Request to renew Exemption 1(e)

under the RoHS Directive 2011/65/EU

Mercury in single-capped (compact) fluorescent lamps with circular or square structural shape

Dae: January 15, 2015

Contents

1 Name and contact details

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2 Reason for application

LightingEurope submits this application to:	*request for extension of existing exemption* ***no. 1(e) in Annex III***
LightingEurope proposes to continue using the existing wording which is:	*Mercury in single capped (compact) fluorescent lamps not exceeding (per burner): 1(e)* *For general lighting purposes with circular or square structural shape and tube diameter ≤ 17 mm* *No limitation of use until 31 December 2011; 7 mg may be used per burner after 31 December*
LightingEurope requests a duration of	Maximum validity period required

3 Summary of the exemption request

Per DIRECTIVE 2011/65/EU Article 5(2) Annex III Exemption 1(e) will expire automatically per 21/07/2016, unless an application for renewal has been made to the Commission in accordance with Annex V.

With reference to the above, this request concerns the extension of the current Annex III exemption 1(e) regarding mercury in single-capped (compact) fluorescent lamps for general lighting purposes with circular or square structural shape and tube with a diameter <17 mm and Hg content < 7 mg.

Lamps in exemption 1(e) are clearly a different group of lamps than in the other exemption requests under 1 because of their different shape and specific application. Lamps in this category can be with integrated driver (CFL-i) or without (CFLni)

Over the last decade CFL lamps have strongly contributed to the achieved energy savings and to the reduction of CO_2 emissions in Europe (Figure 1)[1]. As such CFL lamps have also contributed to reduce mercury emission from fossile fuel operated power plants.

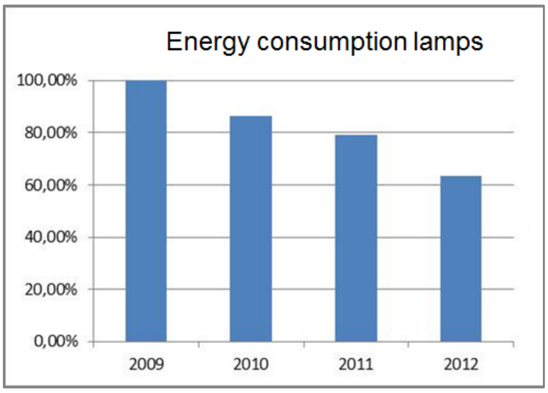

Figure 1 Almost 40% reduction in energy consumption in Europe by consumer lamps. Source : LightingEurope

At the same time the level of mercury dosed per compact fluorescent lamp has been decreased considerably during the last years under the RoHS directive from no limitations to to max 7 mg/lamp (2006 - 2011) .Figure 2 shows the achieved mercury reduction of the total fluorescent family. Nevertheless, the fluorescent technology inherently needs a minimal amount of mercury in order to function through the full indicated lifetime and to deliver the energy efficiency benefits.

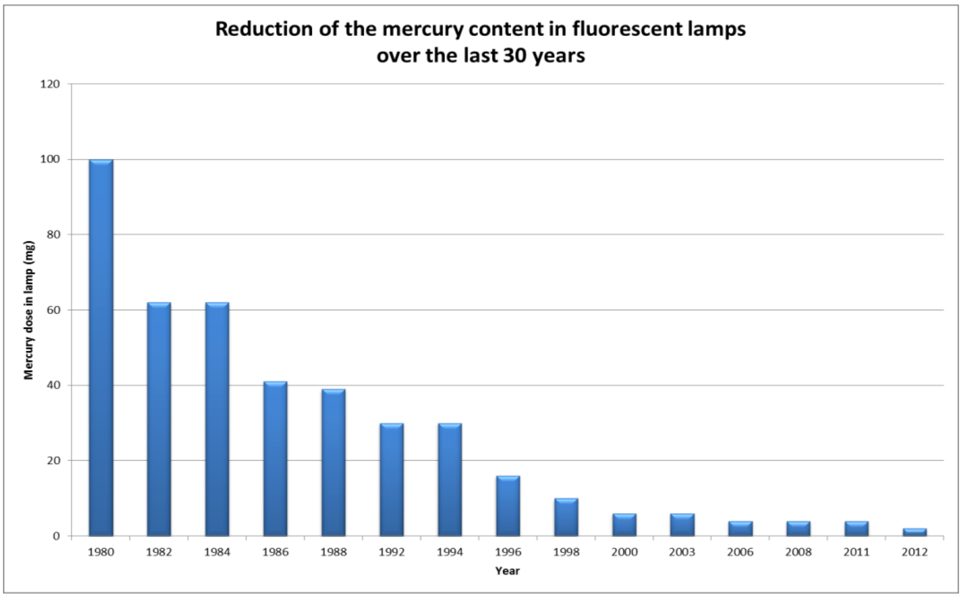

Figure 2: Mercury content of fluorescent lamps

Waste management (WEEE) measures by EU authorities and industry together have resulted in still increasing collection & recycling rates, reducing the environmental impact of mercury even further.

[1] Source: LightingEurope
[2]http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_VI/Request_7/Request_No7_1st_Clarification_Questions_20120622_final.pdf

More and more LED solutions come to the market; however they cannot always serve as a fully compatible replacement for consumers and professional end users. The following replacement issues in existing luminaires will not be solved by the LED technology on short notice: size, form factor, light distribution, light output, weight, heat management. Next to these issues lamps operated on separate ballasts can face problems with electrical compatibility, because many different types of gears are installed in the European market. Examples of these problems are reduced performance in dimmed mode and flickering. The person installing a LED based solution on ballasts originally designed for CFL is in most cases executing the rewiring and will as such be responsible to check if the new combination fulfils all requirements, including when the original lamp type is installed back again. This could mean that the CE conformity label of the complete luminaire is no longer valid.
Based on above arguments LightingEurope is of the opinion that not for all CFL lamp types in all applications a suitable replacement LED lamp is available. Removing CFL lamps from the market would therefor force early new luminaire investments, which would unnecessarily and dramatically increase the waste of hazardous substances. Furthermore, in the residential area, due to the higher product price of the LED alternative, giving the same energy efficiency, the consumer can afford less energy saving lamps.

The segment uses light emitted in all directions from the circular lamps to create a specific light effect. The standard solution in LEDs for for CFL lamps with circular or square structural shape and tube diameter ≤ 17 mm is to generate light only in limited radiation angle (simplifying the lamp construction and the number of LED dies needed to generate the light). The relative small volume of this application and the higher cost of a real replacement lamp (giving the same light characteristics) limits the number of alternative LED lamps offered on the market. The LED retrofit lamps in the market radiate only in one direction (up or down) while the fluorescent lamps emit in both directions. Many applications use this light effect.

LightingEurope believes that above arguments justify the request for extension of the exemption for CFL lamps with circular or square structural shape and tube diameter ≤ 17 mm with a maximum validity period and no expiry date.

4 Technical description of the exemption request

4.1 Description of the lamps and their applications

4.1.1 Lamps covered by this exemption

This exemption covers Single capped (compact) fluorescent lamps

Compact fluorescent lamps in category 1(e) include lamps for specific applications in residential and professional use. They can have the electronic control gear integrated in the product (self-ballasted CFLs or CFLi-s) or their control gear is separated from the lamp (plug-in CFLs or CFLni-s).
The CFL lamps in general have a colour rendering of CRI 80 and are available in a wide range of colour temperatures from warm white (2700K) to cool daylight (6500K). The efficiency and lifetime differ for lamps used in the different applications in the range of 50-80 lm/W and 6000-20000 h respectively.

There is a variety in product designs because of their specific purpose, technology, wattage, size and compactness, life time, internal phosphor coating, production process etc. Below some examples of the various lamp types are shown.

Figure 3 Examples of lamps that fall under exemption 1(e)

4.1.2 Applications covered by this exemption

Compact fluorescent lamps in this exemption category allow the creation of flat luminaires and enables omni-directional light distribution. They are suitable for a wide range of professional and semi-professional applications, and are ideal for use in shops, offices and public areas where they are attractive by their unconventional shape. Their shape makes these also very useful for specific (semi)professional application where a high luminous flux from a diffuse source is required (dentists, beauticians). Below pictures give an indication of the big variety of applications used in homes, offices, restaurants and other applications.

Examples of luminaires:

Figure 4 Example of luminaires that can be used with lamps under exemption 1(e)

Examples of professional applications:

[3] http://www.philips.pl/c-p/403391116/ecomoods-oprawa-wiszaca
[4] http://www.philips.pl/c-p/403423116/ecomoods-oprawa-wiszaca
[5] http://www.philips.pl/c-p/346134816/ecomoods-kinkiet
[6] http://www.philips.pl/c-p/402353116/ecomoods-oprawa-wiszaca

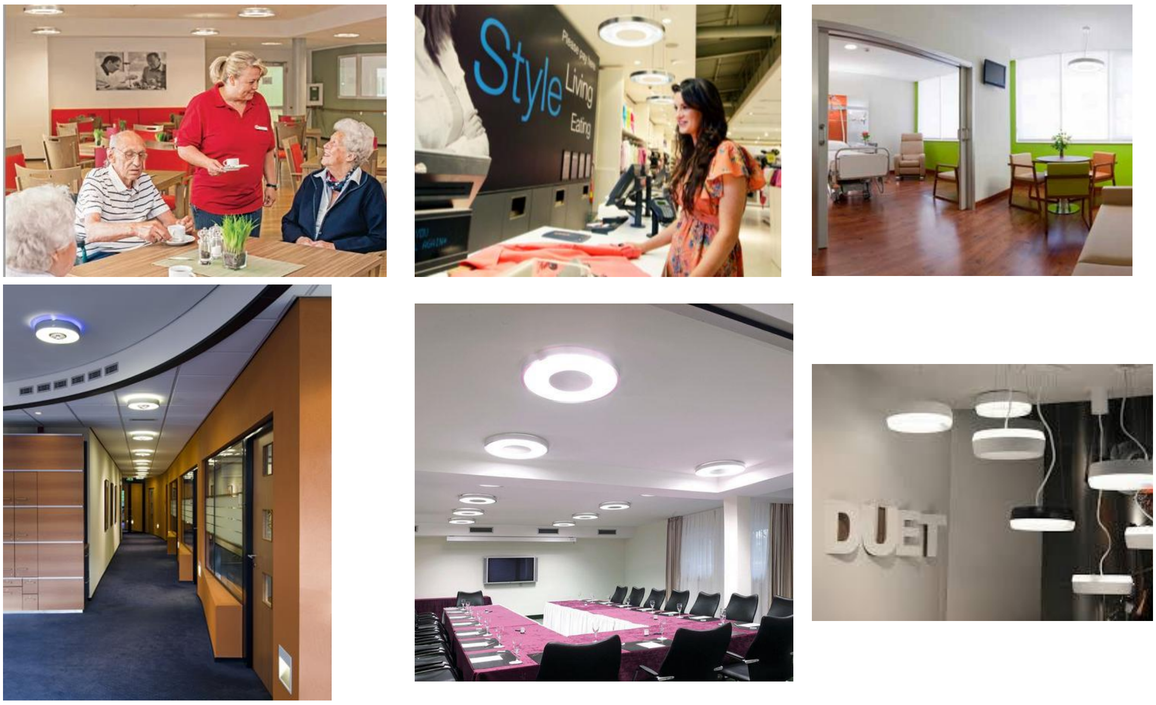

Figure 5 Examples of professional application, that are used with lamps under exemption 1(e)
Source: Philips reference projects, e.g. Elderly Homes, Offices, Dunnes, Hospital Vigo, (http://www.lighting.philips.com/), Atomis reference projects, e.g. Rabobank.(http://www.atomis.nl/)

Examples of residential applications:

Figure 6 Examples of residential application, that are used with lamps under exemption 1(e)
Source: Philips Ecomoods portfolio (http://www.philips.ie/c-p/403391116/ecomoods-suspension-light and http://www.philips.pl/c-p/346134816/ecomoods-kinkiet), Atomis (http://www.archiexpo.com/prod/atomis/recessed-downlights-fluorescent-compact-fluorescent-round-9864-613438.html)

4.1.3 Annex II category covered by this exemption

List of relevant Annex II categories for this exemption

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☒ 5

☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11

Application in other categories, which the exemption request does not refer to: N/A

Equipment of category 8 and 9: N/A

The requested exemption will be applied in

☐ monitoring and control instruments in industry

☐ in-vitro diagnostics

☐ other medical devices or other monitoring and control instruments than those in industry

LightingEurope is of the opinion that lamps in general are category 5, because the most are used for general illumination. However, they have some of the characteristics of components (used in luminaires), consumables (finite lifetime and regularly replaced) or spare parts (lamps in luminaires have to be replaced when they cease functioning). Some manufacturers of electrical equipment in other RoHS categories may install fluorescent lamps into their equipment for general illumination purposes and so they will need to use lamps that comply with the RoHS directive, however the products that they place on the market are not category 6 but may be household appliances, medical devices or potentially in any RoHS category 1 - 11.

LightingEurope is aware of the difficulty to unambiguously classify certain lamps in the category set out by RoHS legislation. For lamp producers it is essential to have legal certainty regarding the possibility to put the products on the market irrespective of the planned application as we are not able to control the use of the lamps in products falling in other categories or out of the RoHS scope. In practice, most lamps are installed in buildings for lighting applications (category 5), but some are used in other types of equipment in all other RoHS categories. The way that lamps are used has no effect on lamp design so will not affect this exemption request

4.2 Description of the substance

4.2.1 Substance covered by this exemption

Lighting Europe is asking for exempting

☐ Pb ☐ Cd ☒ Hg ☐ Cr-VI ☐ PBB ☐ PBDE

4.2.2 Function of mercury in lamps

A small amount of mercury is intentionally dosed in all fluorescent lamps as it is essential for the low-pressure gas discharge. When electric current flows through the lamp bulb (=discharge tube), the mercury atoms inside are excited and produce UV radiation. This UV light is then converted into visible light by the fluorescent coating on the lamp bulb with a high degree of energy efficiency.

4.2.3 Location of mercury in lamps

Mercury is present in the so-called discharge tube (burner).

The mercury is instrumental in the conversion of electrical energy into the UV radiation, which is converted subsequently by a phosphor into the emitted visible light.

4.2.4 Amount of mercury

Mercury is dosed in the discharge tube during lamp manufacturing as homogeneous material (pill, capsule or as amalgam). This technology enables dosing, the small and accurate amount of mercury needed, without unintended losses. The amount of mercury dosed per lamp depends on aspects like lamp power, optical performance and anticipated lamp life. During lamp life, mercury is consumed inside the discharge tube itself. It is bound amongst others to the phosphor layer and the glass.[7]

[7] Reference: I. Snijkers-Hendrickx et al, Low-Mercury Containing Discharge Lamps. Sustainable and Environmental Friendly Lighting Solutions, LS 11

One of the principal design rules to create higher lumen packages in fluorescent lamps is to increase the length of the discharge. Consequently higher lamp wattage involves more glass and phosphor surface, thus more mercury consumption during lamp life and therefore a higher initial mercury dose. Coating of phosphors and glass can give a reduction of the Hg consumption, but in general it remains a function of the lamp dimensions and the lifetime. Next to this, processing has its influence, for instance because the actual dose per lamp scatters around the nominal dose, while the threshold value as set by RoHS directive sets a maximum limit. Non-linear fluorescent lamps always need more mercury compared to linear lamps. The main reason for this effect lies in the production process. Lamp production starts with a linear glass tube, to which coatings on glass are applied as well as the phosphor layer. After these processes the tube is brought in a circular, or other non-linear structural shape. This process has influence on the coating and phosphor layers as small cracks are created where the glass is bent. So more mercury diffuses into the glass tube during operational lamp life meaning more mercury is consumed in these lamps.

For single capped (compact) fluorescent lamps in the scope of the Exemptions 1(e), the maximum dosed mercury is up to 7 mg.

The influence of mercury consumption on the required dose

The amount of mercury which is needed for the low pressure discharge process is very low, significantly below 0.1 mg per lamp. But there are many processes within the burner, potentially more than 100 have been identified, which make a part of the mercury unavailable for the discharge over lifetime. This is called mercury consumption and is the reason why more mercury has to be dosed, so that the intended lifetime is shortened due to low available mercury. Therefore a balance has to be found taking into account mercury needed over lifetime, mercury variance per dosing unit but also the measurement failure when estimating the amount of mercury in a lamp for market surveillance.

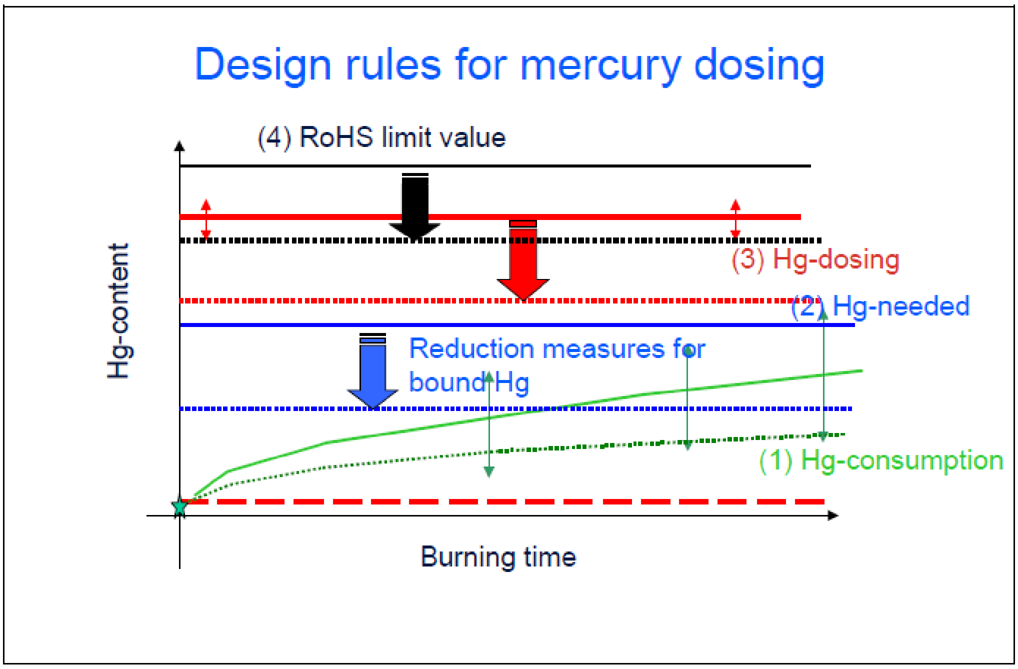

Figure 7 Design rules for mercury dosing in fluorescent lamps, schematically showing the process of setting RoHS limit values based on insights in mercury consumption and mercury dosing.

The lowest (dashed) line in Figure 5 gives the ideal situation for a low pressure mercury discharge: there is just enough mercury for the discharge to properly function. For a compact fluorescent lamp this is typically in the order of 0.005 to 0.05 mg per lamp (in the gas-phase), depending on the lamp dimensions. However, because of the several mercury consumption mechanisms a higher amount must be dosed. So up to now a lamp dosed with only 5 to 50 microgram mercury having normal functional properties over lifetime could not be designed, as explained below.

In practice, mercury from the discharge gets consumed over lamp life. The mercury gets mostly deposited and effectively bonded to the glass and the phosphor layer. This is reflected by the solid curve (1) in Figure 5, which represents more or less a square root relationship with lamp life. The longer the burning time, the higher the amount of mercury needed. The variance in this mercury consumption, as depicted by the arrows, is considerable and depends on many factors (see below for counteracting measures). One could say that, in principle, a fluorescent lamp receives an overdosing of mercury, but that it is required to maintain lamp performance over time.

In order to maintain the properties over lamp life, one determines for a particular lamp design the amount of mercury needed (line 2 in Figure 5). The target mercury dosing (line 3) while taking its own variance into account, should be sufficient to allow for proper lamp life. Alternatively, this target value is called nominal or average value, and can be listed in catalogues. This average value is lower than the threshold value so the actual amount per lamp is lower than the limit set by the directive.

The solid black line 4 in Figure 5 is the line representing the RoHS limit (expressed as mg per lamp), the value of which has to take into account both variances of mercury consumption and of mercury dosing. On the one hand, we like to have this value as low as possible, but on the other hand, it should be safely chosen to (1) eliminate the customer risk of a non-performing product over the designed lamp life and (2) to be able to demonstrate in internal manufacturer's tests and in market surveillance tests, with the least effort, that products comply with the RoHS Directive. This leads to a built-in safety margin on top of the target mercury dose, finally leading to RoHS content limit. Figure 6 shows the dosing variety relatively to the RoHS threshold value.

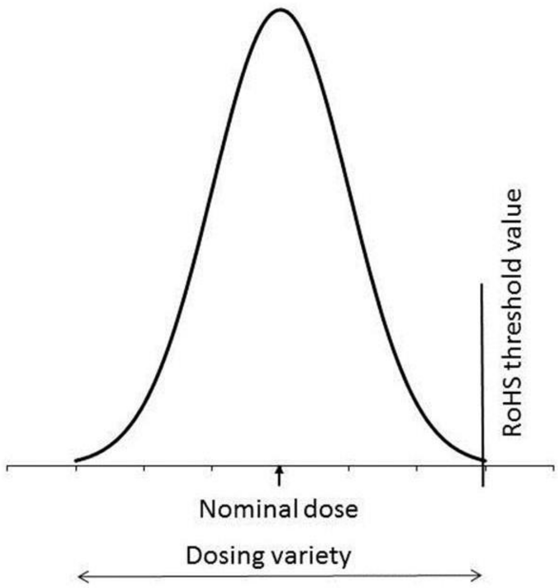

Figure 8 Dosing variety in mercury

Key to reduction of mercury is influencing the factors that determine mercury consumption. These include:

- Glass type and protective coating
- Type phosphor material
- Interaction with gasses and impurities
- Lamp processing during manufacturing
- Lamp-ballast interaction during operation

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It is also important to take into account the technical capability to reduce both the absolute mercury dose to very low values, and to reduce its variance. Hence, by combining a series of interlinked and complex measures, in a consistent manner, the mercury has been reduced, based on scientific and technical progress in the recent years.

4.2.5 Environmental assessments, LCAs

There are several external LCA's performed regarding lighting. There is general agreement, that the main environmental impact is created during the use phase, meaning through electricity consumption when burning the lamp.[8] This means that currently the efficacy of the lamp is the determining parameter. Specifically regarding mercury, the biggest amount is released to the environment by power plants when generating energy (especially when coal is the primary power source).[9] Technological advancements in the lighting industry have resulted in a significant reduction in the amount of mercury used in many types of fluorescent lamps over the last two decades.[10] Manufacturers have developed technology that enables a small amount of mercury to be 'dosed' or placed inside a CFL.[11]

[8] (see Enlighten report, Section 5, Ch. 3 fig. 4 & 5) Ch. 3 fig. 4 & 5, p. 111-112 http://www.learning.enlighten-initiative.org/ebook/en_lighten_english_complete.pdf
[9]see Enlighten report, Section 5, Ch. 3 fig.6, p. 111-112 http://www.learning.enlighten-initiative.org/ebook/en_lighten_english_complete.pdf

[10] ENERGY STAR. (2012). Frequently Asked Questions Information on Compact Fluorescent Light Bulbs (CFLs) and Mercury. Retrieved March 29, 2012, from: http://www.energystar.gov/ia/partners/promotions/change_light/downloads/Fact_Sheet_Mercury.pdf, UNEP toolkit, p.106
[11] Complete paragraph UNEP toolkit, p.106

For the future however the manufacturing part in the LCA becomes more relevant[12], because the energy consumption by the lamp is already dramatically reduced (higher efficacy leads to decreased negative environmental impact).

The total life cycle environmental impact of the light sources is interesting due to the importance of the lighting sector in the total energy consumption. The lighting sector is filled with different light sources of different shapes and sizes. The environmental and economic performance comparison of those various types is difficult, due to lack of established rules for the LCA of light sources. As a result, it creates distortion and makes it difficult to numerically compare the results of the LCAs.

Historically the comparison was done with respect to incandescent lamps[13], where it was concluded that the net mercury emission over life cycle is reduced when changing from incandescent to CFL lamps. More recently LCA is done in comparison with LED sources[14], however here it is even more challenging to compare these various-shaped LED light sources to conventional lamps and luminaires. LED technology provides new possibilities for manufacturers to design luminaires, lamps, components and packages containing LED chips, thus the question on which basis those should be compared remains.[15]
In some analyses the current LED alternative comes close to compact fluorescent lamps. Another however concludes that LED lamp product manufacturing uses approximately three times more energy than does the manufacturing of a CFL with comparable light output[16]. Thus it needs to be acknowledged that no widely accepted consensus exists among experts. However one must consider the improving LED alternative in the right perspective: according to reference[17] the LED sources are expected to have a real

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[12] Life cycle assessment of light sources – Case studies and review of the analyses Leena Tähkämö, Aalto University publication series DOCTORAL DISSERTATIONS 111/2013

[13] Pfeifer RP.Comparison between filament lamps and compact fluorescent lamps. International Journal of Life Cycle Assessment 1996; 1: 8—16.; Parsons D. The environmental impact of compact fluorescent lamps and incandescent lamps for Australian conditions. The Environimental Engineer 2006; 7: 8—14; Gydesen A,Maimann D. Life cycle analyses of integral compact fluorescent lamps versus incandescent lamps: RightLight, Stockholm, Sweden, 1991

[14] Department for Environment, Food and Rural Affairs (DEFRA).Life Cycle Assessment of Ultra-Efficient Lamps.Navigant Consulting Europe Ltd. 2009.; Analysis and comparison of incandescent, compact fluorescent lamps and light emitting diode lamps in residential applications, The scientific consulting group inc. (2010) submitted to the U.S. environmental protection agency office of the science advisor; Life-Cycle Assessment of Energy and Environmental Impacts of LED Lighting Products, The U.S. Department of Energy (DOE) building technologies office; Life cycle assessment of light sources – Case studies and review of the analyses, Leena Tähkämö, Aalto University publication series DOCTORAL DISSERTATIONS 111/2013; Life Cycle Assessment of Ultra-Efficient Lamps SPMT08_069, Navigant Consulting Europe, Ltd. A research report completed for the Department for Environment, Food and Rural Affairs,

[15] Life cycle assessment of light sources – Case studies and review of the analyses Leena Tähkämö, Aalto University publication series DOCTORAL DISSERTATIONS 111/2013, p. 17-18

[16] U.S. Department of Energy. (2012). Life-Cycle Assessment of Energy and Environmental Impacts of LED Lighting Products. Retrieved March 10, 2012 from http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/2012_LED_Lifecycle_Report.pdf

[17] Life-Cycle Assessment of Energy and Environmental Impacts of LED Lighting Products, The U.S. Department of Energy (DOE) building technologies office

advantage in the total life cycle over time, at least if efficiency keeps improving at the same rate and expected long lifetime is proven. .

5 Waste management

5.1 Waste streams

☒ Article is collected and sent without dismantling for recycling

☐ Article is collected and completely refurbished for reuse

☐ Article is collected and dismantled:

- ☐ The following parts are refurbished for use as spare parts: ______
- ☐ The following parts are subsequently recycled: ______

☐ Article cannot be recycled and is therefore:

- ☐ Sent for energy return
- ☐ Landfilled

Single capped (compact) fluorescent lamps are in the scope of EU Directives 2002/96/EC - WEEE and 2012/19/EU– WEEE Recast. Take back systems are installed in all EU Member States: end users and most commercial customers can bring back the lamps free of charge. Single capped (compact) fluorescent lamps are collected separately from general household waste and separately from other WEEE waste. Also a dedicated recycling process exists for lamps because, according to legislation, the mercury shall be removed from the gas discharge lamps. Mercury is recovered in specialised facilities by distillation. Below picture (figure 7) shows the various steps in the recycling process:

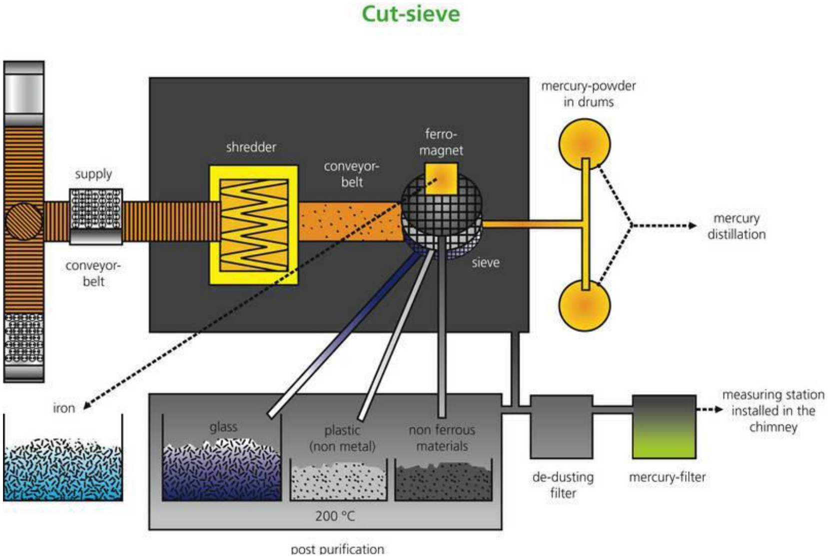


Figure 9 Recycling steps of fluorescent lamps in Indaver (Belgium).
Source:www.indaver.be/waste-treatment/recycling/mercurial-waste.html

Figure 8 illustrates the specifics of recycling the mercury:

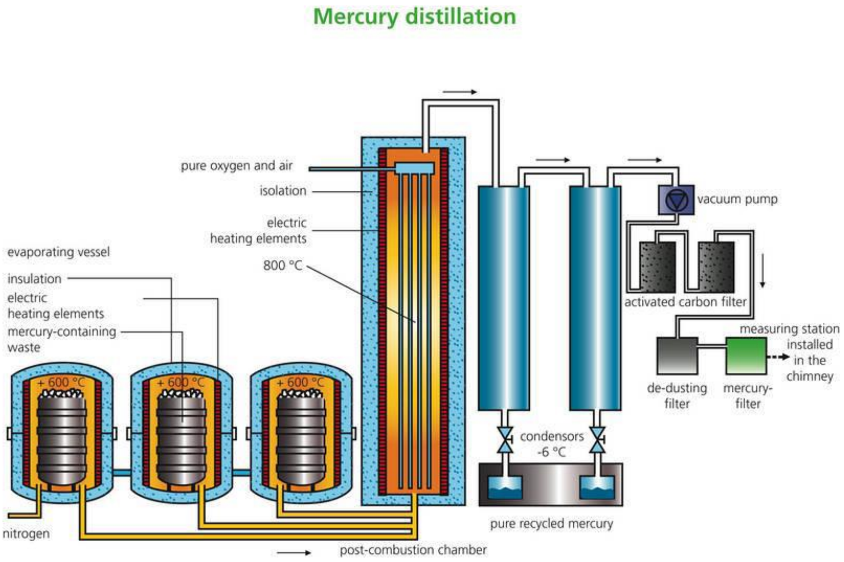


Figure 10 Specific recycling steps of mercury in Indaver (Belgium).
Source:www.indaver.be/waste-treatment/recycling/mercurial-waste.html

European legislation on Waste Electrical and Electronic Equipment makes producers responsible for end of life products within this category as from August 13th, 2005.

Target setting as consequence of the present legislation is 45% of EEE placed in the market by 2016, rising to 65% in 2020 per year for all categories.

European Lamp Companies have founded Collection & Recycling Organizations in the EU Member-States, with the objective to organize the collection and recycling of gas discharge lamps. Goal is to comply with present and probable future EU legislation and meet or exceed national targets.

In general the following channels have been established in the respective member-states providing countrywide coverage:

- Direct collection from large end users:

  Containers have been made available, ad hoc or permanently, and will be collected upon notification by the end user that the container is full.

- Collection through distribution:

  Wholesalers and Retailers place collection means at their premises respectively in their shops. Collection is done upon notification.

Figure 11'JEKKO' collection container

- Collection through municipalities: Where infrastructure allows collection means are placed at municipality depots.

Campaigns are being executed or have been planned to re-enforce the role of the government to educate the population that gas-discharge lamps have to be disposed of in an environmentally friendly way. An example of such a campaign is the distribution of 'Jekko' containers to 1 million households in the Netherlands (figure 9). Amount of mercury in WEEE

☐ In articles which are refurbished
☒ In articles which are recycled
☐ In articles which are sent for energy return
☐ In articles which are landfilled

Amount of substance entering the EU market annually (base year 2013) through application for which the exemption is requested:

Market information from various sources (e.g. McKinsey, IHS, China export data) indicates a total shipped volume of CFL lamps in Western Europe volumes of roughly 600 Mpcs for. This volume includes all wattages.

The collection rate of lamps in Europe compared to the average amount of lamps put on the market during 2010 – 2013 is shown in below graph based on Collection & Recycling

Service Organization (CRSO) data consolidated by Philips Lighting. It also includes the targets set for 2016 and 2019. Please be aware that this graph includes all lamp types, not specifically those under exemption 1(e).

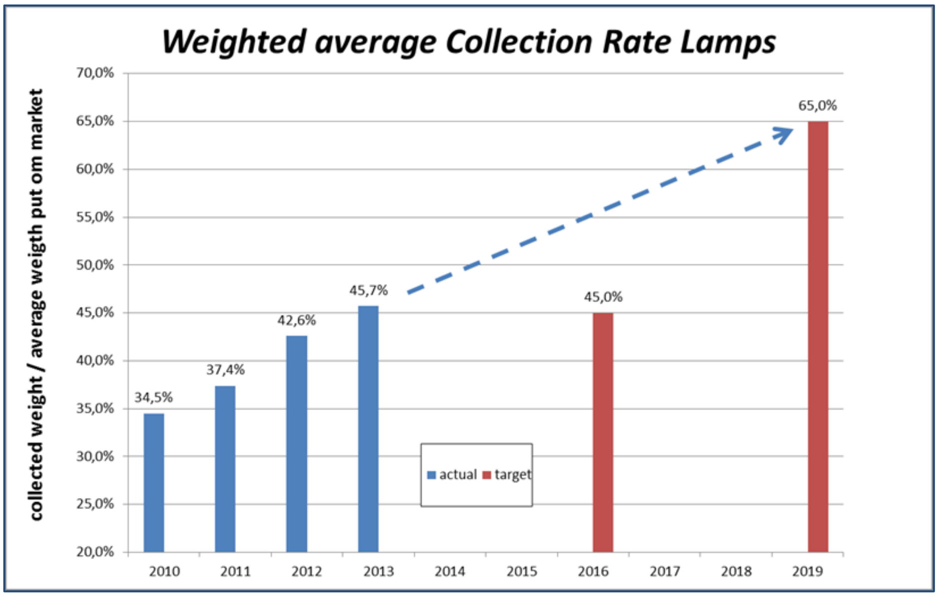


Figure 12: Collection rate of lamps

Reporting on the collection of lamps is available on 2 groups:

- CFL lamps and LED retrofit lamps
- long CFL lamps without integrated ballast, Fluorescent tubes

This makes it impossible to give specific accurate figures for lamps falling under exemption category 1(e) as the available information covers the whole CFL group.

The amount of mercury entering to EU market in this category 1(e) is calculated in a following way:

Total amount of lamps in exemption 1(e) entering European market in 2013 was approximately: 3 mio lamps. Market volume is 600 Mpcs (market volume in pieces taken from McKinsey report)[18]. The estimation of lamps in this category is 0.5 % of the EU CFL market. .

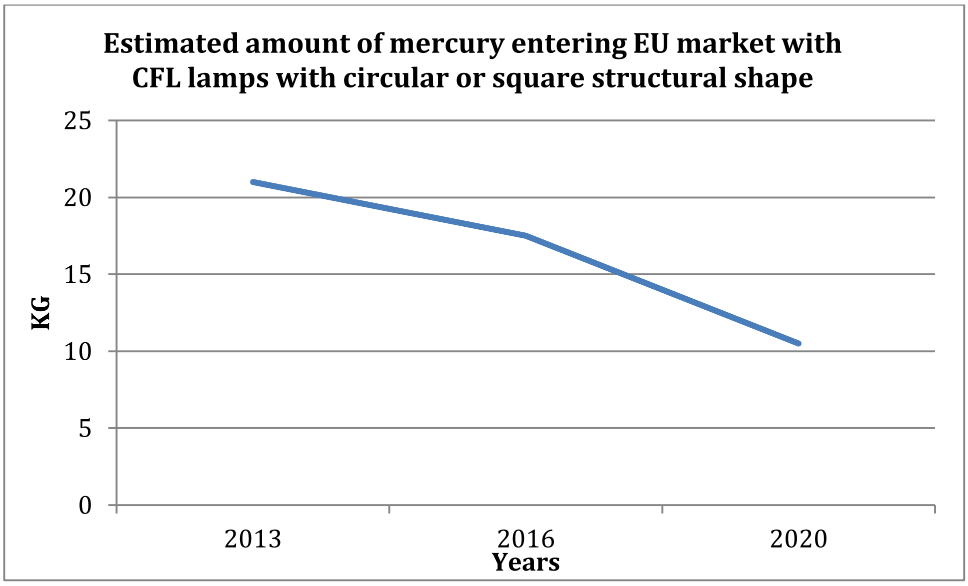
The maximum allowed mercury content for lamps in this category is 7 mg. In 2013 a maximum of 21 kg mercury entered European market in lamps from this exemption.

[18] McKinsey, Lighting the way : Perspectives on the global lighting market, Second edition, Aug. 2012

Using the same information sources gives the following rough forecast for the maximum amount of mercury entering to EU market in category 1 (e) :

2016: 17.5 kg

2020: 10.5 kg



The total amount of mercury entering to the EU market in compact fluorescent lamps covered by this exemption will decrease in the coming years. Main reason for this is the increased penetration of LED alternatives due to their expected decreasing price, improved availability and better replace- ability for the different CFL lamp types. .

It is also important to note that almost every country within EU has a collection and recycling service organisation (figure 13, status per 2009). Collection and recycling rate of CFL lamps is continuously increasing, contributing to the overall mercury reduction program.

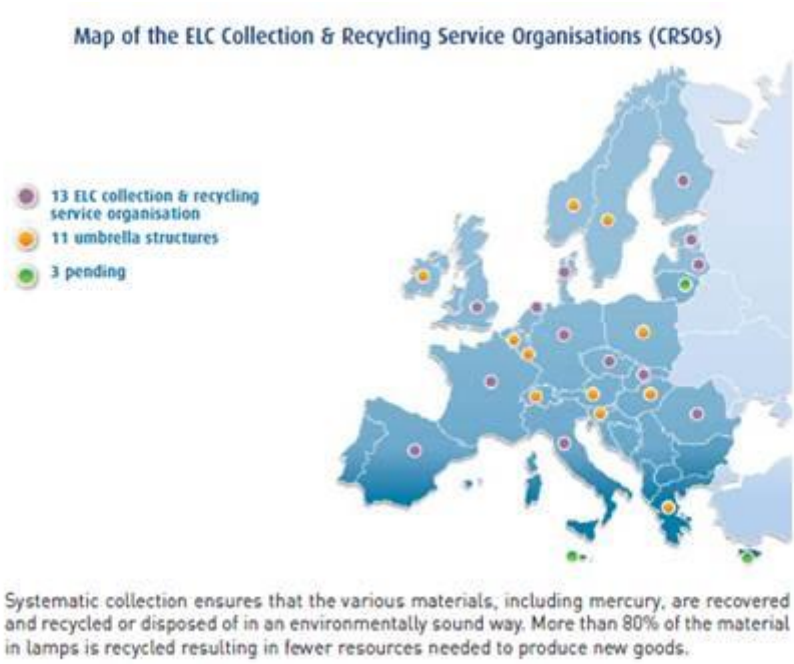


Figure 13 Map of ELC Collection and Recycling Service Organisations (CRSOs).
Source: Environmental aspects of lamps

6 Substitution

Can the substance of this exemption be substituted?

☐ Yes, by
- ☐ Design changes:
- ☐ Other materials:
- ☐ Other substance:

☒ No
Justification: see in below chapters

6.1 Substituting mercury in the fluorescent technology

Fluorescent lighting technology.

Fluorescent lamps need a certain amount of mercury since it is consumed over life. Technology has evolved over the last decade. And the average amount of mercury within fluorescent technology per lamp is considerably reduced (Fig 13)[19]:

[19] http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_VI/Request_7/Request_No7_1st_Clarification_Questions_20120622_final.pdf

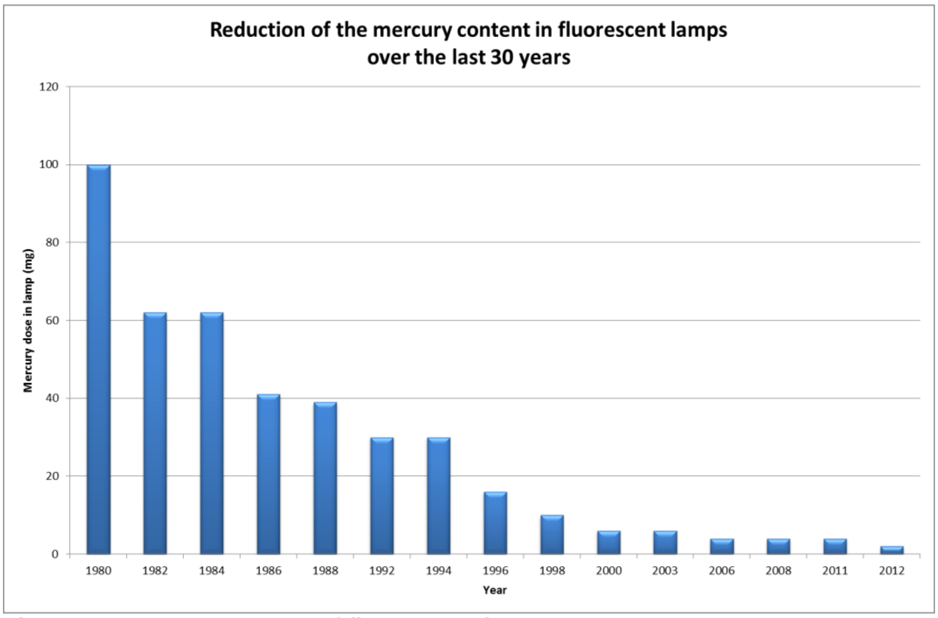


Figure 14: Mercury content of fluorescent lamps

But low pressure fluorescent lamps without mercury are not possible, despite of all the research that has been done on the subject:

The mercury discharge is highly efficient in transforming electrical energy into light. The technology has only two drawbacks: first the generated UV radiation needs to be transformed into visible light, a process for which large losses occur: this is due to the Stokes shift (an energetic UV photon generates a visible photon which has a much lower energy) and secondly the discharge inherently contains mercury as the source to create the UV photons[20].

Attempts to generate UV with noble gases succeeded partially[21]. However the plasma radiates in the deep UV. At such wavelengths, the Stokes shift is even larger causing lower energy efficiency. The lack of suitable phosphors[22] prohibited progress in this direction. Other alternatives investigated are low pressure metal halides (for example InI, InBr, GaI_3)[23]. Such plasma's generate the visible light directly without the Stokes shift of the phosphor[24]. There are alternatives from research but the energy efficiency in

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[20] M Haverlag, Mercury-free discharges for lighting, J. Phys. D: Appl. Phys. 40 (2007)
[21] R Bussiahn, S Gorchakov, H Lange, D Loffhagen and D Uhrlandt, Ac operation of low-pressure He–Xe lamp discharges, J. Phys. D: Appl. Phys. 40, 3882 (2007)
[22] J. Dexpert-Ghysa, Re-processing CRT phosphors for mercury-free applications, J. of Luminescence, 129, 1968, (2009)
[23] D.Smith, J. Michael, V. Midha, G. Cotzas and T. Sommerer D. Smith et al Efficient radiation production in a weakly ionized, low-pressure, nonequilibrium gallium-iodide positive column discharge plasma J. Phys. D: Appl. Phys. 40 3842 (2007). More references can be found in the series: International Symposium on the science and technology of Lighting LS1-14.
[24] An example if a UV photon of 256 nm from mercury is transformed in a visible photon of 555nm (maximum eye sensitivity) 56% of the energy is lost to heat. In xenon the UV photon is formed around 185 nm this loses 67% of the energy when transformed into the same visible photon.

prototypes lamps is significantly reduced to approx. 40lm/W level or below. Mass production is not (yet) feasible. More over these are thus far only found feasible for very high light fluxes.

With the arrival of the first energy efficient LED white light sources and the perspective of further improvements, research to alternative gas discharges has stopped at most companies and universities.

Using noble gases instead of mercury leads to a dramatic energy efficiency drop, well below 40 lm/W. Upgrading to similar performance would imply unjustifiable efforts with unknown chance of success (limit of the technology reached) and possibly resulting in a larger negative environmental impact due to higher energy consumption.

6.2 Substituting fluorescent technology by mercury free technology

Currently, the lighting market is rapidly changing from discharge lamp technology to LED technology, which is mercury free. This change mainly concerns the new installs market, i.e. new luminaires and lighting systems are now frequently based on LED technology. However, for the current installed base of luminaires and lighting systems operating with discharge lamps, a typical refurbishment cycle in shops and offices is on average 7 to 12 years respectively. LEDs in many cases are not suitable drop-in replacements, as will be explained in 6.2.1, so the availability of suitable discharge lamps needs to be secured to prevent a forced, early refurbishment resulting in extra costs and environmental burden.

Towards the development of possible alternatives, the LED technology developments are also addressing one-on-one replacements, but this will not result in a situation which would allow for full replacement of the current discharge lamps portfolio within the timeframe of the exemption. Below pictures shows LED based replacements for CFL circular lamps.

Figure 15 Examples of LED circular lamps showing that light is generated to one side

6.2.1 Feasibility of the alternatives

For CFL lamps replacement by means of LED lamps is not always evident. Specifics to finding alternatives for compact fluorescent lamps include the following issues:

- As explained in 4.1.1 CFL circular lamps are installed in a variety of types, shapes, sizes, wattages and colours. It is questionable if LED retrofit solutions will be developed for the total of this complex and scattered landscape.
- In Europe properties of CFL lamps are regulated in various IEC standards like EN60901, EN60969, EN60968 and EN61199, to make compatibility easy for the users. Such standards are currently not available for LEDs which aim to replace CFLs with external ballast, so customers don't have any reassurance that the LED solution fits the existing installation.
- Inherent to the discharge technology, CFL lamps are more of omnidirectional nature, while LEDs by nature emit their light more directionally which can make the one to one replacement difficult. It is difficult for LED based lamps to achieve an omnidirectional luminous intensity distribution, while also meeting needs for thermal management and electrical regulation. In the application the luminaire might radiate the light in all directions or a reflector is guiding the light into a special direction. Especially in the last case the reflectors are designed for the shape, dimensions and

burning position of a CFL lamp to generate the desired light distribution. The more directional light of an LED will give a different light distribution in the same CFL luminaire with reflector. Therefore bare-lamp performance may not translate when the product is operated in a luminaire. The measurement should be performed with a lamp inside the luminaire. Replacing an omnidirectional fluorescent lamp with a directional LED lamp can result in for example reduced illuminance at the work place, changed uniformity ratios on floor and surroundings and even in unwanted glare.

- The current lamp holders are designed to carry the weight of the existing CFL lamps. Safety standards for CFL lamps (EN61195, EN60968) prescribe a maximum weight and bending moment to prevent a too high loading of the lamp holder. LED lamps have a higher weight and bending moment than CFL lamps due to the necessary heat sink which needs to be close to the LEDs to remove the heat from the diodes. As a result the weight of the LED solution often exceeding the values in the Safety standards for CFL. Specific standards for LED lamps are under development, but currently not available.
- Luminaires for CFL are designed for the thermal properties of a CFL lamp and not to control the heat as required for dedicated LED fixtures. Direct application of LED replacement lamps instead of CFL will cause thermal problems in closed and/or narrow CFL luminaires.
- The lamp driver can be or a conventional ballast or an electronic control gear. The market for new installations is moving toward electronic control gear due to new functionality (e.g. dimmability) and upcoming energy efficient legislation for the driver. Many CFL lamps used by professional end users are designed to be dimmable. Several modes of dimming (e.g. phase cutting) are present in the market. All modes of operation (EM, HF current controlled, power controlled, voltage controlled, preheat, non-preheat) have in common that the light source is expected to behave electrically as a standardised CFL lamp. The large diversity of drivers is not meant for an electronically ballasted LED lamp. This makes it very difficult for a customer to know which ballast is used and what LED lamp to apply as a retrofit. The usually unskilled end-user might be confronted with compatibility issues and wrongly (also unintentionally) chosen LED based replacements, which will work improperly in the

existing application. In such situations one will be forced to take out the control gear from the installation and directly connect a LED source to mains voltage (called rewiring). Currently there is no electrical interface described for LED lamps replacing CFL with external control gear. Standardisation bodies are working on interface standards (related to linear LED based replacement lamps), but it is not expected that these will also become available in the near future for CFL (with external control gear). As a result an end-user, both consumer and professional customer, needs to either have a broad technical knowledge or reach out to professionals to ensure that replacement in safe and the luminaire operates in a proper manner. It requires case-by-case feasibility and measurements.

- A regular separate ballast for a CFL lamp is designed to be used with several subsequent lamps (at least 3 to 4 lamps). So if the combination of the ballast with the LED lamp is not working or is not even available, the ballast needs to be changed prematurely, which could create additional waste.
- CE conformity of luminaires is based on fluorescent lamps (with respect to safety and system responsibility). Furthermore, most alternative lamps in practice need replacement of the luminaire ballast (explained above). Effectively, this would imply that the complete luminaire needs to be replaced because CE conformity is no longer guaranteed. This results in a premature luminaire replacement and produces additional waste when still properly operating components need to be disposed. A typical renovation cycle in the office segment is 12 years and for shops this is 7 years[25].

6.2.2 Availability of substitutes

Looking purely to the capacity to produce LED lamps globally, there will probably be enough capacity to fill the sockets in Europe. But the question is if all sockets can be filled with suitable, replacement LED lamps, fulfilling the requirements of the application. In that case the conclusion is, as described in 6.2.1, that that is not the case yet in 2016. More time is needed in the development of LED technology to become a true replacement for all CFL lamps in all applications

[25] McKinsey, Lighting the way : Perspectives on the global lighting market, July 2011

6.2.3 Impacts of substitution

6.2.3.1 Environmental impact of substitutes

The major environmental impact of lighting is the energy consumption in the use phase. As stated before (see 4.2.5), various LCA's show different results and are as such inconclusive regarding the comparison of LED technology versus CFL technology on their total environmental impact. Both CFL and LED lamps for residential applications use an electronic driver of which the environmental impact is the same. The largest differences are the use of mercury in case of CFL and in case of the LED the aluminium based heat sink and the energy to manufacture the product[26]. Comparing the two is difficult. So no conclusion can be drawn on the statement if LED is a full replacement for CFL.

In case no suitable replacement of a CFL lamp can be found and the ballast and/or luminaire also need to be prematurely replaced, this will result in additional waste.

6.2.3.2 Health and safety impact of substitutes

Although the LED technology doesn't contain mercury, it contains other sorts of substances as lead and plastics. So far researches have not been conclusive in the overall effect of a LED lamp in comparison with a CFL lamp (see section 4.2.5).

Next important aspect of the use of LED based replacement for existing CFL based applications is electrical compatibility. As explained in chapter 6.2.1, the current market situation is far from being comprehensive, due to the big variety of lamp types and gears. Contrary to linear LED based light sources, there is no safety standardization in progress. Safety is the responsibility of the installer and the luminaire should be appropriately labelled afterwards. Special care has to be taken for the use of LED lamps in systems which were designed for a compact fluorescent lamp, including exchange of the lamps by professionals.

[26] U.S. Department of Energy. (2012). Life-Cycle Assessment of Energy and Environmental Impacts of LED Lighting Products. Retrieved March 10, 2012 from http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/2012_LED_Lifecycle_Report.pdf.

6.2.3.3 Socio-economic impact of substitution

Economic effects related to substitution:

- ☐ Increase in direct production costs
- ☒ Increase in fixed costs
- ☐ Increase in overhead
- ☒ Possible social impacts within the EU
- ☒ Possible social impacts external to the EU
- ☒ Other:

Banning these lamps means for our customers that they do not have an alternative. This leads to an increased spent of EU consumers due to enforced luminaire replacements.

Manufacturers offer a wide variety of energy efficient lighting products in their portfolio providing customer choice for professional and residential use. Banning mercury or setting very strict limits on its use will eventually prohibit the use of fluorescent technology for lighting. This means a serious reduction of customer choice for energy efficient lighting solutions.

RoHS is copied by many countries in the world (e.g. Asia, Middle East, the America's). Ending the exemption would have as consequence that also people in other countries would not be able to buy energy efficient and affordable CFL lamps and will go back to using incandescent lamps. This has a very negative impact on the environment.

6.2.3.4 Impact of substitution on innovation

Focus of the current lighting industry is already on the further development of LED technology (paragraph 6.2). An extension of the exemption will have a positive effect on the efforts to further innovate in LED, as CFL is the benchmark to be outperformed by LED.

6.2.4 Future trends of substitution

LED technology performance is developing, however the balance between cost price, lifetime and energy efficiency and the speed in which it will take place is not yet clear and at least needs time.

6.3 Links to REACH, according to RoHS Directive Article 5(1)(a)

Do any of the following provisions apply to the application described?

no

☐ Authorisation
- ☐ SVHC
- ☐ Candidate list
- ☐ Proposal inclusion Annex XIV

☐ Restriction
- ☐ Annex XIV
- ☐ Annex XVII
- ☐ Registry of intentions

☐ Registration

Provide REACH-relevant information received through the supply chain.

Not Applicable

7 Removal of mercury from lamps

Can mercury be eliminated?

- ☐ Yes.
- ☒ No.

8 Reduction of mercury content of lamps

In paragraph 6.1 is explained that various attempt have been made in the industry to reduce the mercury content in fluorescent technology. These attempts have been successful, because the amount of mercury has been drastically reduced in the last decades. At the same time, the fluorescent technology can only operate when a certain limited amount of mercury is used. As stated before, there is interdependency between the amount of mercury, the light output per wattage (efficacy) and the lifetime of the lamp. To be able to keep this fine balance, it is uncertain if the amount of mercury as stated currently in RoHS can be reduced while keeping the requirements of lifetime and energy efficiency.

9 Other relevant information

During the UNEP Minamata Convention on Mercury end 2013 in Japan agreements have been made on limitation of mercury in various products, including compact fluorescent lamps (figure 11). This treaty has been agreed upon and signed by 94 countries around the globe.

Table 1 Section in UN-Minamata treaty on mercury limits for CFL.

Mercury-added products	Date after which the manufacture, import or export of the product shall not be allowed (phase-out date)
Batteries, except for button zinc silver oxide batteries with a mercury content < 2% and button zinc air batteries with a mercury content < 2%	2020
Switches and relays, except very high accuracy capacitance and loss measurement bridges and high frequency radio frequency switches and relays in monitoring and control instruments with a maximum mercury content of 20 mg per bridge, switch or relay	2020
Compact fluorescent lamps (CFLs) for general lighting purposes that are ≤ 30 watts with a mercury content exceeding 5 mg per lamp burner	2020
Linear fluorescent lamps (LFLs) for general lighting purposes: (a) Triband phosphor < 60 watts with a mercury content exceeding 5 mg per lamp; (b) Halophosphate phosphor ≤ 40 watts with a mercury content exceeding 10 mg per lamp	2020

Source: www.mercuryconvention.org

10 Information that should be regarded as proprietary

LightingEurope provides to the European Commission under confidentiality a comprehensive list of lamps with average mercury content, which are in the scope of the obligation to publish such data according to the ErP Directive Implementing Measures 244/2009, 245/2009, 1194/2012 and produced by LightingEurope member companies.

List of abbreviations

ADCO	Administrative Cooperation Group
BASI	Bioanalytical Systems, Inc
BSP	Barium Synthetic (Pb^{2+}) phosphor
CCG	Conventional Control Gear
CDM	Ceramic Discharge Metal Halide
CDV	Committee Draft for Voting
CFL	Compact fluorescent lamp
CRI	Color rendering index
CRSO	Collection & Recycling Service Organization
DEFRA	Department for Environment Food and Rural Affairs
DOE	Department of Energy
ECG	Electronic Control Gear
EEE	Electrical and Electronic Equipment
ELC	European Lamp Companies Federation
EM	Electromagnetic: lamp control gear based on a magnetic coil (= CCG)
EMC	Electro Magnetic Compatibility
ERP	Energy related Products; Directive 2009/125/EC establishing a framework for the setting of eco design requirements for energy-related products
FTE	Full Time Equivalent, indicates the workload of an employed person
HF	High frequency: lamp control gear based on high frequency (= ECG)
HID	High intensity discharge lamps
HPS	High Pressure Sodium (vapor) lamps
Hz	Hertz
K	Kelvin: Unit of color temperature (2700 K warm color, 5600K cool daylight)
Lm	Lumen
LFL	Linear Fluorescent Lamps
LCA	Life cycle assessment
LED	Light Emitting Diode
LPD	Low Pressure Discharge lamp
LVD	Low Voltage Directive

mg	Milligram
MH	Metal halide lamps
OEM	Original equipment manufacturer
OLED	Organic Light-Emitting Diode
PCA	Poly-crystalline alumina
PLL	Pi shaped Long Length, compact fluorescent lamp
R&D	Research and Development department(s)
REACH	Regulation on Registration, Evaluation, Authorization and Restriction of Chemicals, 1907/2006/EC
RoHS	EU Directive 2011/65/EU on the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment
SSL	Solid State Lighting
SVHC	Substances of Very High Concern
TF	Task Force
UMICORE	global materials technology group which focuses on application areas where its expertise in materials science, chemistry and metallurgy makes a real difference.
UNEP	United Nations Environnent Programme
UV	Ultraviolet
VDE	German Association for Electrical, Electronic and Information Technologies
W	Watt unit of (electrical) power
WEEE	Waste Electrical and Electronic Equipment
ZVEI	German Electrical and Electronic Manufacturers´ Association