authors prepared a calculation of a socket-for-socket replacement of a T8 fluorescent lamp with two different LED tubes to check if OSRAM’s reported four-month payback period is applicable in Europe. The table below presents our findings in relation to this assessment. We compared a €3.68 OSRAM 36W T8 linear fluorescent lamp (20 000 hours life) with Philips’ CorePro (entry-level, 30 000 hours life) LED replacement and Philips’ MasterLED (professional-grade, 50 000 hours life) LED retrofit models. Assuming operation for 10 hours per day, the entry-level LED offers a payback of 4.9 months compared to the fluorescent (and will last 1.5 times longer than the fluorescent lamp) and the professional grade lamp offers a payback of 11 months (and will last 13 years, which is 2.5 times longer than the linear fluorescent lamp). These calculations reflect energy costs and bulb costs, but do not incorporate labour costs saved over time from reduced frequency of bulb changes.

³³ <https://www.ledvance.com/professional/products/product-stories/led-tubes-online-special/index.jsp>

Table 7. Life-Cycle Economic Analysis of T8 Lamp Replacement in Europe

Europe		Lamp is on for hours/day:	10	hours/day	
		Electricity price:	0.11	EUR/kWh	
		Annual change in price of Electricity:	4.0%	percent (MEErP)	
		Electricity CO2 intensity:	0.296	kg CO2/kWh	
		Discount Rate:	4.0%	percent	
					
Lamp type		T8 LFL	LED T8 - 1	LED T8 - 2	
Lamp wattage:		36	18	12.5	Watts
Rated lamp lifetime:		20000	30000	50000	Hours
Price for one lamp (EUR):		3.68	6.77	12.74	EUR/lamp
Electricity consumption and savings calculations					
Annual electricity consumption for each lamp type:		131	66	46	kWh/year
Annual electricity savings compared to T8 fluorescent lamp:		---	66	86	kWh/year
Percent electricity savings compared with T8 fluorescent lamp:		---	50%	65%	percent
Electricity cost for operating the lamps each year:		15.10	7.55	5.24	EUR/year
Financial savings of electricity costs per year vs. fluorescent:			7.55	9.86	EUR/year
Life-Cycle Cost (LCC) of one lamp over analysis period shown					
LCC time period of analysis:		13.0	13.0	13.0	years
LCC of operating lamp for 13 years, discounted to 2019:		205.46	109.85	80.89	EUR (NPV, 2019)
LCC savings of more efficient lamp compared with a fluorescent T8:		---	95.61	124.57	EUR (NPV, 2019)
Percent LCC savings compared with a fluorescent T8 lamps:		---	47%	61%	percent
LCC savings are (X) times larger than LED Tube -1 LCC savings:		---	---	1.3	times greater
Payback period and Internal Rate of Return calculations					
Simple Payback period in years, compared with T8 fluorescent:		---	0.41	0.92	years
Simple Payback period in months, compared with T8 fluorescent:		---	4.9	11.0	months
Internal Rate of Return (IRR), compared with T8 fluorescent:		---	259%	118%	percent
CO2 emissions calculations					
CO2 emissions due to electricity for one lamp operating for 13 years:		505.3	252.6	175.4	kg CO2/13 yrs
CO2 savings compared with a T8 fluorescent lamp:		---	252.6	329.8	kg CO2/13 yrs
CO2 savings is (X) percent more than LED Tube 1 CO2 savings:		---	---	31%	percent

Notes: Electricity price of €0.1149/kWh from Eurostat for non-domestic sector³⁴. Electricity price escalation rate of 4% is applied (following the MEErP methodology). CO₂ intensity of 295.8 g CO₂/kWh from European Environment Agency³⁵.

All of the economics presented in this analysis indicate that the replacement of T8 fluorescent lamps is highly cost-effective. On a life-cycle cost basis, discounted to its net present value, end-users will save €95.61 (CorePro) or €124.57 (MasterLED) for each T8 fluorescent lamp replaced. These findings are based on October 2019 market prices and 2018 electricity prices and are indicative of the findings reported by VHK in their review study prepared for the one-lighting regulation. VHK’s original proposal recommended a phase-out of T8 linear fluorescent lamps in September 2020 based on their technical and economic analysis. However the final regulation adopted delayed that phase-out date by three years to September 2023, foregoing the significant benefits discussed in this report (see Annex B) – including the removal of mercury from offices and homes across Europe.

Conducting the same calculation for a T5 replacement, the payback periods are longer than T8, however they are still positive, and end-users will easily recover their investment. In addition, if there were to be a phase-out, T5 LED lamp sales volumes would be expected to rise and prices to fall through competition, yielding shorter payback periods. There isn’t an LED entry-level and professional-grade option in T5, thus a single calculation comparison is performed, comparing a 28-Watt linear fluorescent T5 with an LED direct replacement lamp from OSRAM/LEDvance. The results are presented in Table 8, which shows a payback period of

³⁴ https://ec.europa.eu/eurostat/statistics-explained/index.php/Electricity_price_statistics#Electricity_prices_for_non-household_consumers

³⁵ [Link to European Environment Agency](#) graphic depicting the 2016 CO₂ intensity value of 295.8g CO₂/kWh.

between 3.2 and 3.4 years. The net present value of the life-cycle cost savings is still strongly positive, offering European businesses €67.30 with the OSRAM product or €54.93 with the Philips product for each lamp replaced in terms of electricity savings.

Table 8. Life-Cycle Cost Economic Analysis of T5 Lamp Replacement in Europe

Europe				
Lamp is on for hours/day:	10	hours/day		
Electricity price:	0.11	EUR/kWh		
Annual change in price of Electricity	4.0%	percent (MEErP)		
Electricity CO2 intensity:	0.296	kg CO2/kWh		
Discount Rate	4.0%	percent		

Lamp type	T5 LFL	LED T5 - 1	LED T5 - 2	
Lamp wattage:	28	16	16.5	Watts
Rated lamp lifetime:	24000	60000	50000	Hours
Price for one lamp (EUR):	2.83	19.99	18.12	EUR/lamp
Electricity consumption and savings calculations				
Annual electricity consumption for each lamp type:	102	58	60	kWh/year
Annual electricity savings compared to T5 fluorescent lamp:	---	44	42	kWh/year
Percent electricity savings compared with T5 fluorescent lamp:	---	43%	41%	percent
Electricity cost for operating the lamps each year:	11.74	6.71	6.92	EUR/year
Financial savings of electricity costs per year vs. fluorescent:		5.03	4.82	EUR/year
Life-Cycle Cost (LCC) of one lamp over analysis period shown				
LCC time period of analysis:	16.0	16.0	16.0	years
LCC of operating lamp for 16 years, discounted to 2019:	194.65	127.35	139.72	EUR (NPV, 2019)
LCC savings of more efficient lamp compared with a fluorescent T5:	---	67.30	54.93	EUR (NPV, 2019)
Percent LCC savings compared with a fluorescent T5 lamps:	---	35%	28%	percent
Payback period and Internal Rate of Return calculations				
Simple Payback period in years, compared with T5 fluorescent:	---	3.41	3.17	years
Simple Payback period in months, compared with T5 fluorescent:	---	40.9	38.0	months
Internal Rate of Return (IRR), compared with T5 fluorescent:	---	32%	35%	percent
CO2 emissions calculations				
CO2 emissions due to electricity for one lamp operating for 16 years:	483.7	276.4	285.0	kg CO2/16 yrs
CO2 savings compared with a T5 fluorescent lamp:	---	207.3	198.7	kg CO2/16 yrs


Notes: Electricity price of €0.1149/kWh from Eurostat for non-domestic sector³⁶. Electricity price escalation rate of 4% is applied (following the MEErP methodology). CO₂ intensity of 295.8 g CO₂/kWh from European Environment Agency³⁷.

Conducting the same calculation for a CFLni replacement, the payback periods vary with the LED installed but are all positive, allowing end-users to recover their investment. In this calculation, an OSRAM 2D GR10q 28W is compared with a General Electric LED 2D shaped lamp and a Kosnic LED planar retrofit with the same socket (GR10q). Both LED replacements last more than twice as long as the fluorescent lamp, and the payback periods vary from 1.3 to 3.0 years. The results are presented in Table 9 which shows replacement offering European businesses €63.25 with the GE product or €24.02 with the Kosnic retrofit lamp.

³⁶ https://ec.europa.eu/eurostat/statistics-explained/index.php/Electricity_price_statistics#Electricity_prices_for_non-household_consumers

³⁷ [Link to European Environment Agency](#) graphic depicting the 2016 CO₂ intensity value of 295.8g CO₂/kWh.

Table 9. Life-Cycle Cost Economic Analysis of CFLni Lamp Replacement in Europe

Europe		Lamp is on for hours/day:	10	hours/day	
		Electricity price:	0.11	EUR/kWh	
		Annual change in price of Electricity:	4.0%	percent (MEErP)	
		Electricity CO2 intensity:	0.296	kg CO2/kWh	
		Discount Rate:	4.0%	percent	
					
Lamp type		CFLni - GR10q	LED EM-GR10q	GR10q 2D	
	Lamp wattage:	28	12.5	18.0	Watts
	Rated lamp lifetime:	13000	40000	30000	Hours
	Price for one lamp (EUR):	4.08	12.56	16.60	EUR/lamp
Electricity consumption and savings calculations					
	Annual electricity consumption for each lamp type:	102	46	66	kWh/year
	Annual electricity savings compared to CFLni fluorescent lamp:	---	57	37	kWh/year
	Percent electricity savings compared with CFLni fluorescent lamp:	---	55%	36%	percent
	Electricity cost for operating the lamps each year:	11.74	5.24	7.55	EUR/year
	Financial savings of electricity costs per year vs. fluorescent:		6.50	4.19	EUR/year
Life-Cycle Cost (LCC) of one lamp over analysis period shown					
	LCC time period of analysis:	10.0	10.0	10.0	years
	LCC of operating lamp for 10 years, discounted to 2019:	128.24	64.98	104.22	EUR (NPV, 2019)
	LCC savings of more efficient lamp compared with a fluorescent CFLni:	---	63.25	24.02	EUR (NPV, 2019)
	Percent LCC savings compared with a fluorescent CFLni lamps:	---	49%	19%	percent
Payback period and Internal Rate of Return calculations					
	Simple Payback period in years, compared with CFLni fluorescent:	---	1.30	2.99	years
	Simple Payback period in months, compared with CFLni fluorescent:	---	15.7	35.8	months
	Internal Rate of Return (IRR), compared with CFLni fluorescent:	---	90%	38%	percent
CO2 emissions calculations					
	CO2 emissions due to electricity for one lamp operating for 10 years:	302.3	135.0	194.3	kg CO2/10 yrs
	CO2 savings compared with a CFLni fluorescent lamp:	---	167.3	108.0	kg CO2/10 yrs

The economics of LED direct retrofit lamps for T8, T5 and CFLni fluorescent lamps are all cost effective and beneficial to end-users. The installations considered in these calculations do not require rewiring or modification to the existing fluorescent fixtures, as the lamps are all direct retrofits that can be installed and will operate on the existing fluorescent ballast.

5 Are the societal benefits in terms of energy, CO₂ and cost savings significant?

Yes. The societal benefits in terms of energy and cost savings are significant, as are the reduction of greenhouse gas emissions and the environmental release of mercury both from lamps and from coal-fired power plant operations driven by the higher energy use of CFL products. This section provides an analysis of the financial savings, mercury reductions and energy and greenhouse gas reductions for T8, T5 and CFLni lamps separately and in total. Assuming all RoHS exemptions for these lamp types ended in 2021, mercury reductions would be 2574 kilograms from the lamps and 2212.8 kilograms of mercury emissions avoided at the power station from the electricity savings³⁸. In total then, the avoided mercury emissions associated with lamp disposal and avoided electricity consumption would be **4876.8 kg**.

5.1 Benefits from Phase-Out of T8 Fluorescent Lamps

According to VHK, approximately three-quarters of the energy savings potential of the ecodesign one-lighting regulation³⁹ are derived from the phase-out of three of the most popular lengths of T8 linear fluorescent lamps: 2 foot, 4 foot and 5 foot lengths. This is primarily due to the fact that LED lamps can reduce electricity use by 50% compared with fluorescent lamps, which currently make up the largest source of demand for electricity for lighting in Europe.

Table 10 shows the total energy savings associated with the one-lighting regulation for T8 fluorescent lamps presented in four different years – from 2020, when it was originally proposed by VHK through 2023, when the current exemption is set to expire. Savings from the measure in 2030 are presented, along with the cumulative energy savings between 2015 and 2030. There are two scenarios presented in this table – one where the T8 lamps are phased out as originally proposed by VHK in September 2020 and one where the T8 lamps are phased out in September 2021 (potentially by the RoHS Directive).

The mercury emission reductions from phasing out T8 fluorescent lamps are two-fold: emissions into the environment from broken and improperly disposed lamps is avoided, and by reducing electricity demand, mercury released to the environment from the burning of coal at European power stations is avoided. Research by the DG Joint Research Centre estimates that the generation of 1 kWh emits 0.016 mg of mercury to air, based on an assumption that 31% of the electricity used in the EU comes from coal. If we calculate the sum of mercury from avoided lamp shipments and mercury emissions from avoided electricity production that result from retiring the exemption for T8 fluorescent lamps in 2021, 1832.5 kg Hg is avoided by 2030:

$$(231 \text{ million T8 lamps}) \times 3.5 \text{ mg Hg} = 808.5 \text{ kg Hg}$$

$$64 \times 10^9 \text{ kWh} \times 0.016 \text{ mg Hg} = 1024 \text{ kg Hg powerplant emissions avoided}$$

$$808.5 \text{ kg} + 1024 \text{ kg} = 1832.5 \text{ kg Hg avoided}$$

³⁸ According to the Commission's Joint Research Centre, mercury is released into the air when coal is burned at the power station. The JRC estimates that with the current generation mix of 31% of EU power derived from coal, each kilowatt-hour releases 0.016 mg of mercury into the air. Electricity savings from LED lamps will therefore reduce power station mercury emissions when compared with less efficient fluorescent lamps.

³⁹ 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 and repealing Commission Regulations (EC) No 244/2009, (EC) No 245/2009 and (EU) No 1194/2012 (Text with EEA relevance.) https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2019.315.01.0209.01.ENG&toc=OJ:L:2019:315:TOC

Table 10. Electricity and Cost Savings from the Phase-Out of T8 fluorescent lamps in Europe⁴⁰

Benefits of T8 phase-out	Savings			
	2021	2022	2023	Cumulative (2015-2030)
Electricity & CO ₂ Savings				
T8 fluorescent lamps phase-out in 2020 (TWh)	1.4	3.5	6.1	98 TWh (29 MT CO ₂)
T8 fluorescent lamps phase-out in 2021 (TWh)	0.0	2.1	4.7	64 TWh (18.9 MT CO ₂)
Energy Bill Savings				
T8 fluorescent lamps phase-out in 2020 (billion €)	€0.6	€1.2	€1.8	€7.0 billion
T8 fluorescent lamps phase-out in 2021 (billion €)	€0.0	€0.6	€1.2	€5.0 billion
Mercury Savings				
T8 fluorescent lamps phase-out in 2021 (kg Hg)	--	--	--	808.5 kg – lamps 1024 kg – power plant

Due to the fact that the majority of T8 lamps are phased-out in 2023 under the Ecodesign, the scenarios presented above reflect a slight acceleration in the phase-out date. The initial proposal from the Commission's consultant was to phase-out T8 lamps in 2020, however due to lobbying by industry partners, this was delayed to 2023 in the final regulation published in the OJEU on 5 December 2019. Thus, in terms of lost savings on energy bills, the three-year delay to the phase-out of 2/4/5 foot T8 linear fluorescent lamps wiped out €7 billion Euro of net savings (taking into account lamp purchase cost) for European homes and businesses. If the delay had been held to only one year instead of three and 2/4/5 foot T8 linear fluorescent lamps were phased out in 2021, €5 billion Euro of net savings would be captured for European consumers and businesses.

5.2 Benefits from Phase-Out of T5 Fluorescent Lamps

VHK prepared an analysis using the MELISA European Lighting market model to estimate the energy and economic impact of a phase-out of T5 fluorescent lamps. Two of the scenarios are presented below, namely a phase-out in 2021 and one in 2023. Due to the fact that the market will start correcting in advance of the phase-out effective date, VHK projects a small impact and some energy savings already appearing in 2020 from a September 2021 phase-out date.

Please see Table 11 for an estimate of the savings potential for phasing out T5 lamps. The energy bill savings are slightly negative in the first year of adoption due to a higher first-cost of lamps, however the model goes on to show that the energy savings from a T5 phase-out are significant, completely off-setting the first cost and saving up to 60 TWh of electricity on a cumulative basis, worth €4.7 billion Euro in net savings (including lamp purchase cost) if

⁴⁰ Personal communication and analysis conducted by VHK using the MELISA lighting market model (which was also used for the Impact Assessment for the Ecodesign one-lighting regulation) --as a one-time courtesy, on a strictly personal title and not assuming any liability for the data or its use-- to provide estimates of the savings potential of various scenarios. Communication on 16 October 2019.

fluorescent T5 lamps are phased-out in 2021. The numbers are slightly lower, but still significant if T5 lamps are phased out in 2023: 40 TWh of electricity and €3.1 billion.

Using the same level of carbon intensity (0.296 kg/kWh), the avoided CO₂ emissions would be 17.8 MT of CO₂ for a T5 phase-out in 2021 and 11.8 MT of CO₂ for a phase out in 2023.

The mercury emission reductions from phasing out T5 fluorescent lamps are two-fold: emissions into the environment from broken and improperly disposed lamps is avoided, and by reducing electricity demand, mercury released to the environment from the burning of coal at European power stations is avoided. We calculate the sum of mercury from avoided lamp shipments and mercury emissions from avoided electricity production that result from retiring the exemption for T5 fluorescent lamps in 2021, then 2136.2 kg Hg is avoided by 2030:

$$(391 \text{ million T5 lamps}) \times 3.0 \text{ mg Hg} = 1173 \text{ kg Hg}$$

$$60.2 \times 10^9 \text{ kWh} \times 0.016 \text{ mg Hg} = 963.2 \text{ kg Hg powerplant emissions avoided}$$

$$1173 \text{ kg} + 963.2 \text{ kg} = 2136.2 \text{ kg Hg avoided}$$

Table 11. Energy and Financial Savings from Phase-Out of T5 fluorescent lamps in Europe⁴¹

Benefits of T5 phase-out	Savings			
	2020	2025	2030	Cumulative (2015-2030)
Electricity & CO₂ Savings				
T5 fluorescent lamps phase-out in 2021 (TWh)	0.4	5.9	9.6	60.2 TWh (17.8 MT CO ₂)
T5 fluorescent lamps phase-out in 2023 (TWh)	0.0	3.4	8.2	40.0 TWh (11.8 MT CO ₂)
Energy Bill Savings				
T5 fluorescent lamps phase-out in 2021 (billion €)	€-0.3	€0.3	€1.9	€4.7 billion
T5 fluorescent lamps phase-out in 2023 (billion €)	€0.0	€-0.1	€1.5	€3.1 billion
Mercury Savings				
T5 fluorescent lamps phase-out in 2021 (kg Hg)	--	--	--	1173 kg – lamps 963.2 kg – power plant

5.3 Benefits from Phase-Out of CFLni Fluorescent Lamps

VHK prepared an analysis using the MELISA European Lighting market model to estimate the energy and economic impact of a phase-out of CFLni fluorescent lamps. Two of the scenarios are presented below, namely a phase-out in 2021 and one in 2023. Due to the fact that the market will start correcting in advance of the phase-out effective date, VHK projects a small

⁴¹ Personal communication and analysis conducted by VHK using the MELISA lighting market model (which was also used for the Impact Assessment for the Ecodesign one-lighting regulation) --as a one-time courtesy, on a strictly personal title and not assuming any liability for the data or its use-- to provide estimates of the savings potential of various scenarios. Communication on 18 October 2019.

impact and some energy savings already appearing in 2020 from a September 2021 phase-out date.

Please see Table 11 for an estimate of the savings potential for phasing out CFLni lamps. The energy bill savings are slightly negative in the first year of adoption, however the model goes on to show that the savings from a CFLni phase-out are significant, saving 14.1 TWh of electricity on a cumulative basis and €2.8 billion Euro if fluorescent CFLni lamps are phased out in 2021. The numbers are slightly lower, but still significant if CFLni lamps are phased out in 2023: 9.5 TWh of electricity and €1.5 billion.

Using the same level of carbon intensity (0.296 kg/kWh), the avoided CO₂ emissions would be 4.2 MT of CO₂ for a CFLni phase out in 2021 and 2.8 MT of CO₂ savings for a phase out in 2023.

The mercury emission reductions from phasing out CFLni fluorescent lamps are two-fold: emissions into the environment from broken and improperly disposed lamps is avoided, and by reducing electricity demand, mercury released to the environment from the burning of coal at European power stations is avoided. We calculate the sum of mercury from avoided lamp shipments and mercury emissions from avoided electricity production that result from retiring the exemption for CFLni fluorescent lamps in 2021, then 818.1 kg Hg is avoided by 2030:

$$(237 \text{ million CFLni lamps}) \times 2.5 \text{ mg Hg} = 592.5 \text{ kg Hg}$$

$$14.1 \times 10^9 \text{ kWh} \times 0.016 \text{ mg Hg} = 225.6 \text{ kg Hg powerplant emissions avoided}$$

$$592.5 \text{ kg} + 225.6 \text{ kg} = 818.1 \text{ kg Hg avoided}$$

Table 12. Energy and Financial Savings from Phase-Out of CFLni fluorescent lamps in Europe⁴²

Benefits of CFLni phase-out	Savings			
	2020	2025	2030	Cumulative (2015-2030)
Electricity & CO₂ Savings				
CFLni fluorescent lamps phase-out in 2021 (<i>TWh</i>)	0.1	1.7	1.5	14.1 TWh (4.2 MT CO ₂)
CFLni fluorescent lamps phase-out in 2023 (<i>TWh</i>)	0.0	0.9	1.5	9.5 TWh (2.8 MT CO ₂)
Energy Bill Savings				
CFLni fluorescent lamps phase-out in 2021 (<i>billion €</i>)	€-0.02	€0.23	€0.58	€2.8 billion
CFLni fluorescent lamps phase-out in 2023 (<i>billion €</i>)	--	€0.07	€0.49	€1.5 billion
Mercury Savings				
CFLni fluorescent lamps phase-out in 2021 (<i>kg Hg</i>)	--	--	--	592.5 kg – lamps 225.6 kg – power plant

⁴² “Personal communication and analysis conducted by VHK using the MELISA lighting market model (which was also used for the Impact Assessment for the Ecodesign one-lighting regulation) --as a one-time courtesy, on a strictly personal title and not assuming any liability for the data or its use-- to provide estimates of the savings potential of various scenarios. Communication on 26 October 2019.”

5.4 Cumulative Savings Potential

The total savings potential from this analysis is shown in Table 13 below, noting a cumulative energy savings potential of 138.3 TWh, more than five times the annual energy consumption of Scotland (population: 5 million). The cumulative net savings to households and businesses across Europe (taking into account both lamp purchase costs and energy savings) would be €12.5 billion, CO₂ emissions would be reduced by 40.9 million metric tonnes. Mercury reductions would be 2574 kilograms from the lamps and 2212.8 kilograms avoided through the electricity savings⁴³. In total then, the avoided mercury emissions associated with lamp disposal and coal-based electricity use would be 4787 kg.

Table 13. Net Benefits from Phase-Out of T8, T5 and CFLni Lamps in September 2021








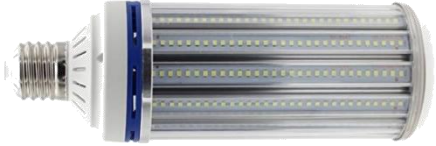


Savings	Cumulative (2015-2030) Savings for:			
	T8	T5	CFLni	Sum
Electricity Savings (TWh)	64.0	60.2	14.1	138.3
Energy Bill Savings (€ billion)	€5.0	€4.7	€2.8	€12.5
CO ₂ Savings (million metric tonnes)	18.9	17.8	4.2	40.9
Mercury savings lamps (kg Hg)	808.5	1173	592.5	4787
Mercury savings at powerplant (kg Hg)	1024	963.2	225.6	

⁴³ According to the Commission's Joint Research Centre, mercury is released into the air when coal is burned at the power station. The JRC estimates that with the current generation mix of 31% of EU power derived from coal, each kilowatt-hour releases 0.016 mg of mercury into the air. Electricity savings from LED lamps will therefore reduce power station mercury emissions when compared with less efficient fluorescent lamps.

Annex A. Images of Mercury-Containing Lighting and LED Replacement

Mercury in single capped (compact) fluorescent lamps not exceeding (per burner):

- 1(a) For general lighting purposes < 30 W:
2,5 mg shall be used per burner after 31 December 2012;
- 1(b) For general lighting purposes ≥ 30 W and < 50 W:
3,5 mg may be used per burner after 31 December 2011;
- 1(c) For general lighting purposes ≥ 50 W and < 150 W: 5 mg;
- 1(d) For general lighting purposes ≥ 150 W: 15 mg;
- 1(e) For general lighting purposes with circular or square structural shape and tube diameter ≤ 17 mm: 7 mg may be used per burner after 31 December 2011; and
- 1(f) For special purposes: 5 mg.





RoHS Exemption	Compact Fluorescent Lighting	LED Lighting (zero Hg)
1(a)		
1(b)		
1(c)		
1(d)		
1(e)		

2(a) Mercury in double-capped linear fluorescent lamps for general lighting purposes not exceeding (per lamp):

- 2(a)(1) Tri-band phosphor with normal lifetime and a tube diameter < 9 mm (e.g. T2):
4 mg may be used per lamp after 31 December 2011
- 2(a)(2) Tri-band phosphor with normal lifetime and a tube diameter ≥ 9 mm and ≤ 17 mm (e.g. T5): 3 mg may be used per lamp after 31 December 2011
- 2(a)(3) Tri-band phosphor with normal lifetime and a tube diameter > 17 mm and ≤ 28 mm (e.g. T8): 3,5 mg may be used per lamp after 31 December 2011
- 2(a)(4) Tri-band phosphor with normal lifetime and a tube diameter > 28 mm (e.g. T12):
3,5 mg may be used per lamp after 31 December 2012
- 2(a)(5) Tri-band phosphor with long lifetime (≥ 25 000 h):
5 mg may be used per lamp after 31 December 2011

2(b) Mercury in other fluorescent lamps not exceeding (per lamp):

- ~~2(b)(1) Linear halophosphate lamps with tube > 28 mm (e.g. T10 and T12): 10 mg Expires on 13 April 2012 (banned)~~
- ~~2(b)(2) Non-linear halophosphate lamps (all diameters): 15 mg Expired on 13 April 2016 (banned)~~
- 2(b)(3) Non-linear tri-band phosphor lamps with tube diameter > 17 mm (e.g. T9):
15 mg may be used per lamp after 31 December 2011
- 2(b)(4) Lamps for other general lighting and special purposes (e.g. induction lamps):
15 mg may be used per lamp after 31 December 2011

RoHS Exemption	Double-Capped Fluorescent Lighting	LED Lighting (zero Hg)
2(a)(2)		
2(a)(3)		

Annex B. WEEE Glossary of Key Terms

Directive 2012/19/EU on waste electrical and electronic equipment (WEEE Directive) sets targets for the collection, recovery and recycling of WEEE. It refers to Directive 2008/98/EC for the definition of the terms ‘hazardous waste’, ‘collection’, ‘separate collection’, ‘prevention’, ‘re-use’, ‘treatment’, ‘recovery’, ‘preparing for re-use’, ‘recycling’ and ‘disposal’.

The terms ‘collection’, ‘separate collection’, ‘re-use’, ‘treatment’, ‘recovery’, ‘preparing for re-use’, ‘recycling’ and ‘disposal’ are relevant to this report, so we have copied the definitions below from Directive 2008/98/EC.

‘collection’ means the gathering of waste, including the preliminary sorting and preliminary storage of waste for the purposes of transport **to a waste treatment facility**;

‘separate collection’ means the collection where a waste stream is kept **separately** by type and nature so as to facilitate a **specific treatment**;

‘re-use’ means any operation by which products or components that are not waste are used again for the same purpose for which they were conceived;

‘treatment’ means **recovery** or **disposal** operations, including preparation prior to recovery or disposal;

‘recovery’ means any operation the principal result of which is **waste serving a useful purpose** by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy. Annex II sets out a non-exhaustive list of recovery operations⁴⁴;

‘preparing for re-use’ means checking, cleaning or repairing recovery operations, by which products or components of products that have become waste are prepared so that they can be re-used without any other pre-processing;

‘recycling’ means any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and

⁴⁴ Recovery operations as per Annex II: R1 Use principally as a fuel or other means to generate energy [\(1\)](#); R2 Solvent reclamation/regeneration; R3 Recycling/reclamation of organic substances which are not used as solvents (including composting and other biological transformation processes) [\(2\)](#); R4 Recycling/reclamation of metals and metal compounds; R5 Recycling/reclamation of other inorganic materials [\(3\)](#); R6 Regeneration of acids or bases; R7 Recovery of components used for pollution abatement; R8 Recovery of components from catalysts; R9 Oil re-refining or other reuses of oil; R10 Land treatment resulting in benefit to agriculture or ecological improvement; R11 Use of waste obtained from any of the operations numbered R 1 to R 10; R12 Exchange of waste for submission to any of the operations numbered R 1 to R 11 [\(4\)](#); R13 Storage of waste pending any of the operations numbered R 1 to R 12 (excluding temporary storage, pending collection, on the site where the waste is produced) [\(5\)](#)

the reprocessing into materials that are to be used as fuels or for backfilling operations;

'disposal' means any operation which is not recovery, even where the operation has as a secondary consequence the reclamation of substances or energy. Annex I sets out a non-exhaustive list of disposal operations;

Annex C. LightingEurope Letter of 8 November 2019

LightingEurope (LE) prepared and submitted a letter dated 8 November 2019 with the subject “Additional Information on Compatibility and Waste – RoHS Mercury Exemptions” in which they are critical of some of the findings in this report. In this Annex, we have taken extracts from LE’s letter and reproduced them below with a light blue shaded background. We have then responded to these criticisms with further analysis and discussion, organised around two themes: C.1 Availability of Mercury-Free LED Substitutes and C.2 Collection of Waste Lamps. We then have subsection C.3 Conclusions, which summarises our findings on these two themes. Annex D includes a letter submitted by a Dutch lighting company called Seaborough B.V. to DG Environment. We reference the Seaborough letter in our response to the LightingEurope comments, therefore we have included it for completeness and transparency.

C.1 Availability of Mercury-Free LED Substitutes

LightingEurope letter:

We understand that during the exchange in the October 21st meeting, there have been discussions on the availability of LED substitutes for certain lamp types, supported by a report of the Swedish Energy Agency and CLASP, and on the impact of waste lamps.

LightingEurope, as the applicant for the renewal of these exemptions, would like to respond that:

- LED substitutes are not available for all lamp types covered by the RoHS mercury exemptions, due to the variety of lamps and applications they are used in and the possible compatibility issues between the LED substitute lamps and the installed lighting fixture.
- Preliminary waste collection data recently gathered in cooperation with EucoLight illustrates that the industry is meeting collection and recycling targets and that the renewal of exemptions will not result in significant additional waste lamps – we estimate a total of 6.6% additional waste as a result of renewing RoHS exemptions 1 and 2.

Herewith some additional details on these two points.

1/ On availability of mercury-free LED substitutes to certain fluorescent lamps:

Model	Status	E*F
OSRAM T8HC80 37W UNIVERSAL	Compatible	1
OSRAM T8HC80 37W UNIVERSAL	Incompatible	2
OSRAM T8HC80 37W UNIVERSAL	Incompatible	3
OSRAM T8HC80 37W UNIVERSAL	Incompatible	4
OSRAM T8HC80 37W UNIVERSAL	Incompatible	5
OSRAM T8HC80 37W UNIVERSAL	Incompatible	6
OSRAM T8HC80 37W UNIVERSAL	Incompatible	7
OSRAM T8HC80 37W UNIVERSAL	Incompatible	8
OSRAM T8HC80 37W UNIVERSAL	Incompatible	9
OSRAM T8HC80 37W UNIVERSAL	Incompatible	10
OSRAM T8HC80 37W UNIVERSAL	Incompatible	11
OSRAM T8HC80 37W UNIVERSAL	Incompatible	12
OSRAM T8HC80 37W UNIVERSAL	Incompatible	13
OSRAM T8HC80 37W UNIVERSAL	Incompatible	14
OSRAM T8HC80 37W UNIVERSAL	Incompatible	15
OSRAM T8HC80 37W UNIVERSAL	Incompatible	16
OSRAM T8HC80 37W UNIVERSAL	Incompatible	17
OSRAM T8HC80 37W UNIVERSAL	Incompatible	18
OSRAM T8HC80 37W UNIVERSAL	Incompatible	19
OSRAM T8HC80 37W UNIVERSAL	Incompatible	20
OSRAM T8HC80 37W UNIVERSAL	Incompatible	21
OSRAM T8HC80 37W UNIVERSAL	Incompatible	22
OSRAM T8HC80 37W UNIVERSAL	Incompatible	23
OSRAM T8HC80 37W UNIVERSAL	Incompatible	24
OSRAM T8HC80 37W UNIVERSAL	Incompatible	25
OSRAM T8HC80 37W UNIVERSAL	Incompatible	26
OSRAM T8HC80 37W UNIVERSAL	Incompatible	27
OSRAM T8HC80 37W UNIVERSAL	Incompatible	28
OSRAM T8HC80 37W UNIVERSAL	Incompatible	29
OSRAM T8HC80 37W UNIVERSAL	Incompatible	30
OSRAM T8HC80 37W UNIVERSAL	Incompatible	31
OSRAM T8HC80 37W UNIVERSAL	Incompatible	32
OSRAM T8HC80 37W UNIVERSAL	Incompatible	33
OSRAM T8HC80 37W UNIVERSAL	Incompatible	34
OSRAM T8HC80 37W UNIVERSAL	Incompatible	35
OSRAM T8HC80 37W UNIVERSAL	Incompatible	36
OSRAM T8HC80 37W UNIVERSAL	Incompatible	37
OSRAM T8HC80 37W UNIVERSAL	Incompatible	38
OSRAM T8HC80 37W UNIVERSAL	Incompatible	39
OSRAM T8HC80 37W UNIVERSAL	Incompatible	40
OSRAM T8HC80 37W UNIVERSAL	Incompatible	41
OSRAM T8HC80 37W UNIVERSAL	Incompatible	42
OSRAM T8HC80 37W UNIVERSAL	Incompatible	43
OSRAM T8HC80 37W UNIVERSAL	Incompatible	44
OSRAM T8HC80 37W UNIVERSAL	Incompatible	45
OSRAM T8HC80 37W UNIVERSAL	Incompatible	46
OSRAM T8HC80 37W UNIVERSAL	Incompatible	47
OSRAM T8HC80 37W UNIVERSAL	Incompatible	48
OSRAM T8HC80 37W UNIVERSAL	Incompatible	49
OSRAM T8HC80 37W UNIVERSAL	Incompatible	50

The SEA/CLASP report selects a few samples of marketing communications and mistakenly claims this is evidence of the availability of mercury-free LED substitutes for all fluorescent lamps and for all the installations they are used in.

The report completely disregards the publicly available technical documentation from these same companies ([Signify](#), [Ledvance](#) and [Tungsram](#)) that illustrates that these LED substitutes are not compatible with all the installed lighting fixtures.

This means that the LED substitutes will not work in all installed lighting fixtures. For example, a survey of the most popular lineal fluorescent lamp types of LightingEurope members illustrates that for more than 2400 tested lamp/installed driver combinations, 23%

result in non-functioning installations, 12% result in variations in light level. *Please see Annex 1 for further examples of the consequences of non-compatibility.*

The SEA/CLASP report only selects a few lamps and does not take into account all the different lengths of tube lamps nor all the different lamp sockets to show that there are mercury-free LED substitutes for all these lengths and socket types. LightingEurope did a quick check on amazon.de and found substitutes available for only 5 of 16 lengths of T8 lamps, i.e. only 30% of all available lengths.

It is because of these compatibility issues and the variety of lamps that the Oeko socio-economic impact assessment, mandated by the European Commission and published in August 2019, arrives to such a substantial cost for substitution (e.g. 250 Billion Euros between 2019-2025 for linear fluorescent lamps-LFLs).

LightingEurope asks regulators not to confuse marketing communications with technical facts and to make decisions based on the latter and taking into account the entire product portfolio used in the lighting fixtures installed across Europe today.

Author's response on point 1/ Availability of mercury-free LED substitutes for certain fluorescent lamps:

Summary of LightingEurope's objections and conclusions from our supplementary research:

- 1) LightingEurope (LE) claims that the technical documentation illustrates that LED substitutes are not compatible with all fixtures
 - ➔ In its response to LightingEurope's argument, Seaborough presented data that 91.3% of T5 and T8 luminaires can accept direct replacement (no rewiring) LED tubes today and technical solutions exist that would solve the compatibility issue for at least a large majority of the rest.
 - ➔ Concerning lamp bases, SEA/CLASP found LED substitutes for 8 of the 9 lamp bases listed by LE for LFL (LE says there are only 3 out of 9 in their comments)(see Table C.3) and we found 16 out of 19 for CFLni (LE says there are only 6 out of 19 in their comments)(see Table C.4). Suppliers informed us that for those base types not available, retrofits could easily be made if an order was placed – so the gaps are simply an issue of demand and volume. This finding underscores the fact that there are mercury-free LED replacements for CFLni widely available today.

- 2) LE is concerned that all the different lengths of tube lamps and sockets are not examined, with only 5 of 16 lengths of T8 available on Amazon.de
 - ➔ We found that 90% of the lengths of fluorescent tubes manufactured by the three largest lamp manufacturers in the world already have direct drop-in T8 LED retrofits at those same lengths (see Table C.6), and we have confirmed that there is no technical impediment to manufacturing linear LED tubes at all lengths to replace all installations.

- 3) LE points to the Oeko-Institut's estimate of €250bn to substitute linear fluorescent lamps
 - ➔ We found that the research and evidence base behind that estimate was conducted in 2016. We have conducted a review of the 2019 product market, and found that the electronics have progressed significantly, making the

retrofit of fluorescent luminaires largely unnecessary – cf. points 1) and 2).

- 4) LE objects to the authors using publicly available technical documentation and lamp finder tools published on their members' websites to determine substitutability / compatibility – calling these customer tools and reference documents “marketing communications”
 - We found that the published technical literature on the LightingEurope members' websites support the claims made in the marketing material of these same members. We believe that the information we have reviewed in preparing this report on the LE members websites is both accurate and truthful.

The details of our findings and responses to these four aspects of point 1/ Availability of mercury-free LED substitutes to certain fluorescent lamps are presented separately below:

C.1.1 Technical documentation on compatibility

LE indicates they have conducted an internal study (not published or peer-reviewed) which looked at compatibility of LED retrofit lamps for 2400 popular fixtures. LE found that of these, 77% of the fixtures were able to operate with LED lamps – 65% of them with no problem and 12% with a variation in light output (unclear whether that variation is higher or lower). LE found 23% of the models were non-functioning. The authors invite LE to publish this study (survey and database), and allow independent scrutiny of it, allowing policy-makers to take decisions based on verifiable evidence.

SEA/CLASP are aware of a compatibility study (see Annex E) recently conducted by Seaborough based on the technical documentation and compatibility tables of LE members. This analysis is presented below, starting with their review of the availability of LED drop-in retrofit lamps for the different lamp/ballast combinations:

- T8 electromagnetic (EM/CCG) ballasts - drop-in retrofit LED tubes designed for T8 luminaires with electromagnetic (EM/CCG) ballasts. Producers currently offer LED tubes that will operate with all of these luminaires. Seaborough estimates that 60% of all installed T8 fluorescent luminaires are EM/CCG.
- T8 electronic (HF/ECG) ballasts - drop-in retrofit LED tubes designed for T8 luminaires with electronic (HF/ECG) ballasts. Seaborough reviewed the compatibility lists published on the supplier websites and found 15% of these luminaire types would not work with the HF LED tubes currently on the market.
- T5 electronic ballasts - drop-in retrofit LED tubes designed for T5 luminaires with electronic ballasts. Seaborough reviewed the compatibility lists published by the producers and found 15% of these luminaire types would not work with the HF LED tubes currently on the market.
- T8 universal lamps - drop-in retrofit LED tubes designed for T8 tubes with either electronic or electromagnetic ballasts. Seaborough reviewed the compatibility lists published by the producers and found 6% of these luminaire types would not work with the “universal” LED tubes currently offered by the producers.

- Direct mains power - it should be noted that for the small percentage of luminaires where the ballast is not compatible with an LED retrofit, the fixture can be replaced or the ballast can be bypassed by an electrician, and a “direct mains” power is supplied to a “universal” tube and it will work.

This research is then presented in Tables C.1 and C.2, which give the percentage of luminaires in the installed stock of Europe that can be retrofitted without a problem with the lamps already on the market today.

Table C.1. Available Drop-in Retrofit LED Tubes for European T8 Luminaires

T8 luminaire ballast type	% share of total T8 installations	% drop-in retrofit LED tubes available	Overall T8 luminaire coverage
Electromagnetic (EM/CCG)	60%	100%	60%
Electronic (HF/ECG)	40%	85%	34%
Totals:	100%		94%

Table C.2. Available Drop-in Retrofit LED Tubes for European T5 Luminaires

T5 luminaire ballast type	% share of total T5 installations	% drop-in retrofit LED tubes available	Overall T5 luminaire coverage
Electronic (HF/ECG)	100%	85%	85%
Totals:	100%		85%

Thus, direct drop-in retrofit LED tubes are widely available today for both T8 luminaires and T5 luminaires. There are compatible mercury-free LED options for 94% of T8 luminaires and 85% of T5 luminaires. Furthermore, Seaborough wrote in its letter to the European Commission that “our company has been proposing for several years solutions to these lamp makers that would solve the compatibility issue of the remaining 15 %,” suggesting that the current gaps in availability of replacements come from a lack of market interest rather than technical issues). Looking across the sector of linear fluorescent lighting as a whole, Seaborough estimates that 70% of the standard fluorescent lamp market is T8 luminaires and 30% of the standard lamp market is T5. Applying those weighting factors to the above availability of drop-in retrofit LED solutions:

$$\text{Availability}_{T8} + \text{Availability}_{T5} = \text{Total_Availability}_{LF}$$

$$(94\% \text{ compatible} \times 70\% \text{ stock}) + (85\% \text{ compatible} \times 30\% \text{ stock}) =$$

$$65.8\% + 25.5\% = \mathbf{91.3\%}$$

of T5 and T8 luminaires can accept direct replacement (no rewiring) LED tubes today.

Thus, the estimate from Seaborough shows that lamp manufacturers offer a variety of direct drop-in replacement LED tubes that can replace standard T8 and T5 fluorescent

tubes in more than 90% of the luminaires installed in the field. Only 8.7% of the installed stock of fluorescent luminaires would have a problem finding compatible LED direct drop-in replacements today. The very high percentage of compatible LED tubes today is what leads the manufacturers to make statements about ‘no need to rewire’ and ‘direct replacement retrofit LED lamps’. This has marketing value, but it is also the reality of the market which is why so many building owners are converting to LED.

According to Seaborough’s letter, technical solutions exist for the lamps that do not have LED replacement today. There is no evidence that those gaps in replacement would not be filled if there was demand from the market.

On the availability of LED substitutes for all lamp bases: LE presented some evidence in their letter indicating that only 3 out of 9 lamp base types are available for linear fluorescent lamps. We checked this finding and do not agree with LE’s evidence base. In fact, with a cursory search we were able to find 8 of the 9 base types available in the market today. Please see the screen capture from the LE letter below, where they have indicated only miniature bipin, medium bipin and G10q base types are available. Table C.3 lists the base types and provides links to the examples we found online.

Comment from Lighting Europe, claiming only 3 of 9 fluorescent lamp base types exist in the market:



Table C.3 SEA/CLASP research on lamp base types for Linear Fluorescent Lamps – 8 out of 9 base types exist

Base Type from LE Comment	Does this Base Type Exist in a Retrofit LED Lamp?	Links to Examples of LED Lamps
Miniature Bipin	Yes	Link to example
Medium Bipin	Yes	Link to example
Single Pin	Yes	Link to example
Recessed Double Contact	Yes	Link to example
4-Pin	Yes	Link to example
Single ended, 4-Pin	Yes	Link to example
2GX-13	Yes	Link to example
Axial	Not found	
G10q	Yes	Link to example

LE presented additional evidence in their letter indicating that only 6 out of 19 lamp base types for non-integrally ballasted compact fluorescent lamps (CFLni) have LED retrofits. We checked this finding and were able to find 16 out of 19 base types available in the market today (85% of the base types listed in the LE comment). Please see the screen capture from the LE letter below, where LE have indicated that 2G11, G23, G24q-1, G24q-3, GX23 and GX24q-1 base types are available. SEA/CLASP’s analysis found ten additional base types already on the market, over and above the six LE indicated exist in the market. Table C.4 lists the base types and provides links to the examples we found online.

Comment from LightingEurope, claiming only 6 of 19 CFLni base types exist in the market:

Example 2: Lamp bases for Compact fluorescent lamps without integrated control gear (CFL-ni) – substitutes for **Six out of nineteen lamp bases**

COMPACT FLUORESCENT PLUG IN BASES



Table C.4 SEA/CLASP research on lamp base types for pin-based compact fluorescent Lamps – 16 out of 19 base types exist

Base Type from LE Comment	Does this Base Type Exist in a Retrofit LED Lamp?	Links to Examples of LED Lamps
2G7	Yes	Link to example
2GX-7	Yes	Link to example
2G11	Yes	Link to example
G23	Yes	Link to example
G23-2	Yes	Link to example

Base Type from LE Comment	Does this Base Type Exist in a Retrofit LED Lamp?	Links to Examples of LED Lamps
G24d-2	Yes	Link to example
G24d-3	Yes	Link to example
G24q-1	Yes	Link to example
G24q-2	Yes	Link to example
G24q-3	Yes	Link to example
GX23	Yes	Link to example
GX23-2	Yes	Link to example
GX24q-1	Yes	Link to example
GX24q-2	Yes	Link to example
GX24q-3	Yes	Link to example
GX24q-4	Yes	Link to example
GX24q-5	Not found*	
GX32d-2	Not found*	
GX32d-3	Not found*	

*For these base types, products could not be found at this time, however we did confirm that there is no technical impediment preventing LED retrofit lamps from being made with these base types, as opposed to any other. We contacted Green Electrical Supply <https://www.greenelectricalsupply.com/> and consulted with their Sales Team to confirmed the technological feasibility of making LED replacements with any CFLni base type.

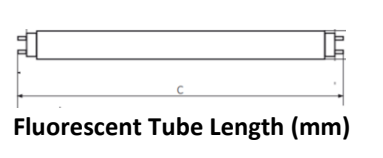
C.1.2 Availability of Different Lengths

LE expressed concern that LED tubes of all different lengths of tube lamps and sockets are not examined, and reviewed Amazon.de to check what lengths of T8 lamps were available. LE found that only 5 of 16 lengths of T8 lamps were available.

In an effort to verify this finding reported by LE, SEA/CLASP downloaded all the technical specification sheets for the T8 (TL-D) fluorescent lamps for Philips/Signify, OSRAM and Tungsten/GE Lighting. SEA/CLASP then compiled that data into a spreadsheet and aligned all the model information according to the length of the lamps offered. SEA/CLASP chose these three companies because they have historically been the world's largest three manufacturer of lamps and because they are all members of LE.

The table below presents all of the "C dimensions" (in millimetres) which is the maximum overall length of the fluorescent tubes, including the pins on both ends. SEA/CLASP only found 10 unique lengths of T8 lamps across the complete catalogues of these three global companies, not 16 as claimed by LE. The table below presents the ten lengths of T8 lamps specified by the companies.

Table C5. Maximum overall lengths of T8 lamps offered in Europe by the three largest global lamp manufacturers

 Fluorescent Tube Length (mm)	451.6 mm	484 mm	604 mm	734 mm	908.8 mm	984.2 mm	1061 mm	1213.6 mm	1514.2 mm	1778 mm
Philips/Signify										
MASTER TL-D Eco			X					X	X	
MASTER TL-D Super 80			X			X		X	X	X
MASTER TL-D Secura			X					X		
MASTER TL-D HF Super 80			X					X	X	
MASTER TL-D Xtreme			X					X	X	
MASTER TL-D 90 De Luxe			X					X	X	
MASTER TL-D 90 Graphica			X					X		
MASTER TL-D Food			X					X		
TL-D Coloured								X		
OSRAM										
LUMILUX T8	X	X	X	X	X	X	X	X	X	
LUMILUX XT T8			X					X		
LUMILUX XXT T8								X	X	
LUMILUX DE LUXE T8			X	X				X	X	
Color proof T8			X					X	X	
Coloured T8			X		X			X	X	
OSRAM NATURA T8	X		X		X			X	X	
LUMILUX T8 1 m						X				
LUMILUX CHIP control T8			X					X		
Tungshram/GE Lighting										
T8 Watt-Miser™			X					X	X	
T8 Polylux XLR™ LongLast™			X					X	X	
T8 Polylux XLR™	X		X		X			X	X	X

Next, SEA/CLASP sought to verify whether there were indeed only five lengths of LED lamps available to replace these lengths of T8 lamps. We were able to find direct replacement LED lamps for 9 out of our 10 lengths on Amazon.DE (see Table C6)– although it should be noted that some of the suppliers offering product are not LightingEurope members. When conducting this search, we noted that some suppliers used the overall length (C length) and others used the B length or a nominal length. The figure below illustrates the standardised measurements used for fluorescent tubes.

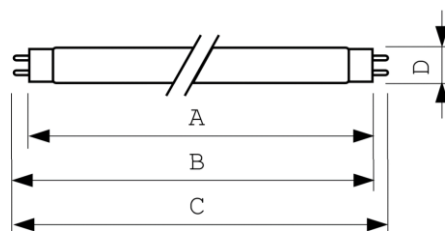


Table C6. Replacement T8 LED lamps on Amazon.DE for lengths identified

C Length	B Length	Product Description on Amazon.DE	Link to Amazon.DE
451.6 mm	438 mm	eLITe PLUS LED Röhre T8 G13 Sockel 1040lm 8W 4000K Neutralweiß FWI: 840 44cm Lang ASW: [Energieklasse A++]	Click here
484 mm	470 mm	This length was not available on Amazon.DE, therefore we contacted Zhejiang Boden Electronic Technology Co., Ltd in Zhejiang, China and confirmed that 470mm can be made, but must order 10,000 pieces. ⁴⁵	n/a
604 mm	590 mm	Osram LED Substitute Star PC T8 Leuchtstoffröhre, in 60 cm Länge mit G13-Sockel, Ersetzt 18 Watt, Kaltweiß - 4000 Kelvin, 1er-Pack [Energieklasse A+]	Click here
734 mm	720 mm	eLITe PLUS LED Röhre T8 G13 Sockel 1300lm 10W 4000K Neutralweiß FWI: 840 72cm Lang ASW: 120° [Energieklasse A++]	Click here
908.8 mm	895 mm	90 cm LED Röhre T8-G13 14 Watt, 300° AUSSTRAHLUNG, 1860 Lumen, Tageslichtweiß/ Kaltweiß 6000 Kelvin, 1:1 Ersatz für 24-30 Watt Leuchtstoffröhren - inclusive LED Starter [Energieklasse A++]	Click here
984.2 mm	970 mm	LED Röhre [kein Starter nötig!] T8 Länge 97,0 cm (!!Sondergröße!!) Leistung 16W Lumen 2240lm Lichtfarbe 4500K Farbreinheit CRI >80 Durchmesser 26mm Sockel G13 [Energieklasse A++]	Click here
1061 mm	1047 mm	Philips Master LEDtube Leuchtstofflampe Value UO T8 1047mm 16 Watt 2300 Lumen 830 3000 Kelvin warmweiß KVG/VVG drehbare Endkappe	Click here
1213.6 mm	1200 mm	Osram LED Substitute Star PC T8 Leuchtstoffröhre, in 120 cm Länge mit G13-Sockel, Ersetzt 36 Watt, Kaltweiß - 4000 Kelvin, 1er-Pack [Energieklasse A+]	Click here
1514.2 mm	1500 mm	Für EVG OHNE Starter, 150 cm LED Röhre T8 / G13, 29 Watt, 330° AUSSTRAHLUNG, 3480 LUMEN, Neutralweiß ~ 4000 Kelvin, ersetzt 58-70 Watt Leuchtstoffröhre. EVG KOMPATIBEL, TÜV zertifiziert [Energieklasse A+]	Click here
1778 mm	1764 mm	Sylvania LED-Tube T8 6Ft = 180cm = 1800mm 3240Lm 840=4000K Sockel G13 für Konventionelle Vorschaltgeräte mit Dummy-Starter [Energieklasse A+]	Click here

SEA/CLASP draw two main conclusions from this analysis of tube lengths:

- First, we have confirmed that there are more than five lengths of T8 lamps available on the European market, even using the Amazon.DE online retail space. We found that 90% (9 out of 10) of the lengths of fluorescent tubes manufactured by the three largest lamp manufacturers in the world already have direct drop-in T8 LED retrofits at those same lengths – some of which are from the same manufacturers.

⁴⁵ Personal communication with Penny Tang, Sales Manager at Zhejiang Bodeng Electronic Technology Co., Limited. Located at No F2-13186 District 2, Yiwu International Trade City Zhejiang. Confirmed that it is technologically feasible to make this length (or any length), and she added: “Making 470mm needs customization. The quantities must be 10,000 pcs.” Communication on 7 December 2019. [Link to manufacturer sales page on Alibaba.](#)

- Second, we have confirmed with a manufacturer of T8 LED retrofit tubes (and from our own understanding of the technology), that there is no technical impediment to manufacturing linear LED tubes at all lengths to replace all installations. It is simply a question of market volume.

We conclude therefore that the availability of different tube lengths is not a problem for drop-in T8 LED retrofits.

C.1.3 Estimated cost of replacing fixtures

LE points to the Oko-Institut's estimate of €250bn to substitute linear fluorescent lamps.

SEA/CLASP contacted the researchers at Oko-Institut to ask them about this estimate. They responded that the research and evidence base behind the estimate was conducted in 2016, thus the LED retrofit lamps that were considered at that time are 3 years out of date and may not reflect the latest innovation and design improvements in LED lamp drivers.

SEA/CLASP have conducted a review of the 2019 product market, and found that the electronics have progressed significantly, and now there are literally thousands of direct-replacement, drop-in retrofit LED lamps for both T5 and T8 applications which operate on the existing ballasts – whether magnetic or electronic – and are available in 90% of the popular lengths already used in the market in Europe.

Thus, the estimate of €250bn to retrofit fluorescent luminaires all over Europe is, as noted by Seaborough, “grossly overrated” and does not reflect the current market. As noted above, Seaborough conducted an analysis that found 91.3% of the existing fluorescent luminaires in Europe are capable of operating with a direct drop-in, mercury-free replacement LED tube.

C.1.4 LE Member Literature Published Online

LE objects to the authors using publicly available technical documentation and lamp finder tools published on their members' websites to determine substitutability/compatibility. LE claims that these customer tools and reference documents published on their members' websites are “marketing communications,” implying that they are not reliable sources.

SEA/CLASP believe that the published technical literature on the LightingEurope members' websites and resources such as their on-line lamp selection tools⁴⁶ are designed for professionals and contain trustworthy information for consumers, building owners and lighting specifiers alike. We believe that the information we have

⁴⁶ Philips Master LED Tubes Selector Tool: <https://www.lighting.philips.com/main/support/support/tools/ledtube-selectortool>

reviewed in preparing this report on the LE members websites is both accurate and truthful.

We stand behind the calculations, the findings, and the conclusions of this study, namely that maintaining the RoHS mercury exemptions for fluorescent lamps is in conflict with the objectives of RoHS and the Minamata Convention and is not warranted on a technical, economic or environmental basis.

C.2 Collection of waste lamps

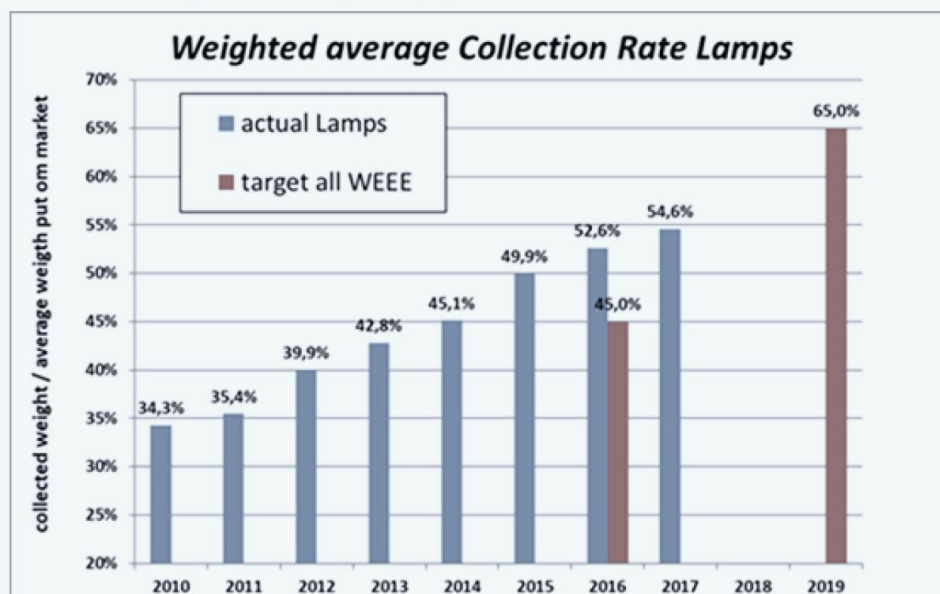
LightingEurope letter:

2/ Updated data on collection of waste lamps

LightingEurope is currently collecting recent collection and recycling numbers in cooperation with EucoLight, the European association representing the WEEE schemes for lighting.

The table below contains the data we have received so far and covers both consumer and professional lamps.

The table illustrates that the lighting industry has met the 2016 target for waste collection and is on the way to reach the 2019 target.



Some general remarks about waste lamps:

- As professional lamps have a long lifetime, only a small fraction is replaced each year. Collection rates will increase over the next few years, as the number of lamps placed on the EU market will decrease.

- Professional lamps have higher collection rates compared to consumer lamps (e.g. CLF-I). LightingEurope agrees that the exemption for such consumer lamps should expire on 1 September 2021, the date communicated to the global market under EU ecodesign rules.
- The bulk of the lamps that will need to be recycled over the next few years are already installed and in service. The renewal of the exemptions will not significantly add to the number of lamps on the EU market that will need to be collected and recycled – LightingEurope estimates that the renewal of RoHS exemptions 1 and 2 will result in an 6.6% increase of the total collection and recycling effort (*see Annex 2 for the details of this calculation*).
- The lamps that will be sold in the next years (according to the EU MELISA model) are only a fraction of these installed lamps. This means that the number of lamps arriving to the waste stream will continue to decrease.

Author's response on point 2/ Updated data on collection of waste lamps

SEA/CLASP are concerned that this new data presented is from an industry association of which LightingEurope is an affiliate⁴⁷, and has not been published for expert/independent review or analysis. Our estimate is based on independent sources – i.e., not the regulated entities – and our estimate is far lower than the values published by LE. As stated in Chapter 3 of this report, the 2014 European Commission study found the collection rate for lamps under the WEEE Directive was only 12% in 2010. This Commission estimate is three times lower than the estimate of 34.3% now presented by LightingEurope/EucoLight for that same year (see figure presented above in LE letter).

When there is such disparity in the claimed values – an independent study prepared by the Commission and an industry association which claims the value is three times higher – this calls into question the collection rates now being reported in this internal analysis by LE/EucoLight. Everyone agrees that collection rates need to improve, but we can also all agree that adding more mercury-containing fluorescent lamps to the installed stock is not going to accomplish that.

Furthermore, SEA/CLASP call upon EucoLight/LE to improve the transparency around the terminology and numbers used in the recovery and recycling of used fluorescent lamps. We have indeed seen the word “collection” be used in different manners in different documents. This issue of lack of clarity and precision in the use of certain terms contaminated a lot of the discussion on waste. For example the definition of “recycling rate” in the WEEE regulation only reflects the share of lamps that are properly handled after being delivered to a recycling centre or similarly specialized facility. Thus, the high recycling rate by definition excludes lamps which are disposed of in the general waste stream. Unfortunately, the majority of fluorescent lamps in Europe are not disposed of correctly and thus the mercury in those lamps ends up not being properly treated, polluting the environment and posing a health risk. To ensure that the magnitude of this mercury problem is fully understood, the collection and recycling rate should take into account all fluorescent lamps removed from service

⁴⁷ <https://www.eucolight.org/our-members>

every year, and “collection” should only cover separate collection of non-damaged lamps that leads to a proper treatment with no leak of mercury into the environment.

As shown in **Figure 10** in this report, incorrect disposal at the end of life represents 50% to 83% of the fluorescent lamps removed from service at their end of life. SEA/CLASP do not see the logic in allowing the exemption to continue for T8, T5 or CFLni lamps, when drop-in, mercury-free alternatives exist and can start to reduce the waste-collection problem. LE states that the additional mercury put on the market if the exemption is maintained would be relatively small in comparison with what is in the stock of mercury lamps today. However, prolonging the use of mercury-containing lamps requires that the whole collection and recycling chain must be maintained and improved for many more years. Furthermore, we are concerned that as the remaining stock declines, this will lead to less attention and increased unitary costs, and therefore a higher risk of non-optimal treatment.

Given that the fluorescent lamp recovery process has been shown to be ineffective, and that there are mercury-free alternatives to these lighting products already available on the market today (i.e., drop-in replacements that do not need rewiring), we conclude that the RoHS exemptions for fluorescent lighting should be expired. Any extension is not warranted and would be in violation of the objectives of the RoHS Directive and the Minamata Convention.

C.3 Conclusion

LightingEurope letter:

In conclusion:

- LED substitutes are not available for all lamp types covered by the RoHS mercury exemptions, due to the variety of lamps and applications they are used in and the possible compatibility issues between the LED substitute lamps and the installed lighting fixture.
- Recent waste collection data illustrates that the industry is meeting targets and that the renewal of exemptions will not result in significant additional waste lamps.

Author’s response on LightingEurope’s Concluding remarks:

In conclusion:

- Mercury-free drop-in retrofit (no rewiring necessary) LED tubular lamps exist for 91.3% of the installed stock of fluorescent lamps in the market in Europe today. Virtually all base types are available (90% of linear fluorescent, 85% of CFLni) and any length of LED lamp or CFLni base type can be produced, with one company in China⁴⁸ offering to do a custom design and production run with an order as small as 10,000 units. There is no technological barrier to

⁴⁸ Personal communication with Penny Tang, Sales Manager at Zhejiang Bodeng Electronic Technology Co., Limited. Located at No F2-13186 District 2, Yiwu International Trade City Zhejiang. Confirmed that it is technologically feasible to make this length (or any length), and she added: “Making 470mm needs customization. The quantities must be 10,000 pcs.” Communication on 7 December 2019. [Link to manufacturer sales page on Alibaba.](#)

commercialising replacements for the remaining 10% of lengths that are not available on the market today, it is just a question of market demand.

- LE cites “recent waste collection data” to demonstrate that rates of collection are improving. However, this data does not come from an independent source, and is not published or made available for independent verification or analysis. The collection rate reported by LE for 2010 is three times higher than the rate reported by the Commission in an independent assessment for that same year. This finding calling into question the percentages claimed by EucoLight/LightingEurope for subsequent years. Our analysis presented in Chapter 3 of this report shows that the collection rate for mercury-containing lamps is between 16% and 50%, meaning that tons of mercury are lost every year to the environment, contaminating landfills across Europe.
- Phasing out the RoHS exemptions for T8, T5 and CFLni lamps will enable avoid 4.8 metric tonnes of mercury being introduced into our living spaces and environment, while also avoiding 41 million metric tonnes of CO₂ emissions, and saving end-users €12.5 billion Euro (accounting for lamp replacement costs and electricity). Mercury-free alternatives to fluorescent lamps are widely available, from many manufacturers, and can lead Europe into a mercury-free, more energy-efficient and resource-efficient future.

Annex D. Letter from Seaborough B.V. to DG Environment at the European Commission



SEABOROUGH

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VIA EMAIL

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Amsterdam, 20-11-2019

Re: RESPONSE TO SUBMISSION OF LIGHTING EUROPE ON SUBSTITUTABILITY AND WASTE

Dear Ms. Lorz,

Seaborough should like to comment on the submission of LightingEurope of 8. November 2019.

In this submission LE challenges the recent study published by the Swedish Energy Agency and CLASP. Basically the LE submission is advocating two issues in support of prolonging the exemptions that technically expired in 2016:

- 1) Lack of availability of substitute LED based, mercury free light sources, and
- 2) Sufficient recycling ratios for mercury recollection

Before addressing each of the LE issues, we should like to make a few clarifications:

The SEA / CLASP study only addresses standard fluorescent lamps i.e. standard T8 and T5 tubes as well as standard CFLI-ni – which are lamp types largely only used in the professional lamp market. It does not address the type of fluorescent lamp – the CFL-i a.k.a. energy saving lamps which is largely only used in the consumer lamp market. The study also does not address the so-called long life fluorescent tube or any of the specialty lamps containing mercury; in the Pack 9 exemption dealt with in



chapters 9 through 16 of the 2016 study¹ of the Öko Institute.

While the Commission is inclined to prolong most exemptions dealt with in chapter 9 through 16, it would appear that at this point the Commission is inclined to (only) terminate the exemption for CFL-i lamps. The T8, T5 and CFL-i and CFL-ni fluorescent lamps account for more than 70% of total mercury pollution coming from the Pack 9 types of lamps².

Although LightingEurope formally represents a 1000+ enterprises of the lighting industry reality is that less than a handful of its members are in fact producers of the standard lamp types for which the Öko Institute, the Swedish Energy Agency and CLASP have proposed to deny further exemptions. These light source producers are Osram/Ledvance, GE/Tungshram, Sylvania and Philips / Signify. Together they form a longstanding oligopoly which maintains a strong financial interest in prolongation of these exemptions³.

Lack of availability of substitute LED based, mercury free light sources

The light source producers claim that exemptions for standard T8 and T5 fluorescent tubes should be prolonged since only a small number of adequate substitute products (LED tubes) are available – resulting in massive replacement of complete fluorescent luminaires at prohibitive cost.

The fundamental argument of the producers is that there are technical compatibility problems with a large number of fluorescent luminaires installed in the field. In particular they argue that the universal compatibility representations made in marketing materials of the producers are false. The reality is as follows:

The available LED replacement tubes for T5 and for T8 are:

- Drop down LED tubes designed for T8 luminaires with electromagnetic (EM/CCG) ballasts: No-one disputes that the producers currently offer LED tubes that will fit with any of such types of luminaires. Around 60 % of all installed fluorescent T8 luminaires are estimated to be of this type⁴.

¹ These are the Annex 3 exemptions 2(b)(3), 2(b)(4), 3(a-c), 4(a), 4(b)(I-III), 4(c)(I-III), 4(e), and 4(f).

² See Table 4.1 of the 2016 Öko Institute Report.

³ In its official shareholder information Philips / Signify openly characterizes the professional lamp market as “highly concentrated” and “dominated by Osram, Philips and GE” (2016 IPO prospectus of Philips Lighting). The same prospectus also informs: “*The transition to LED lighting due to characteristics of the business including competition, technology and lower entry barriers, could have a material adverse effect on the company’s - - operating results.*” In its 2017 Annual Accounts Philips Lighting (the largest lighting company) stated its profits on conventional lamp sales to more than twice of its profits gained from LED lamp sales, and the prospectus also warns that a faster shift to (LED) integrated luminaires may have negative consequences for its financial results. Philips also openly declares that it is pursuing a “last man standing strategy to continue to extract value from the conventional business”

⁴ See page 105 of the 2016 Öko Institute study



- Drop down LED tubes designed for T8 luminaires with electronic (HF/ECG) ballasts: According to compatibility lists published by the producers⁵ an estimated 15% of these luminaire types would not work with the HF LED tubes currently offered by the producers.
- Drop down LED tubes designed for T5 luminaires with electronic ballasts: According to compatibility lists published by the producers an estimated 15% of these luminaire types would not work with the HF LED tubes currently offered by the producers.
- Drop down LED tubes designed for T8 tubes with either electronic or electromagnetic ballasts: According to compatibility lists published by the producers an estimated 6% of these luminaire types would not work with the “universal” LED tubes currently offered by the producers.
- In addition, for those cases where the ballast performs poorly, the option “Direct Mains” is offered by these “universal” tube types. This enables the installer to take out the ballast and connect to the tube directly to mains power supply (liability effects put aside).

Readily available drop down LED tubes for the T8 luminaires installed in the field:

Luminaire ballast type	% share of total T8 installations	% drop down readily available
Electromagnetic (EM or CCG)	60	60
Electronic (HF)	40	34 (85% of 40)
	100	94

Readily available drop down LED tubes for the T5 luminaires installed in the field:

Since T5 operates only on electronic ballast, the % of drop down readily available is 85%.

It is generally accepted that around 70% of the standard fluorescent lamp market comprise of T8 luminaires while some 30% is T5.

Fluorescent tube type	% Readily available LED tube for total luminaire segment	Readily available LED tube for total standard fluorescent market 70/30 EM/HF
T8	94	65,8%
T5	85	25,5%
		91,3%

Accordingly, the lamp producers themselves are at present offering a variety of drop down LED tubes that can replace standard T8 and T5 fluorescent tubes in more than 90% of the luminaires installed in the field⁶. This number is in stark contrast with the assumption (no reference provided) taken in the socio

⁵ Compatibility lists of producers are updated on a regular basis. Osram declares on its web pages that it will publish updates on a quarterly basis.

⁶ Our calculation has not taken into account that further compatibilities may be realized by consolidation of compatibility lists of the producers. Seaborough Research is offering the market technology that enables 100% compatibility with any ballast type.



economic study of the Öko Institute of only 22 %, which presumably was based on market information gathered before 2016. Accordingly the calculated cost of replacement of luminaires in event of termination of the exemptions for standard T8 and T5 fluorescent tubes are grossly overrated⁷.

For the record: our company has been proposing for several years solutions to these lamp makers that would solve the compatibility issue of the remaining 15 %.

In their 8th November submission the producers are also pleading that they should be granted further exemptions as long as their LED tube drop down solutions are not available for all ballast types or for all existing combinations of e.g. colour temperature, colour rendering, dimming, and socket compatibility⁸. Although the compatible drop-down LED tubes may be available today only for the most frequently specified tube lengths, lumen output, colour temperature and colour rendering combinations⁹, it is a routine job that does not require innovation to broaden the use of the drop-down technology to any form of T8 or T5 length, lumen output, colour temperature and colour rendering combination. The same holds for lifetime specification, which in general for LED tubes will be a multiple of that of fluorescent tubes. It is simply wrong to suggest that such broadening to all T8 or T5 variants would require anything but a transition period of 12 months. This is a chicken and the egg balance: The producers will allocate their development resources to any LED tube version which is in demand.

If that (e.g. immediate availability of the complete portfolio) would be the criteria for ending the exemption who would think the oligopoly of light source producers would be motivated to completing the landscape of available combinations? As referred to above (note 3), any substantial market demand for LED based tubes will go against the business interest of the producers and under the current exemptions the industry has the power to suppress or at least direct any such demand.

Sufficient recycling ratios for mercury recollection?

According to the updated recycling statistics of LightingEurope the recollection rate achieved through the WEEE system is improving slightly but is still hovering around 50%. We may reasonably assume that the uncollected part keeps on ending up in the nature of Europe.

The LightingEurope submission also confirms that as per today the lamps installed in the field holds some 21,000 kg's of mercury. This is on top on what the light source producers and importers will have contributed in the form of mercury lamps scrapped since the 1930ties (of which most went straight to the landfills).

We maintain the view that the sooner the authorized use of mercury is brought to an end the better for the European environment.

⁷ It should be recalled that fluorescent tubes belongs predominantly to the professional lighting market wherefore the choice of the right drop down LED tube is made and replacement carried out by electricians. Only some 6% of fluorescent lamps are sold to consumers and this market is confined to EM ballasted luminaires – i.e. no compatibility problems.

⁸ For standard T8 and T5 use of two pin midi and medium is standardized across the EU.

⁹ Actually using LED light sources implies a much broader scope of possibilities for controlling of light, light quality and output compared to conventional fluorescent tube.



And, let us not forget that rapid changeover to LED solutions of Luminaires carrying Fluorescent lamps will lead to energy savings of typically 50 %. For T8 tubes alone this would amount to more than 1.5 % of the GHG reduction target for the EU28 in the Paris treaty.

Seaborough B.V.

Dr. Martijn Dekker

CEO



20-11-2019