Request to renew Exemption 4a

under the RoHS Directive 2011/65/EU

Mercury in other low pressure discharge lamps (per lamp).

No limitation of use until 31 December 2011; 15mg may be used per lamp after 31 December 2014

Date: January 15, 2015

LIGHTINGEUROPE
THE VOICE OF THE LIGHTING INDUSTRY

Contents

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2 Reason for application

Lighting Europe submits this application to:	*request for extension of existing exemption* ***no. 4(a) in Annex III*** *which currently reads Mercury in other low pressure discharge lamps. 15 mg per lamp may be used after 31 December 2011.*
Lighting Europe proposes to continue using the existing wording with amendment as:	*Mercury in other low pressure non-phosphor coated discharge lamps not to exceed 15 mg per lamp.*
Lighting Europe requests a duration of	*Maximum validity period required.*

3 Summary of the exemption request

The validity period of DIRECTIVE 2011/65/EU Article 5(2) will end automatically per 21/10/2016, unless an application for renewal has been made in accordance with Annex V.

With reference to the above, this request concerns the extension of the current Annex III exemption:

4(a) regarding 15 mg mercury content in other low pressure discharge lamps for which there is no suitable alternate technology available to produce the required functions initially and over lamp lifetime.

Annex III of RoHS Directive explicitly names the following fluorescent lamp technologies and families: Exemptions 1(a)-1(f) – compact fluorescent lamps, 2(a)(1) – 2(a)(5) – linear fluorescent lamps, 2(b)(1) – 2(b)(3) - fluorescent lamps and 3((a) – 3(c) – cold cathode fluorescent lamps.

These exemptions do not cover the full range of fluorescent lamps. The scope of exemption 2(b)(4) includes all other fluorescent lamps for general lighting and special purposes, which do not belong to any of the above listed families and technologies.

Fluorescent lamps are low-pressure discharge lamps containing a phosphor coating. The current exemption 4(a) left room for interpretation about which lamps types are included. This exemption renewal clarifies the lamps in this section as those low pressure gas discharge lamps which emit UVC radiation and are characterized by not having a phosphor coating.

These lamps are produced with similar manufacturing techniques as fluorescent lamps but are used in highly specific applications to produce UVC light. The use of special design, materials and process steps provide their special features. This light may be used for bacterial disinfection of air, water or other liquids, solids, or UV curing of surfaces, print media and the like which use UVC to dry the imprinted surface.

These lamps are used in equipment for industrial, commercial or consumer applications with a very broad range of operating requirements, starting requirements, operating conditions and ambient environments and are frequently used with non-standard or custom power supplies. They are mainly niche products with relatively small market sizes compared to general lighting lamps. Fluorescent lamps are very energy and resource efficient lamps highly required in the market. They contain a small amount of intentionally added mercury which is essential to convert electrical energy to light. Lamps in the scope of exemption 4(a) are used in a wide variety of different lamp families with mercury content from < 4 up to 15 mg. They are mainly niche products with low market size compared to the other general lighting or specialty lighting fluorescent lamps. Unlike general lighting lamps, there is no available LED that can produce light in the 185-254nm range of the UVC spectrum or other lighting technology that may use less mercury, or can be used as a substitute for these lamps at this time or foreseeable in the next five to ten years. There are UVC producing LEDs made by companies such as Nichia which are in the early stages of development and use at the higher wavelengths of the UVC spectrum i.e. 365-405nm however these would not perform the same germicidal function as the lamps covered under this request. It is estimated by the LED manufacturers that deep UVC LEDs will not be available for five to ten years due to the high power and long life requirements that are available with low pressure gas discharge lamps.

These UVC lamp types are used in highly specialized fields in relatively small market niches compared to general lighting. The efficiency of this light source to provide UVC watts is much greater compared to other technologies such as medium pressure or high intensity discharge. The potential for emerging LED technology to produce output in this narrow UVC region is not seen as practical in the near term of 5 to ten years. Lighting Europe therefore recommends a an exemption limiting mercury content to a maximum of 15 mg. for the lamps proposed in this exemption which is consistent with the current limit for other specialty low pressure fluorescent lamps but further defines these lamp types and mercury content limits.

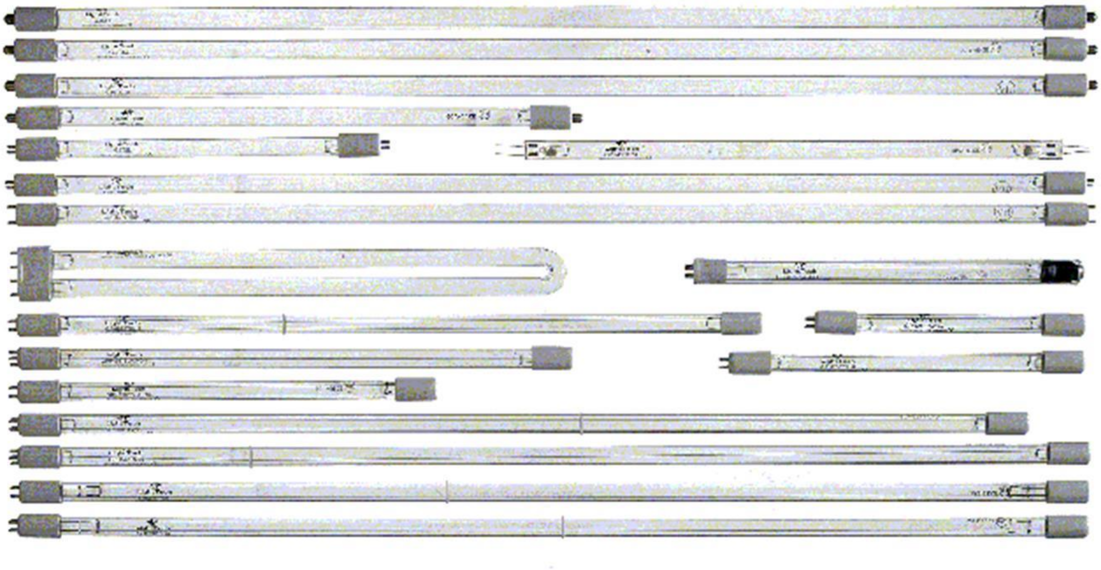
4 Technical description of the exemption request

4.1 Description of the lamps and their applications

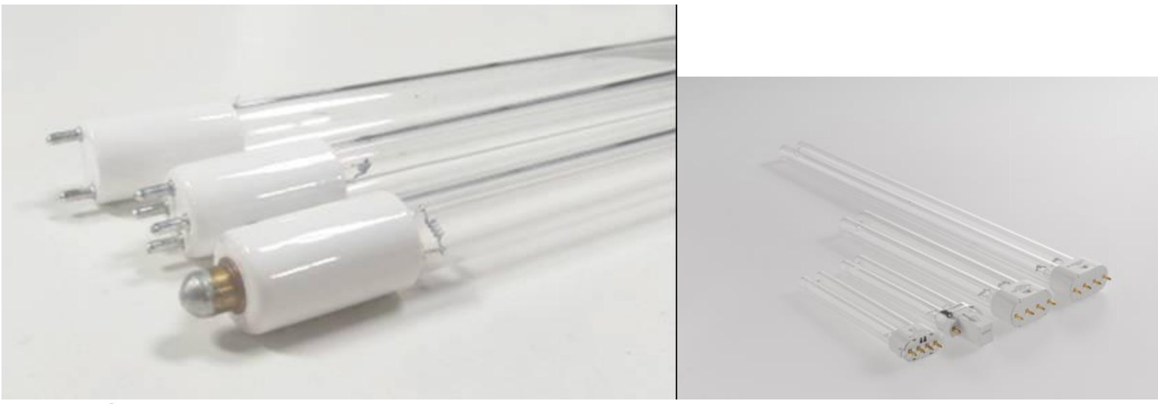
4.1.1 Lamps covered by this exemption

This exemption covers low pressure mercury vapour gas discharge lamps which are not included in any of the other categories of lamps in Annex III whether for general lighting or specialty lighting. The lamps are not phosphor coated and do not produce visible light nor are they intended for illumination purposes. Unlike general visible lighting lamps or specialty lighting lamps which may be produced with soda-lime glass which intentionally block UVC transmission, these lamp types will allow the transmission of light in the deep Ultraviolet C region of 185-254nm. The practical uses of these lamps are for ultraviolet germicidal or bacterial disinfection of: fluids such as drinking water; waste water; water for food, beverage, pharmaceutical preparation; aquaculture; fish farming; semiconductor manufacturing; surface disinfection; air disinfection. The lamps are installed in equipment for industrial, commercial and residential applications and the use of these are growing as they have been accepted by Environmental Agencies worldwide to kill many forms of bacteria including but not limited to giardia and cryptosporidia. These low pressure gas discharge lamp types can be T5, T6, T8, T10 and T12, which are industry standards, but can also include other tubular lamp outside dimensions or compact Hg discharge lamp shapes like single ended bended or bridged 2, 4, or 6 legged lamps. Due to their highly specialized use the lamps may be double ended with standard lighting end caps or may be single ended with standard or custom end cap configurations. Lamps may also be made in custom sizes and lengths and power levels. Power ranges for these lamp types can vary be from 1W to 1000W and are typically dimmed in operation. The operating environment of these lamps varies greatly. The operating temperature range can potentially be 0 C to 100C. They may be operated directly in air, in a sleeve in air, or in a sleeve in water. Thermal control may become a necessity for these lamp types especially in higher powered lamp types.

The pictures below demonstrate some of the lamp types in this category.



Quartz Ultraviolet lamps 1



CFL UVC lamps

Quartz Ultraviolet amalgam lamp 1

4.1.2 Applications covered by this exemption

These lamps will be installed in original equipment manufactured for industrial applications such as waste water discharge or sewers. A waste water plant will include certain equipment to break down solids and effluent followed by a filtration process. The next step is bacterial disinfection which may be done by introduction of chemicals such as chlorine into the waste stream. The UVC germicidal disinfection lamp will be installed in equipment to kill the bacteria present in the water and prevent cell regeneration. The same disinfection process is used for drinking water applications for municipalities, buildings, offices, and residential needs. Other applications include disinfection of swimming pools, spas, and ponds; cooling tower waste water, ocean vessel ballast water discharge; the beverage industry for disinfection of water used for production of drinks, beers, sodas, beverages, bottled water etc. UVC germicidal lamps and equipment are used in hospital rooms, doctors' offices, HVAC systems for air disinfection. Other applications include surface irradiation and disinfection.

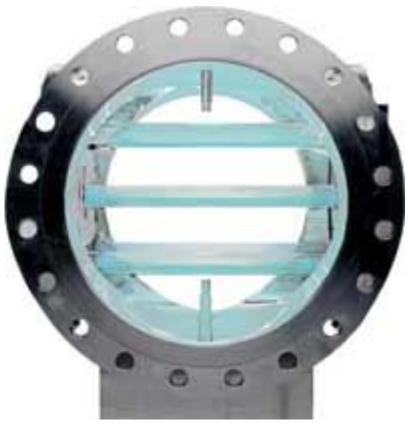
		
Air disinfection unit 1	**Water disinfection unit 1***	**Open channel water disinfection 1***

*photo courtesy of Trojan Technologies

		
Home water purifier	**Waste water disinfection unit 1** **photo courtesy of Trojan Technologies**	**Municipal drinking water UV unit 1**

Point of entry water UV water purifier photo courtesy of Trojan Technologies

In 4(a) we indicate non-fluorescent or not phosphor coated lamps.

4.1.3 Annex I category covered by this exemption

List of relevant Annex I categories for this exemption

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☒ 5

☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11

LightingEurope is of the opinion that lamps in general are category 5 products, but having a character of a component, a consumable as well as a spare-part.

There are numerous applications where lamps can also be regarded as component of a product belonging to any of the other categories 1 - 11 e.g. lamps/lighting in ovens, refrigerators [1], clocks [2], copy machines, projectors [3] TV sets [4], background lighting of tools [6], video games [7], UV lamps in medical equipment [8], control panels for industrial installations [9], UV in automatic dispensers [10] or lamps fixed installed in furniture [11].

LightingEurope believes that lamps covered by exemption 4a might not belong to category 5 equipment only if it is specifically designed as part or component of only one specific other category and there is no intended possibility to use it in others. Examples for the latter case are specific lamps for medical equipment, which have a certain special function in such equipment only, e.g. lamps for vitreoretinal surgical systems Please note that exempted applications for categories 8 and 9 will be reviewed in 2021 at earliest, and are not covered in the current review for other categories, although these applications will continue to need these lamps after July 2016.

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. While for general lighting it is easier comprehensible that they cannot be considered as “spare parts of a luminaire” application specific special purpose lamps indeed can be considered also as a spare part (or consumable) in certain applications such as pool cleaning equipment.

4.2 Description of the substance

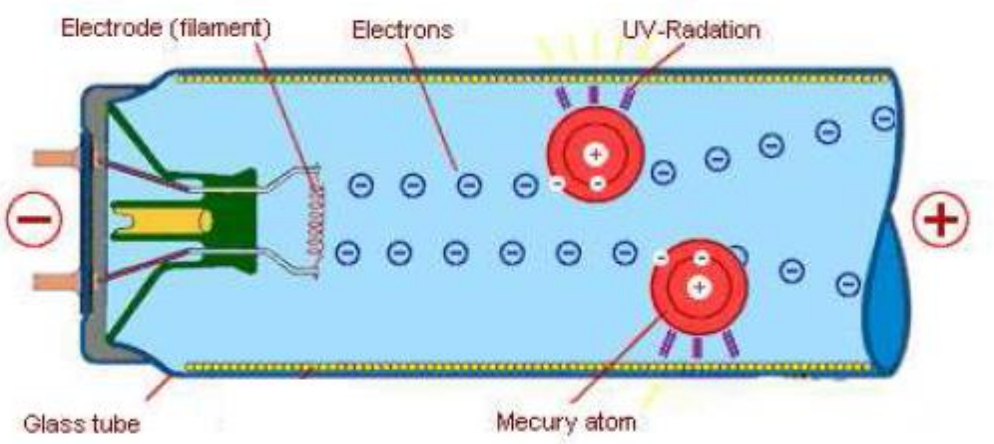
4.2.1 Substance covered by this exemption

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 with a high efficiency. This UV light then passes through the lamp bulb and enters the application



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Electrical current is passed via the two filament electrodes through the tube which is filled with partially ionized gas. The electrons excite mercury atoms to emit short-wave ultra-violet light, which is then transmitted through the specially designed glass envelope in the form of 254nm or 185nm and 254nm. There is no phosphor coating inside these UVC lamps.

4.2.3 Location of mercury in lamps

Mercury is present in the so-called discharge tube or burner. There are various technologies to add it to the discharge tube, the so-called dosing techniques. Over the last decennia the dosing techniques became much more accurate, so less mercury can be applied with a specific variance. This is needed to guarantee both the lifetime of the lamp and to fulfill the ROHS requirements of a maximum mercury dose at the same time. Below the most common dosing technologies for single- and double capped fluorescent lamps are listed and displayed in figure 3.

- Manual pipetting or needle injection of liquid mercury
- Semi- or fully automatic dosing, disc needle injection of liquid mercury
- Glass capsules containing a specified amount of mercury
- Pressed pills containing Fe, Cu with Hg
- Metall alloy shield with Ti_3Hg, an inter-metallic compound
- Dosing amalgams Sn-Hg / Zn-Hg / Bi-Hg/ Bi-In-Hg
- Steering (or control) amalgams Bi-In-Hg / Bi-Sn-In-Hg

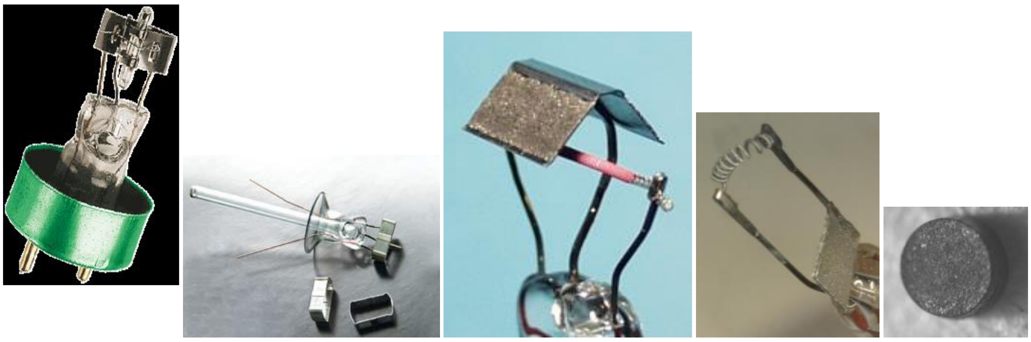

Figure 3: Mercury dosing technologies
From left: Hg-capsule; metal-alloy[1], metal alloy "roof", metal alloy "flag", HgFe pill

[1] I. Snijkers-Hendrickx et. al., Low-mercury containing discharge lamps, 2007,

4.2.4 Amount of mercury

Mercury is dosed in the discharge tube during lamp manufacturing as homogeneous material (pill, capsule). This technology enables dosing of the small and accurate amount of mercury that is 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.[2]

Coating of phosphors and glass can give a reduction of the Hg consumption over lamp life, 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 of 15 mg for the lamps covered by this exemption.

For fluorescent lamps a high effort was necessary to implement all limit changes coming in force in 2010[3] with effect between 2012 and 2013. The maximum mercury content of lamps covered by this exemption had to be reduced to 15 mg per burner as of 1st Jan 2012.

In order to be able to dose the required amounts of mercury precise technologies are necessary and available[4]. But even with accurate technologies there is a certain distribution of the amount of mercury per single dose. The different dosing techniques have different variances. So for example the effective mercury content of lamps with a target or average value of 8 mg can vary between 6,5-9.5 mg (see Figure 4). For manufacturers, an additional "safety margin" (as explained above) is essential to have legal certainty that a product is within the limit. So while in practice the average value may be 8.0 mg, the needed RoHS value in this example may be as high as 10 or higher[5].

Figure 4 also shows that the average value in lamps is clearly much lower than the limit value required per lamp or burner. Manufacturers communicate usually this average lamp mercury content as X.X mg in their product documentation according to ErP Implementing Measure requirement[6].

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

[3] Commission Decision 2010/571/EU of 24 September 2010

[4] Lamp manufacturers have developed their own proprietary solutions, or have co-developed with independent suppliers, who can offer also solutions to other lamp manufacturers.

[5] ELC Exemption request, 2012
http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_VI/Request_7/ELCF_Exemption_Request7_Mercury_long_life_CFL.pdf

[6] Regulation (EC) No 245/2009 amended by Regulation (EC) 347/2010

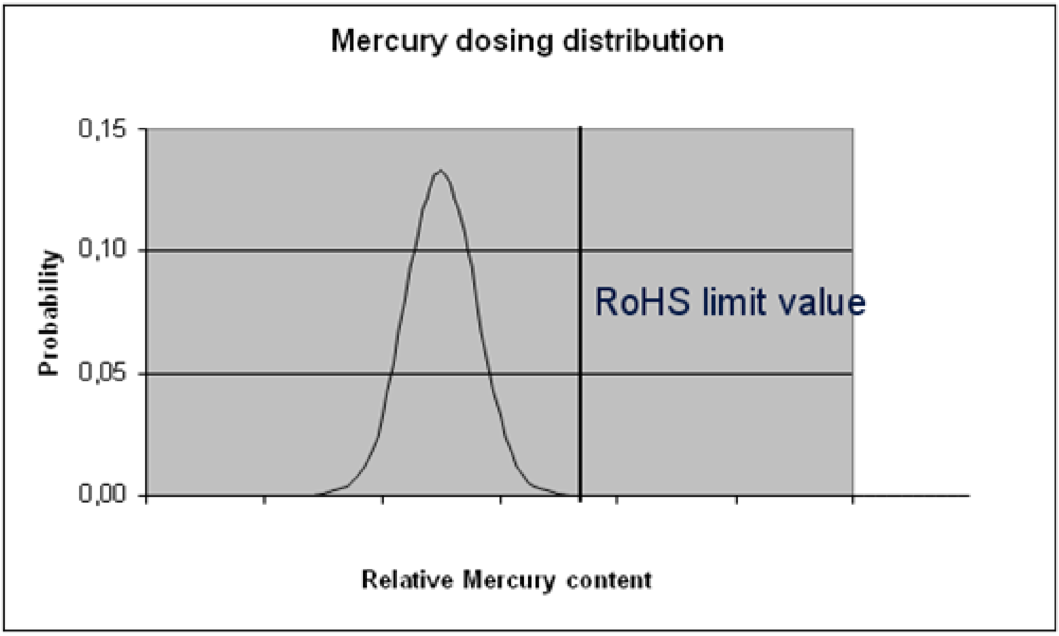

Figure 4: Simplified illustration (example only) of the effect of mercury dosing variance, where average value needs to be chosen lower than the RoHS limit value. The graph displays measurements of the mercury content in dosing units performed as quality control during their production, here FeHg pill.

Another important aspect is the so-called *mercury consumption.* This is the most important factor for lamps falling in exemption 4(a)

The amount of mercury which is needed for the low pressure discharge process is very low, significantly below 100 µg for a double capped linear fluorescent 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.

It is important to understand the basic design rules regarding mercury in fluorescent lamps. One aspect is the dosing technology. As described in 4.2.3 there are different dosing technologies in use developed and implemented by the different manufacturers. The low mercury content nowadays used in modern lamp manufacturing, has resulted in well controlled, safe dosing technologies.

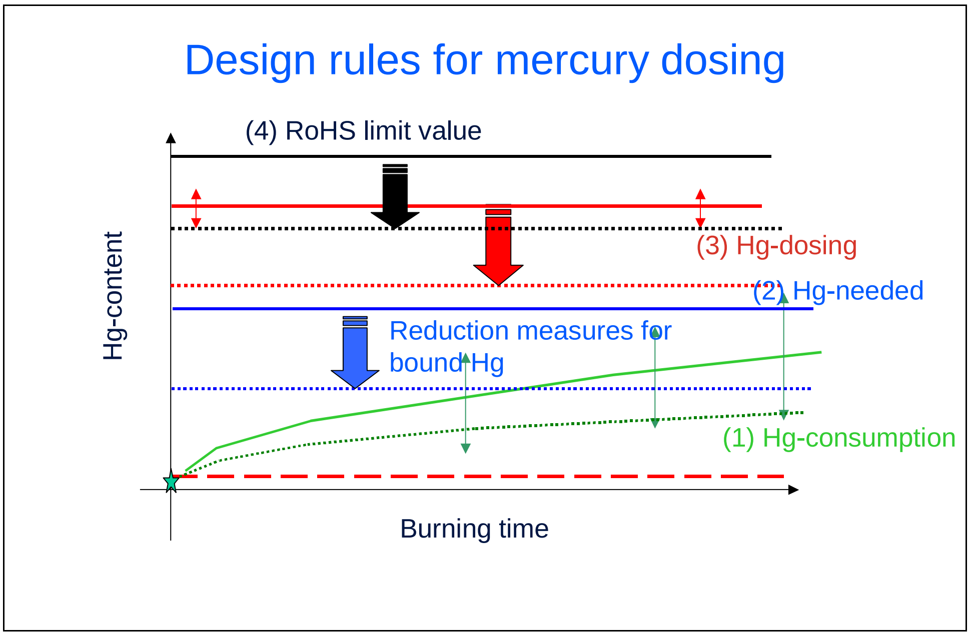

Figure 5: Design rules for mercury dosing in fluorescent lamps, schematically showing the process of setting RoHS limit values based on insights in mercury consumption and mercury dosing.

The lowest (dashed) red 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 typical fluorescent lamp [T8: 26 mm diameter, about 1.2 m length] this is about 60 micrograms per lamp. For CFL lamps this would be even lower. However, up to now a lamp with normal functional properties could not be designed, as explained below.

In practice, mercury from the discharge gets consumed over lamp life, meaning that it is not available anymore for the proper functioning of the lamp. The mercury gets mostly deposited and effectively bonded to the glass and the phosphor layer (if the lamp contains phosphor). This is reflected by the green 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 (blue solid line 2 in figure 5). The target mercury dosing (red solid 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.

The black solid 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.

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

Once mercury is bound to these, it is no longer available to emit ultraviolet light. The schematic effect is the lowering of the solid curve 1 to the dashed curve in figure 5

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Path	Mechanism	Main Promoter	Source	Location of bound Hg
Oxidation	Hg^{+} + x O → HgO_x	impurities prematerials	processing coating	coating
Amalgamation	Hg^{+} + Me → HgMe Me: e.g Ba, Na, Sr,...	emitter impurities glass	processing emitter electrode	coating
Adsorption	Hg^{+} - adsorption on surfaces	surface charge, electronegativity	Hg+, e-, Ions, electric potentials.	coating
Absorption	Hg^{+} - diffusion/Incorporation in bulk	prematerials glass	Hg+, e-, Ions, chemical potentials.	glass, coating, components

Table 4: Main mercury consumption mechanisms oxidation, amalgamation, adsorption and absorbtion. Mercury diffuses into the glass tube or can be found as "inactive" mercury compounds in the phosphor coating and is no longer available for the discharge process.

Table 4 shows an overview on the different major paths of mercury consumption which is oxidation, amalgamation, adsorption and absorption. A part of the mercury dosed in a lamp is "consumed" meaning that it is no longer available for the light-producing discharge process. Mercury diffuses into the glass tube or can be found as "inactive" mercury compounds in the phosphor coating. Depending on many different factors such as phosphor composition, lamp chemicals (e.g. getter, emitter), production, use etc. consumption is individual for every lamp. Since 4a lamps do not contain phosphor this reaction path is less important, however the electrical power density in these lamps is high in many cases, and the wall is warm therefore some of these reactions can go rapidly and the upper limit of 15 mg is needed for this category of lamps.

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 could be reduced, based on scientific and technical progress in the recent years.

Some of the lamps in 4(a) are non-linear lamps which always need more mercury compared to linear lamps .

Measurements of mercury consumption are performed under controlled, optimized laboratory conditions using standardised switching cycles. Operation conditions can significantly increase the consumption (e.g. depending on dimming, switching frequency, high/low temperatures, use as emergency lighting, mains voltage, ballast etc.). This has to be taken into account to find the necessary Hg dosing amount. It is very important that mercury does not reach the limiting factor for the lifetime.

In summary, one has to distinguish between maximum limit value and the mercury content, that on average needs to have a much lower, average or nominal value, to account for variance in lamp manufacturing and operation and to account for market surveillance, with adequate protection of both customer and producer.

Besides the Hg consumption and dosing inaccuracy for high power amalgam lamps another aspect is highly important. These lamps are mainly used for working in a water environment in both cold and warm water conditions. The amalgam takes care that the Hg pressure and with that the light output with respect to water temperature are at proper levels for disinfection. This is regulated by the %Hg in a metal alloy (together they form the amalgam).

For example:

If 15 mg of Hg is dosed in 200mg of allow, you get 7.5% of Hg. This leads to certain (needed) behavior of light output vs temperature, both in the cold as in hot environments. If during life 1 mg Hg consumption occurs (is average in High power amalgam lamp) the lamps ends with 14mg in 200 mg alloy lamp at end of life. This is 7% Hg, leading to practically the same behavior.

If one would start dosing 2 mg in these lamps and would use only 27 mg alloy, this would lead again to ~7.5% Hg.

At end of life of these lamps however, after 1 mg Hg consumption, this lamps now contains 1mg Hg in the 27mg alloy. This is only 3.7% Hg. This means that the light output as function of temperature behavior has changed tremendously!

This is unacceptable for the water treatment applications.

Measurements of mercury consumption are performed under controlled, optimized laboratory conditions using standardised switching cycles. Operation conditions can significantly increase the consumption (dimming, switching, high/low temperatures, use as emergency lighting, mains voltage, ballast etc). This has to be taken into account to find the necessary Hg dosing amount. It is very important that mercury is not getting the limiting factor for the lifetime. The operating temperature ranges of these lamps are a very critical operating parameter and a leading need for the amount of mercury dosage. It is also important to note that the mercury content of quartz UVC germicidal lamps prior to 2011 was on average 20-30mg per lamp and great efforts were made by the manufacturers to reduce this to the current level of 15mg. In addition many of these lamps are high output and very high output lamps which generate significantly higher wall loading than general lighting fluorescent lamps. Combined with the demanding operating environments the mercury dosing required for these lamps is higher than general lighting lamps.

From a market surveillance perspective, it is necessary to take the following sampling aspect into account. LightingEurope proposes a sampling procedure allowing for a relatively small sample size[7]:

Under this sampling procedure, a maximum 1 out of 10 lamps is allowed to fail when tested: *if 1 out of 5 gives higher mercury content than limit, repeat for next 5. If these 5 are lower than limit, compliance is demonstrated. If another measurement is above the limit, the manufacturer's records shall be requested*.

If the limit value is too close to the mean value, much higher numbers of lamps have to be tested in order to have statistical and legal certainty that a certain product is within the limit.

Higher numbers of necessary samples result in higher testing costs, both for manufacturers and market surveillance authorities. LightingEurope believes that market surveillance regarding mercury in lamps in the EU Member States is not at all addressed in an appropriate way.

In summary, one has to distinguish between different mercury values in use. Mercury values publicly communicated to customers are average or nominal values. A maximum limit value has to consider the technical variances in lamp manufacturing processes, mercury dosing and lamp operation as well as market surveillance.

Annual Mercury content of lamps covered by this exemption EU-28:

In the following table the market (number of produced lamps [Mio pieces]) and the corresponding mercury amount put on the EU-28 market is listed from 2009 to 2013[8]. The lamps in table 5 ("Other FL") are all lamps covered by the exemption 1(e), 2(b)(2), 2(b3),

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[7] http://www.elcfed.org/documents/070628_ELC%20guidance%20document%20on%20rohs%20market%20surveillance.pdf

[8] Preparatory Study on Light Sources for Ecodesign and/or Energy Labelling Requirements ('Lot 8/9/19) Draft Interim Report, Task 2, Nov.2014, VITO, VHK

2(b)(4) and 4(a) of Annex III, RoHS Directive. The average mercury amounts per lamp are estimated by LightingEurope member companies as displayed in the table. The corresponding average mercury amount per lamp is also displayed. This can be seen more as a worst case estimation, especially for 2012-2013, where a maximum limit of 15 mg was introduced. The data show a decreasing market from 2009 to 2013. In 2013 ca. 19 Mio non-linear and special purpose lamps have been marketed The overall roughly estimated yearly mercury input decreased from 2009 to 2013 from ca 510 kg to 190 kg (-63%, decrease per lamp: -33%).

EU28	2009	2010	2011	2012	2013
Other FL [Mio pcs.]	34	32	27	23	19
Mercury [kg]	510	480	324	230	190
Average Hg content of lamps [mg]	15,0	15,0	12,0	10,0	10,0

Table 3: Market and mercury content of lamps covered by the exemptions 1(e), 2(b)(2), 2(b)(3), 2(b)(4) and 4(a) of Annex III, RoHS Directive [Mio pcs.]. Data represent sales in EU-28[14].Mercury content has been estimated by LightingEurope.

In Figure 6 the market development as well as the mercury development is displayed graphically for the lamps in the table above. There are no statistical data specifically for 4(a) lamps only. In addition there are also many market players who are not member of LightingEurope.

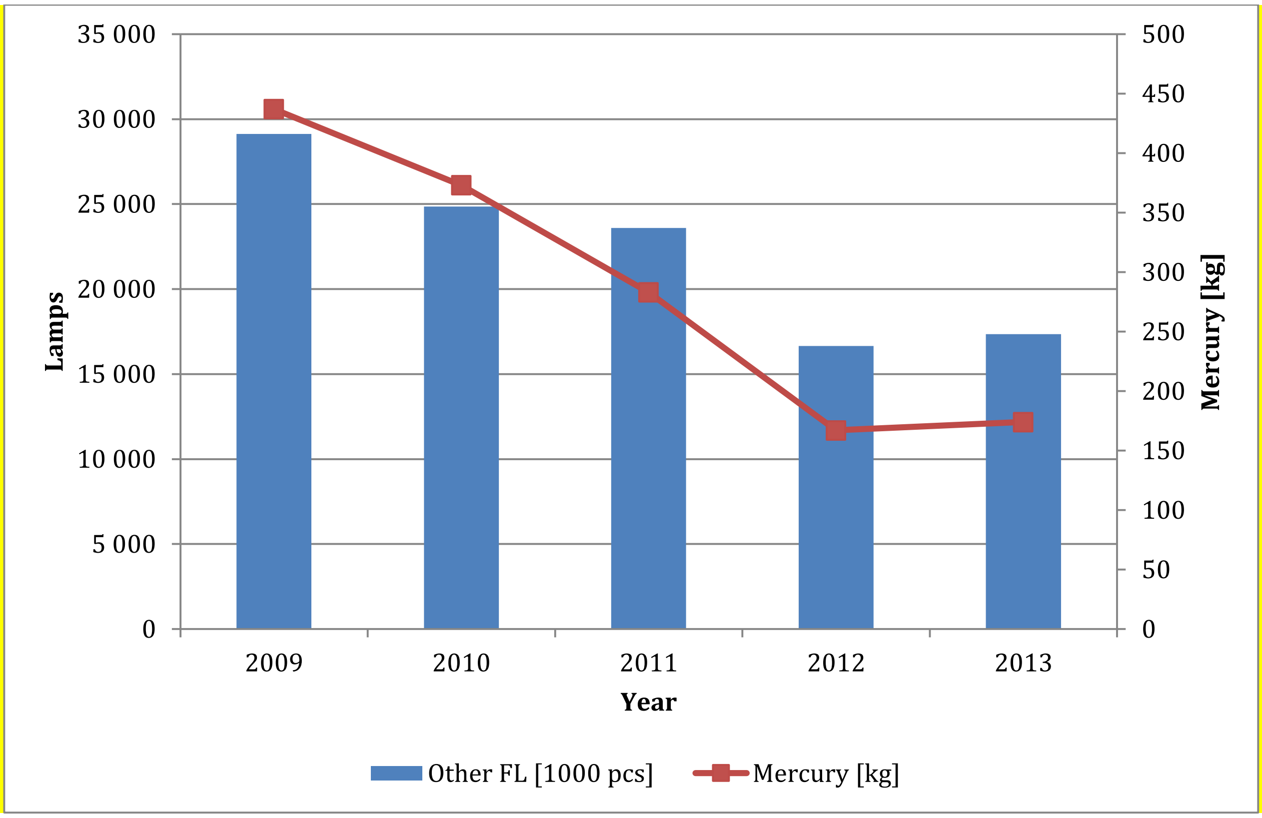


Figure 6: Overall market of most lamps covered by the exemption 1(e), 2(b)(2), 2(b3), 2(b)(4) and 4(a) of Annex III, RoHS Directives [1.000 pcs] and overall mercury amount put on the EU market (+ Norway, plus Switzerland, see text), including tri-band, halophosphate and longlife types. Data were collected by LightingEurope from member companies.

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.[9] This means that currently the efficacy of the lamp is the determining parameter. Low pressure UVC lamps will provide an efficiency of UVC watts/electrical watts of 30-40% depending on the specific lamp, purpose and its operating conditions. This is compared to medium pressure HID lamps which provide 7-

[9] *(see Enlighten report, Section 5, Ch. 3 fig. 4 & 5)*

10% efficiency in the same UVC region of 254nm. There are no LED alternatives to and it only makes sense to perform a LCA comparing it with a mercury-free lamp if the specific characteristics and requirements to the low pressure lamp are met. LightingEurope is not aware of such LCAs.

5 Waste management

5.1 Waste streams

☒ Article is collected and sent without dismantling for recycling

☐ Article is collected and completely refurbished for reuse

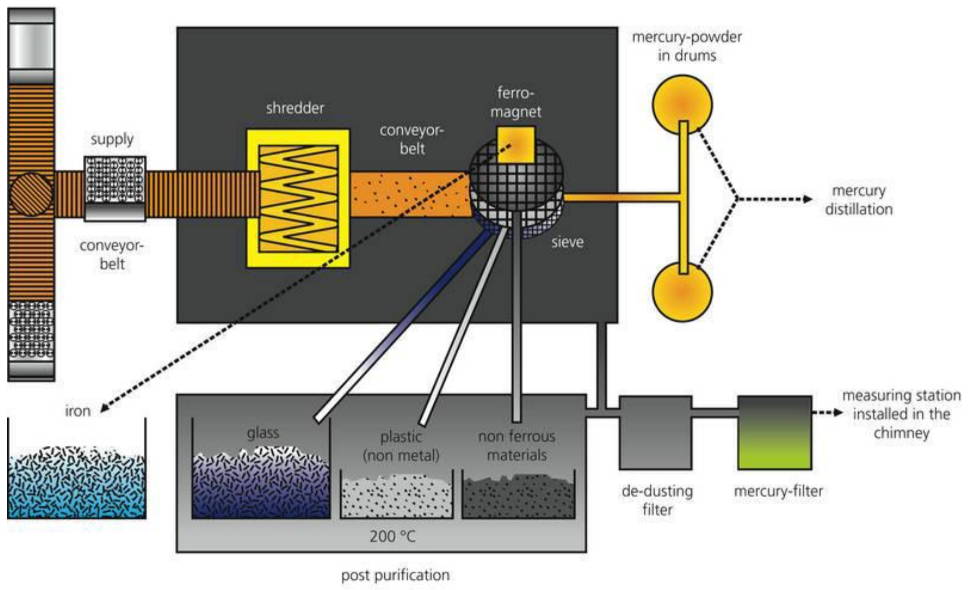
☐ Article is collected and dismantled:

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

☐ Article cannot be recycled and is therefore:

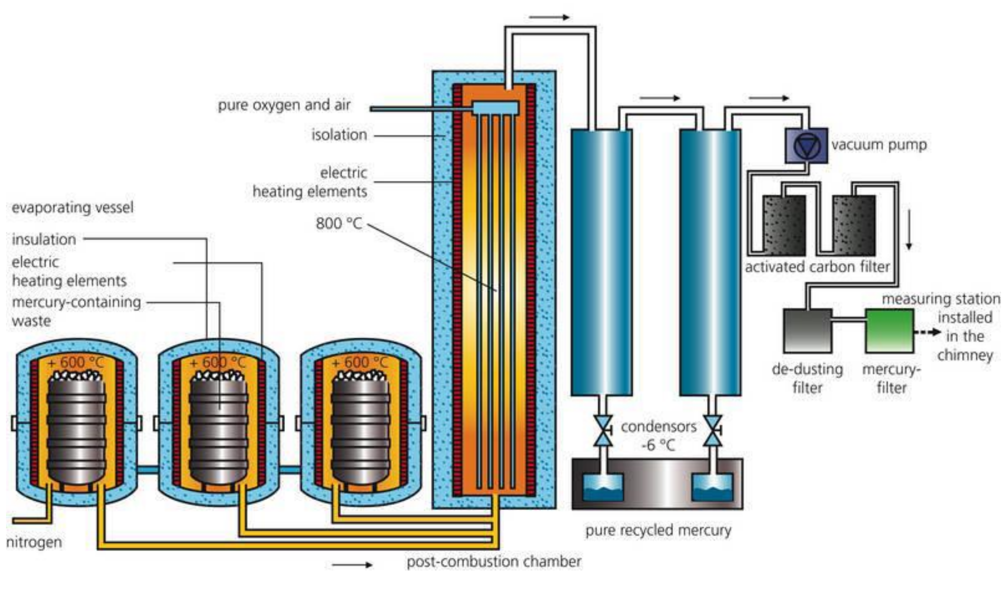
- ☐ Sent for energy return
- ☐ Landfilled

Double capped linear 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. Double capped linear 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 shows the various steps in the recycling process:



The next picture illustrates the specifics of recycling the mercury:

Mercury distillation



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 4 kg per inhabitant 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.

- Collection through municipalities:

  Where infrastructure allows collection means are placed at municipality depots.

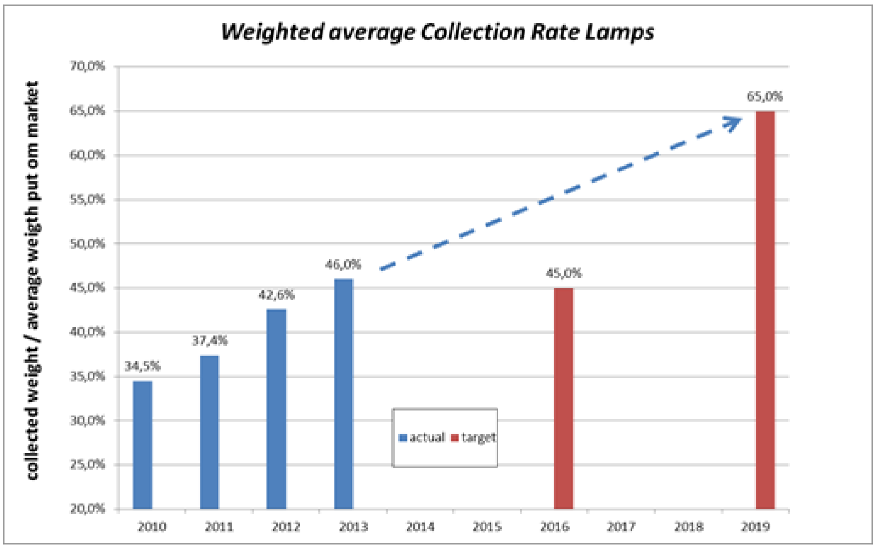
Campaigns are being executed or have been planned to re-enforce the role of the government to educate the population that gas-discharge lamps have to be disposed of in an environmentally friendly way.

5.2 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

Mercury content market:

In table 3 of chapter 4.2.4 the number of produced lamps and the corresponding mercury amount put on the EU (plus Switzerland, plus Norway) market of most lamps falling in the current exemptions 1(e), 2(b)(2), 2(b3), 2(b)(4) and 4(a) of Annex III, RoHS Directive (all non-linear lamps and all lamps for special purposes) is listed from 2009 to 2013. The data show a decreasing market from 2011 to 2012. In 2013 ca 17,3 Mio non-linear and special purpose lamps have been marketed. The overall roughly estimated yearly mercury input decreased from 2009 to 2013 from ca 437 kg to 174 kg (-60%, decrease per lamp: -33%).



of *Figure 7: Weighted average Collection Rate Lamps (all lamps): 2010 – 2013 (blue) and targets 2016-2019 (red)*

The collection rate of lamps in Europe compared to the average amount of lamps put on the market during 2010 – 2013 is shown in graph in figure 7. It also includes the targets set for

2016 and 2019. Please be aware that this graph includes all lamp types, not specific ones. Some lamps falling in exemption 2 (b)(4) and 4(a) are also included in the statistical data for T5 and T8 lamps.

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. It also includes the targets set for 2016 and 2019. Please be aware that this graph includes all lamp types, not specific ones.

As figures for the sale and replacement of these lamps are not available it is impossible to give specific accurate figures for lamps falling into this exemption.

6 Substitution

Can the substance of this exemption be substituted?

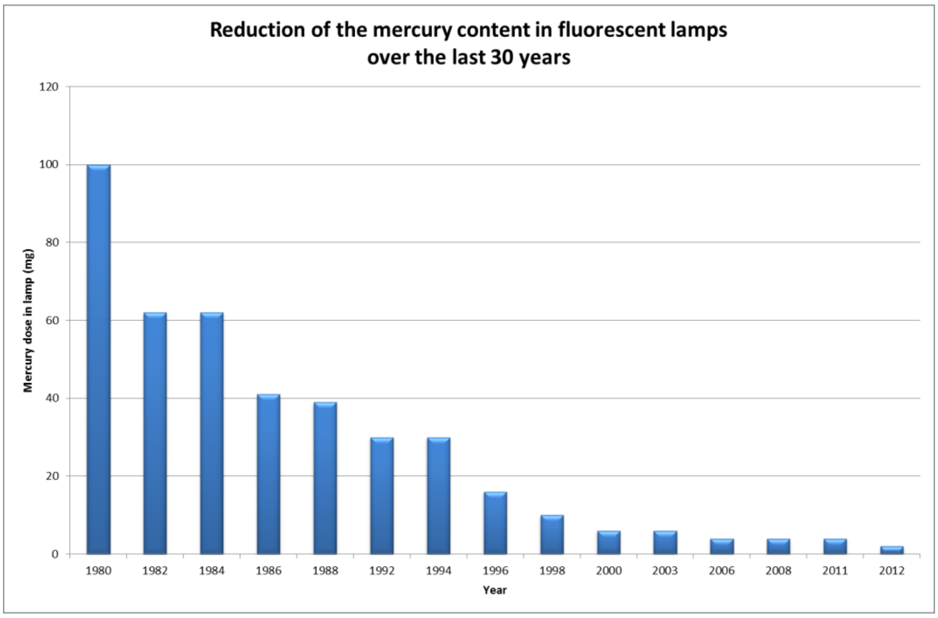
☐ Yes, by
- ☐ Design changes:
- ☐ Other materials:
- ☐ Other substance:

☒ No
Justification: see in below chapters

6.1 Substituting mercury in the fluorescent technology

- Fluorescent 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 (Figure 8)

-



- Figure 8: Mercury content of fluorescent lamps

- During the last decades several approaches have been made to design low pressure discharge lamps where the light producing element Hg is replaced by a less hazardous material. So far no approach yielded a result with comparable luminous efficacy, product cost and product availability as the still state of the art Hg low pressure discharge lamps.

- The mercury discharge is highly efficient in transforming electrical energy into light. Since the UV light is directly used in lamps from 4a, the Stokes shift caused by the phosphor in general lighting lamps does not limit the efficiency of these lamps[10].

- Attempts to generate UV with noble gases succeeded partially[11]. However the plasma radiates in the deep UV and less efficiently. The UV is partially absorbed by the oxygen and water in the air an additional difficulty in designing machines.

- LED technology is not available today and for the foreseeable future in the deep UVC range as per this exemption request 4(a) for UVC lamps.

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[10] M Haverlag, Mercury-free discharges for lighting, J. Phys. D: Appl. Phys. 40 (2007)
[11] 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)

6.2 Substituting fluorescent technology by mercury free technology

In general there are several technologies to produce light with a mercury free technology. Some of them are much less efficient e.g. incandescent lighting as well as tungsten halogen lamp technology. These technologies do not present a viable product for the generation of UVC wavelengths.

A much more promising approach is LED technology, which is the technical basis for many future lighting applications. However the predominant focus in this technology remains today in the much larger available market of general lighting and visible light applications. There are advancements in this art in higher wavelengths in 360 -450nm LEDs but these wavelengths will not perform the same function required for germicidal and bacteria disinfection. The wavelength of 185nm, which is used in applications for ultra-pure water processing for pharmaceuticals and microprocessor manufacturing, is not available. — Wavelengths in the range of 254nm through 267nm is available today, but not nearly at comparable efficiency levels as low pressure Hg technology. LED manufacturers don't expect to see these products commercially available for the next 5-10 years.

6.2.1 Feasibility of the alternatives

For the lamp types covered under this exemption request the low pressure gas discharge lamp is the most effective and efficient light source available today and for the foreseeable future. On a comparative basis these light sources are considerably more efficient than the alternative medium pressure lamps and consume less mercury per UVC watt produced. There have been advances in the reduction of mercury since implementation of the changes effective July 2013 and additional research and development by the lamp manufacturers to further increase the wattage range while maintaining the 15mg mercury limit thus producing higher UVC watts per measure of mercury dosed.

LEDs

LEDs in principle could be chosen as radiation technology for special purposes, provided following criteria are fulfilled.

1. Wall Plug Efficiency (conversion efficiency of electrical power into the useful UV light flux in watts) is comparable to fluorescent lamps
2. Effectiveness is comparable to fluorescent lamps (i.e. same disinfection effect etc.)
3. Regulation/approbation is passed

In the following discussion each of these 3 criteria is discussed.

Wall Plug Efficiency

In contrast to general lighting lamps, (compact) fluorescent lamps for special purposes emit radiation in UV or blue wavelength bands. LEDs for general lighting purposes are made of InGaN, a material that emits blue light which with the help of phosphors is converted into the desired visible wavelengths. Theory says you can only convert from shorter wavelengths to longer. It is therefore impossible to create UV light with LED material as used for visible light LEDs.

There are other materials available from which LEDs can be made that generate UV light (like AlGaN), however the efficiency (radiated power out / electrical power in) of LEDs with those materials is still very low. In the UVC (100-280nm) and UVB (280-315nm), the WPE (wall plug efficiency of LEDs are below 1%), where the wall plug efficiency of low pressure gas discharge UVC lamps are 30-40% or even higher. See below pictures in which public data from several manufacturers are put together in one graph (figure 9).

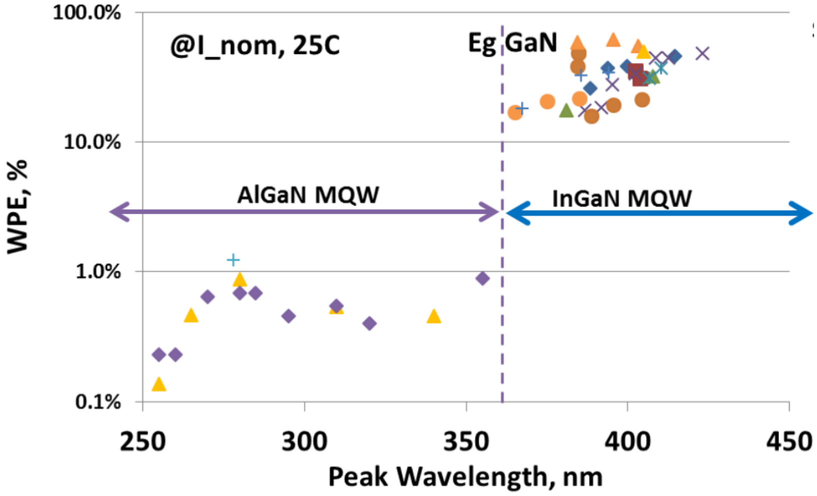

Figure 9 LEDs (UVC-Blue): WPE vs wavelength (data of several manufacturers)

Conclusion: No comparable WPE for LEDs below 380 nm; making LED not suitable soon as a practical alternative for: Disinfection/purification of air/water/surfaces

Effectiveness is comparable

For most special purposes no tests results are available yet w.r.t. effectiveness to reach the desired effect in a comparison study between equipment using (single capped) fluorescent lamps and equipment using LEDs. For most of these applications that is not done yet as no LEDs were available.

Regulation/approbation is passed

CE conformity and other European directives for special purpose applications (like for instance approbation of medical devices for phototherapy) is based on fluorescent lamps (with respect to safety and system responsibility). Furthermore, most alternative lamps in practice need replacement of the equipment ballast. Effectively, this would imply that the complete equipment needs to be replaced, which produces additional waste when still properly operating components need to be disposed.

Current equipment using compact fluorescent lamps is not designed to take care of the heat generated by LEDs. (Where in lamps the generated heat is mostly radiated away, with LEDs the heat has to be transported away by conduction.). Spare part replacement of compact fluorescent lamps with LED based lamps is therefore generally not possible.

Current equipment using compact fluorescent lamps are designed to have a very homogenous spatial radiation distribution compared to LED retrofit lamps. The more directional light of an LED will give a different radiation distribution in the same equipment.

Conclusion is that LEDs do currently not provide a viable alternative for replacing single capped fluorescent lamps for special purposes.

6.2.2 Availability of substitutes

The low pressure gas discharge lamps covered under this exemption request 4(a) are continuing to be developed and advanced for higher efficiency and therefore less mercury consumed per watt of UVC generated. While LEDs are available as substitutes for general lighting applications this is not the case today and in the next 5-10 years as indicated by the LED manufacturers.

UV LEDs are available from several suppliers. However, as is clear from above efficiency is very low. No public roadmaps exist that predict when UV LEDs with acceptable output and efficiency are available. Only after that design and development of LED based equipment can start and after that customer/patient tests could start.

6.2.3 Impacts of substitution

6.2.3.1 Environmental impact of substitutes

For UV-C and UV-B: dramatically higher energy consumption due to low efficiency of currently available UV-C and UV-B LEDs. For UV-A: Also for applications needing below 380 nm energy consumption will go up due to lower efficiency of UV A LEDs in that wavelength region.

For all LED solutions:

Most alternative lamps in practice need replacement of the equipment ballast. Effectively, this would imply that the complete equipment needs to be replaced, which produces additional waste when still properly operating components need to be disposed.

Current equipment using fluorescent lamps is not designed to take care of the heat generated by LEDs. (Where in lamps the generated heat is mostly radiated away, with LEDs the heat has to be transported away by conduction.). Spare part replacement of fluorescent lamps with LED based lamps is therefore not always possible.

Current equipment using fluorescent lamps are designed to have a very homogenous spatial radiation distribution compared to LED retrofit lamps. The more directional light of an LED will give a different radiation distribution in the same equipment. Means to homogenize the light distribution in general lighting applications, may not work in UVA/UVB region as most plastic material cannot withstand the UV radiation.

The lamp driver in an existing application can be conventional electromagnetic ballast or a high frequency electronic driver. 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 discharge lamp. The large diversity of drivers is not meant for an electronically ballasted LED lamp and there is no interface described for LED lamps yet. This makes it difficult to know for a customer which ballast is used and what LED lamp to apply as retrofit. A wrong combination can lead to instable lamp power for the LED (light flicker) and even to safety problems.

For light sources in professional applications, economic and environmental consequence of prohibiting mercury would result in a mandatory refurbishment of installed luminaires while still operating correctly (not yet at end-of-life) when employing right light source component replacements. This would result in the creation of a lot of additional unnecessary waste on the EU market. Typical life cycle of equipment in disinfection, medical and insect trap applications is 20-50 years

6.2.3.2 Health and safety impact of substitutes

Although the LED technology doesn't contain mercury, it may contain other sorts of substances as lead and plastics. So far researches have not been conclusive in the overall effect of a LED lamps in comparison with a CFL lamp. The low pressure lamps used today for large scale water disinfection are replacing chemical forms of disinfection such as the use of chlorine in water purification. This chemical treatment bears its own environmental impacts.

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:

Closing of factories in the EU with accompanying loss of jobs

Banning these lamps leads to an increased spent of EU consumers due to enforced usage of more expensive LED lamps (no cheaper alternative yet) or to an increase of use of less energy efficient alternatives.

Alternative technologies to be implemented implying additional investments

6.2.3.4 Impact of substitution on innovation

Focus of the current lighting industry is already on the further development of LED technology. An extension of the exemption will have no negative effect on the efforts to further innovate in LED.

6.2.4 Future trends of substitution

LED technology performance is developing, however the balance between cost price, lifetime and efficiency and the speed in which it will take place is not yet clear. LED development is fast in general lighting while special purpose lamps are for a niche market where the LED development is somewhat slower and there are no current or near term LEDs available in this spectral output range.

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.

Mercury cannot be removed from fluorescent lamps as described above. No technologies could be developed having similar high efficiencies.

8 Reduction of mercury content of lamps

For fluorescent lamps falling in exemption 2(b)(4) and 4(a) it was necessary to implement a maximum limit of 15 mg coming in force in 2010[12] with effect between 2012 and 2013. But only a part of the lamps had to be changed. Some of them already had lower mercury content as similar mercury reduction measures were adopted for general lighting lamps produced on the same equipment. However this market is characterized by smaller, specialty lamp manufacturers which use slower speed equipment and more handcrafted lamp manufacturing processes especially in the quartz envelope products and very high wattage lamps such as amalgam. In these products as the higher wattages evolve the consumption of mercury per UVC watt produced is Further reduction of mercury might technically be possible with high economic effort and R&D resources. But these financial and human resources are needed for the investments and the running transfer to LED technology. The major part of development resources of lighting companies have already been allocated on LED based alternatives. On the other hand the lamps are required for the existing base of fixtures systems and luminaires, which are also highly efficient and have a long life time.

9 Other relevant information

Reference to Minamata Convention and LE contributions on global mercury reduction.

10 Information that should be regarded as proprietary

[12] Commission Decision 2010/571/EU of 24 September 2010

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