Request to renew Exemption 2(b)(4)-I

under Annex III of the RoHS Directive 2011/65/EU

2(b)(4) -I Lamps for other general lighting and special purposes (e.g. induction lamps): 15 mg may be used per lamp

Date: 01 August 2023

LIGHTINGEUROPE
THE VOICE OF THE LIGHTING INDUSTRY

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1 Name and contact details

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2 Reason for application

LightingEurope submits this application to:	request the extension of the existing exemption **no. 2(b)(4)-I of Annex III** (expires on 24 February 2025)
LightingEurope proposes to slighlty adapt the current wording of the exemption to:	2(b)(4)- I Lamps for special purposes: 15 mg
LightingEurope requests a duration of:	Maximum validity period required

3 Summary of the exemption request

DIRECTIVE 2011/65/EU Article 5(2) states that exemptions have a validity period of up to 5 years for categories 1 to 7, 10 and 11 of Annex I. At the same time, Article 5(5) states that an application for renewal of an exemption shall be made no later than 18 months before the exemption expires.

The current wording of exemption 2(b)(4)-I contains "induction lamps" as an example. Applications using induction lamps have been widely replaced by SSL technologies.

Technically, most induction lamps are usually already covered by exemption 2(b)(3), as most of these lamps on the market are non-linear lamps. Therefore, LightingEurope proposes to delete this example.

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

2(b)(4)- I: Lamps for other general lighting and special purposes (e.g. induction lamps): 15 mg.

LightingEurope asks for renewal of the exemption with a slight change in wording:

2(b)(4)-I: Lamps for special purposes: 15mg

LightingEurope requests a five-year renewal of the exemption. This request is based on the following analysis: most of the fluorescent lamps falling in exemption 2(b)4-I are used in specialized equipment for industrial, commercial and medical fields and are not intended to be used as a source of general lighting. Specific applications and descriptions are given further in this application.

Annex III of the RoHS Directive explicitly names the following fluorescent lamp technologies and families:

- Compact fluorescent lamps (Exemptions 1(a)-1(g))
- Linear triband phosphor lamps for general lighting (2(a)(1) – 2(a)(5))
- Nonlinear triband phosphor lamps (2(b)(3))
- Cold cathode fluorescent lamps (3(a) – 3(c)).

These exemptions do not cover the full range of fluorescent lamps. The scope of exemption 2(b)(4)-I includes 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. Low-pressure discharge lamps without a fluorescent phosphor layer (e.g. UV-lamps) as well as medium and high pressure discharge lamps are covered by exemptions 4(a) – 4(f).

Exemption 2(b)(4)-I includes an inhomogeneous group of lamps with, amongst others, different:

- Form factors and lamp bases, e.g. linear, circular, square shape
- Technologies e.g. external ignition
- Colour spectra, e.g. white, coloured (red, green, blue, yellow), blue / UV spectra
- Applications and purposes, e.g., colour, explosion protection, colour comparison, studio lighting, medical and pharmaceutical use, inspection, sorting and binning,

insect pest management in horticulture, agri-food and hospitals and curing/drying (e.g., flexo printing / polymerisation).

Fluorescent lamps are very energy- and resource efficient lamps, highly required in the market. They contain a small amount of intentionally added mercury in the discharge tube, which is essential to convert electrical energy to light. Mercury consumption of fluorescent tubes dropped approximately 90% in the past 20 years by implementing energy efficiency regulations, RoHS requirements and innovation programs. Lamps in the scope of exemption 2(b)(4)-I are in different lamp families with mercury content from < 2 mg up to 15 mg. They are mainly niche products with very low market shares compared to the other (fluorescent) lamps. According to the calculations made by LightingEurope (chapter 4), taking the mean of all different lamps and lamp types sold on the EU market by LightingEurope members the average amount of mercury per lamp is around 8 mg. The total amount of mercury put on the EU market per year is far below 4 kg. More detailed data on number of pieces and mercury content is provided separately in confidentiality.

With their limited sets of components, fluorescent tubes are very resource efficient. There are systems in place for efficient recycling (WEEE), resulting in reduced impact of mercury and other materials on the environment.

There is a growing market for mercury-free lamps based on LED technology, with features such as energy efficiency and design flexibility. These solutions have primarily been in the field of general lighting and, in some limited cases, for special light sources which are not included in this application.

The special purpose portfolio offered to the market within this exemption addresses fragmented, specialized niche applications with a vast variety of parameters (form, fit, factor, length, spectrum, etc.), that cannot be easily replaced by LED technology. Therefore, LED technology is not available in the market for most applications. In fact, the functional objective and requirements of its special purpose applications are not met, for instance, as LED chips or retrofit lamps have different light spectra compared to various special fluorescent lamp spectra.

In case certain LED retrofit lamps might be offered in the market, it must be decided on a case-by-case basis whether they can be applied as effective and suitable replacement lamps for the existing equipment for a certain special purpose application. It mostly requires involvement of people with professional expertise due to the following challenges:

1) Electrical compatibility: an LED retrofit lamp has to operate on the installed control gear without any problems. Therefore, it is essential to know what kind of control gear is present in the luminaire or equipment. It can require technical changes (rewiring), especially in equipment with an electronic control gear. Full compatibility with all installed conventional or electronic control gears is not possible.
2) Applicable legal and compliance requirements like mandatory conformity assessments, CE declarations, and labelling of the changed luminaire, fixture or other electrical or electronic equipment have to be fulfilled. The person installing the LED based solution is responsible to perform testing and measure to ensure that the new system fulfils these requirements including when the original lamp type is installed again. It is inevitable that LED retrofit and conversion lamps will also be installed by people who are not qualified professionals if corresponding fluorescent lamps are no longer available. There is a risk that this will not be carried out correctly. This risks the safety of consumers and operators or that the lighting will not be suitable.
3) Different light and spectral distribution: due to the LED tubes changed optical characteristics vs. the existing lamp the light plan could be no longer optimal for the application. Changes in the spectral power distribution can alter the performance of the equipment resulting in recalibration, recertification, incompatibility or false results. Expert knowledge is needed to get a good result. Especially in medical applications small spectral differences (1 nanometer shifts of a peak) can mean the difference between a successful treatment or substandard performance and possible injury.

For most of the special purpose lamps covered by this exemption, there are currently no LED retrofit or conversion lamps.

The requirements mentioned in Article 5(a) of the RoHS Directive for the inclusion of materials and components of EEE for specific applications in the list in Annex III are met for mercury in fluorescent lamps covered by exemption 2(b)(4)-I not exceeding 15 mg per lamp as summarized in Table 1.

For this reason, an exemption for mercury in lamps covered by the exemption is required with a maximum validity period and with no expiry date.

Requirement according RoHS Article 5(a)	Status for mercury in fluorescent lamps covered by this exemption not exceeding 15 mg per lamp
their elimination or substitution via design changes or materials and components which do not require any of the materials or substances listed in Annex II is scientifically or technically impracticable,	The replacement of mercury in fluorescent lamps is scientifically and technically impracticable. Lamps in the scope can be replaced only in very limited cases by some LED lamps. As a result, installed equipment has to be replaced in some circumstances with very high socio-economic impact by mercury-free fixtures that normally need lead exemptions in some component materials.
the reliability of substitutes is not ensured,	Only very limited LED replacement lamps are available for special purpose applications; hence the applicability, reliability and lifetime of the product cannot be judged.
the total negative environmental, health and consumer safety impacts caused by substitution are likely to outweigh the total environmental, health and consumer safety benefits thereof.	LED based equipment so far does not reveal a clear general environmental benefit e.g. due to higher energy efficiency during the use phase. Lamps falling in exemption 2(b)4-I usually must fulfill special requirements making them suitable for the desired application. It must be analyzed case by case whether a fluorescent lamp can be technically replaced and whether the substitute LED based lamp can fully fulfill all required functionalities.

Table 1: Requirements according RoHS Article 5/a) and their fulfilment for mercury in fluorescent lamps covered by this exemption, not exceeding 15 mg per lamp

4 Technical description of the exemption request

4.1 Description of the lamps and their applications

4.1.1 Lamps and applications covered by this exemption

Annex III of the RoHS Directive explicitly names the following fluorescent lamp technologies and families:

- Compact fluorescent lamps (Exemptions 1(a)-1(f))
- Linear triband phosphor lamps for general lighting (2(a)(1) – 2(a)(5))
- Nonlinear triband phosphor lamps (2(b)(3))
- Cold cathode fluorescent lamps (3((a) – 3(c))

These exemptions do not cover the full range of fluorescent lamps. The scope of exemption 2(b)(4)-I 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. Low-pressure discharge lamps without a fluorescent phosphor layer (e.g. UV-lamps) as well as medium and high pressure discharge lamps are covered by exemptions 4(a) – 4(f), see also Figure 1.

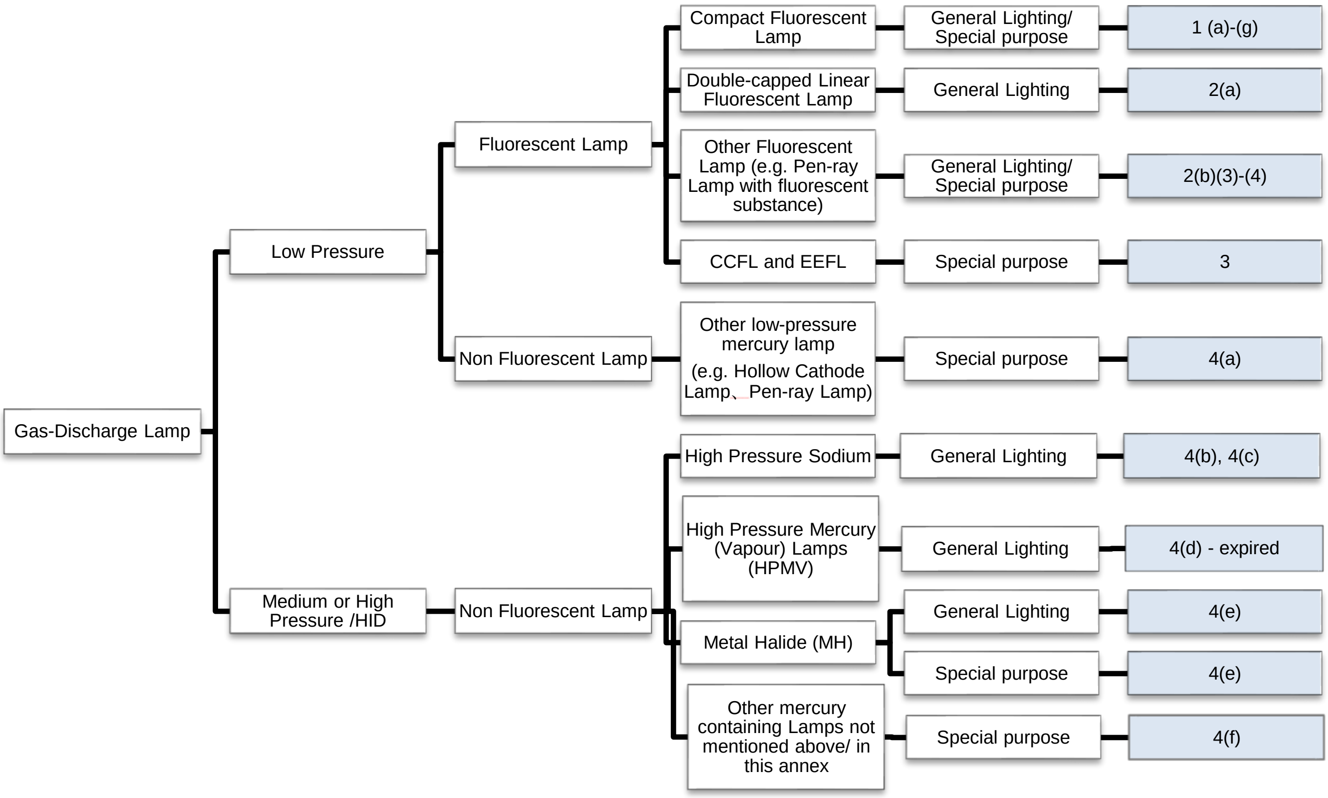


Figure 1: Chart on the hierarchy of lamps and exemptions.

In exemption 2(b)(4)-I the term "special purpose'' is introduced. Similarly to "general lighting" (purpose), there is no definition for special purpose lamps in the RoHS Directive. This is a different approach compared to the new Commission Regulation (EU) 2019/2020 of 1 October 2019 laying down ecodesign requirements for light sources. There, special purpose lamps are exempted from many obligations.

LightingEurope's Definition of "general purpose" lamps:

The regulation 2019/2020[1] on Ecodesign requirements is listing light sources exempted from the requirements of the regulation in its Annex III (see also chapter 9).

[1] Commission Regulation (EU) 2019/2020 of 1 October 2019 laying down ecodesign requirements for light sources and separate control gears pursuant to Directive 2009/125/EC of the European Parliament and of the Council and repealing Commission Regulations (EC) No 244/2009, (EC) No 245/2009 and (EU) No 1194/2012 (Text with EEA relevance.)

This list was compiled to adress exemptions from mainly energy efficiency requirements.

A main focus in the exemptions of the RoHS Directive is to reduce mercury to the lowest technical possible content in lamps sold in high amounts such as regular T5, T8, CFL. Separate exemptions have been defined where higher amounts were needed for technical reasons in order to fulfill requirements which the aforementioned lamps could not fulfil. These technical reasons included different phosphors, phosphor additives, special Hg dosing, external ignition strips.

Therefore, a slightly different definition for ‘’special purpose’’ lamps is needed for the RoHS Directive. LightingEurope has developed the following definitions for “general lighting” (purpose) as well as “special purpose” lamps:

Definition of general lighting

General lighting is substantially uniform lighting of an area without provision for special local requirements (ref.: definition in IEC 60050(845, ed.2.0)).

General lighting lamps are primarily marketed or commercialized for visible light applications. They have standard shape, dimensions and cap. General lighting applications are those, which are not covered by the “special purposes” definition, where more specific local requirements apply.

Examples of general lighting applications are:

- Indoor lighting (e.g., offices, hospitals, elderly homes, apartment buildings, public buildings, theatres, train- and metro stations, retail shops, industry halls, etc.)
- Outdoor lighting (e.g., streets, highways, tunnels, façades, parks, sport facilities)

Definition of special purposes

Special purposes are applications where specific requirements apply. Lamps for special purpose applications have documented and communicated application-specific features. These lamps have a specific design, specification or materials or are tested and approved for these specific applications.

Examples of special purpose applications with specific lighting requirements related to exemption 2(b)(4)-I are listed below:

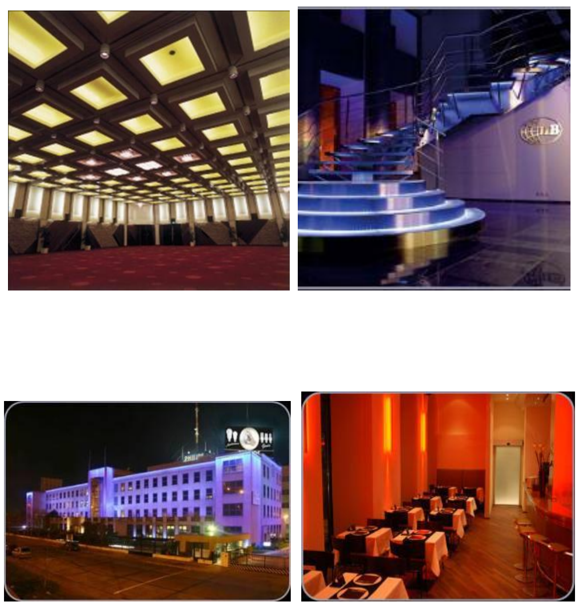
- Technical lighting for colour comparison
- Studio lighting

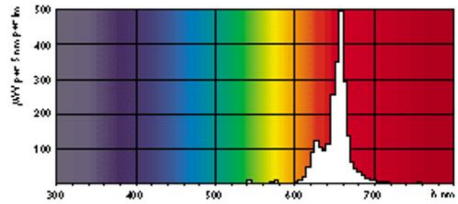
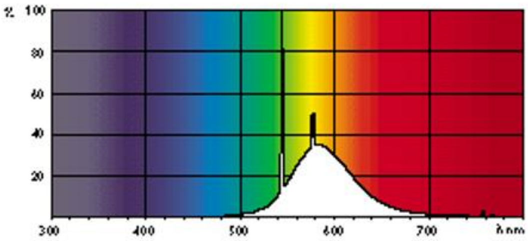
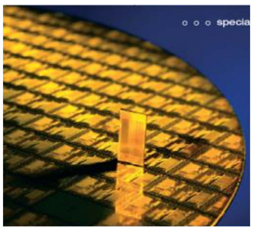
- Coloured lighting (incl. saturated colours), e.g., coloured, black light blue
- Blue Light Therapy
- Potentially explosive atmospheres (e.g., requiring special ignition strips or special lamp bases)
- Medical polymerization, Medical equipment, Pharmaceutical equipment
- Inspection
- Sorting and Binning
- Graphic arts (see Viewing Standard)
- Pest management in horticulture, agri-food and hospital

Exemption 2(b)(4)-I includes an inhomogeneous group of lamps falling in most of the above mentioned examples. They reveal amongst others different:

- Form factors and bases, e.g. linear, circular, square shape
- Technologies e.g., induction, external ignition strips
- Phosphor types and blends
- Mercury content, from < 2 mg up to a maximum of 15 mg, average 8 mg
- Technical Standards

In the following table a selection of lamps falling in 2(b)(4)-I is listed.

Lamps and applications	Example
1. Colour applications Coloured fluorescent lamps are a cost-effective, creative illumination and decoration, providing uniform light along the entire length of the lamp. Areas of application are mentioned below:	
1.1 Decorative applications: Shops, supermarkets and department stores, clubs, bars, restaurants, hotels, accent lighting. Needed as replacement lamps for existing installations.	Decorative lighting 

1.2. Photographic dark room: **Red** lamps are used in photographic studios for photographic development of film material.	  
1.3. Clean Room lighting: **Yellow** lamps are used for photolithography to avoid unwanted exposure of photoresist by light of shorter wavelengths (semiconductor industry (wafer), printing industry (lithography)) (https://en.wikipedia.org/wiki/Cleanroom)).	Clean room lighting    

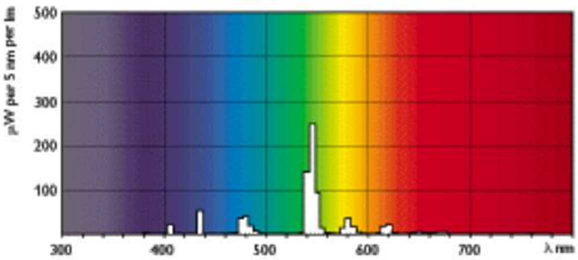
1.4. Food and Horticulture pest management:

Green colour lamp are used in horticulture, agri-food, hospitals to avoid the spread of diseases and contamination, etc. They are also used for photo-chemical reaction to make a vitamin derivative.

The different spectral eye sensitivity curves of different insect species requires also a different lampspectrum for effectivity reasons (e.g., combined with UV- lamp (RoHS ex. 2(b)(4)-II)). Green LED retrofit lamps are either not available or not effective (see Ecological control of insect pests - abiotec.com).

Horticulture and Food pest management:

(insect control and photo-chemical)

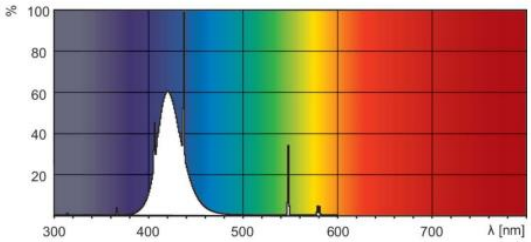


2. Curing, polymerisation etc.

Fluorescent **Blue** spectral lamps (mainly light in the blue spectrum) are used for effective and safe curing of large areas of plastic, for hardening paints, lacquers and modern adhesives, and for flexo-printing polymerization.

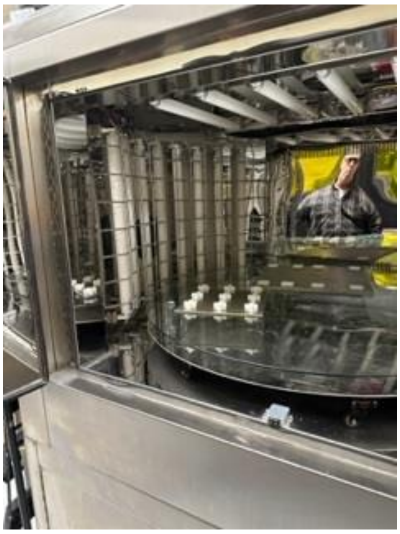
(Lamps with spectrum mainly in UV are covered by exemption 2b4-II)

Photometric data

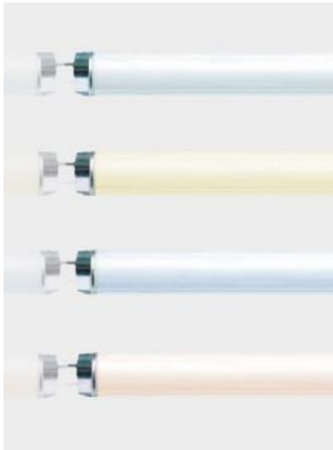


Spectral Power Distribution Colour - TL 140W/03

Curing and polymerisation device:



Flexo-graphic printing:

3. Applications with specific technical requirements: **T12, T8, T5 lamps** Applications include explosion sensitive atmospheres: Lamps for explosion proof luminaires in places with higher risk of fire or explosion. Mainly used for installations such as oil riggs, chemical plants (Fa6 base)	 
4. Special visibility task lighting Colour Proof Lamps are used to increase visibility for special tasks in special purpose applications such as the printing industry, graphic art workshops, colour matching, industrial inspection, sorting, binning, etc.	  

5. Medical, Photo therapy

Lamps with special spectra for medical applications such as

- Medical equipment,

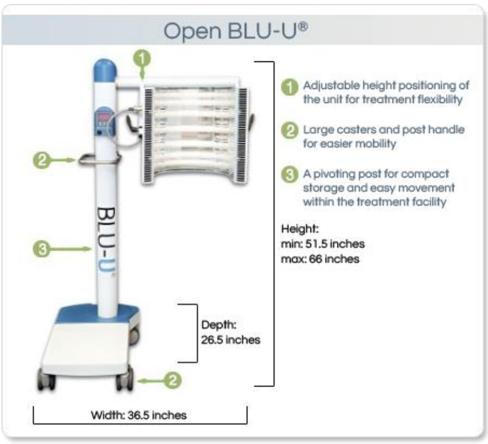
- Drug activation,

- Skin cancer therapy

- non-UV phototherapy treatment

- Pharmaceutical drug testing

- Dental practice treatments illumination (light features)



See more BLU-U information

Table 2: Non-exhaustive list of fluorescent lamps falling in exemption 2(b)(4)-I

Out of those applications listed above, for this request, the exemption is no longer needed for coloured lamps used for new decorative lighting installations (section 1.1.) as LED technology is available for new equipment. However, coloured LED retrofit lamps are not available. Therefore, the sale of coloured fluorescent lamps is still required for existing installations to avoid early replacement of the equipment. These lamps will continue to be sold as spare parts according to Articles 3(27) and 4(4)(f) RoHS Directive after the exemption finally expires (‘repair as produced principle’).

However, other special purpose applications still need coloured lamps (or other special spectra) for new installations (see sections 1.2, 1.3, 1.4, 2, 3, 4, 5 above in Table 2).

Fluorescent lamps are essential parts of an installed lighting equipment. Because of the physics of gas discharge, fluorescent lamps cannot be operated on its own directly on a mains voltage. Conventional control gears (CCG) have traditionally been used to limit the current. Fluorescent lamps in a luminaire with a CCG usually need a so-called starter, an electronic component which is replaced together with the lamp due to a limited life time. The introduction of electronic control gears (ECG) brought several advantages compared to CCG regarding power consumption, lifetime, maintenance costs, temperature behaviour, switching, flicker, dimming etc.

Some of the lamps falling in exemption 2(b)(4)-I can be used with CCG as well as with ECG. There are numerous different control gears available on the market offering various functionalities. They are used depending on customer requirements and/or equipment design, such as dimming or temperature range. This is especially important for commercial, professional and industrial applications as these systems typically have very specific requirements for lamp operating, light output and performance specifications.

International standards make sure that lamps, control gears and light management systems can be operated in a safe and efficient way and that lamps and the control gear can be exchanged while keeping a reliable system.

4.1.2 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

Lamps covered by exemption 2(b)(4)-I are considered to be category 5: "Lighting equipment" in case they are used in luminaires. But they can also be used in addition or exclusively in other RoHS categories 4, 6, 8, 9 and 11 (if they are used in equipment).

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

Equipment of category 8 and 9:

➔ yes

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

4.2 Description of the substance

4.2.1 Substance covered by this exemption

LightingEurope is asking for exempting

☐ Pb ☐ Cd ☒ Hg ☐ Cr-VI ☐ PBB ☐ PBDE

☐ DEHP ☐ DBP ☐ BBP ☐ DIBP

4.2.2 Function of mercury in lamps[2]

Mercury is intentionally applied to fluorescent lamps in homogenous materials exceeding the limit value of 0.1% weight. Fluorescent lamps are low-pressure discharge lamps. When electric current flows through the lamp bulb (=discharge tube), the mercury atoms in a gas phase inside it are excited and produce UV radiation. This UV light is then converted into visible light by the fluorescent coating on the internal surface of the glass tube of the lamp bulb (see figure 2 below). The composition of the coating determines light colour and colour rendering.

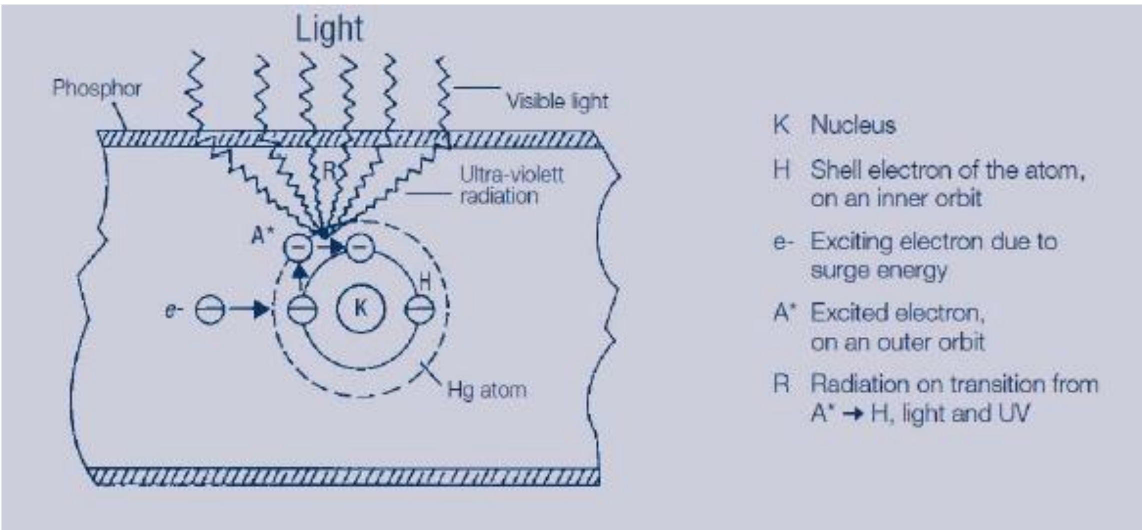


Figure 2: Electrical current is passed via the two filament electrodes through the tube, which is filled with partially ionized gas. The electrons excite mercury atoms to emit short-wave ultra-violet light, which is converted into visible light in the phosphor layer on the inside of the tube. Different light colours are produced depending on the phosphor mix.

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. The most common dosing technologies for fluorescent lamps are listed and displayed below in figure 3.

- Manual pipetting or needle injection of liquid mercury
- Semi- or fully automatic dosing, disc needle injection of liquid mercury

[2] This text is the same as in our 2015 exemption renewal request, the only difference is with regard to the mercury put on the market at the end of paragraph 4.2.4.

- 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

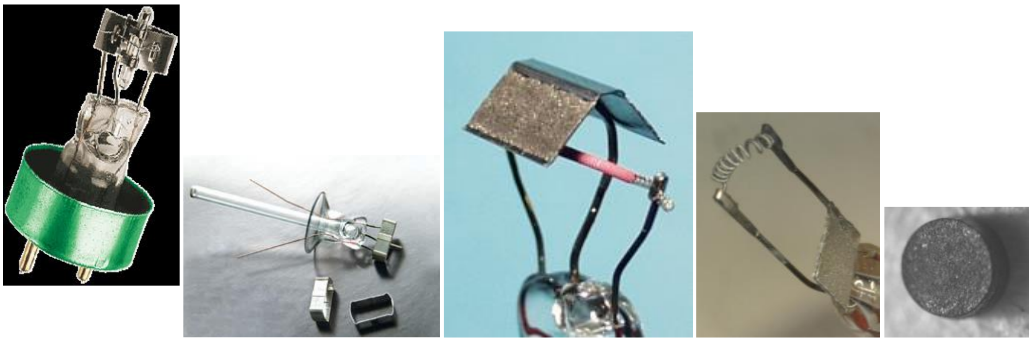


Figure 3: Mercury dosing technologies
From left: Hg-capsule; metal-alloy[3], metal alloy "roof", metal alloy "flag", HgFe pill

4.2.4 Amount of mercury

Mercury is dosed in the discharge tube during lamp manufacturing as homogeneous material (pill, capsule, liquid). 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 the lamp's life, mercury is consumed inside the discharge tube itself. It is bound amongst others to the phosphor layer and the glass.[4]

Coating of phosphors and glass can give a reduction of the Hg consumption over the lamp's 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 the RoHS Directive sets a maximum limit of 15 mg for the lamps covered by this exemption.

In order to be able to dose the required amounts of mercury, precise technologies are necessary and available[5]. But even with accurate technologies there is a certain

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[3] I. Snijkers-Hendrickx et. al., Low-mercury containing discharge lamps, 2007.
[4] I. Snijkers-Hendrickx et al, Low-Mercury Containing Discharge Lamps. Sustainable and Environmental Friendly Lighting Solutions, LS 11.

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

distribution of the amount of mercury per single dose. The different dosing techniques have different variances. 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.[6]

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 the ErP Ecodesign regulation requirement.[7]

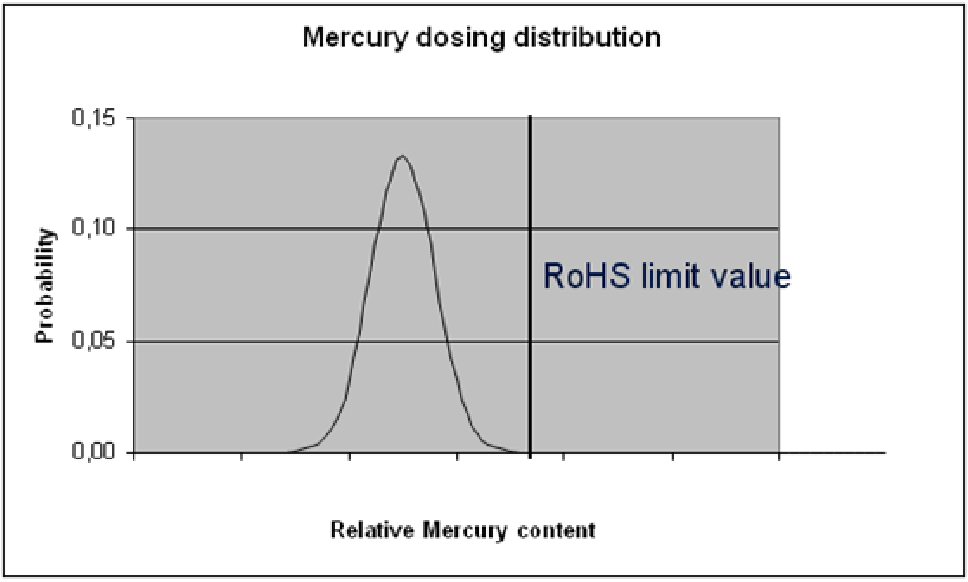

Figure 4: Simplified illustration (example only) of the effect of mercury dosing variance, where an average value needs to be chosen lower than the RoHS limit value. The graph displays measurements of the mercury content in dosing units performed as quality control during their production.

The most important aspect of Hg content in lamps is the so-called *mercury consumption.*

The amount of mercury which is needed for the low pressure discharge process is very low, significantly below 100 µg for a 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 not shortened due to a too low available amount of mercury. A balance has to be found taking into account mercury needed over lifetime, mercury variance per dosing

[6] ELC Exemption request, 2012.
[7] Commission Regulation (EU) 2019/2020 of 1 October 2019.

unit, but also the measurement failure when estimating the amount of mercury in a lamp for market surveillance.

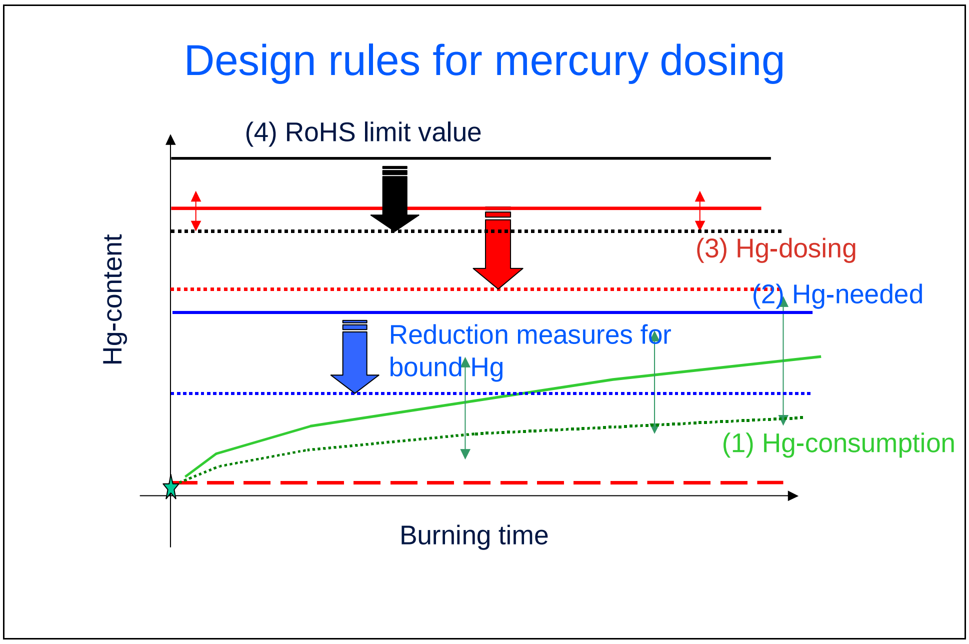

Figure 5: Design rules for mercury dosing in fluorescent lamps, schematically showing the process of setting RoHS limit values based on insights in mercury consumption and mercury dosing.

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 (in the gas-phase), depending on the lamp dimensions. However, because of the several mercury consumption mechanisms a significantly higher amount must be dosed (which will be explained below).

In practice, mercury from the discharge gets consumed over lamp life. The amount of this consumption is much higher than that what the gas discharge needs for functioning. The mercury gets mostly deposited and effectively bonded to the glass and the phosphor layer. This is reflected by the solid green 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). To obtain the designed lamp life, the right amount of mercury must be dosed, taking into account the consumption during lamp lifetime and the variance. In Figure 5 the solid blue line 2 represents the typical amount that is needed and the solid red line 3 is the amount that also incorporates the variance. 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 RoHS Directive.

The black solid line 4 in Figure 5 represents 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 the RoHS content limit.

The key to the 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.

Table 3 shows an overview of 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. The consumption is individual for every lamp, depending on many different factors such as phosphor composition, lamp chemicals (e.g. getter, emitter), production, use etc.

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.

Path	Mechanism	Main Promoter	Source	Location of bound Hg
Oxidation	$Hg^{+} + x\,O \rightarrow HgO_x$	impurities prematerials	processing coating	coating
Amalgamation	$Hg^{+} + Me \rightarrow HgMe$ 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 3: Main mercury consumption mechanisms oxidation, amalgamation, adsorption and absorption. 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.

Non-linear fluorescent lamps always need more mercury compared to linear lamps, also special phosphors and additives are causing higher mercury consumption in lamps falling in exemption 2(b)(4)-I.

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

Annual Mercury content of lamps covered by this exemption EU-27:

The total lamp sales for the special purpose lamps in this exemption have declined. While these numbers are not available from any published data bases, LightingEurope members estimate that under exemption 2(b)(4)-I far below 4kg mercury are placed on the EU market each year. The exact market data is shared in confidentiality.

We assume that the market for 2(b)(4)-I lamps will be rather stable in the next years.

4.2.5 Environmental assessments, LCAs

There are several external LCA's which have been performed for 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. On the other hand, for lamps covered by the exemption 2(b)(4)-I the specific purpose is essential. It only makes sense to perform an LCA and compare it with a lead- and mercury-free lamp if the specific characteristics and requirements of the fluorescent lamp are met. LightingEurope is not aware of such LCAs from public, independent sources.

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

Linear fluorescent lamps are in the scope of the WEEE Directive (2012/19/EU). Take back systems are installed in all EU Member States: end users and most commercial customers can bring back the lamps free of charge. Linear fluorescent lamps are collected separately from general household waste and separately from other WEEE waste. Additionally, a dedicated recycling process exists for lamps as legislation dictates that the mercury shall be removed from the gas discharge lamps. Mercury is recovered in specialised facilities by distillation.

The picture below shows the various steps in the recycling process:

[8] See Enlighten report, Section 5, Ch. 3 fig. 4 & 5.

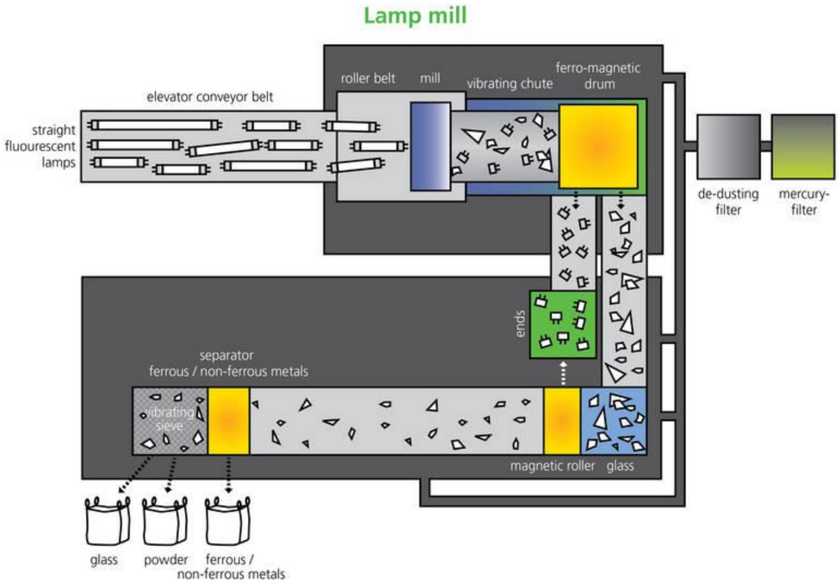

Figure 6a: Recycling steps of fluorescent lamps in Indaver (Belgium).
Source: www.indaver.be/waste-treatment/recycling/mercurial-waste.html

The next picture illustrates the specifics of recycling the mercury:

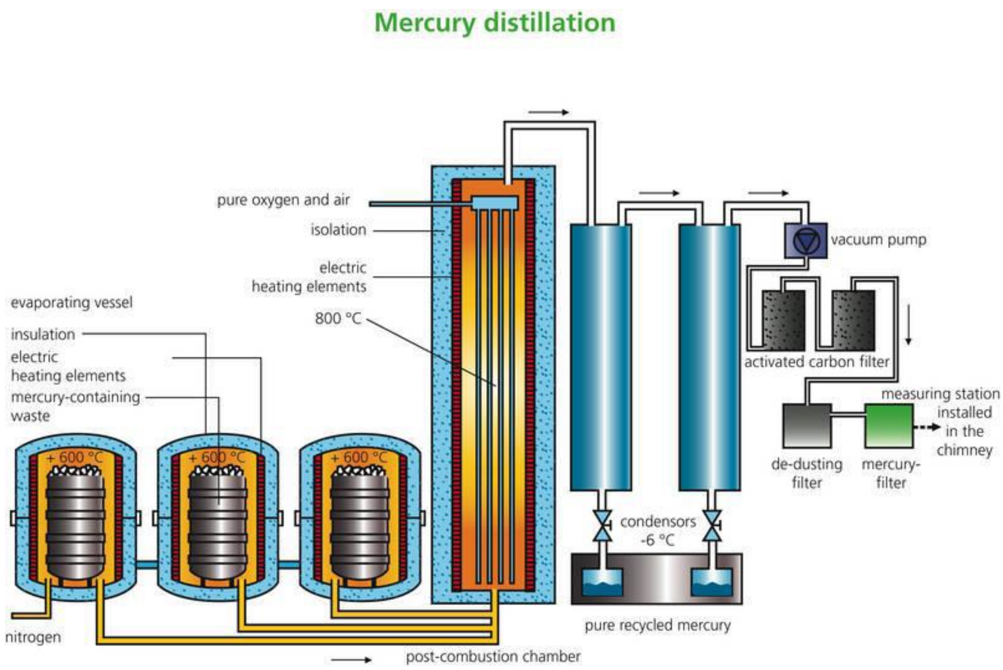

Figure 6b Specific recycling steps of mercury in Indaver (Belgium)

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

The targets that were set as a consequence of the present legislation are 45% of EEE placed in the market in 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. The goal is to comply with present and upcoming 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 / in their shops. Collection is done upon notification.
- Collection through municipalities:

  Where infrastructure allows collection means are placed at municipality depots.

Figure 7: Stibat/Wecycle-collection street as present in the Dutch Do-it-yourself shops of Gamma.

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.

Mercury content market:

Lamps covered by exemption 2(b)(4)-I are a small, declining, but still important segment of all fluorescent lamps.

The total lamp sales for the special purpose lamps in this exemption have declined. While these numbers are not available from any published data bases, LightingEurope members estimate that under exemption 2(b)(4)-I far below 4kg mercury are placed on the EU market each year. The exact market data is shared in confidentiality.

The collection rate of lamps in Europe compared to the average amount of lamps put on the market during 2010 – 2018 is shown in the graph below. It also includes the targets set for 2016 and 2019. Please be aware that this graph includes all lamp types, not specifically the lamps in this exemption. The collection rate illustrated in the graph below is based on a preliminary data collection exercise from 9 EU Member States carried out together with EucoLight.

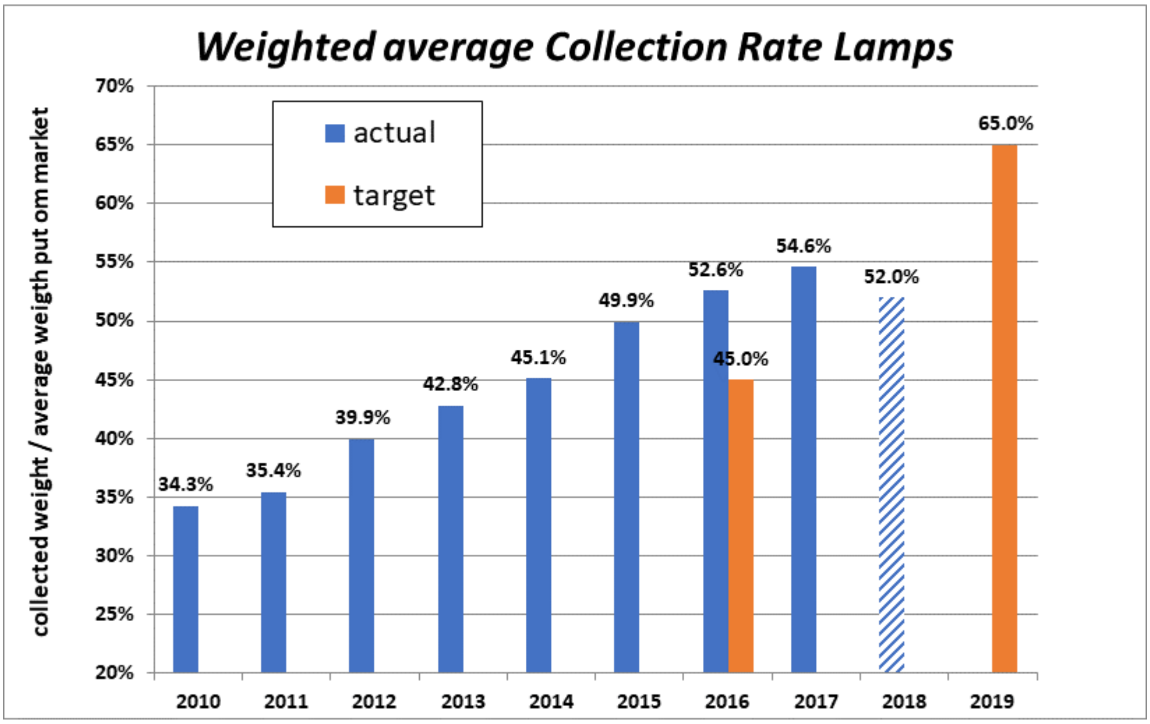

Figure 8: Weighted average Collection Rate Lamps (all lamps): 2010 – 2018 (blue); targets 2016-2019 (orange) and preliminary results from 9 EU Member States (blue stripes). Please be aware that this graph includes all lamp types, not only the specific fluorescent lamps in this exemption.

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

- CFL lamps and other non-linear low- or high pressure lamps as well as LED retrofit lamps
- Fluorescent tubes, long CFL without integrated ballast

Linear fluorescent lamps are recycled separately, however, the recyclers cannot see the difference between a normal fluorescent tube or a tube for special lighting. Thus, the collection rate for lamps in 2(b)4-I cannot be measured separately. The lamps in exemption 2(b)4-I are replaced by professionals and their collection rate is higher than from lamps in households. It is also important to note that almost every country within the EU has a collection and recycling service organisation (figure 9, status per 2019).

The material re-use of fluorescent lamps is impressive - more than 80% of the material is re-used. The glass and metals are easy to recycle. The alternative LED based light-sources, containing plastics, electronics, cooling bodies and thermal glue are more difficult to recycle.

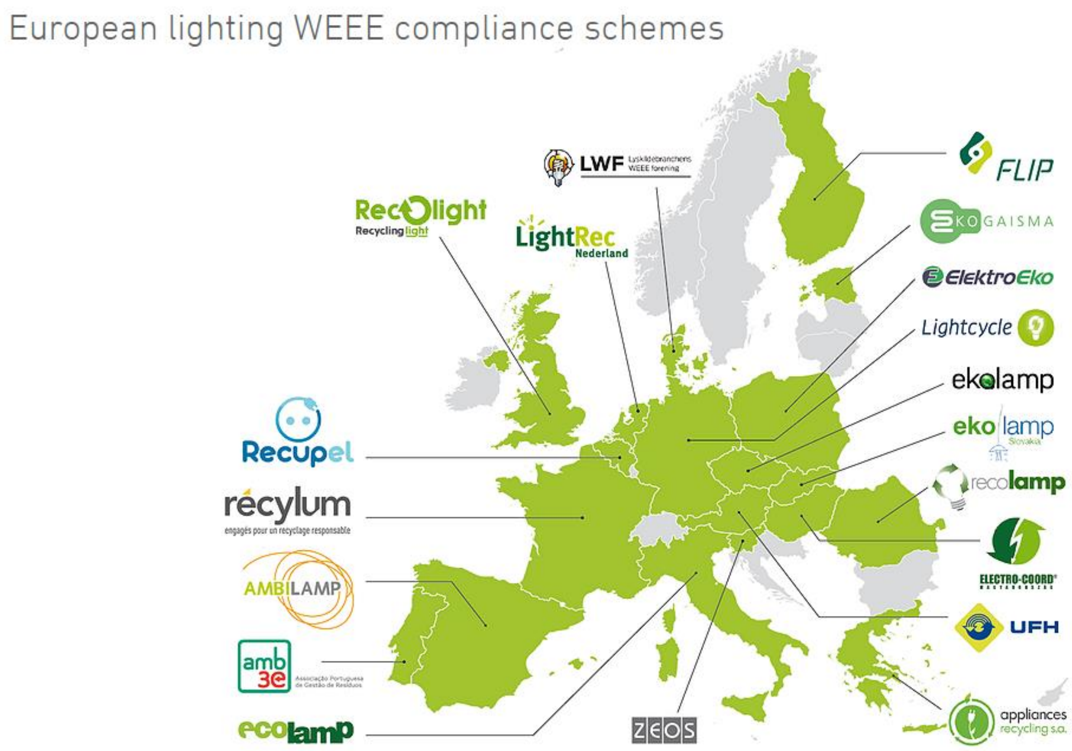

Figure 9: Map of European lighting WEEE compliance schemes [9]

6 Substitution

Can the substance of this exemption be substituted?

☐ Yes, by ☒ No

- ☐ Design changes: Justification: see in below sections
- ☐ Other materials:
- ☐ Other substance:

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[9] EucoLight: https://www.eucolight.org/our-members

6.1 Substituting mercury in the fluorescent technology

Fluorescent lamps need a certain amount of mercury since it is consumed over their life. The technology has evolved over the last decade and the average amount of mercury within special purpose fluorescent technology per lamp has considerably been reduced.

During the last decades several attempts 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 alternatives for the use of mercury in discharge lamps as discussed below have been determined not to be practicable for special purpose applications and are added as background information on replacement efforts made.

The mercury discharge is highly efficient in transforming electrical energy into light. There are only two drawbacks: first, the generated UV radiation needs to be transformed into visible light, where large losses occur (this is due to the Stokes shift (an energetic UV photon generates, a much lower energy, visible photon)). Secondly, the discharge contains mercury.[10]

Attempts to generate UV with noble gases succeeded partially.[11] However, the plasma radiates in the deep UV. At these wavelengths, the Stokes shift is even larger causing lower efficiency. The lack of suitable phosphors[12] prohibited progress in this direction. Other alternatives investigated are low pressure metal halides (for example InI, InBr, GaI3).[13] Such plasmas generate the visible light directly without the Stokes shift of the phosphor.[14] There are alternatives from research but the efficiency in prototypes lamps is significantly reduced to approx. 40lm/W level or below. Mass production is not (yet) feasible.

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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).
[12] J. Dexpert-Ghysa, Re-processing CRT phosphors for mercury-free applications, J. of Luminescence, 129, 1968, (2009).
[13] 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.
[14] 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.

One approach has been the dielectric barrier discharge, which uses a Xe excimer as light producing species. It had been developed into a product with an efficacy of about 20 lumen/W. However, this is not applicable to special purpose lamps as defined above.

Using rare gases instead of mercury leads to a dramatic efficiency drop. 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.

Low operating temperature and immediate lumen output could be reached if a light producing species is used which is in gaseous state at room temperature. There had been the theoretical idea that it might be possible to find a suitable operating regime for a nitrogen - rare gas low pressure discharge. In cooperation with the University of Augsburg and the Bayerische Forschungsstiftung (BFS) a project had been started to develop such a light source. The status of research work has been published in a Diploma Thesis and a publication.[15] In 2013, it became quite clear that an efficacy of more than 10lm/W cannot be realized with the approaches followed so far. Therefore the BFS cancelled the project support and in consequence the whole research work has been stopped.

Another approach has been to use metal halide compounds as light source in low pressure discharge. This activity has been carried out in manufacturer's laboratories as well as in cooperation with the University of Augsburg. In his PhD thesis "Spectroscopic Investigation of Indium Halides as Substitutes of Mercury in Low Pressure Discharges for Lighting Applications", published 2011 at the University of Augsburg, S. Briefi shows that about 30 lm/W might have been reached with a potential to get up to 60 lm/W. This efficacy is still much lower than that of Hg containing LPD lamps. Furthermore, a metal halide LPD lamp needs to be heated up to > 200°C to get the lighting salt evaporated. This causes special issues for safety and very slow run-up behavior. With the arrival of equally efficient LED light sources, research to alternative discharges has fully stopped.

6.2 Substituting fluorescent technology by mercury free technology

Two key ways to use LED technology in order to substitute fluorescent lamps can be distinguished:

(1) Replacement lamps

[15] Diploma Thesis "Spektrale Intensität der N2-Strahlung in einer Argon-Niederdruck-Bogenentladung für den Einsatz als Lichtquelle", published 2009 by R. Friedl at the University of Augsburg; „Spectral intensity of the N2 emission in argon low-pressure arc discharges for lighting purposes", R. Friedl, U. Fantz, New J. Phys. 14 043016 ,2012.

(2) New installation

For most cases of special purpose lamps this results in the need to install new equipment with an LED light source instead of a fluorescent lamp.

6.2.1 Feasibility of the alternatives

The fluorescent lamps falling in exemption 2(b)4-I in practice have only one mercury free alternative, LED. In case a luminaire or a light-source containing EEE is newly installed, new LED-based fixtures are increasingly used. However, due to the small market size for these lamps and equipment this is either impractical or there are no LED substitutes available for the specialty equipment manufacturer. LightingEurope is not aware of any relevant available LED lamp retrofit solutions. There are several key aspects that need to be considered when evaluating potential LED based replacement for conventional fluorescent based lighting applications: (1) electrical compatibility, (2) light distribution and lumen or UV radiation output, (3) lack of standards.

According to information from installers and experts working in the field of replacing fluorescent lamps by LED lamps for general lighting, the requirements are summarized below. The experience of these experts is relevant for those cases where LED replacement lamps start entering the market for special purpose lamps. In practical situations these experts use guidance included in the compatibility tables published by the manufacturers of the LED retrofit lamps[16] but still many issues occur.

It is focused on compatibility issues for LED lamps replacing double ended fluorescent lamps. The exchange of a fluorescent lamp for an LED alternative can lead to:

1. A well operating lamp
2. A lamp that is giving light but not at the right operating point (too high or too low light flux)
3. An LED lamp that does not give light at all
4. A flickering lamp that extinguishes regularly
5. An LED lamp that is broken, or the control gear that gets damaged
6. Safety issues.

So far LED lamps falling in exemption 2(b)4-I are in practice not existing. In theory some additional aspects would have to be considered:

[16] Signify: https://www.assets.signify.com/is/content/PhilipsLighting/Assets/philips-lighting/global/20190920-led-tube-compatibility-list-q3.pdf,
Ledvance: https://www.ledvance.com/professional/services/led-lamps-compatibility/ecg-compatibility/index.jsp

7. A lamp fulfilling the special purpose fully
8. A lamp fulfilling the special purpose partly
9. A lamp fulfilling the special purpose not at all or that has even negative side effects, damaging the equipment in which it is used or the radiated person or object
10. Compliance of the EEE with CE regulations / approval
11. Economically feasible (cost of replacement technology)

This is why, an increasing number of equipment and solutions are newly developed using integrated LED light sources. Due to the better usability of LED, smaller and new applications and fixtures are possible. But the required investment can be a serious roadblock.

LEDs in principle could be chosen as radiation technology for special purposes, provided that the following (retrofit) criteria are fulfilled:

1. The effectiveness is comparable to fluorescent lamps (i.e. same, photo-therapeutical effect, insect attraction rate etc.)
2. Regulation/approval is passed (certification to regulatory standards and clinical & medical testing and certification)

1. Effectiveness is not comparable

Retrofit LED lamps were tested by equipment makers but did not meet the required specifications. Special purpose lamps rely on highly specific spectral output under specific operating conditions. While LEDs may have the potential to have some of the spectral output requirements, the specific LED lamps have not been developed yet to meet the operating and performance characteristics of the fluorescent lamps subject to this exemption application.

2. Regulation/approval is passed

CE conformity and other European directives for special purpose applications (e.g., for approval of medical devices for phototherapy or the Q1B standard noted above), or applicable standards in the USA are based on fluorescent lamps (with respect to safety and system responsibility). Furthermore, in practice most alternative lamps 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.

Linear fluorescent lamps used in current equipment 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.

The lamp driver can be conventional electromagnetic ballast or a high frequency electronic driver. The market for new installations is moving towards electronic drivers due to new functionalities (e.g. dimmability) and upcoming energy efficiency legislation for the driver. Many professional fluorescent lamps 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 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 use as retrofit. A wrong combination can lead to instable lamp power for the LED (light flicker) and even to safety problems. A regular ballast for a professional fluorescent lamp is designed to be used with several subsequent lamps (at least 3-4 lamps). So if the combination of the ballast with the LED lamp is not working or even not available, the ballast needs to be changed prematurely.

The conclusion is that currently LEDs do not provide a viable alternative for replacing fluorescent lamps as covered by exemption 2(b)(4)-I.

6.2.2 Availability of substitutes

Currently, LightingEurope has no reliable market data about LED retrofit/conversion lamps which could be used as substitute for the diverse group of lamps falling in exemption 2(b)(4)-I. The equipment manufacturers have stated that there are no mercury free alternative light sources, such as LED, that meet the highly specified spectral output demands to provide the necessary functions in the use of their equipment. They are not aware of any LED manufacturers that provide a directly substitutable light source especially given the extremely small market size compared to general lighting lamps. In addition, in the case of medical lamps if substitutes were to become available, they could only be used after the units have passed the necessary extensive clinical testing (10 year process – see additional documents provided). For more detailed explanations of equipment manufacturers using these lamps see the additional confidential folder.

6.2.2.1 Environmental impact of substitutes

LED light sources are a promising technology to improve the energy efficiency of a lighting system as a whole.

LCA data of several lighting systems clearly showed that the system efficacy (use phase) has the highest impact on the environment during the Product Life Cycle. For an optimal system where the LED solution gives exactly the designed light distribution and an acceptable glare level, the LED solution can save energy and have a smaller footprint. Since the LED efficiency for UV sources is lower or at least not much higher than that of fluorescent lamps, and the lifetime is comparable, the difference in LCA is small. For LED based light sources for visual applications like studio lighting the LCA for "reparing" the existing equipment with a new lamp or installing fully new LED based equipment will depend on the complexity of the application where the lamp is used.

The purpose of every single luminaire at its place of operation has to always be considered, especially regarding lamps falling in exemption 2(b)(4)-I.

The new functionalities of LED solutions (colour changing, flexible form factors, tailor made seizes etc.) in the meantime lead to new lighting options and extension of the use of these products.

From a material composition it is also necessary to have a case by case view. Fluorescent lamps contain glass, metals, phosphors and mercury. These lamp components can be effectively recycled. LED based alternatives contain electrical and electronic components such as a control gear and a light engine with mounted LEDs. Electronic LEDs contain components and other materials using substances regulated in RoHS but exempted in certain applications (e.g. lead in high melting temperature type solders in diodes, lead in glass or ceramic in electronic components, lead in aluminium alloys used for the heatsink, lead in copper alloys etc.).

6.2.2.2 Health and safety impact of substitutes

This question is not applicable as there is no available substitute. However, if in new products or applications an LED based substitute is used, like in all CE relevant products, it is essential to make sure that the equipment is safe.

As described above special care has to be taken for the use of LED retrofit and conversion solutions in systems which were designed for a fluorescent lamp, including exchange of the lamps by professionals. It is inevitable that LED replacement lamps would also be installed by people who are not qualified professionals if these lamps are no longer available. There is a risk that this will not be carried out correctly creating safety risks for consumers or that the lighting will not be suitable.

6.2.2.3 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:

There is a severe change in the lighting market, also covering the production of lamps covered by exemption 2(b)(4)-I.

More and more applications are successfully entering the EU market using mercury-free technology. But the lamps covered by this exemption are still needed. If these lamps are no longer available, this could have severe consequences, which cannot be calculated here, but only qualitatively highlighted:

- Loss of jobs for the producers of the lamps, producers of the EEE using lamps and also for the users of EEE using lamps in case no alternative technologies are available. For more details on socio-economic impact please see the confidential folder of statements by customers.
- Banning of these lamps also leads to an increased creation of premature waste for equipment in the market that need replacement lamps, which are not available.
- Alternative technologies to be implemented require additional high investments (>100.000 €) for new equipment, e.g. therapy equipment. These products need a lot of materials and do also contain like all electronic equipment, certain hazardous substances, including lead. In medical devices a ban on these lamps would mean discontinuation of the equipment without an available substitute replacement. This equipment includes direct patient treatment with the lamp providing specific wavelengths for interaction with topical treatments for cancer patients. The loss of this will result in direct loss of this treatment protocol. There is no substitute. Other devices include calibration equipment and measurement for pharmaceuticals requiring conformance with ICH Q1B Option 2. ICH Q1B is the guideline for pharmaceutical drug testing. It is used by all major pharmaceutical drug developers & manufacturers all over the world.

- The ICH Q1B op 2 standard specifically requires a halo-phosphorous lamp. No LED can be used. If the exemption is lost, there could be lives impacted by the disruption in pharmaceutical drug distribution if companies would have to re-qualify their drugs under a different protocol.

6.2.2.4 Impact of substitution on innovation

LED lighting is a very innovative technology offering a high variety of new functionalities, high and still increasing energy efficiency and overall performance in nearly all areas.

The focus of the lighting industry is already on the further development of LED technology. An extension of the exemption will therefore have no negative effect on the efforts to further innovate in LED. The number of new equipment clearly shows that this technology has and continues to be very successful in the market even though the fluorescent lamps are available. Producers of EEE and especially customers of these products need certainty that spare parts are available for the promised and expected EEE lifetime. Otherwise, they would be much more careful in investing high amounts of money in new technologies if after a few years the products could probably no longer be used.

6.2.3 Future trends of substitution

As described above, in new products and applications there is a fast increase of the use of LED based technologies. On the other hand, LED retrofit or conversion lamps replacing lamps covered by exemption 2(b)(4)-I are nearly not available in the EU market. Fluorescent lamps are very efficient and reliable as they have been in the market for decades.

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 ☐ Restriction ☐ Registration

☐ SVHC ☐ Annex XIV

☐ Candidate list ☐ Annex XVII

☐ Proposal inclusion Annex XIV ☐ Registry of intentions

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

In paragraph 6.1 it is explained that various attempts 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. However, research and the development of the lighting industry is now completely focussed on mercury-free LED based solutions. Further work on reduction of mercury in fluorescent lamps would need high effort in research and investment in new production equipment. This would not make sense.

9 Other relevant information

NA.

10 Information that should be regarded as proprietary

LightingEurope provided a separate confidential document containing details on lamp numbers and total mercury content placed on the EU Market each year, as well as a separate confidential folder with statements made by customers regarding application specificities and socio-economic impact.