Assistance to the Commission on Technological Socio-Economic and Cost-Benefit Assessment Related to Exemptions from the Substance Restrictions in Electrical and Electronic Equipment:

Study to assess renewal requests for 29 RoHS 2 Annex III exemptions [no. I(a to e -lighting purpose), no. I(f - special purpose), no. 2(a), no. 2(b)(3), no. 2(b)(4), no. 3, no. 4(a), no. 4(b), no. 4(c), no. 4(e), no. 4(f), no. 5(b), no. 6(a), no. 6(b), no. 6(c), no. 7(a), no. 7(c) - I, no. 7(c) - II, no. 7(c) - IV, no. 8(b), no. 9, no. 15, no. 18b, no. 21, no. 24, no. 29, no. 32, no. 34, no. 37]

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Report for The European Commission

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Disclaimer:

Eunomia Research & Consulting, Oeko-Institut and Fraunhofer Institute IZM have taken due care in the preparation of this report to ensure that all facts and analysis presented are as accurate as possible within the scope of the project. However no guarantee is provided in respect of the information presented, and Eunomia Research & Consulting, Oeko-Institut and Fraunhofer Institute IZM are not responsible for decisions or actions taken on the basis of the content of this report.

4.0 Exemptions 1-4 Regarding the Use of Mercury in Lamps – General Aspects

Declaration

In the sections that precede the "Critical Review" the phrasings and wordings of stakeholders' explanations and arguments have been adopted from the documents provided by the stakeholders as far as required and reasonable in the context of the evaluation at hand. Formulations have been altered in cases where it was necessary to maintain the readability and comprehensibility of the text. These sections are based exclusively on information provided by applicants and stakeholders, unless otherwise stated.

Acronyms and Definitions

CFL	Compact fluorescent lamps
Danish EPA	The Ministry of Environment and Food of the Danish Environmental Protection Agency
EEE	Electrical and electronic equipment
EEB	European Environmental Bureau
Health FGOV	Belgish Federal Public Services for Health, Food Chain Safety and Environment
Hg	Mercury
EoL	Early end of life
Lm/W	Lumen per watt
LEU	LightingEurope
MPP	The Mercury Policy Project
NARVA	NARVA Lichtquellen GmbH + Co. KG
PZPO	The Polish Association of Lighting Industry
RPN	The Responsible Purchasing Network
WEEE	Waste EEE

LightingEurope (LEU), a lighting industry association and NARVA Lichtquellen GmbH + Co. KG (NARVA)[6], a manufacturer, each submitted multiple applications requesting the renewal of some of the exemptions related to mercury in lamps listed in Annex III of RoHS (exemptions 1-4, for further details see Section E.2.0 as well as Chapters 5.0 through 16.0 to see what exemptions are being evaluated in the course of this project). Though there may be some differences in their individual requests, many aspects raised in their documentation and in the documents provided by stakeholders throughout the consultation are of general relevance to the Hg lamp exemptions. For this reason, the following chapter summarises general aspects in respect to the Hg lamp exemptions. Where possible, first conclusions and recommendations are made, that shall be referenced where relevant, in the evaluation of the specific exemptions under review (to follow in the next chapters).

4.1 Background

Exemptions 1-4 of Annex III of the RoHS Directive permit the use of mercury in various types of discharge lamps. In general, gas discharge lamps are a family of artificial light sources that generate light by sending an electrical discharge through an ionized gas. LightingEurope[7] explains that a small amount of mercury (Hg) is intentionally dosed in such lamps in order to create the gas discharge. When electric current flows through the lamp bulb (=burner), the mercury atoms inside are excited and produce UV radiation. For example, in fluorescent discharge lamps this UV light passes through a fluorescent coating on the interior of the lamp bulb glass and is thus converted into the required spectra of light (mostly into visible light) emitted from the lamp.

The exemptions for Hg in discharge lamps, listed in Annex III of the RoHS Directive and under review in the context of this evaluation process explicitly name the following technologies and families (only technologies falling in the scope of exemptions for which a renewal has been requested by LEU and/or by NARVA are named below):

- Fluorescent:
  - Compact fluorescent lamps (Ex. 1(a)-1(f));
  - Linear triband phosphor lamps for general lighting (Ex. 2(a)(1-5));
  - Nonlinear triband phosphor lamps (Ex. 2(b)(3));
  - Induction lamps (Ex. 2(b)(4));
  - Cold cathode fluorescent lamps (Ex. 3((a) – 3(c)).

[6] NARVA (2014a), NARVA Lichtquellen GmbH + Co. KG , Exemption request for using of mercury in fluorescent lamps, submitted 19.12.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_1_a-e_/NARVA/01_02_a__2b3_4a.pdf

[7] LEU Ex. 1a (2015a), Lighting Europe, Request to Renew Exemption 1(a) under the RoHS Directive 2011/65/EU Mercury in Single-Capped (Compact) Fluorescent Lamps Below 30 W, submitted 15.1.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_1_a-e_/Lighting_Europe/1a_LE_RoHS_Exemption_Req_Final.pdf

- Non-Fluorescent:
  - Low pressure discharge lamps (Ex. 4(a))
  - High pressure sodium (vapour) lamps (Ex. 4(b)(I-III) and Ex. 4(c)(I-III))
  - Metal halide lamps (HPMV – Exemptions 4(e))

4.2 Annex I Category Covered by this Exemption

LightingEurope[8] is of the opinion that lamps in general are category 5 because the most are used for general illumination. However, they have some of the characteristics of components (used in luminaires), consumables (finite lifetime and regularly replaced) and spare parts, lamps in luminaires have to be replaced when they cease functioning). Some manufacturers of electrical equipment in other RoHS categories may install fluorescent lamps into their equipment for general illumination purposes and so they will need to use lamps that comply with the RoHS Directive, however the products that they place on the market are not category 5 but may be household appliances, medical devices or potentially any RoHS category 1 - 11.

LightingEurope[9] is aware of the difficulty to unambiguously classify certain lamps in the category set out by RoHS legislation. For lamp manufacturers it is essential to have legal certainty regarding the possibility to put the products on the market irrespective of the planned application as manufacturers are not able to control the use of the lamps in products falling in other categories in or out of the RoHS scope. In practice, most lamps are installed in buildings for lighting applications (category 5) but some are used in other types of equipment, potentially, in all other RoHS categories. The way that lamps are used has no effect on lamp design so will not affect the exemption requests.

Therefore lamp manufacturers consider the lamps in scope of this document to belong exclusively to category 5 as individual products.

The Test and Measurement Coalition (TMC)[10] includes the seven leading companies in the sector representing roughly 60% of the global production of industrial test and measurement products. It is TMC's understanding that, according to the RoHS Directive, the exemptions listed in Annex III and Annex IV for which no expiry date has been specified, apply to sub-category 9 industrial with a validity period of 7 years, starting from 22 July 2017. This is also said to be explained in the RoHS FAQ, p. 26 http://ec.europa.eu/environment/waste/rohs_eee/pdf/faq.pdf. TMC, thus does not interpret the current exemption evaluation related to package 9 to concern category 9 industrial equipment, for which the exemptions evaluated in pack 9 are understood to remain valid, and has not provided exemption specific information.

[8] Op. cit. Lighting Europe, Ex. 1a (2014a)
[9] Op. cit. Lighting Europe, Ex. 1a (2014a)
[10] TMC (2015), Test & Measurement Coalition, General comments related to RoHS exemption package 9, submitted 16.10.2015, available under http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_1_a-e_/General_Contribution_Test___Measurement_Coalition_package_9_exemptions_20151016.pdf

Though similar contributions have not been made by other sectors, the aspect raised is understood to be of relevance to all products of categories, which first came into scope under RoHS 2 and for which Article 5(2) specifies durations different from those relevant to categories 1-7 and 10, namely Cat. 8 (medical devices) and Cat. 9 (monitoring and control instruments).

4.3 Justification for the Exemption Renewals

For many of the exemptions for Hg-based lamps, the main argumentation revolves around a few main points that shall be detailed shortly below:

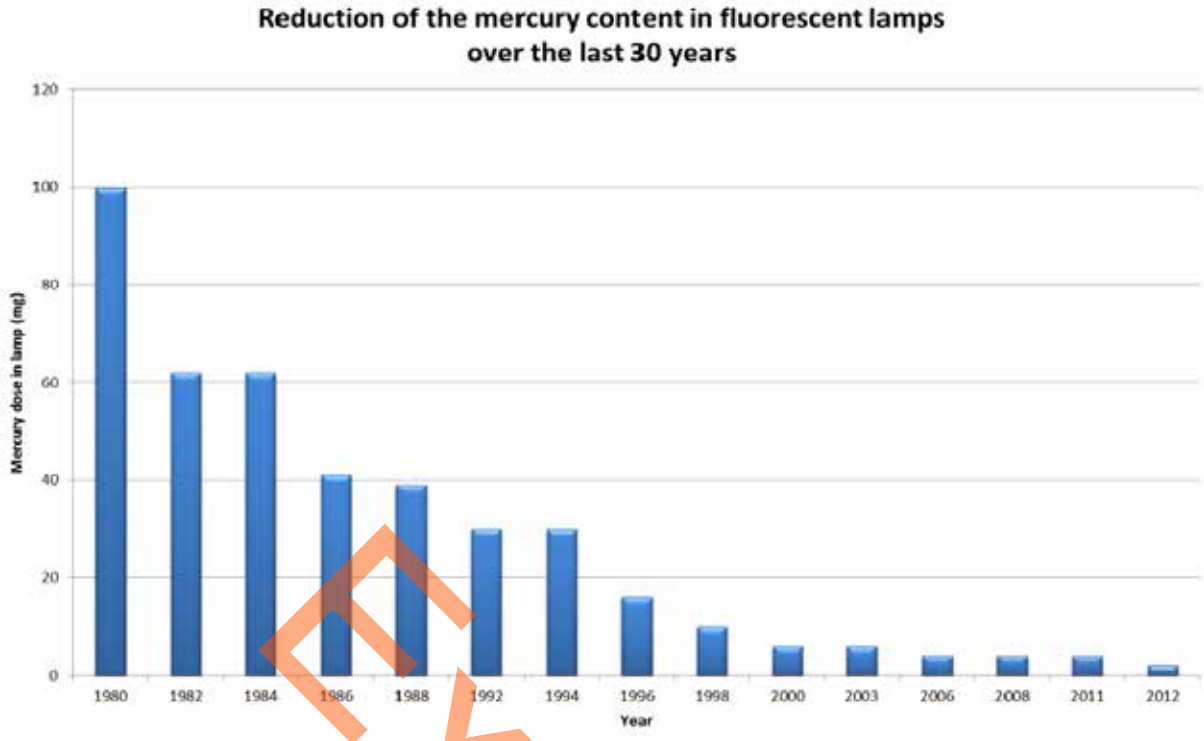
- The limited potential for reducing the amount of Hg dosed in lamps;
- The lack of substitutes for Hg in lamps covered by Ex. 1-4 (substance substitute);
- The limited applicability and product range of Hg-free lamps that may allow eliminating the use of Hg associated with Ex. 1-4, as well as possible restrictions to their use as replacements;
- Possible environmental costs and benefits related to the use of Hg-based lamps and to their possible early phase-out.

Though some of these points require a detailed discussion in the context of the specific exemption, many general aspects are common aspects that have been addressed and evaluated in the following sections. These aspects shall only be further detailed in the exemption specific chapters where detailed information is relevant for the exemption at hand. The critical review of each exemption shall otherwise make reference to this section and only shortly summarise the main conclusions of relevance, where this serves the purpose of supporting exemption-specific conclusions and recommendations.

4.3.1 Amount of Mercury Used under the Exemptions

LEU explains that the level of mercury dosed in fluorescent lamps has decreased considerably during the last years. Examples of this decrease are given in the various requests for exemption renewal. Likewise, LEU has provided Figure 4-1, to show the achieved mercury reduction of the total fluorescent family.

Figure 4-1: Mercury content of fluorescent lamps



Source: Lighting Europe, Ex. 1a (2014a)

LEU[11] states that mercury is dosed in the burner during lamp manufacturing as a homogeneous material (pill, capsule or as amalgam). 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. In some of the Annex III exemptions, this is reflected through the specification of a maximum allowance of mercury permitted per burner. During lamp life, apparent consumption of mercury takes place inside the burner itself. Throughout operation Hg bonds to the glass and in some lamps to the phosphor layer, after which, it is no longer available to emit ultraviolet light. LEU provides further indication of aspects that may influence the availability of Hg during lamp life and thus of considerations for determining the optimal Hg dose of a specific lamp, among others mentioning:

- Lamp dimensions – "*higher lamp wattage involves more glass and phosphor surface, thus more mercury consumption during lamp life and therefore a higher initial mercury dose*";
- Lamp life time;

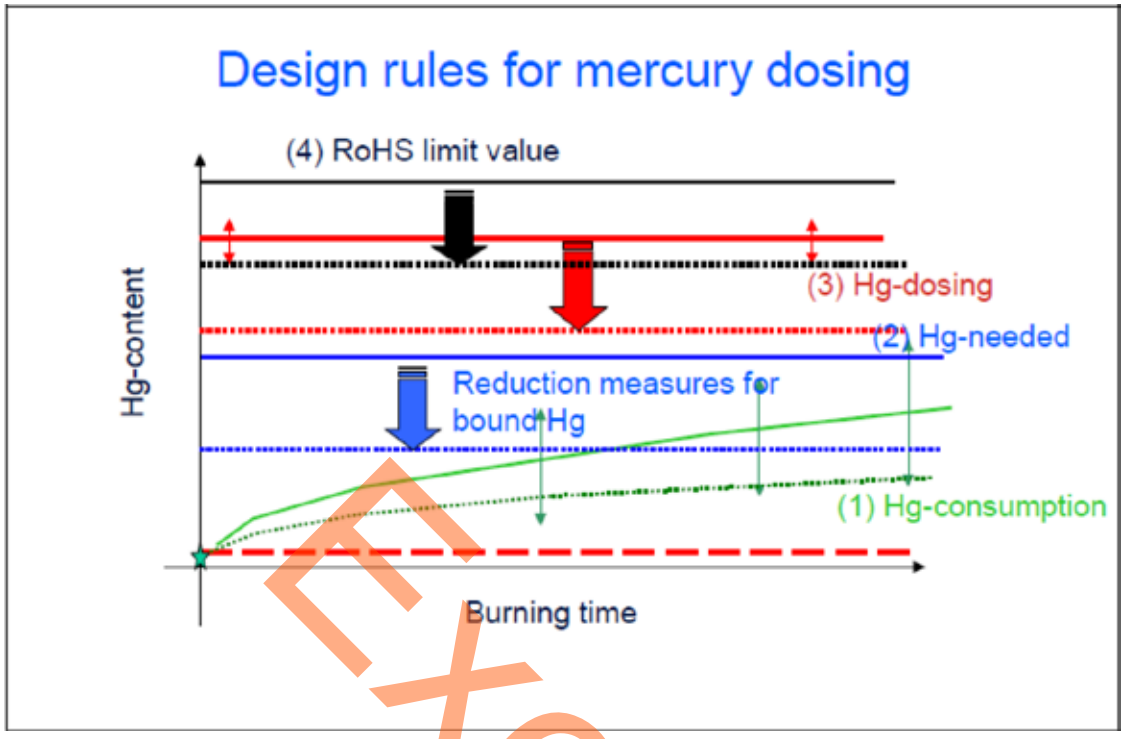
[11] Op. cit. LEU Ex. 1a (2015a)

- *"Coating of phosphors and glass can give a reduction of the Hg 'consumption' over lamp life"*;
- Lamp processing during manufacturing – "*actual dose per lamp scatters around the nominal dose, while the threshold value as set by RoHS directive sets a maximum limit*"
- Mercury 'consumption' – *"processes within the burner, which make a large part of the mercury unavailable for the discharge over lifetime. This is the reason why more mercury has to be dosed to make sure the intended lifetime is not shortened due to too little available mercury"*, e.g. lamp-ballast interaction during operation and interaction with gasses and impurities.

LEU goes on to explain – "*Therefore a balance has to be found between mercury needed over lifetime, mercury variance per dosing unit but also the measurement accuracy when estimating the amount of mercury in a lamp for market surveillance. The lowest (red dashed) line in* Figure 4-2 *gives the ideal situation for a low pressure mercury discharge: there is just enough mercury for the discharge to properly function... However, because of the mercury consumption mechanisms a significantly higher amount must be dosed... In practice, mercury from the discharge is consumed over lamp life. The mercury is mostly deposited and effectively bonded to the glass and the phosphor layer. This is reflected by the full green curve (1) in* Figure 4-2*, 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 green arrows, is considerable and depends on many factors (see below for counteracting measures). To obtain the designed lamp life, the right amount of mercury has to be dosed, taking into account the consumption during lamp lifetime and the variance. The solid blue line 2 in* Figure 4-2 *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 Directive. The solid black line 4 in* Figure 4-2 *is the line representing the RoHS limit (expressed as mg per lamp), the value of which, as explained before, has to take into account both variances of mercury consumption and of mercury dosing. On the one hand, we would 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 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*."[12]

[12] Op. cit. LEU Ex. 1a (2015a)

Figure 4-2: 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.



Source: Lighting Europe, Ex. 1a (2014a)

4.3.1.1 Overview of Mercury in Lamps

Where available, information is detailed in the various exemption evaluation reports as to the amounts of mercury brought on the European market through discharge lamps of various types. Table 4-1 provides an overview of this information in order to provide context for the individual figures and to allow an indicative understanding of the total amount of mercury placed on the market through lamps. Unless otherwise stated, data originates from the documents provided by LightingEurope and is referenced in the separate chapters where the amounts are discussed.

Table 4-1: Overview of Hg amounts brought on the market through discharge lamps

Ex. (entry)	Hg dose per lamp general comments	2013 unless otherwise stated				Comments
		Number of lamps	Average Hg per lamp	Hg	Share of total	
1	**Various CFL lamps**			**947 kg**	**33.01 %**	**Calculated total**
1(a)		291 million	2.5 mg	727 kg	25.34 %	
1(b)		34 million	3.5 mg	120 kg	4.16 %	
1(c)		10 million	5 mg	51 kg	1.78%	
1(d)		2 million	15 mg	26 kg	0.91 %	
1(e)		3 million	7 mg	21 kg	0.73 %	
1(f)	Up to 5 mg per lamp	400	Not	2 kg	0.07%	

Ex. (entry)	Hg dose per lamp general comments	2013 unless otherwise stated				Comments
		Number of lamps	Average Hg per lamp	Hg	Share of total	
	(exemption limit)	thousand	detailed			
2(a)	**Various tri-band phosphor LFL lamps**			**982 kg**	**34.23 %**	**Calculated total**
2(a)(1)		400 thousand	2.5-5 mg	1-1.2 kg	0.03 % (calculated for 1 kg)	
2(a)(2)		76 million	2.5 mg	190 kg	6.62 %	
2(a)(3)		247 million	3 mg	751 kg	26.18 %	
2(a)(4)	-	-	-	-	-	Entry not applied for by LEU. Data not provided by NARVA
2(a)(5)		8-10 million in 2014	4 mg in 2014	40 kg in 2014	1.39 %	
2(b)(3)	Up to 15 mg lamp (exemption limit)	18.6 million*	10 mg*	188 kg*	6.55 %*	*Data provided for exemptions 1(e), 2(b)(2), 2(b)(3), 2(b)(4) and 4(a) – Ex. 1(e) figures have been subtracted. Ex. 2(b)(2) share assumed negligible as it expires in April 2015
2(b)(4)	8 mg average; Up to 15 mg lamp (exemption limit)	18.6 million*	10 mg*	188 kg*	6.55 %*	*Data provided for exemptions 1(e), 2(b)(2), 2(b)(3), 2(b)(4) and 4(a) – Ex. 1(e) figures have been subtracted. Ex. 2(b)(2) share assumed negligible as it expires in April 2015
3	3.5-13 mg per lamp (exemption limit)	Not detailed	Not detailed	Less than 2 kg	< 0.07 %	
4(a)	Hg content from < 4 mg - 15 mg	18.6 million*	10 mg*	188 kg*	6.55 %*	*Data provided for exemptions 1(e), 2(b)(2), 2(b)(3), 2(b)(4) and 4(a) – Ex. 1(e) figures have been subtracted. Ex.

Ex. (entry)	Hg dose per lamp general comments	2013 unless otherwise stated				Comments
		Number of lamps	Average Hg per lamp	Hg	Share of total	
						2(b)(2) share assumed negligible as it expires in April 2015
4(b), 4(c), 4(e)	**Various high intensity discharge lamps (HID)**			**528.5 kg**	**18.42 %**	**Calculated total**
4(b)	Up to 30 mg for entry (I) and up to 40 mg for entries (II and III)	Not detailed	Not detailed	5-10 kg	0.26 % (calculated for 7.5 kg)	
4(c)	Hg amounts vary between 1 - 40 mg	23 million	15 mg	345 kg	12.03 %	
4(e)	In most lamps 3-30 mg, but higher power lamps 200mg is more common and up to 2 gram can be dosed in a small share of lamps	16 million	11 mg (mean)	176 kg	6.14 %	
4(f)	**Various lamps**			**211 kg**	**7.7 %**	**Calculated total**
4(f) Projection lamps	10-40 mg	3 million	15 mg	45 kg	1.57 %	
4(f) UV short arc mercury	up to 100 g per lamp	Not detailed	1 g	20 Kg	0.7 %	
4(f) UV curing lamps	10-3000 mg	132 thousand lamps in 2012[13]	Not specified	75 kg in 2014	2.61 %	Market increase of 6% was applied to 2012 data
4(f) UV Disinfection lamps		178 thousand in 2012[13]		81 kg	2.82 %	Data mentioned in VDMA application for exemption. LEU estimates that 45.7% of lamps are collected for recycling (see Figure 4-3).
Calculated Total				**2868 kg**	**100%**	

Source: Compiled from Information Available from Applicants, see references in individual exemption evaluation reports

[13] Referenced as "UV LED Market" report from Yole Dveloppement, 2012

4.3.2 Alternatives to Hg-based Discharge Lamps

4.3.2.1 Possible Alternatives for Substituting RoHS Substances

Regarding the possible substance substitution of Hg in lamps NARVA[14] states that low pressure discharge lamps do not work without mercury.

LEU[15] agrees with this point, explaining that the mercury discharge is highly efficient in transforming electrical energy into light. The technology has only two drawbacks: first that the generated UV radiation needs to be transformed into visible light, a process from which large energy losses occur due to the Stokes shift[16] and secondly that the discharge inherently contains Hg as the source to create the UV photons. Attempts to generate UV with noble gases have succeeded partially. However the plasma radiates in the deep UV and at such wavelengths that the Stokes shift is even larger causing lower energy efficiency. Some alternatives were developed on the basis of research, however the energy efficiency in prototype lamps is said to be significantly reduced (40 lm/W or below)[17]. In light of the progress of developing alternatives to the discharge lamp (e.g. LEDs) research of substance alternative gas discharges has stopped at most companies and universities. Some additional examples are detailed in the application dossiers; however, none are explained to have resulted in a substance-substitute for Hg in discharge lamps.

4.3.2.2 Possible Alternatives for Eliminating RoHS Substances

Regarding possible technological substitutes for mercury-based discharge lamps, the main mercury free alternatives that have been (or that are becoming) available on the market are incandescent lamps, halogen lamps and light emitting diodes (LEDs).

The well-known conventional incandescent lamps and halogen lamps are less efficient in terms of lm/W and in this respect exhibit negative environmental impacts related to energy and energy related environmental impacts. These would need to be considered under the Article 5(1)(a) criteria related to environmental and health impacts of substitutes. However, both lamp types are subjected to various restrictions through the EcoDesign Directive under which the placing on the EU market of lamps with an energy class lower than B shall be forbidden from 2018. This is expected to effectively ban most incandescent and halogen lamps, and in any case those used for general lighting. Such

[14] Op. cit. NARVA (2014a)

[15] LEU Ex. 2(a)(1)(2015a), Lighting Europe, Request to Renew Exemption 2(a) under the RoHS Directive 2011/65/EU 2(a) Mercury in double-capped linear fluorescent lamps for general lighting purposes not exceeding (per lamp): 2(a)(1) Tri-band phosphor with normal lifetime and a tube diameter < 9 mm (e.g. T2): 4 mg may be used per lamp after 31 December 2011, submitted 15.1.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_2_a__1-5_/Lighting_Europe/2a1_LE_RoHS_Exemption__Req_Final.pdf

[16] LEU explains that an energetic UV photon generates a visible photon which has a much lower energy.

[17] Such values differ depending on technology; however for comparison CFL lamps currently available on the market often have energy efficiencies of 50-65 lm/w, LFLs exhibit energy efficiencies of 80-100 lm/w.

lamps would thus not comprise a practical alternative and shall therefore not be discussed further in detail, unless relevant to the discussion on a specific exemption.

The quickly developing LED technology offers a wide range of Hg-free alternatives that could serve to substitute fluorescent lamps in many cases, thus eliminating the need to use Hg-based technologies. Various stakeholders, including LEU[18] and NARVA[19], claim that the discussion on the suitability of LEDs as technological substitutes for discharge lamps needs to distinguish between two cases:

- Use **as replacement lamps** in existing installations; and
- Use in new installations and **in replacement installations** - new luminaires used to replace luminaires compatible with discharge lamps with ones compatible with LEDs (in some cases luminaires with integrated LED).

LEU[20] explains that new luminaires and lighting systems are now frequently based on LED technology. However, it is claimed that for the current installed base of luminaires and lighting systems operating with discharge lamps, LEDs may in some cases not be suitable drop-in replacements. Towards the development of possible alternatives, the LED technology developments are also addressing one-on-one replacements, but this will not result in a situation which would allow for full replacement of the current discharge lamps portfolio within the timeframe of the exemptions. On this basis it is argued that the availability of suitable discharge lamps needs to be secured to prevent a forced, early refurbishment of installations resulting in extra costs and environmental burden.

Related to lamp replacement, LEU describes three replacement strategies:

- **Retrofit route**: a discharge lamp is substituted by a Hg-free lamp (e.g., LED). The luminaire itself is not rebuilt. Where relevant, the control gear remains in the installation. Driver compatibility is assumed in such cases.
- **Conversion route**: the discharge lamp is replaced, and technical changes also need to be made to the luminaire: ballasts and/or internal wiring may need to be replaced or altered – it is explained that this shifts the responsibility for the technical and the safety consequences of the conversion to the party carrying out the conversion.
- **Rewiring route** – replacing the discharge lamp with an Hg free alternative requires removing the control gear (CG) from the existing installation to establish driver compatibility.[21]

[18] Op. cit. LEU Ex. 2(a)(1) (2015a)
[19] Op. cit. NARVA (2014a)
[20] Op. cit. LEU Ex. 2(a)(1) (2015a)
[21] The exact difference between rewiring and conversion is not clear from the available information, however it can be understood that the scope of changes to the equipment in conversion is wider than in rewiring. A conversion can include rewiring adjustment, but also replacement of drivers, dimmers, etc.

In the exemption renewal documents, LEU[22] describes various aspects that may limit the applicability of LED substitutes as replacements for the full range of discharge lamps covered by the exemptions. Among others the following points are raised:

- Limited variety in terms of shape, sizes, wattage, colour;
- Lacking suitability of LED replacements in light of thermal performance or electric compatibility when used in discharge luminaires;
- Lacking comparability in light output (luminous flux; light pattern and distribution);
- Lack of standards to support product safety certification and to assist in identifying compatible replacement lamps;

4.3.3 Environmental Arguments

4.3.3.1 Life Cycle Aspects

According to LEU[23] several external life-cycle-analysis' (LCA) have been performed regarding lighting. LEU explains that there is general agreement, that the main environmental impact is created during the use phase, meaning through electricity consumption when burning the lamp. This means that currently the energy efficiency (i.e. during the use phase) of the lamp is the determining parameter for almost all environmental impacts throughout the life cycle of a lamp. Specifically regarding mercury, the biggest amount is released to the environment by power plants when generating energy (especially when fossil fuel is the primary power source).

A summary and critical review of the more recent LCA studies cited is presented in Section 5.5.2.2 of the review on Ex. 1(a-e). The location of this information has been determined in light of most of the comparative LCAs to have been performed between LED lamps, incandescent and compact fluorescent lamps. Though the general statements are assumed to be indicative of performance in comparison to other discharge technologies, results of available studies do not address this in detail and are therefore not discussed in depth in this chapter.

4.3.3.2 Use of Materials and Hazardous Substances

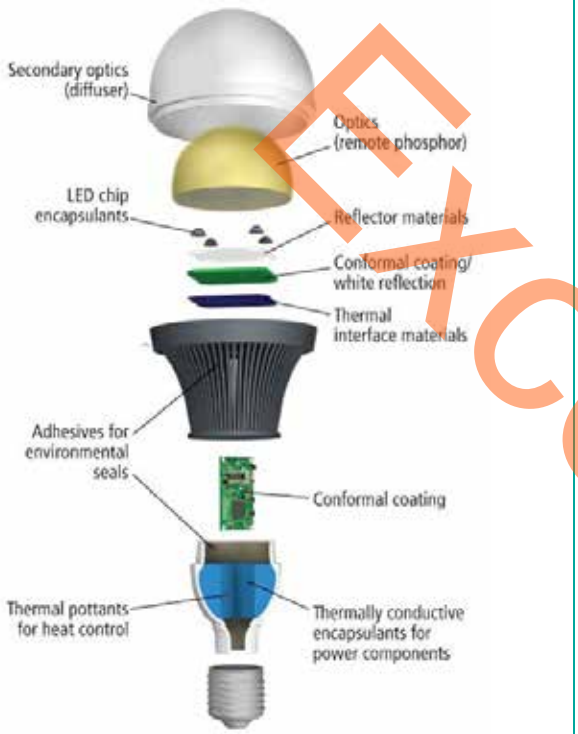
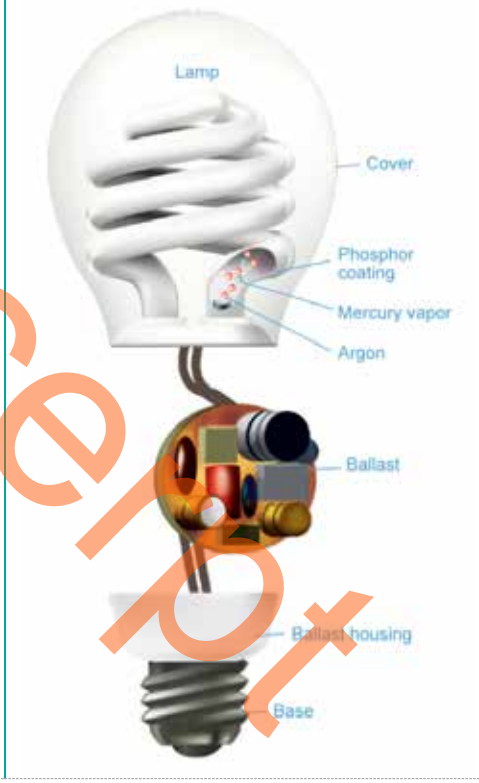
LEU[24] claims that concerning material composition it is also necessary to have a case by case view. Fluorescent lamps contain glass, metals, phosphors and mercury. These components can be effectively recycled. LED based alternatives contain electrical and electronic components such as a control gear and a light engine with mounted LEDs. Like in most other electrical and electronic equipment electronic LED luminaires contain components and other materials using substances regulated in RoHS but exempted in certain exempted applications (e.g. lead in high melting temperature type solders in

[22] Op. cit. LEU Ex. 2(a)(1) (2015a)
[23] Op. cit. LEU Ex. 1a (2015a)
[24] Op. cit. LEU Ex. 2(1)(a) (2015a)

diodes, lead in glass or ceramic in electronic components, lead in aluminium alloys used for the heatsink, lead in copper alloys etc.).

LEU was asked to further substantiate statements related to the use of materials and hazardous substances in discharge lamps and in LEDs. In this regard LEU[25] answered that both lamp technologies use similar electronic circuits and similar components. The lamps as well as luminaires might use exemptions 5(b), 6(a, b, c), 7(a), 7(c)(I, II, IV) or 15, all permitting the use of the element lead. No differentiation between lamps covered by different exemptions is observed. Examples provided can be observed in Table 4-2 (general examples of lamp composition) and Table 4-3 (real examples of electronics used in LED retrofit and compact fluorescent lamps).

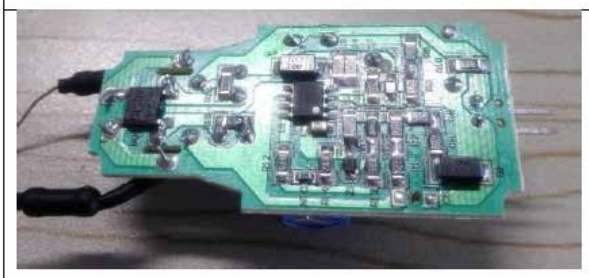
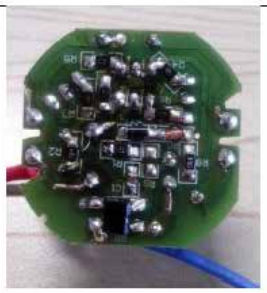
Table 4-2: General composition of LED and CFLi lamps

Example of a LED lamp composition	Example of a compact fluorescent (with integrated ballast) lamp composition
	

Source: Sources provided in LEU (Ex. 1-4) (2015a) by LEU as follows: Left image: http://www.ledsmagazine.com/content/dam/leds/migrated/objects/features/9/10/14/MoldableFig3.jpg Right image: Source: U.S. EPA/ DOE Energy Star Program. "Learn About Compact Fluorescent Light Bulbs" http://www.energystar.gov/index.cfm?c=cfls.pr_cfls_about

[25] LEU Ex. 1-4 (2015a), LightingEurope, Response To Oeko-Institut regarding the 1st Questionnaire Exemption No. 1-4 (renewal requests) General Questions for Lamp Exemptions Related to Mercury, submitted 25.9.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Contribution_Exemption_1-4/LE_Ex_1-4_LightingEurope_General_Clarification-Questions_Final.pdf

Table 4-3: Example of electronics used in LED and CFLi lamps

Example of a LED electronic driver	Example of a compact fluorescent driver (lamp with integrated ballast)
	
	

Source: Source provided in LEU (Ex. 1-4) (2015a) as LightingEurope

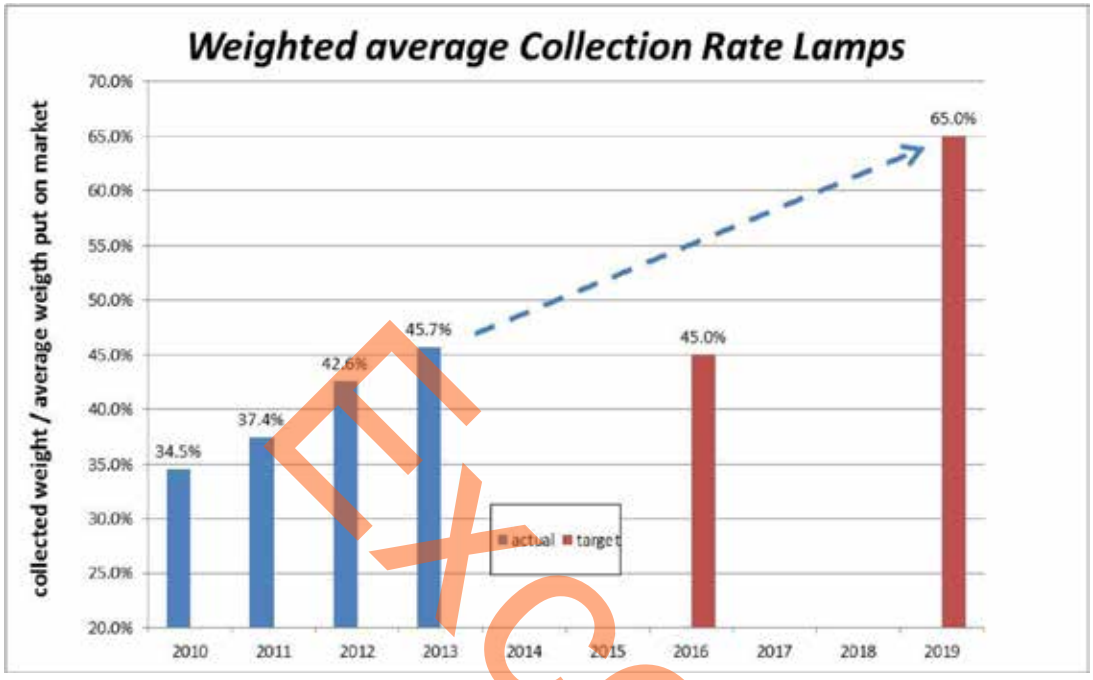
4.3.3.3 Waste management

Information in many of the LEU exemption requests regarding waste streams and recycling is very similar and based on the general approach of industry in the EU towards recycling as a result of the WEEE Directive. LEU[26] states that lamps are in the scope of EU Directives 2002/96/EC (WEEE) and 2012/19/EU (WEEE Recast). The WEEE European legislation stipulates that producers are responsible for end of life products within this category as from August 13th, 2005. Target setting as consequence of the present legislation is 45%/annum of EEE placed on the market by 2016, rising to 65%/annum in 2020. The European Lamp Companies are explained to have founded 'Collection & Recycling Organisations' in the EU Member-States, with the objective to organise the collection and recycling of gas discharge lamps. The goal is to comply with present and probable future EU legislation and to meet or exceed national targets. "*Take back systems are installed in all EU Member States: end users and most commercial customers have to bring back the lamps free of charge... 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.*"

[26] Op. cit. LEU Ex. 1a (2015a)

LEU[27] provides Figure 4-3 showing the collection rate of lamps in Europe compared to the average amount of lamps put on the market during 2010 – 2013. The figure is based on Collection & Recycling Service Organization (CRSO) data for all lamp types, consolidated by Philips Lighting and includes the targets set for 2016 and 2019.

Figure 4-3: Collection rate of lamps in Europe compared to the average amount of lamps placed on the market between 2010 and 2019



Source: LEU Ex. 1a (2015a)

4.3.4 Socio-economic Impact of Substitution

Regarding the costs of substitution, LEU[28] claims that for many applications the prices of LED-based alternatives for discharge lamps (especially for increased wattages) are still significantly higher while the system energy efficiency and lifetime in principle are comparable. This means higher investments and a longer payback time are to be expected. This statement is referenced to a McKinsey Report[29] from 2011.

LEU expects a premature phase out of discharge lamps to result in (amongst others):

- Increase in fixed costs;
- Possible social impacts within the EU;
- Possible social impacts external to the EU;

[27] Op. cit. LEU Ex. 1a (2015a)
[28] Op. cit. LEU Ex. 2(1)(a)(2015a)
[29] Quoted as: McKinsey, Lighting the way : Perspectives on the global lighting market, July 2011

- "*…an increased spend of EU consumers due to enforced usage of more expensive LED lamps (no cheaper alternative yet) and pre-mature refurbishment in professional applications*" [quote unchanged from the LEU text to avoid any unintended shift in the interpretation];
- Banning mercury shall result not only in a reduction of product choice in general but particularly in relation to energy efficient lighting solutions.
- Some discharge lamp families are manufactured in Europe. Not granting the exemptions will lead to the closing of such factories in the EU, and to subsequent loss of jobs.
- "*RoHS is copied by many countries in the world (e.g. Asia, Middle East, the America's). Ending the exemption would have as consequence that also people in other countries would not be able to buy energy efficient and affordable CFL lamps and will go back to using incandescent lamps. This has a very negative impact on the environment*."
- An extension of the exemptions will have a positive effect on the efforts to further innovate in LED technologies, as CFL is the benchmark to be outperformed by LED.

Further information substantiating and quantifying the magnitude of the possible impacts mentioned was not detailed.

4.3.5 Road Map to Substitution

In its various exemption renewal application documents LEU[30] explains that further extension of the various exemptions shall not affect innovation into new LED technologies. It further clarifies that innovative R&D related to discharge lamps has already ceased as LEDs are seen as the future substitute.

4.3.6 The Minamata Convention

The Minamata Convention on Mercury is a global treaty to protect human health and the environment from the adverse effects of mercury. It was agreed at the fifth session of the Intergovernmental Negotiating Committee in Geneva, Switzerland on 19 January 2013. The Convention draws attention to a global and ubiquitous metal that, while naturally occurring, has broad uses in everyday objects and is released to the atmosphere, soil and water from a variety of sources. Controlling the anthropogenic releases of mercury throughout its lifecycle has been a key factor in shaping the obligations under the convention. [31]

Among others the convention requires that:

[30] See for example LEU Ex. 2(1)(a) (2015a)
[31] UNEP, 2016, Minamata Convention on Mercury Website, http://www.mercuryconvention.org/Convention last accessed 4.3.2016

"Article 4(1): Each Party shall not allow, by taking appropriate measures, the manufacture, import or export of mercury-added products listed in Part I of Annex A after the phase-out date specified for those products, except where an exclusion is specified in Annex A or the Party has a registered exemption pursuant to Article 6…"

Annex A specifies the following products relevant to the Hg discharge lamp exemptions dealt with in this report:

"*Mercury-added products*

The following products are excluded from this Annex:

… (c) Where no feasible mercury-free alternative for replacement is available, switches and relays, cold cathode fluorescent lamps and external electrode fluorescent lamps (CCFL and EEFL) for electronic displays, and measuring devices;

Part I: Products subject to Article 4, paragraph 1

Mercury-added products	***Date after which the manufacture, import or export of the product shall not be allowed (phase-out date)***	**Consultants comments**
Compact fluorescent lamps (CFLs) for general lighting purposes that are ≤ 30 watts with a mercury content exceeding 5 mg per lamp burner	*2020*	Covers lamps falling under Ex. 1(a)
Linear fluorescent lamps (LFLs) for general lighting purposes: *(a) Triband phosphor < 60 watts with a mercury content exceeding 5 mg per lamp;* *(b) Halophosphate phosphor ≤ 40 watts with a mercury content exceeding 10 mg per lamp*	*2020*	Covers lamps falling under Ex. Covers lamps falling under Ex. 2a
High pressure mercury vapour lamps (HPMV) for general lighting purposes	*2020*	Covers lamps falling under Ex. 4(d), which has expired
Mercury in cold cathode fluorescent lamps and external electrode fluorescent lamps (CCFL and EEFL) for electronic displays: *(a) short length (≤ 500 mm) with mercury content exceeding 3.5 mg per lamp* *(b) medium length (> 500 mm and ≤ 1 500 mm) with mercury content exceeding 5 mg per lamp* *(c) long length (> 1 500 mm) with mercury content exceeding 13 mg per lamp*	*2020*	Covers lamps falling under Ex. 3(a-c)

The restrictions above apply to all countries who have signed the convention, however it is also mentioned that "*nothing in this Convention prevents a Party from taking additional domestic measures consistent with the provisions of this Convention in an effort to protect human health and the environment from exposure to mercury in accordance with that Party's other obligations under applicable international law.*"

4.4 Stakeholder Contributions

A number of contributions have been made by stakeholders with general comments regarding the lamp exemption (Annex III Ex. 1-4) as well as with comments specific to a certain exemption. The latter shall be discussed in the exemption specific chapters to follow, whereas the former are summarised below.

Ministry of Environment and Food of the Danish Environmental Protection Agency (DEPA)

DEPA[32] has sent a few documents as reference to the lamp exemptions. Though some of these documents were in Danish, a summary in English was provided:

- The first reference provides results of a web based survey performed in October 2014 with 1152 consumers (age 18 years or above).
- The second reference regards data on LED and Hg containing lamps (Baggrundspapir, kviksølv og sparepærer …) with relevant references in English that could be consulted. Furthermore, a first calculation of the possible energy, CO_2 and Hg saved if all energy saving lamps in Denmark are replaced with LEDs is made. The calculation is made on the assumption that the LED lamps use approx. 25% less energy compared to CFLs. For Denmark the result is 46.8 GWh, 16983 tons CO_2 and 0.4 kg Hg. This corresponds all in all to approximately €15 million.

[32] Danish EPA (2015a), Ministry of Environment and Food of the Danish Environmental Protection Agency, Contribution to RoHS Stakeholder Consultation Regarding 29 Exemptions, submitted 8.9.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Contribution_Exemption_1-4/Stakeholder_consultation_RoHS_-_29_exemption_in_Annex_III.pdf, links to referenced document: Tabbelraport in Danish: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Contribution_Exemption_1-4/Tabelrapport_med_kryds_-_Kampagneevaluering_elsparepaerekampagne_-_Praetest.pdf
Baggrundspapir vedr. kampagne om sparepærer og kviksølv in Danish: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Contribution_Exemption_1-4/Baggrundspapir__kviksoelv_og_sparepaerer_5.2.12_GODKENDT.pdf
Survey and health assessment of mercury in compact fluorescent lamps and straight fluorescent lamps: http://mst.dk/service/publikationer/publikationsarkiv/2010/jul/survey-and-health-assessment-of-mercury-in-compact-fluorescent-lamps-and-straight-fluorescent-lamps/
Commission Regulation implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for nondirectional household lamps: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Contribution_Exemption_1-4/sec_2009_327_impact_assesment_en.pdf

- The third reference is to a Danish survey and health assessment of mercury in compact fluorescent lamps and straight fluorescent lamps. The report presents methodology and results of an assessment of the health risk associated with breakage of these kinds of lamps in a private home.
- A last reference is to a Commission impact assessment regarding possible measures considered for implementation under the EcoDesign Directive. DEPA explains that in this assessment from 2009, a large share of the energy consumption was from fossil fuels. DEPA requests that the validity of this argumentation be revised, as it is understood that the share of energy produced from alternative energy sources (e.g. windmills) in the EU has increased. Thus the balance between Hg used in lamps to reduce energy consumption and Hg emissions associated with energy production is expected to have changed and this argumentation may no longer be valid.

In later correspondence DEPA[33] submitted the following revised table from the EPINION survey with data as to how Danish people have disposed of lamps in the past, highlighting which methods are understood to be correct (marked in yellow) and which are not (marked in red).

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

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

Source: Provided by DEPA (2016a), referencing data from the EPINION 2014 survey.
Note: In the table the clearly correct and incorrect way of discarding worn out bulbs is marked with yellow and red respectively. For special bulbs it is not possible to indicate correct way of discarding them since this headline covers different bulbs. In some area a special box for collecting bulbs is put up in the bulky waste area. It is therefore not possible to say if this way of discarding the lamps is correct or incorrect, unless the numbers are crossed with the municipalities and their collection system is checked. Bulbs can be delivered as hazardous waste, then the staff will always make sure the lamp is handled correctly, however this is not always the recommendation by the local authorities.

[33] Danish EPA (2016a), Ministry of Environment and Food of the Danish Environmental Protection Agency, Answers to Clarification Questions as to Contributed Documents, Prepared Towards Meeting at Oeko-Institut e.V., Berlin, Friday 5th February 2016, submitted per email 4.2.2016

Further information regarded the amount of light bulbs placed on the market in various years and collected through the various collection mechanisms:[34]

- "In Denmark DPA-system administers the mandatory producer responsibility system. According to the **2014 statistics of the DPA-system** 1547 tons of bulbs (the various types of bulbs are not specified) were put on the market for consumers and 199 tons for professionals, for a total of 1746 tons of bulbs[35]. Concerning collection 765 tons of bulbs were collected from consumers and 12 tons from professionals, amounting to 777 tons and corresponding to a collection percentage of 45%. [36]. According to **statistical data from the DPA system for 2006,** in 2006 Denmark achieved an overall collection rate of 36%[37]. Data from 2010 shows an overall collection rate of 43%.
- In a Ph.D.-thesis from 2014 based on waste composition analysis, it has been estimated that every household in Denmark delivers 1 gram of energy saving bulbs (containing mercury)/week as domestic waste. This number is based on statistics from 3129 households[38]. 1 gram/week corresponds to approximately 50 gram/year[39]. Having 2.775 million households this corresponds to ca. 140 tons of bulbs/year.

DEPA[40] refers to an assessment made in 2015 by FORCE Technology commissioned by the Danish EPA, which among others looked into the influence of the mixture of bulbs and the influence on energy consumption using numbers from the Danish Energy Agency[41].

[34] Op. cit. DEPA (2016a)
[35] DEPA (2016a) refers to DPA system (Danish Producer responsibility), WEEE, BAT og ELV Statistik 2014 (https://www.dpa-system.dk/da/DPA/Dokumenter?id=7854eb59-7b8d-4fcc-b58a-221f6d0b9ad5 - available in English for 2013 file:///C:/Users/doble/Downloads/UK_WEEE%20%20BAT%20og%20ELV%20Statistik%202013.pdf)
[36] Ibid.
[37] DEPA (2016a) refers to DPA system (Danish Producer responsibility), Data og statistik for 2006 (file:///C:/Users/doble/Downloads/WEEE-Statistik%202006.pdf)
[38] DEPA (2016a) refers to Bigum 2014, Life cycle assessment of special waste types: WEEE and batteries, Ph.D. Thesis, Danish Technical University
[39] Ibid.
[40] Op. cit. DEPA (2016a)
[41] DEPA (2016a) refers to Danish Energy Agency, ELMODELBOLIG Statistik, http://statistic.electric-demand.dk/TekniskRap/Resultater?AppGrTek=60&AppTek=61&SpmTek=1&SubSpmTek=1&disp=1&res1ser=4&App=61&ExtraDevice=0&CheckExtradevice=False&Spm=1&Sub=0&QuestId=0

Table 4-5: Energy consumption totals by bulbs type in 1998 and 2012

Bulbs	1998 (GWh)	2012 (GWh)
Incandescent bulbs	1200.5	236.2
Energy Saving bulbs	50.1	197.8
Fluorescent tubes	155.5	148.8
Halogen bulbs	112.4	382.5
Total consumption for lighting	**1518.5**	**963.3**

Source: DEPA (2016a) refers to Danish Energy Agency, ELMODELBOLIG Statistik, See footnote 41

Polish Association of Lighting Industry

The Polish Association of Lighting Industry (PZPO)[42] have submitted general comments concerning the lamp exemptions.

- PZPO reiterates the impracticability of reducing Hg quantities besides a certain point, in light of the negative impacts that this could have on lamp life and subsequently increasing the replacement frequency and waste generation: "*Although technological advances facilitated reduction in the quantity of mercury in fluorescent light sources, there is a certain threshold value responsible for a significant drop in lamp's lifespan*."
- PZPO further raises concern as to the possible influence that fluorescent light source availability could have on the further development of LEDs: *"This is due mainly to the possibility of changing one lighting system to another as well as to the possibility to increase the energy savings... The demand for higher energy savings triggered the development of LED sources, with fluorescent lamps continuing to be the main points of reference. Imposing restrictions on fluorescent sources may lead to a halt in the development of LED sources."*

Belgian Federal Public Services for Health, Food Chain Safety and Environment

The Belgian Federal Public Services for Health, Food Chain Safety and Environment (Health FGOV)[43], submitted comments regarding Hg in lamps, explained to specifically target lamps falling under Ex. 1 (compact fluorescent lamps). However the points raised are of a general nature and may thus be of relevance to Hg lamps in general. In this respect, a main concern regards the collection and treatment of lamps at EoL. The lack of

[42] PZPO (2015a), Polish Association of Lighting Industry, Comments to Annexes III and IV Directive 2011/65/EU (RoHS), submitted 5.10.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_1_a-e_/Directive_RoHs_-_PZPO_comments_05_10_15_eng.pdf

[43] Health FGOV (2015a), The Belgish Federal Public Services for Health, Food Chain Safety and Environment, Belgian communication for the public consultation on the renewal of the ROHS exemptions on the Mercury containing lamps, submitted 16.10.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Contribution_Exemption_1-4/Ex_1-4_FPS_Health__Food_chain_safety_and_Environment_Be_position_Hg_lamps_20151016.pdf

information as to the actual collection and treatment rates throughout Europe does not allow understanding the efficacy of the mechanism in place to handle this type of WEEE. Two concerns are mentioned in this respect, the one related to the possible need to evaluate the loss of mercury where lamps are not collected and treated properly (i.e. potentially emitted to the environment). The other questions the fate of Hg in the short and medium term, explaining that there are decreasing options for future use of recycled Hg. This could result in the long term in environmental impacts which should be assessed, related to the continued marketing of Hg lamps and their EoL.

European Environmental Bureau (EEB) the Mercury Policy Project, and the Responsible Purchasing Network

The European Environmental Bureau (EEB), the Mercury Policy Project, and the Responsible Purchasing Network[44] submitted general comments while also including specific conclusions and recommendations for some of the specific exemptions, to be detailed in chapters to follow. EEB et al. are concerned about LEU's request to renew several RoHS exemptions for continued use of mercury for the maximum validity period and with the present maximum mercury limits. This concern is mainly associated with their understanding that equivalent products with no or less mercury are widely available. Some of which (LEDs), are also more energy-efficient and have a longer rated life than Compact Fluorescent Lamps (CFLs). Such alternatives are expected to rapidly become more cost competitive, especially when their long life and ability to cut energy, replacement, and waste disposal costs are considered. EEB et al. do not favour the length of many of the requested mercury exemptions mainly based on the statement that equivalent LED lamps are not a practical replacement today for every application. They request definite, near-term expiry dates in certain categories of lamps on the basis that LEDs are environmentally preferable and practical for most applications. To support this opinion they support this view with various sources – including the EC and its consultants – that are predicting the availability, performance and price of LED lamps to continue to quickly improve. In some other lamp categories[45], they propose lower Hg limits, that they expect can be achieved when the present expiry dates go into effect – or shortly thereafter (within the next 2 years).

KEMI Kemikalieinspektionen, Swedish Chemicals Agency

KEMI Kemikalieinspektionen, Swedish Chemicals Agency (KEMI)[46], submitted comments for two exemptions[47], explaining that the comments are the same in nature. Aspects of

[44] EEB et al. (2015a),The European Environmental Bureau, the Mercury Policy Project, and the Responsible Purchasing Network, Environmental NGOs Response to Stakeholder consultation 2015 #2 on mercury-containing lamps – Exemption 1-4 (Review of Annex to the RoHS directive), submitted 19.10.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_1_a-e_/Ex_1-4_EEP-RPN-MPP_Comments_on_RoHS_Request-final_20151016.pdf

[45] EEB et al. have suggested reductions in the thresholds set for Ex. 1(b), Ex. 1(d), 2(b)(3) and 4(c). Recommendations are also made for Ex. 1(a); Ex. 2(a)(2-5), Ex. 4(b), Ex. 4(e).

[46] KEMI (2015a), Kemikalieinspektionen, Swedish Chemicals Agency, Contribution to Stakeholder

general relevance to all Hg exemptions are shortly summarised here. KEMI mention voluntary business initiatives such as that of IKEA who has communicated that it shall switch to selling only LED lamps in various EU countries throughout 2015 and 2016[48]. Further reference is made to an effective phase-out of mercury vapour lamps in the US mentioned in a study for the update of Ecodesign requirements for light sources prepared by VHK, in cooperation with VITO and JeffCott Associates[49]. The study is cited as follows (pg. 131): "*There is value in highlighting the mechanism used by the US to phase-out mercury vapour lamps, i.e. through prohibiting sale of the ballast rather than the lamp itself*." KEMI conclude that a phase-out of mercury in lamps is possible, even if the mechanism to achieve it may vary.

4.5 Critical Review

General note: Lamps are generally understood to be a product, which undergoes relatively short design cycles (in comparison with for example medical devices (average design cycles of 7 years). Currently the lamp sector is in the midst of a transformation from conventional technologies such as incandescent, halogen and discharge lamps towards LED technologies. Within this transition, development is understood to be quick, with some products coming onto the market only for short periods. VHK & VITO for example write in this regard "*The technology is still evolving rapidly and therefore the methods and materials used today could be outdated and outperformed in the (nearby) future*."[50]

Against this background, the study team has consciously attempted to limit the review of existing literature (studies forecasting developments of the lighting sector, available reports of comparative studies, etc.) to more recent reports, where such documents were available. In this respect, it should also be kept in mind that such studies are usually based in the best case on data collected at least half a year before the study was published and in some cases on data collected a year or two prior to publication. Thus where more recent literature was available, studies published before 2013 have not been revisited, with the understanding that results based on earlier data shall be limited in their applicability to products available on the market in 2016.

Consultation 2015-2 Request for extension of exemption 1(a-e), submitted 19.10.2015, available under http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_1_a-e_/Ex_1a-e_KEMI_Answer_to_SC_RoHS_20151016.pdf

[47] Ex. 1(a-e) and Ex. 2(a)(1-5)

[48] See provided reference http://www.ikea.com/gb/en/catalog/categories/departments/lighting/

[49] Reference provided by KEMI: Reference: http://ecodesign-lightsources.eu/sites/ecodesign-lightsources.eu/files/attachments/LightSources%20Task1_Main%20Final%2020151031.pdf See page 140 as report version has been updated.

[50] VITO & VHK (2015), Preparatory Study on Light Sources for Ecodesign and/or Energy Labelling Requirements ('Lot 8/9/19'), Final report, Task 4, Technologies, Prepared for the European Commission, DG ENER.C.3, pg. 26, available under http://ecodesign-lightsources.eu/sites/ecodesign-lightsources.eu/files/attachments/LightSources%20Task4%20Final%2020151031.pdf

4.5.1 REACH Compliance – Relation to the REACH Regulation

Appendix A.1.0 of this report lists Entry 18 of Annex XVII of the REACH Regulation, which restricts the use of mercury. According to this entry, mercury and its compounds shall not be placed on the market or used as substances or in mixtures where the substance or mixture is intended for use:

- to prevent fouling;
- in the preservation of wood;
- in the impregnation of heavy-duty industrial textiles and yarn; and
- in the treatment of industrial waters.

Entry 18a is also listed, not allowing mercury to be placed on the market:

- In fever thermometers;
- In other measurement devices intended for sale to the general public;
- In specified measuring devices intended for industrial and professional uses;

None of the above restrictions apply to the use of mercury in CFL lamps falling under the scope of Ex. 1(a-e).

Annex XVII of the REACH Regulation also lists Entry 30 in Annex XVII of the REACH Regulation, stipulating that Hg and its compounds shall not be placed on the market, or used, as substances, constituents of other substances, or in mixtures for supply to the general public.

In the consultants' understanding, the restriction for substances under entry 30 of Annex XVII does not apply to the use of mercury in this application. Hg is used in lamps, which in the consultants' opinion is not a supply of mercury as a substance, mixture or constituent of other mixtures to the general public. Hg is part of an article and as such, Entry 30 of Annex XVII of the REACH Regulation would not apply.

No other entries, relevant for the use of mercury in the requested exemption could be identified in Annex XIV and Annex XVII (status February 2015).

Based on the current status of Annexes XIV and XVII of the REACH Regulation, the requested exemption would not weaken the environmental and health protection afforded by the REACH Regulation. An exemption could therefore be granted if other criteria of Art. 5(1)(a) apply.

4.5.2 Scientific and Technical Practicability of Substitution

From the information available it can be followed that substance substitutes for Hg in discharge lamps have not become available in products on the market. Various research of such alternatives have not resulted in technologies with comparable performance to that of the various discharge lamps to be discussed in the next chapters and research has been discontinued.

Regarding mercury reduction, as shall be presented in some of the chapters to follow, it is observed that progress has been made in the reduction of the amounts of Hg used in various lamps. Though it is possible that in some cases further reductions are possible, it

can be followed that this could require further research into dosing optimisation technologies and use of various materials and components that affect the "consumption" of mercury throughout lamp life and thus the need to preserve a minimal presence of mercury. As it is understood that for some discharge lamp types, a technology alternative in the form of LED is either in development or to some degree already available, it can be followed that the industry is focusing research efforts in this direction. However, as the development stage of LED alternatives differs between technologies, abandoning the reduction strategy shall need to be discussed in the context of specific technologies and sub-groups of exemptions in the following chapters. These discussions relate to the expected availability of LED alternatives and how this could affect the need for exemptions for Hg in discharge lamps in the decades to come. If exemptions are to be considered relevant despite the availability of LED substitutes (i.e. for replacement lamps) over the next few decades, the consultants cannot follow that abandoning further research in to Hg reductions is to be accepted as justified. In this respect, the consultants differentiate between the following cases:

- Cases where it is observed that implementation of LED substitutes is already widespread (or could be widespread, where obstacles such as conformity with standards or price based competition with conventional technologies could be removed). Here achieving further reductions of mercury should be dismissed in favour of adapting measures that shall facilitate the shift to LED, such as limiting exemption validity and exemption revoke.
- Cases where substitutes are still scarce and/or where available retrofit-lamps still provide inferior performance (e.g. in relation to light quality, energy efficiency, electrical compatibility, compatibility with existing luminaires in terms of dimensions, etc.). In such cases it may be relevant to further require a reduction strategy:
    - In some cases this could be accomplished through a shift to long-life lamps, for which it can be followed that in total, a lower Hg amount shall be needed to establish a certain functional life time, as compared to "normal life" lamps.
    - In other cases, though reduction should be promoted, this reduction strategy should not go so far as to create a situation in which the lack of mercury affects the functionality of the lamps (i.e., resulting in premature failures, shifts in spectral output, etc.).

Though in some cases, other Hg-free alternatives may exist, it can be understood that for the most part industry is focusing on LED technologies to deliver alternatives for the various Hg-based discharge lamp technologies. LEU mentions various aspects that need to be considered when evaluating the applicability of LED alternatives, however the relevance of such aspects is case specific and is thus discussed in relation to the various exemptions.

4.5.3 Environmental Arguments

4.5.3.1 Use of Materials and Hazardous Substances

From the information provided it can be understood that both types of lamps use similar electrical components, including the RoHS restricted substance lead, permitted in certain applications through various exemptions. Though differences may be of relevance, available information does not allow a comprehensive comparison in this respect and it can be expected that such a comparison would in any case be case specific. Where information is available to allow a more detailed discussion in relation to specific technologies, it is detailed in the chapters of relevance.

4.5.3.2 Early End of Life and Waste Management

LEU's main concern in relation to LED replacement lamps is that where they are not fully compatible as substitutes, that the early phase-out of Hg-based discharge lamps could cause an early end-of-life of installations, as once a lamp shall malfunction the luminaire shall be useless. The consultants can understand that this aspect is of concern, in light of luminaires which would need to be scrapped early, meaning that the resources used in their making shall have not served their planned product-life potential. However, this aspect needs to be observed against the types of waste that shall be created under different scenarios.

To begin with, as long as discharge lamps containing mercury are to be placed on the market, mercury shall be an aspect of concern in the waste stream, only to be resolved years after the last lamp has been placed on the market. As shortly shown in information provided by stakeholders, and as discussed below and in Section 4.5.6, it is apparent that less than the half of lamps put on the market are properly collected and subsequently disposed of and it is thus to be concluded that possible mercury emissions from such lamps are to some degree not sufficiently controlled. Regardless of the compliance of collection and recycling mechanisms with WEEE targets, the understanding that many lamps are not collected separately raises concern as to the fate of such lamps and the potential for Hg emissions. Where collection is not carried out properly, it is assumed that at least part of the mercury available in such lamps shall end up as diffuse emissions in the environment.

As for the possible early EoL of luminaires, for which replacement lamps shall not be available and the waste resulting in such cases, this argumentation should be observed with caution. To begin with, as shall be discussed in some of the exemptions, it is observed that when carried out by trained personnel, in many cases luminaires can be converted so that LED replacements can be used once modifications are applied. In such cases, though certain components may become waste (for example drivers, dimmers and reflectors) this would not apply to the whole luminaire. In a similar fashion, it can also be expected that conversion-kits shall become quickly available on the market for some luminaires, as is already the case in the USA, where conversion-kits for linear

fluorescent luminaires are addressed in studies dealing with the comparability of LFL and LED technologies[51]. Where such conversions support a shift towards more efficient and Hg-free lamps, such waste would be acceptable as it allows for other environmental benefits. It should be noted in this respect that as compact discharge lamps came onto the market, similar problems occurred as to their incompatibility with luminaires of other technologies (incandescent, halogen) in terms of weight and dimensions. This incompatibility was however accepted, as it was understood that the shift would create environmental benefits in terms of energy savings. In the shift from discharge technologies to LED technologies, in some cases energy savings can also already be observed, whereas in others they are expected in the future under the assumption of further developments of LED technologies. Furthermore, LED technology enables the elimination of mercury, which also needs to be considered as an environmental benefit to be weighed against environmental impacts of early-end-of-life of luminaires (further discussed below). It also needs to be kept in mind that early EoL of luminaires shall in any case be expected to some degree, as consumers decide to change their installations as a result of changing fashion and as a result of additional technical capabilities of new luminaires (for example in the case of LED applications: adjustable colour, or smart applications that can be controlled through the internet and through cellular applications etc.).

A further point of importance in this respect is that the RoHS Directive and its substance restrictions have been in force since 2002. The lighting industry members, which manufacture discharge lamps and, which are in many cases already shifting towards LED technologies, have been aware of these regulations for over a decade as all lamps using mercury needed an exemption from the RoHS restrictions to allow their placement on the market. In this sense, this industry who is leading the development of LED technologies has been aware for many years that a time would come where exemptions for Hg in lamps would expire in light of the development of LED alternatives. Especially as this industry faced similar problems when discharge lamps first came on the market, it is expected that the development of LED technologies be carried out so as to facilitate their uptake on the market and so as to avoid incompatibility of new lamps with old luminaires.

LEU argues that waste from EoL of luminaires is a concern, should exemptions be revoked. However, new luminaires designed for discharge lamps, explained to have life expectancies of 15-20 years or more are continuously placed on the market. The RoHS Directive restricts the use of certain substances, among others mercury, and requires products with such substances to be removed from the market where substitutes available. As lamps and luminaires are usually sold separately, the Directive cannot restrict the further sales of new luminaires designed for discharge lamps. Thus as long as luminaires can be placed on the market, the relevance of the early end-of-life argument is extended indefinitely. If the exemptions should remain available in the long term to

[51] See for example CALiPER studies, some of which are quoted in Section 8.0 of this report.

ensure the availability of replacement lamps for existing luminaires, this could prolong the use of mercury lamps indefinitely. Though one may argue that the market should be allowed to evolve naturally, this argument, principally related to environmental impacts, needs to be seen in context of other environmental aspects of the various lamp technologies, such as energy efficiency and the phase-out of mercury. Against this background, the consultants believe that should exemptions duration be extended, measures beyond the RoHS Directive should be devised to promote the uptake of Hg-free LED technologies, and subsequently the reduction of mercury and the phase-out of mercury using products.

In relation to waste, it can be followed that a recycling mechanism has been developed and is functioning towards the targets for collecting and proper treatment of Hg-based discharge lamps. Though the consultants can follow that these arguments are made to clarify that industry is in compliance with the obligations regarding the end-of life of their products, in lack of specific data relevant for each of the exemptions at hand, this information does not provide a basis for concluding as to the collection rates and the achieved recycling rates of lamps in the EU, neither in general nor in regard to a particular sort of lamp discussed in the requests at hand. Though in some cases argumentation is made against the early application of substitutes, in light of the lack of a developed collection and recycling mechanism for the newer lamp types, the information presented above only clarifies that it is in any case the obligation of industry to elaborate existing mechanisms and to provide for the collection and recycling of new types and models once these are placed on the market.

Information regarding the recycling rates of various lamp types at present is only partially available and does not allow understanding the full effectiveness of such systems. Nonetheless, from other available information it can be understood that the collection and recycling rates are still not as high as is required in general for EEE under the WEEE Directive in all Member States.[52] This, in itself, is of concern in light of the mercury contained in such lamps and the uncertainties as to the fate of such lamps at EoL.

In light of this information the consultants can follow that a further effort is still required to improve the various mechanisms, among others in light of the difficulty to promote consumers to participate in the separate collection of lamps. In any case it is assumed that should new types of lamps come onto the market in the coming years in larger quantities, that industry would be required to further develop existing mechanisms so as to also handle such items at end-of-life to enhance collection and to improve recycling techniques.

[52] For example, information provided by DEPA and by Health FGOV for example cites collection rates below those provided by LEU in relation to specific countries.

The Fate of the RoHS Exemptions for Mercury in Lamps and Subsequent Impacts on the Environment

In general, for a specific application, the provision of an exemption means that RoHS restricted substances are brought on to the European market through that application, while once an exemption expires, the environmental impact related to that substance is avoided. Each of these scenarios, however, results in additional impacts on the environment, related to the use of resources of the application or its substitutes, impacts related to their end-of-life, etc. For the lamp this suggests that it would be necessary to evaluate the two following scenarios in the context of the RoHS Directive and its criteria for exemptions:

- Prolongation of existing exemptions for Hg lamps, resulting in diffuse Hg emissions in the environment in the magnitude of half of the amount of Hg applied in lamp production (i.e. assuming the other half is collected and recycled).
- Revoke of existing exemptions for Hg-lamps, resulting in less diffuse Hg emissions in the environment but additional emissions from waste management procedures due to the early end-of-life of existing installations / luminaires.

Information by LEU in this respect however remains general in nature and does not allow understanding the range of possible impacts nor the various factors that would need to be considered to understand the volume of such impacts. In this respect it is worth noting some of the factors of relevance.

On the component level, various LCAs have been performed (see further details in Section 4.3.3.1 and also Section 5.5.2.2 for the review of such information) between certain discharge technologies and their respective LED alternatives. The most common focus of such studies has been the comparison of CFLs with incandescent lamps and LED alternatives therefor. However, some LCA data or other types of comparative comparisons are also available for example for LFLs as well as for high intensity discharge (HID) lamps. LCA comparisons of single products are complex and do not provide a basis for clear conclusions as to other technologies. However, LEU itself states that "*There is general agreement, that the main environmental impact is created during the use phase, meaning through electricity consumption when burning the lamp. This means that currently the efficacy of the lamp is the determining parameter. Specifically regarding mercury, the biggest amount is released to the environment by power plants when generating energy (especially when coal is the primary power source).*"[53] In this sense it can be concluded that if the efficacy of LED alternatives is comparable to the discharge technology that it is replacing, that from a component perspective that LEDs could be considered at least similar in terms of their environmental impact. The "components" for which this statement needs to be scrutinized more carefully are on the one side the Hg

[53] This statement appears in many of the applications. See for example LEU Ex. 2(b)(3)(2015a)

containing component of discharge lamps (dosed for example as amalgam pills in some cases) and on the other the heat sink of LEDs when it is based on aluminium. During use, however once efficacy is comparable, LEDs would be understood to have an advantage as the Hg emission related to energy consumption would be similar and LEDs do not contain mercury.

If to go a step further, on the system level, the potential for early-end-of life of luminaires needs to be weighed against the actual waste produced and how it is handled. As explained above, even were an exemption for a certain technology to be revoked, it should not be assumed that the respective luminaire stock would be scrapped as a result thereof.

- In some cases luminaires would have been scrapped anyway, in light of natural end-of-life or decisions of consumers to replace luminaires in light of new technological advantages, changing fashions, renovation of buildings, etc. Some of the existing luminaires may indeed be scrapped gradually as last lamps burn-out. For such installations it can be understood that the luminaires would be collected and handled along with other electronic waste. As a large share of such articles is expected to be various metals such as iron, copper and aluminium, it can be expected that such materials would be recycled and would return to the market as secondary materials.
- In others it can be expected that consumers would be able to use available LED alternatives in existing discharge luminaires to enable their further use, even if these would require conversions in some cases. In other words for some of these luminaires early EoL is not expected, while for other early EoL is only relevant for the parts scrapped through conversion (for example electric components such as ballasts). Here too a share of such components can be expected to be recycled and returned to the market as secondary material.

The share of luminaires scrapped as detailed above can be expected to vary for different technologies, depending on the availability of different types of alternatives as well as on the age distribution within the luminaire stock and its respective lifetime. Materials to be recycled would reduce to some degree the expected “cost” of early EoL. In parallel, these impacts would also need to be weighed against the potential of new technologies (such as LED) to save energy and of course to eliminate mercury. On the one side, LED luminaires may in some cases be more resource intensive than discharge ones, for example, where they require measures for dissipating heat such as in lamps with higher lumen output. On the other side, in technologies where larger amounts of mercury need to be dosed, the elimination of Hg from the lamp may balance out the Hg related to energy consumption of luminaire production.

This discussion is only indicative; however it should serve to show the larger context in which the argumentation of early EoL of lamps should be observed.

4.5.4 Safety Aspects

LEU raises concern related to the possible revocation of the exemptions for Hg in discharge lamps, on the basis that where replacement lamps are not available as drop-in substitutes, that adaptation of the installations to accept available alternatives may affect the warranty as well resulting in possible safety impacts. In the consultants view, it needs to be assumed that where such changes should be needed, that they would be carried out (at least for the most part) by technical professionals. Such professionals are expected to have the capability to perform rewiring and conversions without resulting in safety related consequences and in this sense this argumentation cannot be understood to justify an exemption in light of possible future safety issues. Furthermore neither type, nor probability, of the safety issues are described sufficiently in order to assess whether these issues outweigh the benefits from substitution.

4.5.5 Road Map to Substitution

LEU explains that research and development efforts into substitutes for Hg in discharge lamps have ceased, and that all present efforts are directed at the further development of LED technologies. The consultants understand the reference to such research to relate to the possibility of enabling further reductions of Hg doses in discharge lamps as well as to research into possible substance alternatives for Hg in such lamps. There have been cases in the past where exemptions were extended as it became clear that alternatives needed a few more years of development to ensure the applicability of substitutes and their reliability for the respective product range or to ensure the availability of a suitable volume of products on the market. However in contrast to such cases, the case of discharge lamp technology as presented by LEU is not understood to require a grace period of another few years but of a much longer period.

In parallel LEU explains that a full transition to LED in some product groups should only be considered after sufficient time has been provided to resolve the technical issues described and to allow EU users time to make changes without negative safety or socio-economic impacts. The consultants understand from these statements that where LED alternatives shall not enable substitution of discharge lamps within existing installations, that there is no intention of developing other alternatives. LEU, further explains in their documents, that Hg-based discharge lamps could be needed in some cases for over 25 years to avoid possible environmental costs of early EoL of luminaires. LEU was thus asked to clarify if the renewal for some exemptions could be limited to the application of Hg in lamps to be used in installations placed on the market in the past.

LEU explains:

> "*at the moment mercury containing lamps are still used in new installations… Luminaires for general lighting are usually marketed without the lamp. There is no legal ground within the RoHS Directive to prohibit a luminaire or fixture if prohibited substances are not contained exceeding the threshold of RoHS. This would also be very difficult to survey. In every exemption there are many applications where no alternative technology is available, that is fully suitable for the customers' purpose and has comparable or better technical, environmental or*

safety characteristics. Customers must have the option to buy a new luminaire fitting to their existing installation e.g. additional luminaires of exactly the same type to be able to realize the desired solution…".

Though such argumentation may be relevant for phasing out of certain technologies, the consultants are of the opinion that a situation in which a new product using a certain component is still placed on the market cannot be considered a near phase-out situation. This is particularly so given that LEU argues that availability of lamps (i.e. the component) in such products could be relevant for over 25 years in some cases. It also needs to be noted in respect with the last part of the above statement that customers may not always have the chance of purchasing a *"new luminaire fitting to their existing installation"*, regardless of the fate of the discharge lamps, because luminaire models are changed and adapted with time and as a reaction to fashion. In this sense, this argumentation cannot be followed as a justification for extending the Hg exemptions, according to the applicants' requests, for what could be a cumulative period of 15 to 20 years.

4.5.6 The Minamata Convention

LEU rightly claims that lamps allowed on the market through the current exemptions comply with the restrictions of the Minamata convention. However, it is noted that:

> "*nothing in this Convention [i.e. Minamata – consultants addition] prevents a Party from taking additional domestic measures consistent with the provisions of this Convention in an effort to protect human health and the environment from exposure to mercury in accordance with that Party's other obligations under applicable international law*".[54]

The restrictions specified in the Minamata Convention are understood to aim at a global mercury reduction. This is to be accomplished by, inter alia, ensuring that countries where legislation for regulating the use and the emissions of Hg are not as developed or are lacking, are required to apply minimum requirements, which have evolved in some of the other countries.

RoHS restricts the use of mercury in general, and only in some cases are exemptions for further use provided. The fact that products made available on the EU comply with the Minamata restrictions is not understood to contribute to the discussion on the renewal of the remaining exemptions for Hg in lamps. This aspect does not relate to the Article 5(a) criteria for justifying an exemption and is thus not a relevant argument for this purpose.

[54] Op. cit. UNEP, 2016

4.5.7 Stakeholder Contributions

DEPA provides estimations as to the risks associated with lamp breakage, as well as presenting results of surveys where private consumers were asked if they had had to deal with breakage of an Hg lamp in the past and how this was done.

The consultants agree that the information presented justifies concern that emissions of Hg during the use phase of lamps are of relevance and thus cannot be considered to be sufficiently controlled at present.

LEU mentions the mechanism for the collection and recycling of discharge lamps and provides general data as to the collection rates estimated for all discharge lamps. Though the consultants do not disregard the effort made to develop this mechanism, information provided by different stakeholders show that its achievements need to be observed in perspective:

- Health FGOV raises concern as to the number of lamps not collected by the mechanism and as to their fate and that of the mercury contained in their burners. It explains that there are indications that less than 50% of CFL lamps have been collected through the mechanism in 2014 in Belgium. It also points out that the WEEE Directive does not require 100% collection, but that industry is merely required to meet certain targets. Concern is also raised as to future uses for recycled mercury from lamps, which can be expected to still enter the waste stream for many years, even after the Hg-lamp exemptions are to expire.
- DEPA raises concern as to the fate of lamps which are not recycled properly and provide information from consumer surveys as to lamp disposal. A study estimating the amount of mercury present in Danish municipal waste is also provided, raising concern as to the possible emissions related to such lamps when not disposed of properly.

As for the contributions of KEMI and EEB et al., the main aspects arising from these documents are discussed in the context of the specific exemptions to which they are related. The reference of KEMI to the possibility of prohibiting the sale of ballasts rather than prohibiting the sales of lamps is an interesting approach. However, developing such a measure under RoHs could only be relevant as long as the RoHS substance, in this case mercury, is present in the component. Ballasts for example can be regulated through the EcoDesign Directive to ensure energy efficiency and this could also be done to promote the uptake of LED alternatives where they provide higher energy efficiency. Nonetheless, under RoHS this proposal would not be feasible as ballasts for example do not contain mercury and can thus not be denied market access as a way of eliminating this RoHS restricted substance.

The consultants can follow that the risk of emissions from Hg lamps during the end-of-life phase are of concern, despite the collection rates stated by LEU. Despite the efforts made and the first achievements, which should not be disregarded, the consultants' are of the opinion that Hg emissions in the end-of-life phase cannot be considered to be sufficiently controlled in light of improper lamp disposal by consumers.

The contribution submitted by TMC raises a legal question as to the availability of the current exemption to category 9 equipment. Regardless of TMCs claims as to the availability of Annex III exemptions to sub-category 9 industrial for 7 years starting in 22.7.2017, in the case of the lamp exemptions the wording formulation limits their applicability to lamps. Though in theory, such lamps could be used in Cat. 9 products, this aspect has not been raised by the applicant or other stakeholders to be an area of application. Furthermore, should such a lamp be used as a component in EEE of Cat. 9, it would still benefit from the exemption as long as it is valid and as long as the wording remains unchanged. Should substitutes become available however, it would be of importance to evaluate their applicability in all possible applications at the same time. In this sense, in the consultants opinion, though some Cat. 9 products could enjoy a validity period of the current exemption up till 2024 (Cat- 9 industrial), it would still be considered beneficial to align the exemption validity of all categories. In contrast, should certain entries of the exemption change, or be revoked, the current formulation would need to remain available to Cat. 9 Articles, which at least from a legal perspective are entitled to benefit from the current exemption for a longer period (until 2021 or 2023, depending on sub-category). This logic is also understood to apply to CFL lamps used in devices falling under Cat. 8.

4.5.8 The Scope of the Exemption

A further aspect that should be considered is the availability of lamps falling under Exemptions 1-4 to EEE in other categories. In general, a lamp is understood to be a component, either used in light equipment that would fall under Cat. 5, or used in other equipment of other categories. As long as an exemption is available, the use of lamps covered by such exemptions as a component in equipment is understood to be possible in equipment of all categories. In this respect, the consultants would generally recommend limiting the exemption entries to category 5.

That said, in the case of Cat. 8 (medical devices) and Cat. 9 (monitoring and control devices) this aspect may need to be handled differently. Only for a few of the entries covered by Exemptions 1-4 is there information that allows concluding that EEE falling under these categories actually makes use of lamps covered by the various entries as components. For example, some of the lamps falling under Ex. 1(f) are used in medical equipment. However where such information is not available, the opposite (i.e. that the exemption is not relevant for such equipment) cannot be concluded at present. In light of Article 5(2), from a legal perspective, excluding EEE falling under Cat. 8 and 9 from the scope of these exemptions may not be possible; however the consultants' are also concerned that extended availability of such lamps for these categories may create a loophole for consumers seeking lamp replacements covered by entries that are due to expire. If possible, the Commission should investigate limiting the sales of such lamps to a business-to-business basis to avoid such misuse.

4.6 References Exemptions 1-4 – General Aspects

Danish EPA (2015a) Ministry of Environment and Food of the Danish Environmental Protection Agency, Contribution to RoHS Stakeholder Consultation Regarding 29 Exemptions, submitted 8.9.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Contribution_Exemption_1-4/Stakeholder_consultation_RoHS_-_29_exemption_in_Annex_III.pdf,

Danish EPA (2016a) Ministry of Environment and Food of the Danish Environmental Protection Agency, Answers to Clarification Questions as to Contributed Documents, Prepared Towards Meeting at Oeko-Institut e.V., Berlin, Friday 5th February 2016, submitted per email 4.2.2016

EEB et al. (2015a) The European Environmental Bureau, the Mercury Policy Project, and the Responsible Purchasing Network, Environmental NGOs Response to Stakeholder consultation 2015 #2 on mercury-containing lamps – Exemption 1-4 (Review of Annex to the RoHS directive), submitted 19.10.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_1_a-e_/Ex_1-4_EEP-RPN-MPP_Comments_on_RoHS_Request-final_20151016.pdf

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KEMI (2015a) Kemikalieinspektionen, Swedish Chemicals Agency, Contribution to Stakeholder Consultation 2015-2 Request for extension of exemption 1(a-e), submitted 19.10.2015, available under http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_1_a-e_/Ex_1a-e_KEMI_Answer_to_SC_RoHS_20151016.pdf

LEU Ex. 1-4 (2015a) LightingEurope, Response To Oeko-Institut regarding the 1st Questionnaire Exemption No. 1-4 (renewal requests) General Questions for Lamp Exemptions Related to Mercury, submitted 25.9.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Contribution_Exemption_1-4/LE_Ex_1-4_LightingEurope_General_Clarification-Questions_Final.pdf

LEU Ex. 1a (2015a) Lighting Europe, Request to Renew Exemption 1(a) under the RoHS Directive 2011/65/EU Mercury in Single-Capped (Compact) Fluorescent Lamps Below 30 W, submitted 15.1.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_1_a-e_/Lighting_Europe/1a_LE_RoHS_Exemption_Req_Final.pdf

LEU Ex. 2(a)(1)(2015a) Lighting Europe, Request to Renew Exemption 2(a) under the RoHS Directive 2011/65/EU 2(a) Mercury in double-capped linear fluorescent lamps for general lighting purposes not exceeding (per lamp): 2(a)(1) Tri-band phosphor with normal lifetime and a tube diameter < 9 mm (e.g. T2): 4 mg may be used per lamp after 31 December 2011, submitted 15.1.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_2_a__1-5_/Lighting_Europe/2a1_LE_RoHS_Exemption__Req_Final.pdf

NARVA (2014a) NARVA Lichtquellen GmbH + Co. KG, Exemption request for using of mercury in fluorescent lamps, submitted 19.12.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_1_a-e_/NARVA/01_02_a__2b3_4a.pdf

PZPO (2015a) Polish Association of Lighting Industry, Comments to Annexes III and IV Directive 2011/65/EU (RoHS), submitted 5.10.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_1_a-e_/Directive_RoHs_-_PZPO_comments_05_10_15_eng.pdf

TMC (2015) Test & Measurement Coalition, General comments related to RoHS exemption package 9, submitted 16.10.2015, available under http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_1_a-e_/General_Contribution_Test___Measurement_Coalition_package_9_exemptions_20151016.pdf

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VITO & VHK (2015) Preparatory Study on Light Sources for Ecodesign and/or Energy Labelling Requirements ('Lot 8/9/19'), Final report, Task 4, Technologies, Prepared for the European Commission, DG ENER.C.3, pg. 26, available under http://ecodesign-lightsources.eu/sites/ecodesign-lightsources.eu/files/attachments/LightSources%20Task4%20Final%2020151031.pdf

6.0 General Recommendation Regarding Exemptions for Special Purpose Lamps

The current review has investigated four exemptions which permit the use of mercury in special purpose lamps. Through the review of the available information, an attempt was made to clarify differences in applications and in technologies falling under these exemptions, and to understand if overlapping's exist between these exemptions and other exemptions that needed to be considered in the reformulation of certain exemptions.

- **Ex. 1(f)**: "1: Mercury in single capped (compact) fluorescent lamps not exceeding (per burner):
  (f) For special purposes: 5 mg"
- **Ex. 2(b)(4)**: "*Lamps for other general lighting and special purposes (e.g. induction lamps): 15 mg may be used per lamp after 31 December 2011"*
- **Ex. 4(a)**: "*Mercury in other low pressure discharge lamps (per lamp: No limitation of use until 31 December 2011; 15 mg may be used per lamp after 31 December 2011*"
- **Ex. 4(f)**: "*Mercury in other discharge lamps for special purposes not specifically mentioned in this Annex*"

Such differences have been discussed in the various chapters reporting on the evaluation of these exemptions, and taken into consideration in the recommendations therein as far as possible. See Chapters 7.0, 10.0, 12.0 and 16.0 for the individual review reports.

Generally, the consultants view the term "special purposes" as very broad and open to false interpretations, possibly making market surveillance complex and ineffective. In the past, exemptions were provided for Hg for a large range of technologies in light of the absence of sufficient substitutes. At that time, the use of such a general term in the formulation of exemptions could be considered acceptable, as the respective discharge lamps were to come onto the market through one exemption or through another. Possible overlaps could have still been perceived as unconcise regulation; however, the outcome in terms of products that could be placed on the market would have been the same. However, at present it is observed that for many lamp applications alternatives are coming on the market or are already available, usually in the form of light emitting diode (LED) technologies. In light of these developments, recommendations have been made in the course of this evaluation to restrict the scope of some exemptions as far as reasonable. Against this background, it is apparent that avoiding the use of general formulations is pertinent, as these may leave loopholes that could be misinterpreted or misused, leading to restricted articles, containing Hg, being placed on the market.

Towards this purpose an effort has been made to clarify the term “special purposes”. Among others, in each of these exemptions, attempts have been made to understand what types of lamps (applications or technologies) are considered to fall under the specific exemption. As a second stage, other exemptions were reviewed to ensure if certain lamps might be covered by multiple exemptions. Finally, where possible recommendations were developed, proposing adjustments in exemption formulations so as to clearly demarcate technologies and/or applications included in the scope of a particular exemption. In some cases, where available information did not support this exercise, short termed exemptions have been provided to allow industry to provide further clarification before the possible revoke of the exemption for some technologies.

This process has allowed identifying two cases, where exemptions are currently considered justified (see details in respective evaluation reports in Chapters XXXX), and where the consultants believe that further separating these cases from the current exemptions could be beneficial:

- UV Lamps – The justification for the further use of Hg in discharge lamps that emit in the UV range is two-fold. Current substitutes are understood to be limited in terms of their spectral output and thus do not provide a comparable performance in this respect. Furthermore, where alternatives are available that do emit in a limited range of the UV spectrum, their wall-plug-efficiency is currently significantly lower than that of discharge lamps. The early phase-in of such lamps would result in an increase in energy consumption and in other words in a negative environmental impact. Against this background, for all UV lamps it can currently be followed that exemptions are currently justified on the basis of Article 5(1)(a). In parallel however, once substitutes are to become available, their applicability to the full range of UV lamps should be investigated. In this sense, merging all special lamps which emit in the UV range into a separate exemption would be beneficial as it would ensure that future evaluations for such technologies would be carried out at the same time and focussing on comparable technical questions. To this end, and to address the various differences addressed in the various special purpose exemptions for such lamps, the following wording has been suggested as an exemption alternative for UV lamps, and should be considered as an alternative to the separate entries recommended for such lamps in each of the respective exemptions:

  “*Mercury in discharge lamps, emitting mainly in the ultra-violet (UV) spectrum:*

  (I) in single capped (compact) fluorescent lamps, not exceeding 5 mg per burner;

  (II) in other than single capped (compact) fluorescent lamps, not exceeding 15 mg per burner;

  (III) in low pressure non-phosphor coated lamps, not exceeding 15 mg per burner;

  (IV) in medium and high pressure lamps used for curing and disinfection applications;

Valid for Cat. 5 until 21 July 2021"

Entry (II) could alternatively be formulated as "*in fluorescent lamps not covered by entry (I) not exceeding 15 mg per burner*;". However, this would create a dependency between exemption entries (I) and (II), which may lead to legal uncertainties should the entry formulations be adapted with time, without proper consideration of the dependency.

- Emergency lamps – In the application for Ex. 2(b)4, the necessity of retaining an exemption for Hg used in lamps used for emergency lighting was communicated. The given justification was that for emergency lighting, safety regulation and standards specify what lamps can be used as replacement lamps in respective luminaires. Assuming that at least in some cases, such regulation and standards do not specify Hg-free lamps that can be used to replace lamps that have malfunctioned, the consultants agree that an exemption would need to be retained. Though relevant regulation and standards may be updated with time to allow the use of Hg-free lamps (where relevant specifying if and how luminaires must be converted to ensure safety), the consultants can follow that an exemption could be restricted to cases where this is still forthcoming through the following formulation:

  "*Mercury in discharge lamps used in emergency lighting applications, where safety regulation and standards do not permit the use of mercury-free replacement lamps;*

  Valid for Cat. 5 until 21 July 2021"

Should the European Commission choose to follow this recommendation, the suggested entries proposed for UV lamps and emergency lighting lamps under Ex. 1(f), Ex.2(b)(4), Ex. 4(a) and Ex. 4(f) should be omitted.

12.0 Exemption 4(a)"Mercury in other low pressure discharge lamps (per lamp): (a) 15 mg per lamp"

Declaration

In the sections that precede the “Critical Review” the phrasings and wordings of stakeholders’ explanations and arguments have been adopted from the documents provided by the stakeholders as far as required and reasonable in the context of the evaluation at hand. Formulations have been altered in cases where it was necessary to maintain the readability and comprehensibility of the text. These sections are based exclusively on information provided by applicants and stakeholders, unless otherwise stated.

Acronyms and Definitions

AlGaN	Aluminium gallium nitride
CFL	Compact fluorescent lamp
DNA	Deoxyribonucleic acid
EEE	Electrical and Electronic Equipment
Hg	Mercury
JBCE	Japan Business Council
LCA	Life cycle assessment
LED	Light Emitting Diode
LEU	LightingEurope
NARVA	NARVA Lichtquellen GmbH + Co. KG
UV	Ultraviolet (subtypes UVA, UVB, UVC)
WPE	Wall plug efficiency
W	Watt unit of (electrical) power

12.1 Background

NARVA Lichtquellen GmbH + Co. KG (NARVA)[295] and Lighting Europe (LEU)[296] has submitted requests for the renewal of the above mentioned exemption.

LEU summarizes that Ex. 4a-lamps cover low pressure mercury vapour gas discharge lamps with a maximum Hg content of 15 mg per burner. These lamps are explained not to be included in any of the other categories of lamps in Annex III, neither for general lighting nor specialty lighting. The lamps are not phosphor coated and do not produce visible light nor are they intended for illumination purposes. The larger installations use high power lamps providing higher UVC dosage (germicidal function[297] is a key aspect of the specific spectrum) to produce the required treatment processes, such as destruction of DNA in the microorganisms, ozone generation and/or maintaining advanced oxidation processes[298].

NARVA Lichtquellen GmbH + Co. KG (NARVA) requests the exemption be renewed with the same wording[299]:

> "*Mercury in other low pressure discharge lamps (per lamp: No limitation of use until 31 December 2011; 15 mg may be used per lamp after 31 December 2011*"

Lighting Europe (LEU)[300] requests a modification of the current exemption wording as follows:

> *"Mercury in other low pressure non-phosphor coated discharge lamps not to exceed 15 mg per lamp"*

Both applicants request the maximum duration to be provided for the exemption.

[295] NARVA (2014a), NARVA Lichtquellen GmbH + Co. KG, Exemption request for using of mercury in fluorescent lamps, submitted 19.12.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/

[296] LEU Ex. 4a(2015a), LightingEurope, Request to renew Exemption 4(a) under the RoHS Directive 2011/65/EU Mercury in other low pressure discharge lamps (per lamp), submitted 15.1.2015, available under http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_4_a_/Lighting_Europe/4a_LE_RoHS_Exemption_Req__Final.pdf

[297] A germicidal lamp is a special type of lamp which produces ultraviolet light (UVC).

[298] LEU Ex. 4a (2015b): Response to Oeko-Institut regarding the 1st Questionnaire Exemption No. 4a (renewal request); Exemption for "Mercury in other low pressure discharge lamps (per lamp) - 15 mg may be used per lamp after 31 December 2011" Date of submission: September 15, 2015, available under http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_4_a_/Lighting_Europe/Ex_4a_LightingEurope_1st_Clarification-Questions_final.pdf

[299] Op. cit NARVA (2014a)

[300] LEU Ex. 4a(2015a), LightingEurope, Request to renew Exemption 4(a) under the RoHS Directive 2011/65/EU Mercury in other low pressure discharge lamps (per lamp), submitted 15.1.2015, available under http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_4_a_/Lighting_Europe/4a_LE_RoHS_Exemption_Req__Final.pdf

12.2 Description of Requested Exemption

According to LEU[301], such lamps are produced with similar manufacturing techniques as fluorescent lamps, but are used in highly specific applications to produce light in the ultra-violet C (UVC) region. *"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 blocks UVC transmission, these lamp types will allow the transmission of light in the deep UVC 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 is growing as they have been accepted by Environmental Agencies worldwide to kill many forms of bacteria including, but not limited to giardia and cryptosporidia[302]. 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 types 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 from 1W/5W 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 100˚C. 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."*

Both LEU and NARVA[303] confirm that Ex. 4a-lamps transmit in the 185-254nm range of the UVC spectrum.

NARVA does not provide additional details in its application regarding the lamps covered under Ex. 4a.

LEU explains that the current Ex. 4(a) formulation leaves room for interpretation as to which lamp types are included in its scope. Their application details what low pressure lamps are understood to fall under the scope of other Annex III exemptions, and on this basis LEU concludes that lamps falling under the scope of Ex. 4a are low pressure gas discharge lamps which emit UVC radiation and which are characterized by not having a

[301] Op. cit. LEU Ex. 4a(2015a)
[302] So-called "Cryptosporidium"
[303] NARVA (2015): NARVA Lichtquellen GmbH + Co. KG, Additional information provided after first questions for clarification Date of submission: August 24, 2015, available under http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_4_a_/NARVA/Ex._4_a__Narva_Answers_2_Clarification_Questions_24.8.2015.JPG

phosphor coating. LEU proposes an amendment of the exemption formulation to reflect its applicability for such lamps as specified in Section 12.1.

In the following table a non-exhaustive selection of lamps falling under Ex. 4(a) is listed.

LEU[304] explains the function process of mercury for these lamps in Table 12-1. In this process, a small amount of mercury is intentionally dosed as it is essential for the low-pressure gas discharge. When electric current flows through the lamp (=discharge tube), the mercury atoms inside are excited and produce UV radiation with a high efficiency. This UV light then passes through the tube and enters the application. This principle of the low pressure gas discharge lamp is the same for all fluorescent lamps (exemption entries 1 and 2).

Table 12-1: Non-exhaustive list of lamps falling in exemption 4(a)

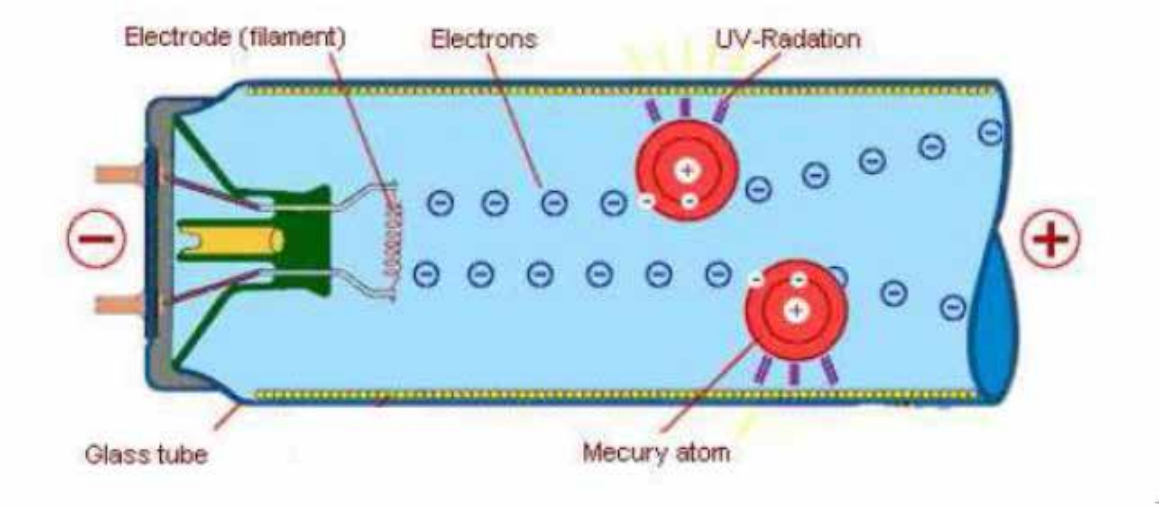
Lamps and applications	Example
Lamps types	
Ultraviolet lamps	
CFL UVC lamps	

[304] Op. cit. LEU Ex. 4a (2015a)

Lamps and applications	Example	
Quartz Ultraviolet amalgam lamp		
Application Types		
Air disinfection unit	Water disinfection unit	Open channel water disinfection
		
Home water purifier	Waste water disinfection unit photo courtesy of Trojan Technologies	Municipal drinking water UV unit
		

Source: taken from LEU Ex. 4a(2015a)

Figure 12-1: Function of mercury in lamps



Source: taken from LEU Ex. 4(a) (2015a)

12.2.1 Amount of Mercury Used under the Exemption

LEU explains that lamps in the scope of exemption 4(a) have mercury content from < 4 mg and up to 15 mg. According to LEU it is not possible to give specific figures on market size and mercury amount for lamps falling under this exemption as there is no specific data for lamps of this exemption. To allow some insight, LEU provides data for lamps placed on the market falling under the exemptions 1(e), 2(b)(2), 2(b3), 2(b)(4) and 4(a), specifying sales of 19 million lamps for such lamps in 2013. [305] However, it is not clear how many of 19 million lamps would be distributed within Ex. 4(a) as many suppliers are based outside the EU[306].

In this respect it should be noted that according to information submitted by LEU, numbers and mercury amounts related to Ex. 1(f) can be estimated: Based on experience of LEU, single ended CFLs for special purpose lamps covered by Ex.1(f) count for 0,1% of the total CFL market share in Europe, which means approximately 400.000 special purpose lamps and a maximum of 2 kg of mercury entering the EU. [307]

Furthermore, the renewal of Ex. 2(b)(2) was not requested and it is thus expected to expire on the 13 April 2016. The consultants thus expect that in the 2013 data presented

[305] Op. cit. LEU Ex. 4a (2015a)
[306] Op. cit. LEU Ex. 4a (2015b)
[307] LEU Ex. 1f (2015a), LightingEurope, Request to renew Exemption 1(f) under Annex III of the RoHS Directive 2011/65/EU Mercury in single capped (compact) fluorescent lamps not exceeding (per burner) for Special purposes: 5 mg, submitted 15.1.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_1_f/Lighting_Europe/1f_LE_RoHS_Exemption_Req_Final.pdf

above related to the number of lamps placed on the market, that the volume of Ex. 2(b)(2) lamps would be negligible.

It can thus be assumed that in 2013 around 18.6 million lamps were placed on the EU market for Exemptions 2(b3), 2(b)(4) and 4(a). concluding as to how this volume is allocated between the three exemptions is not possible.

LEU claims[308] that this category of lamps is becoming more and more important (i.e. market segment is in growth) due to the importance of stopping the spread of diseases or germs and bacteria

12.3 Applicant's Justification for Exemption

LEU claims[309] that at present *"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. There are UVC producing LEDs 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."*

12.3.1 Possible Alternatives for Substituting RoHS Substances

LEU details some of the efforts in seeking an alternative for mercury in the discharge lamps, concluding that substitutes for Hg in the discharge technology are not available. Details can be found in the application documents as well as in part in Section 4.5.2 of this report.

Regarding the reduction of the mercury content LEU provides further indication of aspects that may influence the availability of Hg for the various discharge processes over the lifetime or over different operation conditions. Such lamps are understood to be produced with similar manufacturing techniques as fluorescent lamps, but to be used with more mercury in highly specific applications where UVC light with a specific spectrum is needed. According to LEU following the last evaluation an exemption was granted requiring a reduction of the maximum limit for Hg to 15 mg for Ex. 4(a) lamps. This is explained to have required a great effort, as lamps are for niche applications and are produced by smaller and special manufacturers. It is possible that in some cases further technical reductions are possible, however only with high economic effort and research and development resources. Such resources have been directed towards the further development of LED technologies. Thus according to the applicant for lamps falling under Ex. 4(a) the maximum limit of 15 mg cannot be reduced further.

[308] Op. cit. LEU Ex. 4a (2015a)
[309] Op. cit. LEU Ex. 4a (2015a)

12.3.2 Possible Alternatives for Eliminating RoHS Substances

LED based light sources are not a viable alternative, as the correct light spectrum is currently not reproduced in lamps available on the market. There are differences in wall plug efficiency (WPE), effectiveness, regulation / approbation and in the compatibility with the variety of ballasts used in relevant equipment.

Where it is possible to produce LEDs with non-visible UV light spectra (through AlGaN-LED) the efficiency is still very low. In the UVC (100-280nm) and UVB (280-315nm), the WPE of LEDs is below 1%, whereas the WPE of low pressure gas discharge UVC lamps is 30-40% or even higher. The rated life-time of Hg-lamps is also explained to be higher than that of UVC LED[310].

To illustrate this, LEU provides a performance comparison between UVC LEDs and conventional UVC lamps (see Table 12-2). The following comparison in the table below displays two examples:

- Residential water purification;
- Municipal / industrial water purification.

Table 12-2 Comparison of discharge lamps UVC with LED UVC lamps

	Residential purification		Municipal purification	
	Residential Hg UVC lamp	UVC LED	municipal Hg UVC amalgam lamp	UVC LED
input power (W)	9	0.1	325	0.1
output power (UVC W)	2.2	0.002	115	0.002
efficiency	24%	2%	35%	2%
price (Euro)	5.00	10.00	100.00	10.00
lifetime (h)	9000	3000	9000	3000
total number of units [for the compared application – consultants comment]	1	3300	1	172500
total price (Euro)	5.00	33.000	100.00	1725000
total input power (W)	9	110	325	5750

Source: taken from LEU Ex. 4(a) (2015b)

[310] However, the available power range of UVC LEDs as indicated below does not lend itself to today's typical applications for UVC lamps (Op cit LEU Ex. 4a(2015b)). Moreover no test results are available yet to allow evaluating the effectiveness of new technologies to reach the desired effect from studies (Op cit. LEU Ex. 4a(2015a)).

12.3.3 Road Map to Substitution

According to the applicant[311] currently the demand for the development of substitutes is low, so development efforts would result in higher costs for the smaller manufactures.

It is estimated by the LED manufacturers that deep UVC LEDs will not be available for five to ten years. This is the time explained to be needed before LEDs could provide comparable performance in relation to the high power and long life-time requirements of low pressure gas discharge lamps.

12.4 Stakeholder Contributions

A number of contributions of general nature have been made by stakeholders. These are summarised in Section 4.4 of the general chapter.

Two further contributions were submitted specifically related to Ex. 4(a) during the stakeholder consultation and are detailed below:

- Contribution by JBCE – Japan Business Council in Europe in a.i.b.l, submitted 15 October 2015[312]
- Contribution by Baxter Healthcare Corporation, submitted 15 October 2015[313],

JBCE explains that the category 8 & 9 should not be in scope of this exemption evaluation.

Baxter Healthcare requests the renewal of Exemption No. 4a of Annex II with the same wording formulation because of the need of an effective treatment of bacterial proliferation in dialysis water storage and distribution with ultraviolet wavelengths. Moreover Baxter states that no substitution will be available in the next ten years

12.5 Critical Review

12.5.1 Scientific and Technical Practicability of Substitution

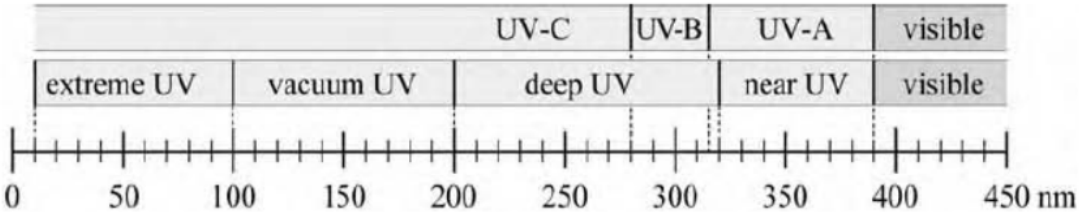
LEU attests to the accomplishments in terms of Hg reduction and does not provide a roadmap related to further efforts for improvement of this technology. The consultants can follow that the potential for this strategy has been implemented for the most part

[311] Op cit LEU Ex. 4a (2015a)
[312] JBCE (2015a): Japan Business Council (JBCE), Comment on public consultation of 4(a): "Mercury in other low pressure discharge lamps (per lamp) in 2015 Consultation submitted 14 October 2015, available under http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_4_a_/Comment_on_public_cousulation_of_Exemption_request_2015-2_4_a_.pdf
[313] Baxter Healthcare (2015): Baxter Healthcare Corporation, Request for renewal of Exemption 4(a) "Mercury in other low pressure discharge lamps (per lamp) in 2015 Consultation submitted 15 October 2015, available under http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_4_a_/Ex_4a_Baxter_Healthcare_Corporation_151015.pdf

and that further research is focusing on the development of LED alternatives and not on Hg reduction.

In order to discuss the issue of the wavelengths it is useful to illustrate the wavelength (nm) for the UV spectrum.

Figure 12-2 Classification of UV radiation



Source: https://www.fh-muenster.de/fb1/downloads/personal/juestel/juestel/AlGaN_____UV-LEDs_MatthiasMueller_.pdf

According to LEU, Ex. 4(a)-lamps are produced with similar manufacturing techniques as fluorescent lamps and lamps falling under Ex. 2(b)(4), but are used in highly specific applications (disinfection/purification of air/water/surfaces) to produce light in the deep ultra violet C (UVC) region with wavelengths of 185-254nm. There are materials available from which LED can be made that generate UV light (like AlGaN) but these do not produce a radiation in the spectral range required for UVC lamps. The consultants can follow as described in LEU's exemption request that the wall plug efficiency (radiated power out / electrical power in) of UV-LEDs with AlGaN materials is also still very low, and thus that even if they would be comparable in spectral output, their efficiency would still be much lower, resulting in higher energy consumption.

Interestingly the applicant claims that there are UV LEDs in the early development phase for use in the higher wavelengths of the UV spectrum i.e. 365-405nm, which would not perform the same UVC (germicidal) function as the lamps in the range of 185-254nm covered under this request. Based on the latter point the consultants agree with the statement regarding the lack of alternatives for the UVC range of 185-254nm.

12.5.2 Environmental Arguments

Regarding the environmental arguments made by LEU, most of these are not specific for lamps falling under Ex. 4(a) and are discussed in the general chapter (see Section 4.3.3).

The consultants are not aware of comparative LCAs in the public realm of relevance to low pressure discharge lamps and their LED replacements. However it is considered plausible that comparisons of low pressure discharge lamps and possible LED replacements may be more challenging due to the lack of products which are sufficiently comparable (UV wavelengths, wall plug efficiency etc).

As for aspects raised regarding possible reduced wall plug efficiency of current candidate alternatives, these are discussed above.

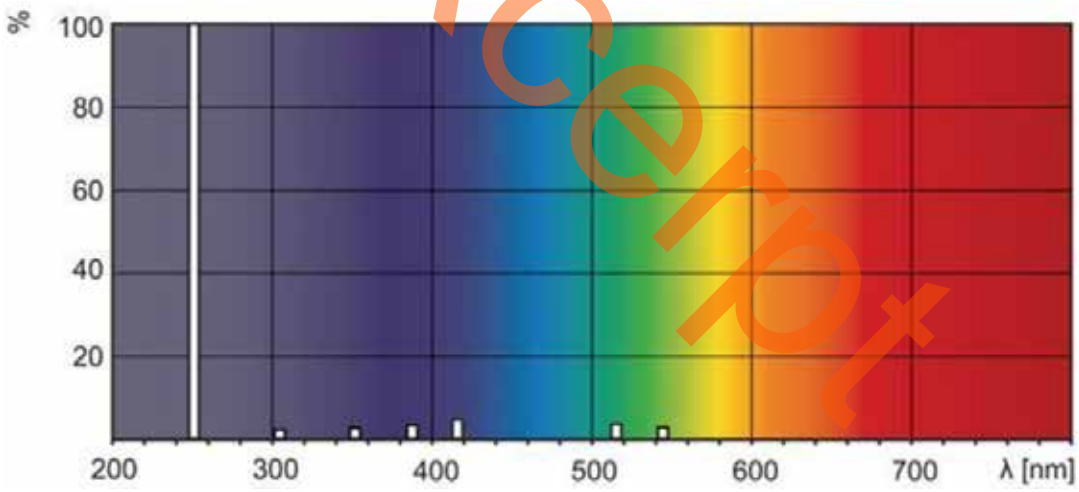
12.5.3 The Scope of the Exemption

LEU proposes an amendment of the current wording to limit the scope of the exemption to low pressure discharge lamps that are **not phosphor coated**. The information provided by LEU, however, also clarifies that lamps benefiting from this exemption and respectively placed on the EU market by LEU members can further be defined as lamps that transmit in the **185-254nm range of the UVC spectrum**. The other applicant NARVA also confirms that the lamps of Ex. 4(a) emit in the UV spectrum range of 185-254nm.

From information available regarding Ex. 4a, the consultants can understand that lamps that would fall under the scope of this exemption are low pressure gas discharge lamps which emit **UVC radiation** and are characterized by **not having a phosphor coating**.

LEU was thus asked if the exemption could further be limited to the UVC spectral output range. LEU[314] does not agree with this proposal, as lamps with fluorescent material for special purposes are covered in exemptions 1(f) and 2(b)(4). The interpretation of LEU is that 4a covers low pressure mercury lamps without phosphors. Although the definition of UV-C is the range of wavelength between 200-280 nm, the typical mercury lines at 184.95, 253.65, 296.73 and 365.02 nm etc. (see Figure 12-3, noting that wavelengths here are as specified by LEU, despite differences as would appear from the chart – consultant's comment) may also be transmitted with these lamps so the further limitation of the scope in this manner is not supported.

Figure 12-3: Example spectrum of a low pressure mercury discharge



Source: LEU Ex. 4a (2015b)

The consultants conclude that the function of these lamps is enabled through their radiation in the UVC Spectrum. Though lamps may emit some radiation in other ranges of the spectrum, Figure 12-3 clearly demonstrates that the main output is in the UVC range. In the consultants view, limiting the exemption to lamps emitting mainly in the

[314] Op. cit. LEU Ex. 4a(2015b)

UVC spectrum would not restrict their radiating in other parts of the spectrum, and so this further limitation is concluded to be possible.

12.5.4 Exemption Wording Formulation

As mentioned above the consultants agree that the exemption can be limited to low pressure lamps without phosphor coating as suggested by LEU and as supported by NARVA. It is further suggested to limit the scope of the exemption to lamps emitting in the UVC spectral range, as this is understood to be an important spectral aspect of such lamps for their various applications. The following wording formulation is thus proposed:

> "*Mercury in low pressure non-phosphor coated discharge lamps, where the application requires the main range of the lamp-spectral output* ***to be in the UVC spectrum****; up to 15 mg mercury may be used per lamp*."

Though this formulation would require lamps covered by this exemption to emit in the UVC spectral range, the consultants do not understand this formulation to exclude lamps that have marginal radiation in other parts of the spectral range.

It can be understood however, that for lamps to radiate mainly in the UVA or UVB spectrum, that the use of phosphors would be needed. The consultants thus conclude that restricting the scope of the exemption to UV lamps as opposed to UVC lamps would have the same impact in terms of the actual lamps to be placed on the market. Ex. 4(a) lamps are explained to have some radiation beyond the UVC spectral range (see Figure 12-3). In the consultants' opinion, restricting the exemption to the whole UV range and not only to the UVC range would provide industry with more certainty that relevant lamps still fall under the scope of the exemption, while still defining a clearer and more narrow scope.

12.5.5 Conclusions

Article 5(1)(a) provides that an exemption can be justified if at least one of the following criteria is fulfilled:

- 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 **reliability** of substitutes is not ensured;
- 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.

Such lamps are understood to be produced with similar manufacturing techniques as fluorescent lamps, but to be used in highly specific applications where UVC light enables the main function. They are understood to 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 radiation to dry the imprinted surface.

It can be followed that alternatives are currently not available for applications with specific characteristics covered by Ex. 4(a), as the spectral output of available LEDs

radiating in the UV spectrum is only in the UV spectrum with longer wavelength range (365-405nm): Such a spectral output would not provide for the function of lamps covered by this exemption, for which the main spectral output needs to be in the shorter wavelength UVC range of 185-254nm. Furthermore, current LED alternatives do not provide sufficient wall-plug-efficiency and would thus result in higher energy consumption should alternatives be in the relevant spectral output range.

12.6 Recommendation

The consultants recommend amending the exemption as proposed below and granting it only for Cat. 5, as lamps are understood to be components falling under this category, and thus could still be used as components in EEE of other categories.

In light of Article 5(2), from a legal perspective, it may not be possible to exclude EEE falling under Cat. 8 and 9 from the scope of this exemption.

Exemption 4(a)	Duration*	Comments
4(a)-I: Mercury in low pressure non-phosphor coated discharge lamps, where the application requires the main range of the lamp-spectral output to be in the UV spectrum; up to 15 mg mercury may be used per lamp.	*For Cat. 5: 21 July 2021*	The maximum transition period should be granted for other applications and other categories (18 months);
4(a)-II: Mercury in other low pressure discharge lamps (15 mg may be used per lamp)	*For Cat. 8 and Cat. 9: 21 July 2021* *For Sub-Cat. 8 in-vitro: 21 July 2023* *For Sub-Cat. 9 industrial: 21 July 2024*	

Note: As it can be understood that the exemption duration may vary for various categories on the basis of Article 5(2), expiration dates have been specified here for all categories either on the basis of the requested duration in the exemption request which the consultants perceive to be justified, or on the basis of the validity periods specified in Article 5(2) for categories, which are newly in scope.

12.7 References Exemption 4(a)

Baxter Healthcare (2015) Request for renewal of Exemption 4(a) "Mercury in other low pressure discharge lamps (per lamp) in 2015 Consultation submitted 15 October 2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_4_a_/Ex_4a_Baxter_Healthcare_Corporation_151015.pdf

JBCE (2015a) JBCE comment on public consultation of 4(a): "Mercury in other low pressure discharge lamps (per lamp) in 2015 Consultation submitted 14 October 2015, available under; http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_4_a_/Comment_on_public_cousulation_of_Exemption_request_2015-2_4_a_.pdf

LEU Ex. 1f (2015a) LightingEurope, Request to renew Exemption 1(f) under Annex III of the RoHS Directive 2011/65/EU Mercury in single capped (compact) fluorescent lamps not exceeding (per burner) for Special purposes: 5 mg, submitted 15.1.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_1_f/Lighting_Europe/1f_LE_RoHS_Exemption_Req_Final.pdf

LEU Ex. 4a (2015a) LEU Ex. 4a(2015a), LightingEurope, Request to renew Exemption 4(a) under the RoHS Directive 2011/65/EU Mercury in other low pressure discharge lamps (per lamp), submitted 15.1.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_4_a_/Lighting_Europe/4a_LE_RoHS_Exemption_Req__Final.pdf

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