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:

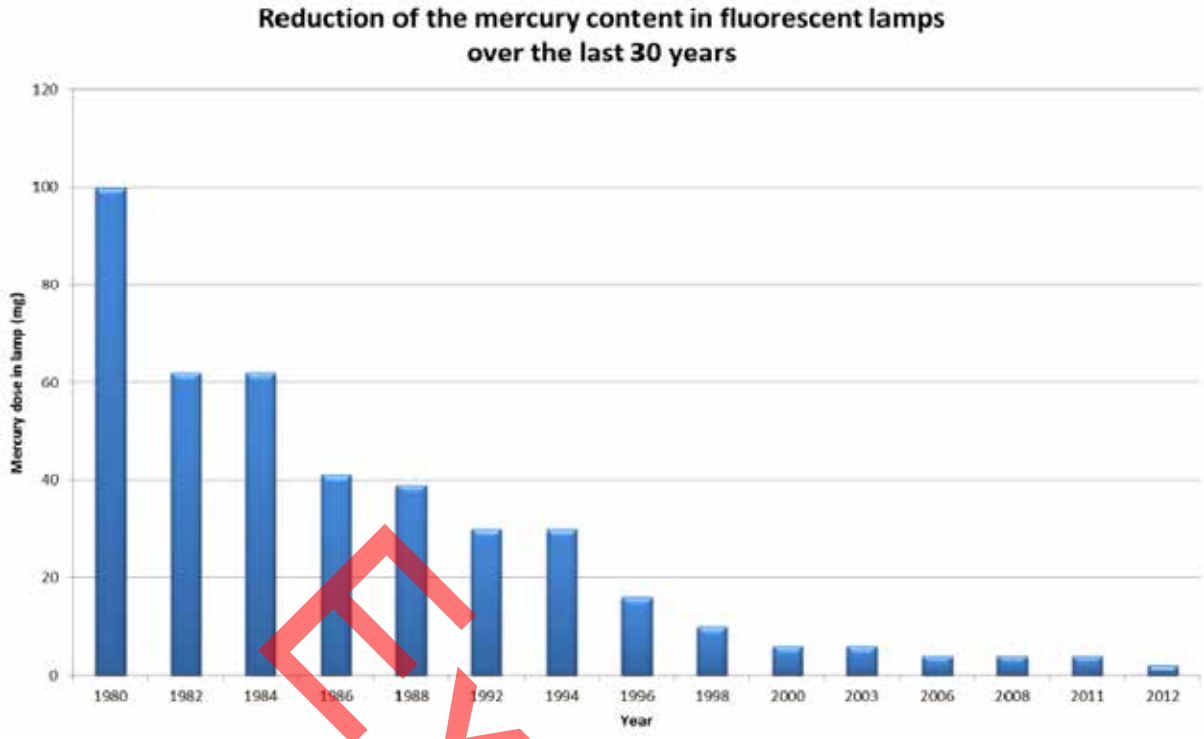
- The limited potential for reducing the amount of Hg dosed in lamps;
- The lack of substitutes for Hg in lamps covered by Ex. 1-4 (substance substitute);
- The limited applicability and product range of Hg-free lamps that may allow eliminating the use of Hg associated with Ex. 1-4, as well as possible 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;

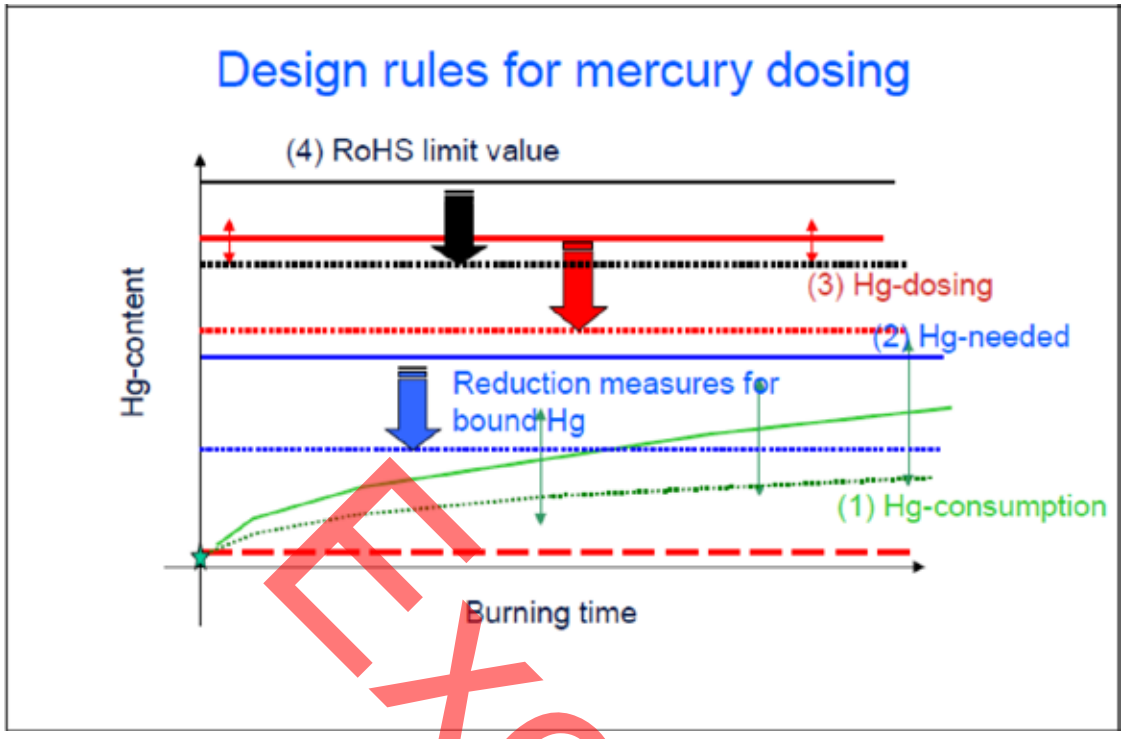
[11] Op. cit. LEU Ex. 1a (2015a)

- *"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

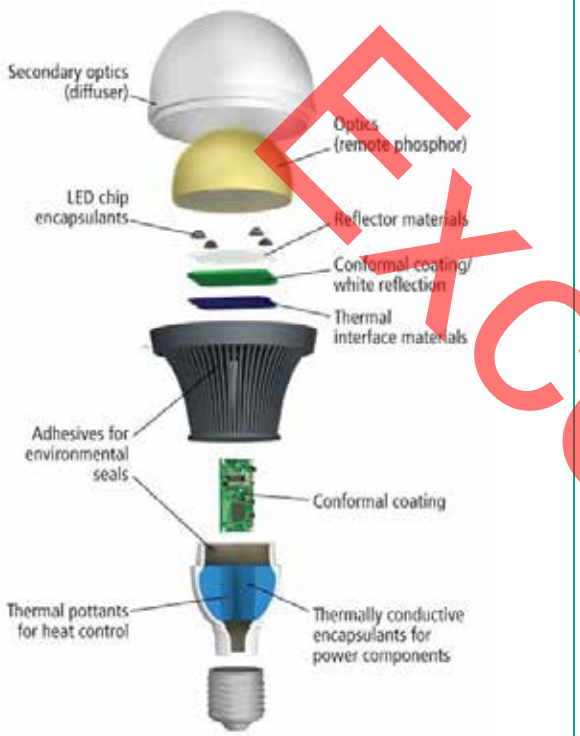
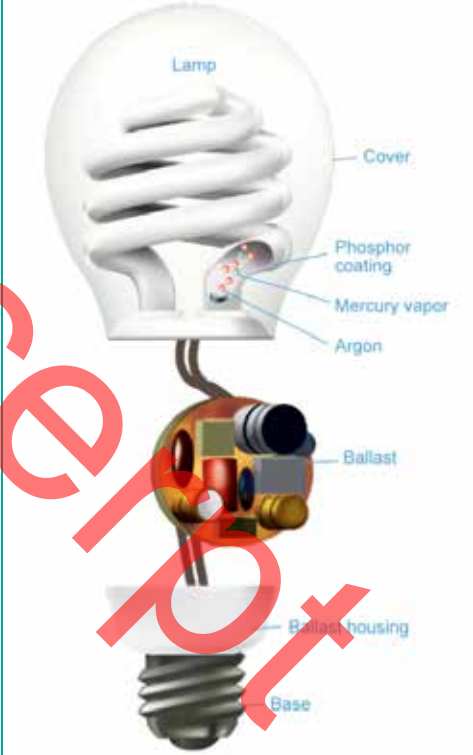
LEU[24] claims that concerning material composition it is also necessary to have a case by case view. Fluorescent lamps contain glass, metals, phosphors and mercury. These components can be effectively recycled. LED based alternatives contain electrical and electronic components such as a control gear 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).

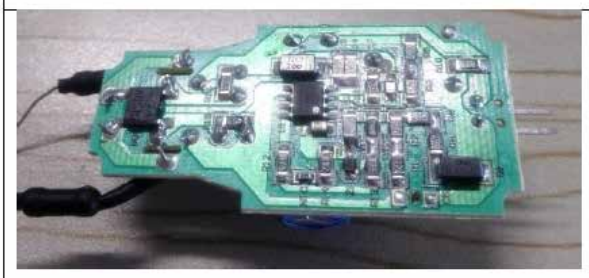
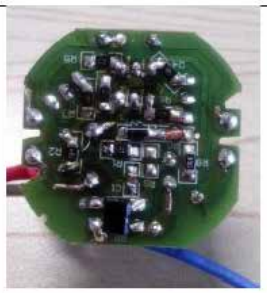
Table 4-2: General composition of LED and CFLi lamps

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

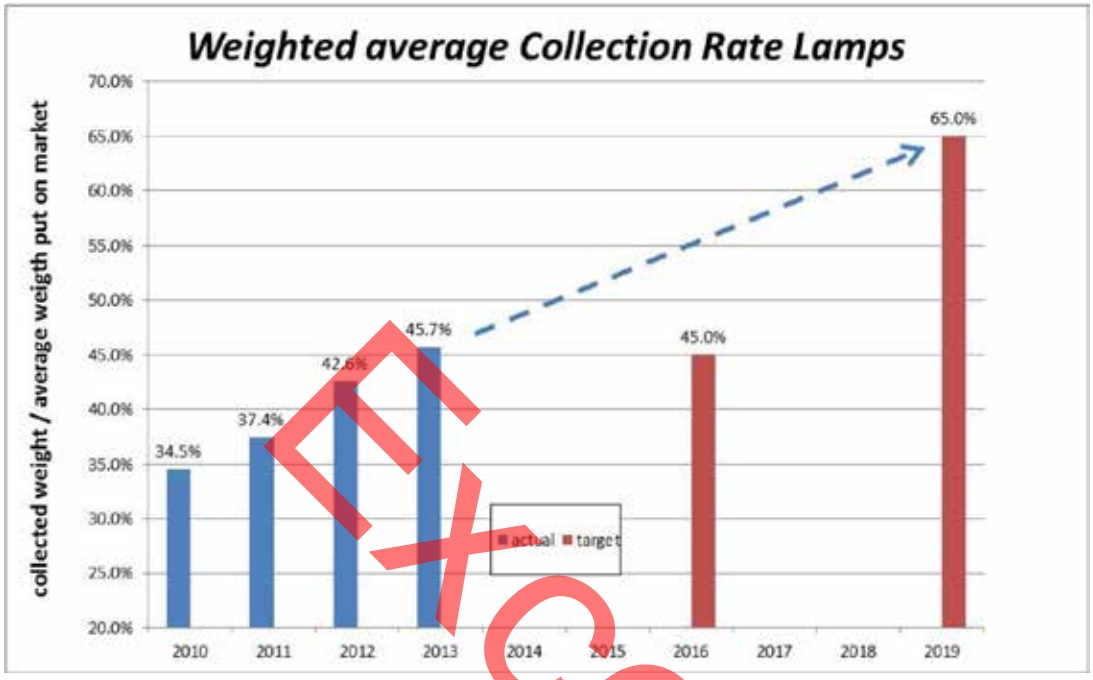
4.3.3.3 Waste management

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.

7.0 Exemption 1(f): Mercury in single capped (compact) fluorescent lamps not exceeding (per burner) For Special purposes: 5 mg

Acronyms and Definitions

AlGaN	Aluminium gallium nitride
CFL	Compact fluorescent lamp
CRI	Colour Rendering Index
DBD	Dielectric barrier discharge
EEE	Electrical and Electronic Equipment
EoL	End of Life
LED	Light Emitting Diode
LEU	LightingEurope
NARVA	NARVA Lichtquellen GmbH + Co. KG
OLED	Organic Light-Emitting Diode
UV	Ultraviolet (subtypes UVA, UVB, UVC)

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.

7.1 Background

LightingEurope (LEU)[129] and NARVA Lichtquellen GmbH + Co. KG (NARVA)[130] submitted requests for the renewal of exemption 1(f) of Annex III of the RoHS Directive.

Lamps in Exemption 1(f) can be used both in professional and consumer applications. They differ in construction from general lighting lamps by the use of different glass and phosphors (for some no phosphor is applied), typically emitting in UV or blue wavelength bands. These lamps are used for several areas in medical, disinfection and other applications, where an efficient source for UV light is needed. The power of compact fluorescent lamps (CFL) for special purposes ranges from 5W – 110W. Typical life cycle of equipment in disinfection, medical and insect trap applications is 20-50 years.

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. These numbers are expected to remain stable.

LEU explains that substitutes are currently not available to allow a phase-out of lamps covered by this exemption. A further reduction of the current mercury threshold specified in the exemption is also explained not to be practical.

Against this background, LEU and NARVA do not expect the availability of LED alternatives to allow for a full phase-out of Ex. 1(f) lamps within the coming 5 years[131], and thus requests a renewal of the exemption with following wording:

Annex III:

> *"1: Mercury in single capped (compact) fluorescent lamps not exceeding (per burner):*
>
> *(f) For special purposes: 5 mg"*

7.2 Applicant's Justification for Exemption

The applications under the special purpose exemption are in majority applications that are not used for general illumination. LEU[132] claims that Ex. 1(f) lamps can be applied

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[129] 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

[130] 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

[131] A maximum validity period, expiry date not required

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

both in professional and consumer applications and generates for the most part UV light. Such lamps are used in various application areas where an efficient source for UV light or blue wavelength bands is needed. They differ in construction from general lighting lamps by the use of different technology, wattage, size and compactness, life time, glass and phosphor coating (for some no phosphor is used). Special purposes are explained to include:[133]

- Disinfection of air, water or surfaces;
- Skin treatment (medical), including:
  - Tanning;
  - Narrowband and Broadband UVB phototherapy;
  - PUVA phototherapy; and
  - UVA-1 phototherapy;
- Treatment of neonatal jaundice;
- Insect attraction in insect traps;
- Photo-polymerization of plastics (nail curing, contact lens manufacturing, etc.);
- Counterfeit detection (money checkers);
- Forensic investigation (UV light to detect organic material);
- Enhancing colours of fish in aquaria;
- Fluorescence by black lights in disco's; and
- Many other applications;

Examples of CFL lamps falling under Ex. 1(f) are presented in Figure **7-1**.

LEU further explains[134] that for some of these applications dedicated lamps are marketed, like medical reprography and insect traps, but other lamps are sold in general with a special spectral characteristic and it is unknown which lamp types are used for which applications.

Only a small number of special purpose lamps generate visible light. These have special applications like colour comparison, lamps with high CRI> 90, or lamps with special spectra for poultry farms. However, LEU states[135] that requirements for specifying terms besides the spectral sensitivity are very challenging and mostly depend on the application. Most of the special purpose radiation is dose related. This means that the applied energy during a certain period of time leads to the desired effect but also that undesired side-effects might occur. The dose is a combination of output and time, where time is completely determined by the application and output is the irradiance which

[133] Op. cit. LEU Ex. 1f (2015a)
[134] LEU Ex. 1f (2015b), Lighting Europe, Response to Oeko-Institut regarding the 1st Questionnaire, Exemption Request No. 1(f) (renewal request, submitted 15.9.2015, available under http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_1_f/Lighting_Europe/Ex_1_f__LightingEurope_1st_Clarification-Questions_final.pdf
[135] Op. cit. LEU Ex. 1f (2015b)

depends on the distance, the amount of lamps in the appliance and the used drivers to provide the electrical power. Thus the lamp manufacturers have only control on the nominal output measured under standardized circumstances and the spectral shape.

Figure 7-1: Examples of CFL 1(f) lamps and applications

Source: Top image: Typical shapes and forms, taken from LEU Ex. 1f (2015a); Bottom image: examples of lamps applications falling under Ex. 1(f), taken from LEU (2015a).

7.2.1 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 4.3.2.1 of this report (the general lamp chapter).

LEU also explains that the amount of mercury used in compact fluorescent lamps has decreased considerably during the last years, but that the technology needs the maximum dosed mercury amount, which is set at 5 mg, in order to function properly throughout the full indicated lifetime.

7.2.2 Possible Alternatives for Eliminating RoHS Substances

According to the applicant more and more LED solutions for general lighting are coming on to the market, while special purpose lamps are a niche market where the development of LED alternatives is slower. LEU[136] states further that only LED and DBD (dielectric barrier discharge) can be considered at present as substitution candidates. Whereas other lighting technologies i.e. halogen and OLED lamps, are not taken into account as substitutes because they cannot produce radiation in the range that is required for applications of Ex. 1(f) lamps.

However, LEU explains that LED and DBD are not considered to allow a proper replacement of the full range of CFL lamps for the various special purposes. 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, effectiveness, regulation / approbation and in the compatibility with all varieties of ballasts used in relevant equipment. Thus it can be difficult for a customer to choose between LED alternatives and to know when technical "*conversion*" changes are needed to ensure the compatibility of the LED with the existing installation.

LEU reminds that special purpose lamps are installed in a huge variety of types, shapes, sizes, wattages and colours, and explains that LED retrofit solutions and new LED equipment currently cannot be used as replacements (retrofit) for the full range of applications. It is questionable if LED retrofit solutions will be developed for the total range of applications, which is characterised as a scattered landscape with often small series per type. LEU supports its argument regarding the lack of alternatives for a proper full compatible replacement of Ex. 1(f) CFL lamps with specific retrofit criteria. The criteria to determine whether a new technology can replace existing fluorescent lamps using mercury in existing equipment are[137]:

- Similar spectral power distribution;
- Safety and reliability must be assured;

[136] Op. cit. LEU Ex. 1f (2015a)
[137] Op. cit. LEU Ex. 1f (2015a)

- Compatibility must be assured (electrical and mechanical specification);
- Effectiveness to reach the desired effect (tanning result, phototherapeutic effect, insect attraction rate, etc.) must be met;
- Compliance with CE regulations / approbation;
- No (negative) side effects;
- Economically feasible (cost of replacement technology);
- UVA and UVB output must be similar [important only for new technology – consultants comment];
- Similar radiation output [important only for retrofit solutions – consultants comment];

The criteria must be fulfilled both for lamp replacement and for placing new LED equipment on the market. The main difference whether a new technology can replace existing fluorescent lamps using mercury in existing equipment is explained to be justified as all technologies cannot produce radiation output in the range that is required for applications considered to be special purpose CFLs. In a similar fashion, this argument applies also to new LED-based equipment, as the UVA and UVB output must be similar.

LEU demonstrates as an example an alternative technology[138] for the use in water dispensers without mercury. However these lamps cannot replace the current installed base of CFLs, since the electrical and mechanical interface is completely different.

Consideration needs to be given to the following three criteria:

- Comparability of 'Wall Plug Efficiency' to fluorescent lamps;
- Comparability of effectiveness to fluorescent lamps (i.e. same tanning effect, photo-therapeutic effect, insect attraction rate etc.); and
- Regulation/approbation for replacement lamps/alternative equipment is approved.

Wall plug efficiency describes the useful UV power divided by the power used by the whole lighting device (including control gear) from the mains power supply.

On a technical basis the applicant states that achieving the required spectral output is only possible when converting from shorter wavelengths to longer. CFL emit radiation in the non-visible UV spectra and LED primarily emit only in the visible light spectra, of higher wavelengths. It's therefore impossible to create UV light with materials currently used to produce visible light LEDs.

Where it is possible to produce LEDs with non-visible UV light spectra (through AlGaN-LED) the efficiency is still very low. For e.g. according to the applicant[139] studies on insect

[138] A disinfection lamp system for water dispensers, based on a dielectric barrier discharge. Op. cit. LEU Ex. 1f (2015a)
[139] Op. cit. LEU Ex. 1f (2015a)

trap applications (not yet published) looking into LEDs currently show negative results with respect to their ability to attract insects as compared to CFL lamps.

Therefore, according to the applicant[140], LED is not expected any time soon to be suitable as a practical alternative for:

- Disinfection/purification of air/water/surfaces;
- Broadband and Narrowband UVB Phototherapy;
- PUVA phototherapy; and
- Tanning

Regarding the **effectiveness**, for most special purposes, no test results are available yet from studies comparing CFL-based equipment with LED-based equipment, to allow evaluating the effectiveness of new technologies to reach the desired effect. For some applications, for which LED-based equipment is on the market (e.g. nail curing equipment using LEDs) it turns out to be less effective and longer curing/treatment times are necessary. For some other curing applications new photo-initiators have been developed to be able to cure at wavelengths where LEDs are available at a reasonable price. Nonetheless, retrofit LED lamps cannot be used as replacements, due to approbation requirements. Renewal of [medical device – consultants comment] approbation with retrofit LED lamps is not endorsed by equipment companies.

Another example provided by the applicant regards black lights and aquarium lamps. In these applications the visual effects of single CFLs and LEDs are not comparable and therefore LED alternatives cannot be considered compatible.

Regulation (with respect to safety and system responsibility) such as CE[141] conformity and other European directives for special purpose applications (like for instance approbation of medical devices for phototherapy) is based on fluorescent lamps. If the intent is to convert existing equipment to LED alternatives, as most alternative lamps will in practice require a replacement of the equipment ballast to ensure their compatibility, this would be imply that the complete equipment needs to be replaced resulting in an increase of waste. LEU thus claims[142] that spare part replacement of compact fluorescent lamps with LED based lamps is therefore generally not practical.

Thermal Aspects: Current equipment using compact fluorescent lamps is not designed to take care of the heat generated by LEDs. Where in CFL-type lamps the generated heat is mostly radiated away, with LEDs the heat has to be transported away by conduction. Furthermore CFLs for special purpose are designed to have a very homogenous spatial radiation distribution compared to LED retrofit lamps. The more directional light of an LED will give a different radiation distribution in the same equipment.

[140] Op. cit. LEU Ex. 1f (2015a)
[141] CE marking is a mandatory conformity marking for certain products sold within the European Economic Area (EEA)
[142] Op. cit. LEU Ex. 1f (2015a)

Electrical Configuration: LEU [143] further explains that luminaires can use conventional electromagnetic ballasts or high frequency electronic drivers. The market for new installations is moving towards electronic drivers due to new functionality (e.g. dimmability) and upcoming legislation for drivers related to energy efficiency. Professional CFL lamps are designed to be dimmable. Several modes of dimming (e.g. phase cutting) are present on the market. All modes of operation (EM, HF current controlled, power controlled, voltage controlled, preheat, non-preheat) have in common that the light source is expected to behave electrically as a standardised CFL lamp. The large diversity of drivers is not intended for an electronically ballasted LED lamp and there is no interface description for LED lamps yet. Thus, in the case of existing installations where the life of the lamp is shorter than that of the luminaire, a customer does not know which ballast is used and which LED lamp to apply as retrofit. A wrong combination can lead to instable lamp power for the LED and to safety consequences. Ballasts for professional CFL lamps are designed to be used with several subsequent lamps (at least 3-4 lamps before the ballast itself has to be replaced). So if the combination of the ballast with the LED lamp is not working or not available, the ballast needs to be changed earlier.

It is understood that the argumentation made regarding ballasts compatibility could only be a concern for lamps with external ballasts, as from the fixtures observed in figure Figure **7-1** not all lamps falling under Ex. 1(f) shall have an external ballast.

LEU concludes[144] that LEDs currently do not provide a viable alternative for replacing single capped fluorescent lamps for special purposes based on the following results:

- For UV-C and UV-B: higher energy consumption (see example in report of Ex. 18b, Chapter 27.0) due to low efficiency of currently available UV-C and UV-B LEDs;
- For UV-A: For applications with a spectral output below 380 nm, energy consumption will also go up due to low efficiency of UV-A LEDs in that wavelength region;
- Applicable for all applications: In practice, most alternative lamps need replacement of the equipment ballast. Effectively, this would imply that the complete equipment needs to be replaced, which produces additional waste when still properly operating components need to be disposed.

7.2.3 Environmental Arguments

In addition to the overall environmental arguments detailed in Section 4.3.3 of the general chapter, the applicant further argues that although the LED technology doesn't contain mercury, it may contain other sorts of substances as lead and plastics. The applicant advocates to first carry-out further research into the overall substance effect

[143] Op. cit. LEU Ex. 1f (2015a)
[144] Op. cit. LEU Ex. 1f (2015a)

of LED lamps in comparison with CFL lamps. LEU later substantiated such statements revealing that discharge lamps and LED alternatives may have similar electronic components and thus may contain similar hazardous materials (see Section 4.3.3.2 of the general chapter). However, should new materials need to be developed to allow for LED substitutes to improve in spectra and in energy wall efficiency, this statement may be observed differently.

Argumentation related to lower wall-plug efficiency is also of environmental relevance, but is not presented here again as it appears in the sections above.

7.2.4 Road Map to Substitution

With regards to Ex. 1(f)-lamps, the applicant states (since special purpose lamps are a niche market) that LED development is slower in comparison to the general lighting application range. LED technology performance is developing and some UV-LEDs are available from several suppliers. However the balance between cost price, differences in wall plug efficiency, effectiveness, the difficulties in regulation/approbation and the time needed to approve approbation is not yet clear. The most difficult of these issues to overcome is likely to be the differences in spectral output. For different applications the time needed for implementing development efforts to allow releasing equipment to the market may differ significantly for various applications. For example for medical treatment applications, with the risk of side effects, equipment releases could be extremely costly, time consuming and difficult.

According to the applicant an extension of the exemption will have no negative effect on the efforts to further innovate in LED, because the future focus of the lighting industry is already on the further development of such technologies.

7.3 Stakeholder Contributions

Five contributions were submitted during the stakeholder consultation, however none of these provide specific information related to Ex. 1f –lamps. General aspects raised can be viewed in Section 4.4 of the general chapter.

7.4 Critical Review

7.4.1 Scientific and Technical Practicability of Substitution

LEU does not provide a roadmap related to efforts for further improvement of CFL technology and it can be understood that such research is no longer being performed. It can be concluded that all efforts towards development of alternatives are focused on LED technologies. Moreover the amount of mercury has been drastically reduced in the last decades in mercury-based lamp applications. Thus it is uncertain if the amount of mercury of 5mg currently permitted through Ex. 1(f) can be reduced while ensuring comparable performance in terms of lifetime, optical performance and energy efficiency.

Halogens lamps are explained to be a non-practical alternative as they consume significantly more energy during their use. The consultants agree with this point and thus they are not further discussed in this respect.

The applicant mentions that organic light-emitting diode (OLED) lamps cannot produce radiation in the range that is required for applications of lamps for special purposes. In a first clarification round[145] the applicant described these alternatives as not suitable for special purpose lamps. OLEDs are similar to LEDs in the sense that both use solid-state semiconductor materials that emit light from a p-n-junction. They are different in the sense that LEDs use inorganic materials while OLEDs use organic (carbon based) materials. OLED material is designed to function in the visible light range and is used for display or general illumination purposes. In order to create UV light (radiation) other materials need to be tested. Furthermore, most of the organic materials are very unstable under UV conditions and rapidly degrade. This argument however, can only support that OLEDs are not a practical substitute for special purpose lamps with a spectral output in the non-visible range.

LEU explains that there are UV LEDs, which in principle could be used for special purposes, available from several suppliers. However such alternatives cannot produce radiation in the spectral range required for various applications of special purpose CFLs. In the consultants view this argumentation is only substantiated for applications for which the main function of the lamp is to provide spectral output in the non-visible light range, for instance tanning lamps, broadband and narrowband UVB phototherapy; PUVA phototherapy or disinfection/purification applications, and black light referred to as a UV-A light that emits long wave (UV-A) ultraviolet light and not much visible light. For such applications, it can be followed that current alternatives do not provide a comparable spectral output (UVB/UVC), and/or that wall plug efficiency of the applications effectiveness are lower.

It is further explained that lamps covered by the exemption for professional use are subject to application specific EU regulations or CE marking. Replacing lamps in such installations so that they adhere to such norms may require a new lighting plan because, for example, the required illuminance levels can't be reached with the same number of light points. This can influence the total energy use negatively.

LEU did not provide any roadmap that predicts when UV LEDs with acceptable spectral output and efficiency shall become available. According to the applicant the presence of mercury in such special purpose Ex. 1(f) – UV lamps is understood to still be necessary as performance of alternatives is still not comparable to CFLs (spectral output, efficiency, etc.). This argumentation can be followed.

In contrast, for special purpose lamps where the main function is understood to be in the visible spectral output range, the provided argumentation does not explain why substitution is currently not possible. Arguments are similar to those provided for Exemption entries 1(a-e) and it is not sufficiently explained why such applications are to be understood to be special purposes and not general lighting and why possible alternatives cannot achieve comparable performance (such as higher CRI's). Lighting

[145] Op. cit. LEU Ex. 1f (2015b)

Europe further does not confirm that detailed applications are exhaustive (i.e., special purposes cannot be defined comprehensively), and thus additional applications could be placed on the market through this exemption if its wording remains unchanged.

Argumentation related to the availability of substitutes for lamps operating in the visible light spectrum are discussed in the chapter regarding Exemption 1a-e (See Chapter 5.0). In the consultants view, the information provided by LEU as to possible LED substitutes is very general in its nature. Many of the specific design limitations raised as problems of LED technologies have been communicated in the past reviews and are understood to have been resolved in applications on the market. As LEU does not provide specific information to substantiate its claims in relation to Ex. 1(f) lamps operating in the visible-light range, it cannot be concluded if such developments have also been implemented in LED alternatives on the market that are relevant for this exemption.

In contrast, the consultants can follow the argumentation that despite development efforts, that LED alternatives for UV sources do not provide comparable performance related to application effectiveness and lifetime. As the UV lamp area is a niche application are, it can also be followed that such developments shall be slower than for other lamp applications with larger market shares.

7.4.2 Environmental Arguments

Regarding the environmental arguments made by LEU, most of these are not specific for lamps falling under Ex. 1(f) and are discussed in the general chapter (see Section 4.5.3).

As for aspects raised regarding possible reduced wall plug efficiency of current candidate alternatives, these are discussed in Section 7.4.1 and can be followed.

7.4.3 The Scope of the Exemption

LEU was asked to clarify exhaustively the scope of exemption 1(f) in terms of lamp type sub-groups, in order to determine what applications fall under the term “special purposes” and what the respective characterisations of lamps are. LEU explains that the majority of the applications are not in the visible output range. There are only a small number of special purpose lamps that generate visible light. According to the applicant these lamps differ in their colour, with high colour rendering >CRI 90. However LEU delivers no further arguments and data as to such applications and states that lighting manufacturers do not know exactly which lamp types are used in which applications. The applicant thus argues that it is difficult to classify certain lamp types.

According to the applicant the power rating of CFL for special purposes ranges from 5W – 110W. Fluorescent lamps can be distinguished into general lighting purpose lamps and special purpose lamps as well as single-capped (CFL), and double-capped (LFL) linear lamps. Ex. 1(f) covers CFLs with the same range of wattages also addressed under the existing exemption entries 1(a-c). The use of the undefined term “special purposes” is thus understood to potentially create loopholes, under which lamps falling under the scope of Ex. 1(a-c) could be placed on the market through Ex. 1(f), should the term not be clearly defined. Such loopholes have also been discussed among others, in the preparatory Study on Light Sources for Ecodesign and/or Energy Labelling Requirements

('Lot 8/9/19') prepared by VHK & VITO and in the Omnibus study[146]. There is a need to clearly define what technologies are to be considered to fall under "special purpose uses" so as to eliminate such loopholes in exemptions where this term is referred to, particularly at a time where it is expected that some exemptions may be revoked. However, LightingEurope and other studies do not provide an exhaustive definition at present and arriving at such a definition is also not possible on the basis of the information provided by the applicants, where detailed applications are specified as not exhaustive. Information provided by LEU clarifies that lights emitting in the UV spectrum would fall under this exemption. Though additional applications are named, the only parameter mentioned as characteristic of such lamps is colour rendering index (CRI) values of above 90. However information is not provided to explain why alternatives do not provide comparable performance, nor is it clear why such applications would be considered to fall under special purposes, particularly as LEU could not provide information as to the range of relevant applications. As long as the lighting industry cannot provide information clearly demonstrating what applications and respectively what performance aspects would be relevant for special purpose, the only way to avoid loop-holes is to limit the scope of the exemption. Such a limitation can only consider articles clearly understood to be of relevance, not to be covered by other exemptions and for which argumentation is provided to justify the applicability according to Article 5(1)(a).

LEU explains that the lamp manufacturers only control the nominal spectral output measured under standardized circumstances. Though it can be followed that in some cases manufacturers do not know for what purposes their lamps are used in practice[147], the consultants cannot follow LEU's general argumentation that it is not possible to exhaustively define what lamps are covered under this exemption (for example through specifying typical spectral output specifications and colour performance aspects). This is further an issue of concern as without such specifications it cannot be determined if certain lamps placed on the market through Exemption 1(f) would not also fall under the scope of Ex. 1(a-c). In the consultants view it is essential to distinguish between visible (to most human eyes) and non-visible light in order to allow differentiating between applications for which argumentation justifies the renewal of the exemption and applications for which this is not understood to be the case.

[146] Op. cit. Omnibus (2014)

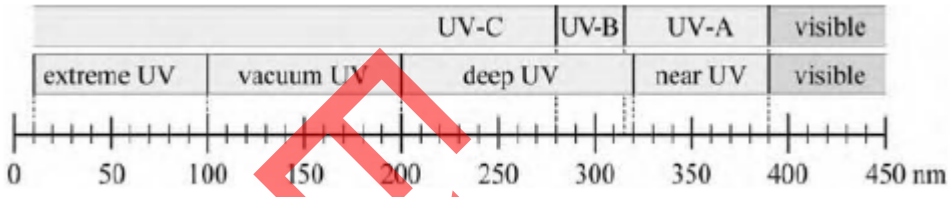
[147] When a lamp is placed on the open market, the manufacture cannot guarantee that it shall only be installed in equipment for which it was designed. Nonetheless, the consultants expect that the lighting industry be able to detail the range of lamps covered by a certain exemption as they are aware of what is manufactured (dimensions, technical parameters, etc.) and for which applications it is designed (i.e. what functions the lamp needs to fulfil).

7.4.3.1 Lamps Designed for Emitting Light in the Non-Visible Spectrum

Ultraviolet (UV) light is that part of electromagnetic radiation between the lower wavelength extreme of the visible spectrum and the X-ray radiation band, which is commonly used in medicine. The spectral range of UV light is between 100 and 400 nm (1 nm=10-9m) and is invisible to human eyes[148]. The spectral range can be produced by light of a narrow band of wavelengths. The spectrum is continuous, with no clear boundaries between one colour and the next classification. Using the CIE classification[149] the UV spectrum is subdivided into three subtype bands UVA, UVB, UVC. Each has different penetration properties and potential for damage to human health.

In order to discuss the issue of the wavelengths it is useful to illustrate the Wavelength (nm) for the UV spectrum, as shown in Figure 7-2.

Figure 7-2: Classification of UV radiation



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

In general, the following types of UV light are distinguished:

- UVA (long-wave) / near UV-Black Light 315-400 nm[150];
- UVB (medium-wave) 280-315 nm;
- UVC UV C (short-wave) / far UV-Germicidal 100-280 nm.

The most important application of UV lamps is probably in tanning devices (e.g. solariums). It is estimated that there are around 50.000 tanning facilities (salons, beauty parlours, hot baths and spas)[151]. However there is a huge variety of lamps used for additional applications, i.e., medical, disinfection, etc. (see detail in Section 7.2).

There are other types of non-visible light e.g. infrared light, X-Rays, microwaves etc. some of which may also be relevant for special purposes lamps (e.g. infrared). The consultants assume that special purpose lamps emitting infrared wavelength are not

[148] Visible light lies in the wavelength range around 400 to around 700nm
[149] http://www.cie.co.at/index.php/Technical+Committees
[150] (in DIN only defined to 380 nm, in practice often down to 400 nm)
[151] VHK (2015b): Preparatory Study on Light Sources for Ecodesign and/or Energy Labelling Requirements ('Lot 8/9/19'). Final report, Task 1, Annexes, Standards, Legislation, by Prepared by VHK, in cooperation with VITO and JeffCott Associates, 31 October 2015; Prepared for the European Commission, DG ENER.C.3

part of the requested exemption at hand as the applicant did not detail any applications related to that spectra.

7.4.4 Exemption Wording Formulation

The applicant has requested the renewal of the exemption with the following wording formulation.

> *"1: Mercury in single capped (compact) fluorescent lamps not exceeding (per burner):*
>
> *(f) For special purposes: 5 mg"*

The analysis of the term special purpose lamps under the current lighting regulations (RoHS and Ecodesign) and the information highlighted by LEU does not allow specifying an exhaustive definition for this term.

As argumentation for justifying the exemption only supports the lack of substitutes for applications in the non-visible range, the consultant recommends a distinction between visible and non-visible light. The consultants note that distinctions between visible and non-visible have been made before; for instance, the definition for the initial scope in legislation drafted for the Commission consequence to the Preparatory Study on Light Sources for Ecodesign and/or Energy Labelling Requirements ('Lot 8/9/19') refers to visible light as "mainly visible optical radiation in a wavelength of 380-780 nm".

7.4.5 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

In the consultants' opinion, lamps for special purposes are needed where application specific characteristics are prescribed. They generally have the following characteristics:

- Special purpose lamps are generally manufactured on the basis of general purpose lamp production technologies.
- The use of special design, materials and process steps provides their special features and CFLs for special purposes cover a very broad range of different lamps with different characteristics.
- Special purpose lamps covered by Ex. 1(f) are estimated to have relevance very small market share (most of them are not supported by market data) in comparison to other CFL lamps discussed above.

The applicant puts forward information that clearly shows that substitution on the substance level is not practical and it can also be followed that further reducing Hg amounts per burner may not result in significant environmental benefits. All efforts towards development of further substitutes are understood to be focused on LED technologies.

Based on the available information the consultants conclude that most of the applications operate mainly in the non-visible radiation range such as UV lamps. For such lamps, the argumentation that substitutes do not provide comparable performance as a consequence of insufficient wall-plug efficiency, non-comparable spectral output and lacking application effectiveness. Application approbation shall only be possible after resolving these issues. The consultants' can follow that the last stages of substitution may thus require more time.

- LEU explains that some CFL-lamps operate in the visible radiation range; however, justification for the exemption is only presented for lamps operating in the non-visible range (i.e. where the main function of the application requires the spectral output to be in the non-visible range). This does not allow understanding whether the exemption renewal would be justifiable for lamps operating in the visible range. Further argumentation to support the lack of substitutes for such lamps does not allow concluding that such lamps would not fall under Ex. 1(a-c) and to what degree LED substitutes are available or not. Whether these lamps are indeed to be considered as special purpose applications can also not be derived from the available information. For example, Ex. 4(b) also concerns lamps with special colour performance and relevant applications are addressed in the exemption as "general purposes". Specific information as to alternatives for Ex. 1(f) lamps operating in the visible light range are not provided. Though some alternatives may be available for such applications, it cannot be dismissed that availability may still be insufficient.

Since most of LEU's examples for lamps that are "Ex. 1(f) special purpose lamps" are in the non-visible light spectrum and since for such lamps the argumentation can be followed, it would be practical to renew the exemption for such types. Thus splitting the exemption to address lamps designed for emitting light in the visible spectrum and in the non-visible spectrum would be practical. However, in the visible radiation range sufficient justification is not provided and the application list is not exhaustive, nor is other specification data available to allow a clear demarcation of lamps covered under the exemption. For such lamps manufacturers should be required to specify what types of lamps would fall under the exemption and why, based on the Article 5(1)(a) criteria to show the exemption is still justified. Manufacturers could be required to identify such lamps when placed on the market as "for special purpose" in order to allow collecting more specific information for future revisions of the Directive.

7.5 Recommendation

The consultants recommend granting an exemption as follows:

For lamps designed to emit light in the visible spectrum, technical justification has not been provided. The consultants can neither conclude that an exemption is justified nor that it is not, as specific information as to the application range and as to available substitutes are lacking. The consultants recommend revoking the exemption for such applications or allowing a short termed exemption so that industry can request new exemptions where data and information show justification on the basis of Article 5(1)(a). The consultants believe the definition of exemptions and of special purpose lamps should be application specific and based on technical parameters for all applications (sub-groups) of relevance.

For the special purpose lamps with UV radiation it is recommended to grant the exemption with the maximum available duration.

In light of Article 5(2), from a legal perspective, excluding EEE falling under Cat. 8 and 9 from the scope of this exemption may not be possible; however the consultants' are also concerned that extended availability of such lamps for these categories may create a loop hole for consumers seeking CFL replacements covered by entries due to expire. If possible, the EU Commission should investigate limiting the sales of such lamps to a business to business basis to avoid such misuse.

Exemption 1	**Duration***	**Comments**
Mercury in single capped (compact) fluorescent lamps not exceeding (per burner),		
(f)-I For lamps designed to emit light in the ultra-violet spectrum: 5 mg	*For Cat. 5: 21 July 2021*	The maximum transition period should be granted for other applications and other categories (18 months); Integrating this entry into a UV lamp exemption should be considered.
(f)-II For special purposes: 5 mg	*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*	The COM should consider adopting measures to limit product availability to B2B transactions.

7.6 References Exemption (1f)

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. 1f (2015b) Lighting Europe, Response to Oeko-Institut regarding the 1st Questionnaire, Exemption Request No. 1(f) (renewal request, submitted 15.9.2015, available under http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_1_f/Lighting_Europe/Ex_1_f__LightingEurope_1st_Clarification-Questions_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

VHK (2015b) Preparatory Study on Light Sources for Ecodesign and/or Energy Labelling Requirements ('Lot 8/9/19'). Final report, Task 1, Annexes, Standards, Legislation, by Prepared by VHK, in cooperation with VITO and JeffCott Associates, 31 October 2015; Prepared for the European Commission, DG ENER.C.3