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.

Executive Summary

Under Framework Contract no. ENV.C.2/FRA/2011/0020, a consortium led by Eunomia Research & Consulting was requested by DG Environment of the European Commission to provide technical and scientific support for the evaluation of exemption requests under the new RoHS 2 regime. The work has been undertaken by Oeko-Institut and Fraunhofer Institute IZM, and has been peer reviewed by Eunomia Research & Consulting.

E.1.0 Background and Objectives

The RoHS Directive 2011/65/EU entered into force on 21 July 2011 and led to the repeal of Directive 2002/95/EC on 3 January 2013. The Directive can be considered to have provided for two regimes under which exemptions could be considered, RoHS 1 (the former Directive 2002/95/EC) and RoHS 2 (the current Directive 2011/65/EU).

- The scope covered by the Directive is now broader as it covers all EEE (as referred to in Articles 2(1) and 3(1));
- The former list of exemptions has been transformed in to Annex III and may be valid for all product categories according to the limitations listed in Article 5(2) of the Directive. Annex IV has been added and lists exemptions specific to categories 8 and 9;
- The RoHS 2 Directive includes the provision that applications for exemptions have to be made in accordance with Annex V. However, even if a number of points are already listed therein, Article 5(8) provides that a harmonised format, as well as comprehensive guidance – taking the situation of SMEs into account – shall be adopted by the Commission; and
- The procedure and criteria for the adaptation to scientific and technical progress have changed and now include some additional conditions and points to be considered. These are detailed below.

The new Directive details the various criteria for the adaptation of its Annexes to scientific and technical progress. Article 5(1)(a) details the various criteria and issues that must be considered for justifying the addition of an exemption to Annexes III and IV:

- The first criterion may be seen as a threshold criterion and cross-refers to the REACH Regulation (1907/2006/EC). An exemption may only be granted if it does not weaken the environmental and health protection afforded by REACH;
- Furthermore, a request for exemption must be found justifiable according to one of the following three conditions:

- Substitution is scientifically or technically impracticable, meaning that a substitute material, or a substitute for the application in which the restricted substance is used, is yet to be discovered, developed and, in some cases, approved for use in the specific application;
- The reliability of a substitute is not ensured, meaning that the probability that EEE using the substitute will perform the required function without failure for a period of time comparable to that of the application in which the original substance is included, is lower than for the application itself;
- The negative environmental, health and consumer safety impacts of substitution outweigh the benefits thereof.

- Once one of these conditions is fulfilled, the evaluation of exemptions, including an assessment of the duration needed, shall consider the availability of substitutes and the socio-economic impact of substitution, as well as adverse impacts on innovation, and life cycle analysis concerning the overall impacts of the exemption; and
- A new aspect is that all exemptions now need to have an expiry date and that they can only be renewed upon submission of a new application.

The current study presented here, evaluates a total of 29 exemption renewal requests for existing exemptions approaching their expiry date.

E.2.0 Key Findings – Overview of the Evaluation Results

The exemption requests covered in this project and the applicants concerned, as well as the final recommendations and proposed expiry dates are summarised in Table 1-1. The reader is referred to the corresponding section of this report for more details on the evaluation results.

The – not legally binding – recommendations for the requests for the renewal of exemptions (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) were submitted to the EU Commission by Oeko-Institut and have already been published at the EU CIRCA website on 27 June 2016. So far, the Commission has not adopted any revision of the Annex to Directive 2011/65/EU based on these recommendations.

Table 1-1: Overview of the exemption requests, associated recommendations and expiry dates

Exemption No.	Wording: Main Entry	Sub-Entry	Applicant	Recommendation: Proposed Exemption Wording Formulation	Proposed Duration	Comments
n. 1	Mercury in single-capped (compact) fluorescent lamps not exceeding (per burner):		NARVA Lichtquellen GmbH + Co. KG LightingEurope	Mercury in single-capped (compact) fluorescent lamps not exceeding (per burner)		
a to e (lighting)		1(a) For general lighting purposes < 30 W: 5 mg 1(b) For general lighting purposes ≥ 30 W and < 50 W: 5 mg 1(c) For general lighting purposes ≥ 50 W and < 150 W: 5 mg 1(d) For general lighting purposes ≥ 150 W: 15 mg 1(e) For general lighting purposes with circular or square structural shape and tube diameter ≤ 17 mm: 7 mg		(a) For general lighting purposes < 30 W: 2.5 mg (b) For general lighting purposes ≥ 30 W and < 50 W: 3.5 mg	For Cat. 8 and Cat. 9: 21 July 2021; For Sub-Cat. 8 in-vitro: 21 July 2023; For Sub-Cat. industrial: 21 July 2024	The maximum transition period should be granted to other categories (18 months); The COM should consider adopting measures to limit product availability to B2B transactions.
				(c) For general lighting purposes ≥ 50 W and < 150 W: 5 mg (d) For general lighting purposes ≥ 150 W: 15 mg	For Cat. 5: 21 July 2019; 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	

Exemption No.	Wording: Main Entry	Sub-Entry	Applicant	Recommendation: Proposed Exemption Wording Formulation	Proposed Duration	Comments
				(e) For general lighting purposes with circular or square structural shape and tube diameter ≤ 17 mm	7 mg may be used per burner until 31.12.2019, 5 mg may be used per burner after 31.12.2019 For Cat. 5: 21 July 2019 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	
f (special purpose)		1(f) For special purposes: 5 mg	NARVA Lichtquellen GmbH + Co. KG LightingEurope	**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.

Exemption No.	Wording: Main Entry	Sub-Entry	Applicant	Recommendation: Proposed Exemption Wording Formulation	Proposed Duration	Comments
				(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.
n. 2 (a)	Mercury in double-capped linear fluorescent lamps for general lighting purposes not exceeding (per lamp):		NARVA Lichtquellen GmbH + Co. KG LightingEurope	**Mercury in double-capped linear fluorescent lamps for general lighting purposes not exceeding (per lamp)**		
(1-5)		(1) Tri-band phosphor with normal lifetime and a tube diameter < 9 mm (e.g. T2): 5 mg		1) Tri-band phosphor with normal lifetime and a tube diameter < 9 mm (e.g. T2): 4 mg	For Cat. 5, 8 & 9: 21 July 2021; For Sub-Cat. 8 in-vitro: 21 July 2023; For Sub-Cat. 9 industrial: 21 July 2024	
		(2) Tri-band phosphor with normal lifetime and a tube diameter ≥ 9 mm and ≤ 17 mm (e.g. T5): 5 mg (3) Tri-band phosphor with normal lifetime and a tube diameter > 17 mm and ≤ 28 mm (e.g. T8): 5 mg (4) Tri-band phosphor with normal lifetime		(2) Tri-band phosphor with normal lifetime and a tube diameter ≥ 9 mm and ≤ 17 mm (e.g. T5): 3 mg (3) Tri-band phosphor with normal lifetime and a tube diameter > 17 mm and ≤ 28 mm (e.g. T8): 3.5 mg (4) Tri-band phosphor with normal lifetime and a tube diameter > 28 mm (e.g. T12): 3.5 mg	For Cat. 8 & 9: 21 July 2021; For Sub-Cat. 8 in-vitro: 21 July 2023; For Sub-Cat. 9 industrial: 21 July 2024	The maximum transition period should be granted for other applications and other categories (18 months);

Exemption No.	Wording: Main Entry	Sub-Entry	Applicant	Recommendation: Proposed Exemption Wording Formulation	Proposed Duration	Comments
		and a tube diameter > 28 mm (e.g. T12): 5 mg (5) Tri-band phosphor with long lifetime (≥ 25 000 h): 8 mg		(5) Tri-band phosphor with long lifetime (≥ 25 000 h): 5 mg	For Cat. 5, 8 & 9: 21 July 2021; For Sub-Cat. 8 in-vitro: 21 July 2023; For Sub-Cat. 9 industrial: 21 July 2024	
n. 2 (b) (3)		(3) Non-linear tri-band phosphor lamps with tube diameter > 15 mm (e.g. T9)	NARVA Lichtquellen GmbH + Co. KG LightingEurope	2(b) Mercury in other fluorescent lamps not exceeding (per lamp) (3) Non-linear tri-band phosphor lamps with tube diameter > 17 mm (e.g. T9)	For Cat. 5: 21 July 2019; For Cat. 8 & 9: 21 July 2021; For Sub-Cat. 8 in-vitro: 21 July 2023; For Sub-Cat. 9 industrial: 21 July 2024	
n. 2 (b) (4)		(4) Lamps for other general lighting and special purposes (e.g. induction lamps): 15 mg per lamp	LightingEurope	(I) Lamps for other general lighting and special purposes (e.g. induction lamps); 15 mg may be used per lamp after 31 December 2011	For Cat. 8 & 9: 21 July 2021; For Sub-Cat. 8 in-vitro: 21 July 2023; For Sub-Cat. 9 industrial: 21 July 2024	

Exemption No.	Wording: Main Entry	Sub-Entry	Applicant	Recommendation: Proposed Exemption Wording Formulation	Proposed Duration	Comments
				(II) Lamps emitting light in the non-visible spectrum: 15 mg per lamp	For Cat. 5: 21 July 2021	Integrating this entry into a UV lamp exemption should be considered.
				(III) Emergency lamps: 15 mg per lamp	For Cat. 5: 21 July 2021	
				(IV) Mercury in other fluorescent special purpose lamps not specifically mentioned in this Annex: 15mg per lamp	For Cat. 5: 21 January 2019	
n.3	Mercury in cold cathode fluorescent lamps and external electrode fluorescent lamps (CCFL and EEFL) for special purposes not exceeding (per lamp):		LightingEurope	Mercury in cold cathode fluorescent lamps and external electrode fluorescent lamps (CCFL and EEFL) for special purposes not exceeding (per lamp):		
		(a) Short length (≤ 500 mm): 3.5 mg per lamp (b) Medium length (> 500 mm and ≤ 1 500 mm): 5 mg per lamp (c) Long length (> 1 500 mm): 13 mg per lamp		(a) Short length (≤ 500 mm), 3,5 mg may be used per lamp; (b) Medium length (> 500 mm and ≤ 1 500 mm), 5 mg may be used per lamp; (c) Long length (> 1 500 mm) 13 mg may be used per lamp	For Cat. 8 & 9: 21 July 2021; For Sub-Cat. 8 in-vitro: 21 July 2023; For Sub-Cat. 9 industrial: 21 July 2024	

Exemption No.	Wording: Main Entry	Sub-Entry	Applicant	Recommendation: Proposed Exemption Wording Formulation	Proposed Duration	Comments
				(d) Short length (≤ 500 mm), 3,5 mg may be used per lamp in EEE placed on the market before 22 July 2016* (e) Medium length (> 500 mm and ≤ 1 500 mm), 5 mg may be used per lamp in EEE placed on the market before 22 July 2016* (f) Long length (> 1 500 mm) 13 mg may be used per lamp in EEE placed on the market before 22 July 2016*	For Cat. 5: 21 July 2021	*Or before the EC's decision date on this exemptions renewal
				(g) For back-lighting liquid crystal displays, not exceeding 5 mg per lamp, used in industrial monitoring and control instruments placed on the market before 22 July 2017	Alternative a: For Cat. 5: 21 July 2021; or Alternative b: For Sub-Cat. industrial: 21 July 2024	To be considered should Ex. 35 of Annex IV be transferred to Annex III
n.4 (a)	Mercury in other low pressure discharge lamps (per lamp): 15 mg per lamp		NARVA Lichtquellen GmbH + Co. KG LightingEurope	4(a)-I: Mercury in low pressure non-phosphor coated discharge lamps, where the application requires the main range of the lamp-spectral output to be in the UV spectrum; up to 15 mg mercury may be used per lamp.	For Cat. 5: 21 July 2021	The maximum transition period should be granted for other applications and other categories (18 months);

Exemption No.	Wording: Main Entry	Sub-Entry	Applicant	Recommendation: Proposed Exemption Wording Formulation	Proposed Duration	Comments
				4(a)-II: Mercury in other low pressure discharge lamps (15 mg may be used per lamp)	For Cat. 8 and Cat. 9: 21 July 2021; For Sub-Cat. 8 in-vitro: 21 July 2023; For Sub-Cat. 9 industrial: 21 July 2024	
n.4 (b)	Mercury in High Pressure Sodium (vapour) lamps for general lighting purposes not exceeding (per burner) in lamps with improved colour rendering index Ra > 60:		LightingEurope	Mercury in High Pressure Sodium (vapour) lamps for general lighting purposes not exceeding (per burner) in lamps with improved colour rendering index Ra > 60:		
		I) P ≤ 155 W: 30 mg per burner II) 155 W < P ≤ 405 W: 40 mg per burner III) P > 405 W: 40 mg per burner		(I) P ≤ 155 W; 30 mg may be used per burner (II) 155 W < P ≤ 405 W; 40 mg may be used per burner	For Cat. 5, 8 & 9: 21 July 2021; For Sub-Cat. 8 in-vitro: 21 July 2023; For Sub-Cat. industrial: 21 July 2024	
				(III) P > 405 W; 40 mg may be used per burner	For Cat. 8 & 9: 21 July 2021; For Sub-Cat. 8 in-vitro: 21 July 2023; For Sub-Cat. 9 industrial: 21 July 2024	It is understood that these lamps are no longer placed on the market. Thus the exemption appears to have become obsolete, however is specified for Cat. 8 and Cat. 9 in light of Article 5(2).

Exemption No.	Wording: Main Entry	Sub-Entry	Applicant	Recommendation: Proposed Exemption Wording Formulation	Proposed Duration	Comments
n.4 (c)	Mercury in other High Pressure Sodium (vapour) lamps for general lighting purposes not exceeding (per burner)		LightingEurope	Mercury in other High Pressure Sodium (vapour) lamps for general lighting purposes not exceeding (per burner):		
		I) P ≤ 155 W: 25 mg per burner II) 155 W < P ≤ 405 W: 30 mg per burner III) P > 405 W: 40 mg per burner		(I) P ≤ 155 W; 25 mg may be used per burner after 31 December 2011 (II) 155 W < P ≤ 405 W; 30 mg may be used per burner after 31 December 2011 (III) P > 405 W; 40 mg may be used per burner after 31 December 2011	For Cat. 5: 31 August 2018; For Cat. 8 & 9: 21 July 2021; For Sub-Cat. 8 in-vitro: 21 July 2023; For Sub-Cat. 9 industrial: 21 July 2024	
				(IV) P ≤ 405 W; 20 mg may be used per burner (V) P > 405 W; 25 mg may be used per burner	For Cat. 5: from 1 September 2018 until 21 July 2021	
n.4(e)	Mercury in metal halide lamps (MH)		LightingEurope	Mercury in metal halide lamps (MH)	For Cat. 5, 8 & 9: 21 July 2021; For Sub-Cat. 8 in-vitro: 21 July 2023; For Sub-Cat. 9 industrial: 21 July 2024	

Exemption No.	Wording: Main Entry Sub-Entry	Applicant	Recommendation: Proposed Exemption Wording Formulation	Proposed Duration	Comments
n.4(f)	Mercury in other discharge lamps for special purposes not specifically mentioned in this Annex	VskE Lighting Europe VDMA	(I) Mercury in other discharge lamps for special purposes not specifically mentioned in this Annex	For Cat. 8 & 9: 21 July 2021; For Sub-Cat. 8 in-vitro: 21 July 2023; For Sub-Cat. industrial: 21 July 2024	
			(II) Mercury in high pressure mercury vapour lamps used in projectors where an output ≥2000 lumen ANSI is required	For Cat. 5: 21 July 2021	
			(III) Mercury in high pressure sodium vapour lamps used for horticulture lighting	For Cat. 5: 21 July 2021	
			(IV) Mercury in lamps emitting light in the ultraviolet spectrum for curing and disinfection	For Cat. 5: 21 July 2021	
n.5(b)	Lead in glass of fluorescent tubes not exceeding 0,2 % by weight	LightingEurope	Lead in glass of fluorescent tubes not exceeding 0,2 % by weight	For Cat. 5: 21 July 2021; 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	

Exemption No.	Wording: Main Entry Sub-Entry	Applicant	Recommendation: Proposed Exemption Wording Formulation	Proposed Duration	Comments
n.6(a)	Lead as an alloying element in steel for machining purposes and in galvanised steel containing up to 0,35 % lead by weight	Dunkermotoren; The European Steel Association (EUROFER) and European General Galvanizers Association (EGGA) Sensata Technologies	I) Lead as an alloying element in steel for machining purposes containing up to 0,35 % lead by weight	For Cat. 1-7 and 10 and 11: 21 July 2019	
			II) Lead in batch hot dip galvanized steel components containing up to 0.2% lead by weight	For Cat. 1-7 and 10 and 11: 21 July 2021	
			III) Lead as an alloying element in steel for machining purposes and in galvanized steel containing up to 0,35 % lead by weight	For Cat. 8 and 9: 21 July 2021; For Sub-Cat. 8 in-vitro: 21 July 2023; For Sub-Cat. 9 industrial: 21 July 2024	
n.6(b)	Lead as an alloying element in aluminium containing up to 0,4 % lead by weight	AISBL - EAA Sensata Technologies Dunkermotoren	Lead as an alloying element in aluminium		
			I) with a lead content up to 0.4 % by weight, used for the production of parts not machined with shape cutting chipping technologies	For Cat. 1-7 and 10 and 11: 21 July 2021	
			II) for machining purposes with a lead content up to 0.4 % by weight	For Cat. 1-11: 21 July 2021	

Exemption No.	Wording: Main Entry Sub-Entry	Applicant	Recommendation: Proposed Exemption Wording Formulation	Proposed Duration	Comments
			III) Lead as an alloying element in aluminium containing up to 0,4 % lead by weight	For Cat. 8 and 9: 21 July 2021; For Sub-Cat. 8 in-vitro: 21 July 2023; For Sub-Cat. 9 industrial: 21 July 2024	
n.6(c)	Copper alloy containing up to 4 % lead by weight	Bourns Inc. Dunkermotoren Framo Morat Group Sensata Technologies Phoenix Contact GmbH &Co KG; Harting KGaA Lighting Europe	Copper alloy containing up to 4% lead by weight	For Cat. 1-7 and 10 and 11: 21 July 2019; For Cat. 8 and 9: 21 July 2021; For Sub-Cat. 8 in-vitro: 21 July 2023; For Sub-Cat. 9 industrial: 21 July 2024	
n.7(a)	Lead in high melting temperature type solders (i.e. lead-based alloys containing 85 % by weight or more lead)	Bourns Inc. IXYS Semiconductor GmbH Chenmko Enterprise Co., Ltd Yeashin Technology Co., Ltd Freescale Semiconductor Formosa Microsemi Co., Ltd.	I) Lead in high melting temperature type solders (i.e. lead-based alloys containing 85 % by weight or more lead)	For Cat. 8 and 9: 21 July 2021; For Sub-Cat. 8 in-vitro: 21 July 2023; For Sub-Cat. 9 industrial: 21 July 2024	
			Lead in high melting temperature type solders (i.e. lead-based alloys containing 85 % by weight or more lead)		
			II) in all applications not addressed in items III and IV,	For categories 1 to 7 and 10: 21 July 2021	See exemption report for alternative

Exemption No.	Wording: Main Entry Sub-Entry	Applicant	Recommendation: Proposed Exemption Wording Formulation	Proposed Duration	Comments
			but excluding applications in the scope of exemption 24		wording proposal for 7(a)(II-IV).
			III) for die attach	For categories 1 to 7 and 10: 21 July 2019	
			IV) for electrical connections on or near the voice coil in power transducers		
n.7(c)-I	Electrical and electronic components containing lead in a glass or ceramic other than dielectric ceramic in capacitors, e.g. piezoelectronic devices, or in a glass or ceramic matrix compound	Bourns Inc. Sensata Technologies YAGEO Corporation RALEC TECHNOLOGY (KUNSHAN) CO. BANDELN electronic GmbH&Co.KG RALEC TECHNOLOGY (KUNSHAN) CO. Japan Electronics & Information Technology Industries Association Murata Elektronik GmbH EPCOS AG VISHAY BC	7(c)-I: Electrical and electronic components containing lead in a ceramic other than dielectric ceramic in discrete capacitor components, e.g. piezoelectronic devices	For categories 1-7 and 10: 21 July 2019	See exemption report for alternative wording proposal for 7(c)-I
			7(c)-V: Electrical and electronic components containing lead in a glass or in a glass or ceramic matrix compound. This exemption does not cover the use of lead in the scope of exemption 34 (cermet-based trimmer potentiometers).	For categories 1-7 and 10: 21 July 2021	See exemption report for alternative wording proposal for 7(c)-I

Exemption No.	Wording: Main Entry Sub-Entry	Applicant	Recommendation: Proposed Exemption Wording Formulation	Proposed Duration	Comments
		components BEYSCHLAG GmbH SCHOTT AG	7(d): Electrical and electronic components containing lead in a glass or ceramic other than dielectric ceramic in capacitors, e.g. piezoelectronic devices, or in a glass or ceramic matrix compound	For Cat. 8 and 9: 21 July 2021; For Sub-Cat. 8 in-vitro: 21 July 2023; For Sub-Cat. 9 industrial: 21 July 2024	See exemption report for alternative wording proposal for 7(c)-I
n.7(c)-II	Lead in dielectric ceramic in capacitors for a rated voltage of 125 V AC or 250 V DC or higher	Murata Elektronik GmbH EPCOS AG VISHAY BC components BEYSCHLAG GmbH JEITA(Japan Electronics & Information Technology Industries Association)	Lead in dielectric ceramic in capacitors for a rated voltage of 125 V AC or 250 V DC or higher	For Cat. 8 and 9: 21 July 2021; For Sub-Cat. 8 in-vitro: 21 July 2023; For Sub-Cat. 9 industrial: 21 July 2024	
			Lead in dielectric ceramic in discrete capacitor components for a rated voltage of 125 V AC or higher, or for a rated voltage of 250 V DC or higher	For Cat. 1-7 and 10: 21 July 2019	
n.7(c)-III	Recommended modified wording		Lead in dielectric ceramic in discrete capacitor components for a rated voltage of less than 125 V AC, or for a rated voltage of less than 250 V DC	1 January 2013 and after that date may be used in spare parts for EEE placed on the market before 1 January 2013	

Exemption No.	Wording: Main Entry Sub-Entry	Applicant	Recommendation: Proposed Exemption Wording Formulation	Proposed Duration	Comments
n.7(c)-IV	Lead in PZT-based dielectric ceramic materials for capacitors which are part of integrated circuits or discrete semiconductors	ST Microelectronics	Lead in PZT-based dielectric ceramic materials of capacitors being part of integrated circuits or discrete semiconductors	For Cat. 1-7 and 10: 21 July 2019; For Cat. 8 and 9: 21 July 2021; For Sub-Cat. 8 in-vitro: 21 July 2023; For Sub-Cat. 9 industrial: 21 July 2024	
n.8(b)	Cadmium and its compounds in electrical contacts	Sensata Technologies National Electrical Manufacturers Association	8(b) Cadmium and its compounds in electrical contacts	For Cat. 8 and 9: 21 July 2021; For Sub-Cat. 8 in-vitro: 21 July 2023; For Sub-Cat. 9 industrial: 21 July 2024	
			8(c): Cadmium and its compounds in electrical contacts of (I) circuit breakers (II) thermal motor protectors excluding hermetically sealed thermal motor protectors	For Cat. 1-7 and 10: 21 July 2021	

Exemption No.	Wording: Main Entry Sub-Entry	Applicant	Recommendation: Proposed Exemption Wording Formulation	Proposed Duration	Comments
			(III) thermal sensing controls	For Cat. 1-7 and 10: 21 July 2019	
			(IV) AC switches rated at 6 A and more in combination with 250 V AC and more (V) AC switches rated at 12 A and more in combination with 125 V AC and more	Applies to *EEE* in Cat. 1 to 5, 7 and 10 For Cat. 1 to 5, 7 and 10: 21 July 2019	
			(VI) AC switches for corded tools rated at 6 A and more in combination with 250 V AC and more (VII) AC switches for corded tools rated at 12 A and more in combination with 125 V AC and more (VIII) DC switches for cordless tools with a rated current of 20 A and more in combination with at a rated voltage of 18 V DC and more (IX) switches for tools conceived to be used with power supplies of 200 Hz and more	Applies to Cat. 6 EEE: 21 July 2021	

Exemption No.	Wording: Main Entry Sub-Entry	Applicant	Recommendation: Proposed Exemption Wording Formulation	Proposed Duration	Comments
n.9	Hexavalent chromium as an anticorrosion agent of the carbon steel cooling system in absorption refrigerators up to 0,75 % by weight in the cooling solution	Dometic	Hexavalent chromium as an anticorrosion agent applied in carbon steel cooling systems of absorption refrigerators of applications: (I) designed to operate with electrical heater only, with up to 0,75 % by weight in the cooling solution		
			(II) designed to operate with variable energy sources (III) designed to operate with other than an electrical heater	For Cat. 1: 21.7.2019 (three years)	
n.15	Lead in solders to complete a viable electrical connection between semiconductor die and carrier within integrated circuit flip chip packages	Intel Corporation	I) Lead in solders to complete a viable electrical connection between semiconductor die and carrier within integrated circuit flip chip packages	For Cat. 8 and 9: 21 July 2021; For Sub-Cat. 8 in-vitro: 21 July 2023; For Sub-Cat. 9 industrial: 21 July 2024	

Exemption No.	Wording: Main Entry Sub-Entry	Applicant	Recommendation: Proposed Exemption Wording Formulation	Proposed Duration	Comments
			II) Lead in solders to complete a viable electrical connection between semiconductor die and the carrier within integrated circuit flip chip packages where one of the below criteria applies:		
			a) A semiconductor technology node of 90 nm or larger	For categories 1-7 and 10: 21 July 2019	
			b) A single die of 300 mm^2 or larger in any semiconductor technology node	For categories 1-7 and 10: 21 July 2021	
			c) Stacked die packages with dies of 300 mm^2 or larger, or silicon interposers of 300 mm^2 or larger	For categories 1-7 and 10: 21 July 2021	
			d) Flip chip on lead frame (FCOL) packages with a rated current of 3 A or higher and dies smaller than 300 mm^2		The exemption cannot be recommended but is added here in case the Commission would decide that it should be granted

Exemption No.	Wording: Main Entry Sub-Entry	Applicant	Recommendation: Proposed Exemption Wording Formulation	Proposed Duration	Comments
n.18(b)	Lead as activator in the fluorescent powder (1 % lead by weight or less) of discharge lamps when used as sun tanning lamps containing phosphors such as BSP (BaSi 2 O 5 :Pb)	NARVA Lichtquellen GmbH + Co. KG Lighting Europe	Lead as activator in the fluorescent powder (1 % lead by weight or less) of discharge lamps containing phosphors such as BSP (BaSi2O5 :Pb), when used: I. in tanning equipment; or II. in Annex I category 8 medical phototherapy equipment - excluding applications falling under point 34 of Annex IV	For Cat. 5: 21 July 2021	
n.21	Lead and cadmium in printing inks for the application of enamels on glasses, such as borosilicate and soda lime glasses	Lighting Europe	I. Cd when used in colour printed glass to provide filtering functions, used as a component in lighting applications installed in displays and control panels of EEE	For Cat. 1-7 and 10: 21 July 2021	The EU Commission should consider if it would not be more beneficial to add this entry to Ex. 13b.
			II. **Alternative A:** Cadmium in printing inks for the application of enamels on glasses, such as borosilicate and soda lime glasses, when used to comply with harmonised standards specifying the use of	For Cat. 1-7 and 10: 21 July 2021	The EU Commission could consider providing a shorter validity period so as to promote the supply chain to develop a strategy for research and

Exemption No.	Wording: Main Entry Sub-Entry	Applicant	Recommendation: Proposed Exemption Wording Formulation	Proposed Duration	Comments
			particular hues for safety applications. **Alternative B:** Cadmium in printing inks for the application of enamels on glasses, such as borosilicate and soda lime glasses, excluding Cd used in colour printed glass to provide filtering functions.		development of alternatives for Cd-based inks.
			III. Lead in printing inks for the application of enamels on other than borosilicate glasses.	For Cat. 1-4, 6,7 and 10: 21 July 2019	The recommended period should suffice to establish the reliability of Pb-free substitutes in other than borosilicate glasses.

Exemption No.	Wording: Main Entry Sub-Entry	Applicant	Recommendation: Proposed Exemption Wording Formulation	Proposed Duration	Comments
			IV. Lead and cadmium in printing inks for the application of enamels on glasses, such as borosilicate and soda lime glasses	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;	As it can be understood that the exemption duration may vary for various categories on the basis of Article 5(2), expiration dates have been specified here on the basis of the validity periods specified in Article 5(2) for categories, which are newly in scope.
n.24	Lead in solders for the soldering to machined through hole discoidal and planar array ceramic multilayer capacitors	Knowles	Lead in solders for the soldering to machined through hole discoidal and planar array ceramic multilayer capacitors	For Cat. 1-7 and 10: 21 January 2019; 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;	

Exemption No.	Wording: Main Entry Sub-Entry	Applicant	Recommendation: Proposed Exemption Wording Formulation	Proposed Duration	Comments
n.29	Lead bound in crystal glass as defined in Annex I (Categories 1, 2, 3 and 4) of Council Directive 69/493/EEC (1)	EUROPEAN DOMESTIC GLASS and LightingEurope	Lead bound in crystal glass as defined in Directive 69/493/EEC	For Cat. 1-10: 21 July 2021 For Sub-Cat. 8 in-vitro: 21 July 2023 For Sub-Cat. industrial: 21 July 2024	
n.32	Lead oxide in seal frit used for making window assemblies for Argon and Krypton laser tubes	Coherent Inc. JDSU	Lead oxide in seal frit used for making window assemblies for Argon and Krypton laser tubes	For Cat. 1-10: 21 July 2021 For Sub-Cat. 8 in-vitro: 21 July 2023 For Sub-Cat. industrial: 21 July 2024	
n.34	Lead in cermet-based trimmer potentiometer elements	General Electric	Lead in cermet-based trimmer potentiometers	For Cat. 1-7 and 10: 21 July 2019; 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;	

Exemption No.	Wording: Main Entry Sub-Entry	Applicant	Recommendation: Proposed Exemption Wording Formulation	Proposed Duration	Comments
n.37	Lead in the plating layer of high voltage diodes on the basis of a zinc borate glass body	IXYS Semiconductor GmbH General Electric	Lead in the plating layer of high voltage diodes on the basis of a zinc borate glass body	For categories 1-7 and 10: 21 July 2019; For Cat. 8 and 9: 21 July 2021; For Sub-Cat. 8 in-vitro: 21 July 2023; For Sub-Cat. 9 industrial: 21 July 2024	

The report includes the following sections:

Section 1.0: Project Set-up

Section 2.0: Scope

Section 3.0: Links from the Directive to the REACH Regulation

Sections 4.0 through 34.0: Evaluation of the requested exemptions handled in the course of this project.

Contents

List of Tables and Figures

1.0 Project Set-up

Assignment of project tasks to Oeko-Institut, started 29 December 2014. The overall project has been led by Carl-Otto Gensch. At Fraunhofer IZM the contact person is Otmar Deubzer. The project team at Oeko-Institut consists of the technical experts Yifaat Baron and Katja Moch. Eunomia, represented by Adrian Gibbs, have the role of ensuring quality management.

2.0 Scope

The scope of the project covers the evaluation of twenty-nine exemptions for which requests for renewal have been submitted to the European Commission. An overview of the exemption requests is given in Table 1-1 below.

In the course of the project, a stakeholder consultation was conducted. The stakeholder consultation was launched on 21 August 2015 and held for a period of 8 weeks, thus concluding on 16 October 2015.

The specific project website was used in order to keep stakeholders informed on the progress of work: http://rohs.exemptions.oeko.info. The consultation held during the project was carried out according to the principles and requirements of the European Commission. Stakeholders who had registered at the website were informed through email notifications about new steps within the project.

Information concerning the consultation was provided on the project website, including a general guidance document, the applicants' documents for each of the exemption requests, results of earlier evaluations where relevant, a specific questionnaire and a link to the EU CIRCA website. All non-confidential stakeholder comments, submitted during the consultation, were made available on the RoHS Evaluation website and on the EU CIRCABC website (Communication and Information Resource Centre for Administrations, Businesses and Citizens).[1]

The evaluation of the stakeholder contributions led to further consultation including, inter alia, engaging with stakeholders in further discussion, further exchanges in order to clarify remaining questions, cross-checking with regard to the accuracy of technical arguments, and checks in respect of confidentiality issues. Meetings held in the context of the exemptions are detailed in the specific exemption reports.

[1] EU CIRCABC website: https://circabc.europa.eu (Browse categories > European Commission > Environment > RoHS 2014 Evaluations Review, at top left, click on "Library")

The exemptions requested for renewal were evaluated according to the various criteria (Cf. Section E.1.0 for details). The evaluations of each exemption appear in the following chapters. The information provided by the applicants and by stakeholders is summarised in the first sections. This includes a general description of the application and requested exemption (requested renewal or proposed amendment), a summary of the arguments made for justifying the exemption, information provided concerning possible alternatives and additional aspects raised by the applicants and other stakeholders. In some cases, reference is also made to information submitted by applicants and stakeholders in previous evaluations, in cases where a similar request has been reviewed or where a renewal has been requested of a request reviewed in the past. The Critical Review follows these sections, in which the submitted information is discussed, to clarify how the consultants evaluate the various information and what conclusions and recommendations have been made. For more detail, the general requirements for the evaluation of exemption requests may be found in the technical specifications of the project.[2]

[2] Cf. under:
http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_8/RoHS_Pack8_Technical_specifications.pdf

3.0 Links from the Directive to the REACH Regulation

Article 5 of the RoHS 2 Directive 2011/65/EU on "Adaptation of the Annexes to scientific and technical progress" provides for the:

> "*inclusion of materials and components of EEE for specific applications in the lists in Annexes III and IV, provided that such inclusion does not weaken the environmental and health protection afforded by Regulation (EC) No 1907/2006*".

RoHS 2 does not further elaborate the meaning of this clause.

Regulation (EC) No 1907/2006 regulates the safe use of chemical substances, and is commonly referred to as the REACH Regulation since it deals with **R**egistration, **E**valuation, **A**uthorisation and Restriction of **Ch**emical substances. REACH, for its part, addresses substances of concern through processes of authorisation and restriction:

- Substances that may have serious and often irreversible effects on human health and the environment can be added to the candidate list to be identified as Substances of Very High Concern (SVHCs). Following the identification as SVHC, a substance may be included in the Authorisation list, available under Annex XIV of the REACH Regulation: "List of Substances Subject to Authorisation". If a SVHC is placed on the Authorisation list, companies (manufacturers and importers) that wish to continue using it, or continue placing it on the market, must apply for an authorisation for a specified use. Article 22 of the REACH Regulation states that: *"Authorisations for the placing on the market and use should be granted by the Commission only if the risks arising from their use are adequately controlled, where this is possible, or the use can be justified for socio-economic reasons and no suitable alternatives are available, which are economically and technically viable."*
- If the use of a substance (or compound) in specific articles, or its placement on the market in a certain form, poses an unacceptable risk to human health and/or to the environment that is not adequately controlled, the European Chemical Agency (ECHA) may restrict its use, or placement on the market. These restrictions are laid down in Annex XVII of the REACH Regulation: "Restrictions on the Manufacture, Placing on the Market and Use of Certain Dangerous Substances, Mixtures and Articles". The provisions of the restriction may be made subject to total or partial bans, or other restrictions, based on an assessment of those risks.

The approach adopted in this report is that once a substance has been included into the regulation related to authorization or restriction of substances and articles under REACH,

the environmental and health protection afforded by REACH may be weakened in cases where, an exemption would be granted for these uses under the provisions of RoHS. This is essentially the same approach as has already been adopted for the re-evaluation of some existing RoHS exemptions 7(c)-IV, 30, 31 and 40,[3] as well as for the evaluation of a range of requests assessed through previous projects in respect of RoHS 2.[4] Furthermore, substances for which an authorisation or restriction process is already underway are also reviewed, so that future developments may be considered where relevant.

When evaluating the exemption requests, with regard to REACH compliance, we have checked whether the substance / or its substitutes are:

- on the list of substances proposed for the adoption to the Candidate List (the Registry of Intentions);
- on the list of substances of very high concern (SVHCs- the Candidate List);
- in the recommendations of substances for Annex XIV (recommended to be added to the Authorisation List);
- listed in REACH Annex XIV itself (The Authorization List); or
- listed in REACH Annex XVII (the List of Restrictions).

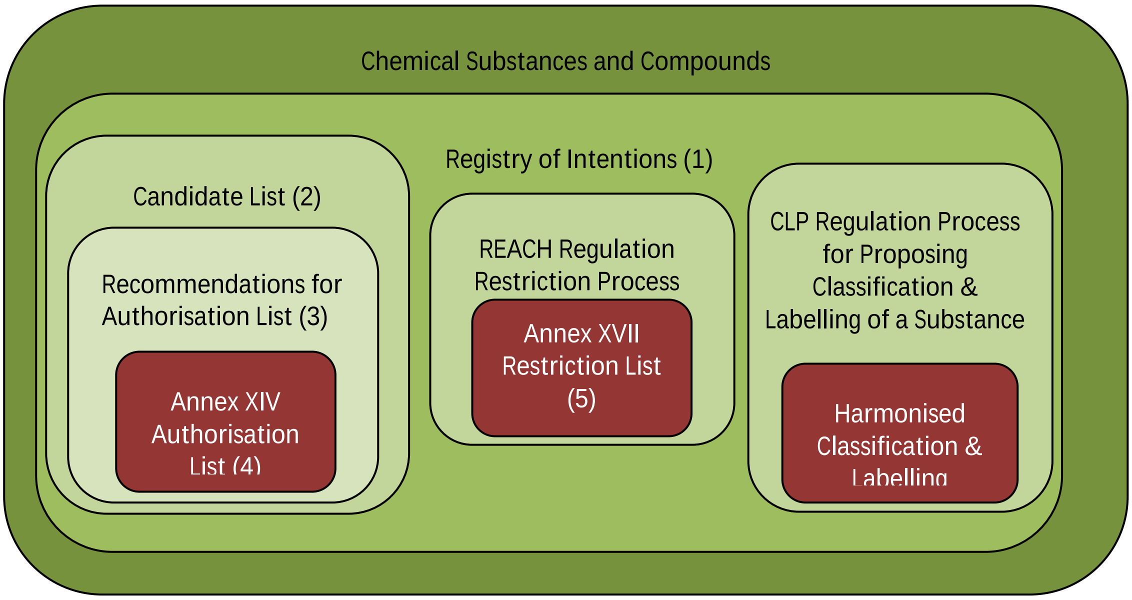
As the European Chemicals Agency (ECHA) is the driving force among regulatory authorities in implementing the EU's chemicals legislation, the ECHA website has been used as the reference point for the aforementioned lists, as well as for the exhaustive register of the Amendments to the REACH Legal Text.

Figure 3-1 shows the relationship between the two processes and categories. Substances included in the red areas may only be used when certain specifications and or conditions are fulfilled.

[3] See Zangl, S.; Blepp, M.; Deubzer, O. (2012) Adaptation to Scientific and Technical Progress under Directive 2011/65/EU - Transferability of previously reviewed exemptions to Annex III of Directive 2011/65/EU, Final Report, Oeko-Institut e. V. and Fraunhofer IZM, February 17, 2012, http://rohs.exemptions.oeko.info/fileadmin/user_upload/Rohs_V/Re-evaluations_transfer_RoHS_I_RoHS_II_final.pdf

[4] Gensch, C., Baron, Y., Blepp, M., Deubzer, O., Manhart, A. & Moch, K. (2012) Assistance to the Commission on technological, socio-economic and cost-benefit assessment related to exemptions from the substance restrictions in electrical and electronic equipment (RoHS Directive), Final Report, Oeko-Institut e. V. and Fraunhofer IZM, 21.12.2012 http://rohs.exemptions.oeko.info/fileadmin/user_upload/Rohs_V/RoHS_V_Final_report_12_Dec_2012_final.pdf

Figure 3-1: Relation of REACH categories and lists to other chemical substances



The following bullet points explain in detail the above mentioned lists and where they can be accessed:

- Member States Competent Authorities (MSCAs) / the European Chemicals Agency (ECHA), on request by the Commission, may prepare Annex XV dossiers for identification of Substances of Very High Concern (SVHC), Annex XV dossiers for proposing a harmonised Classification and Labelling, or Annex XV dossiers proposing restrictions. The aim of the public Registry of Intentions is to allow interested parties to be aware of the substances for which the authorities intend to submit Annex XV dossiers and, therefore, facilitates timely preparation of the interested parties for commenting later in the process. It is also important to avoid duplication of work and encourage co-operation between Member States when preparing dossiers. Note that the Registry of Intentions is divided into three separate sections: listing new intentions; intentions still subject to the decision making process; and withdrawn intentions. The registry of intentions is available at the ECHA website at: http://echa.europa.eu/web/guest/addressing-chemicals-of-concern/registry-of-intentions;
- The identification of a substance as a Substance of Very High Concern and its inclusion in the Candidate List is the first step in the authorisation procedure. The Candidate List is available at the ECHA website at http://echa.europa.eu/web/guest/candidate-list-table;
- The last step of the procedure, prior to inclusion of a substance into Annex XIV (the Authorisation list), involves ECHA issuing a Recommendation of substances for Annex XIV. The ECHA recommendations for inclusion in the Authorisation List are available at the ECHA website at

http://echa.europa.eu/web/guest/addressing-chemicals-of-concern/authorisation/recommendation-for-inclusion-in-the-authorisation-list/authorisation-list;

- Once a decision is made, substances may be added to the Authorisation List available under Annex XIV of the REACH Regulation. The use of substances appearing on this list is prohibited unless an Authorisation for use in a specific application has been approved. The Annex can be found in the consolidated version of the REACH Legal Text (see below);
- In parallel, if a decision is made concerning the Restriction on the use of a substance in a specific article, or concerning the restriction of its provision on the European market, then a restriction is formulated to address the specific terms, and this shall be added to Annex XVII of the REACH Regulation. The Annex can be found in the consolidated version of the REACH Legal Text (see below); and
- As of the 28 of September, 2015, the last amendment of the REACH Legal Text was dated from 28 May 2015 (Commission Regulation (EU) No 2015/830) and so the updated consolidated version of the REACH Legal Text, dated 01.06.2015, was used to check Annex XIV and XVII: The consolidated version is presented at the ECHA website: http://echa.europa.eu/web/guest/regulations/reach/legislation.

Relevant annexes and processes related to the REACH Regulation have been cross-checked to clarify:

- In what cases granting an exemption could "weaken the environmental and health protection afforded by Regulation (EC) No 1907/2006" (Article 5(1)(a), pg.1)
- Where processes related to the REACH regulation should be followed to understand where such cases may become relevant in the future;

In this respect, restrictions and authorisations as well as processes that may lead to their initiation, have been reviewed, in respect of where RoHS Annex II substances are mentioned (i.e. lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBB) and polybrominated diphenyl ethers (PBDE).[5]

Compiled information in this respect has been included, with short clarifications where relevant, in Tables A.1-5, which appear in Appendix A.1.0.

The information has further been cross-checked in relation to the various exemptions evaluated in the course of this project. This has been done to clarify that the Article 5(1)(a) pg.1 threshold-criteria quoted above is complied with in cases where an

[5] This review currently does not address the 4 phthalates, DEHP, BBP, DBP and DIBP, which according to Commission Delegated Directive (EU) 2015/863 of 31 March 2015, have been added to the Annex. Information regarding these substances shall be added in future reviews.

exemption is to be granted / its duration renewed/ its formulation amended/ or where it is to be revoked and subsequently to expire as an exemption. The considerations in this regard are addressed in each of the separate chapters in which the exemption evaluations are documented (Chapters 4.0 through 34.0) under the relevant section titled "*REACH Compliance – Relation to the REACH Regulation*" (Sections 4.5.1 through 34.4.1).

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.

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[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:

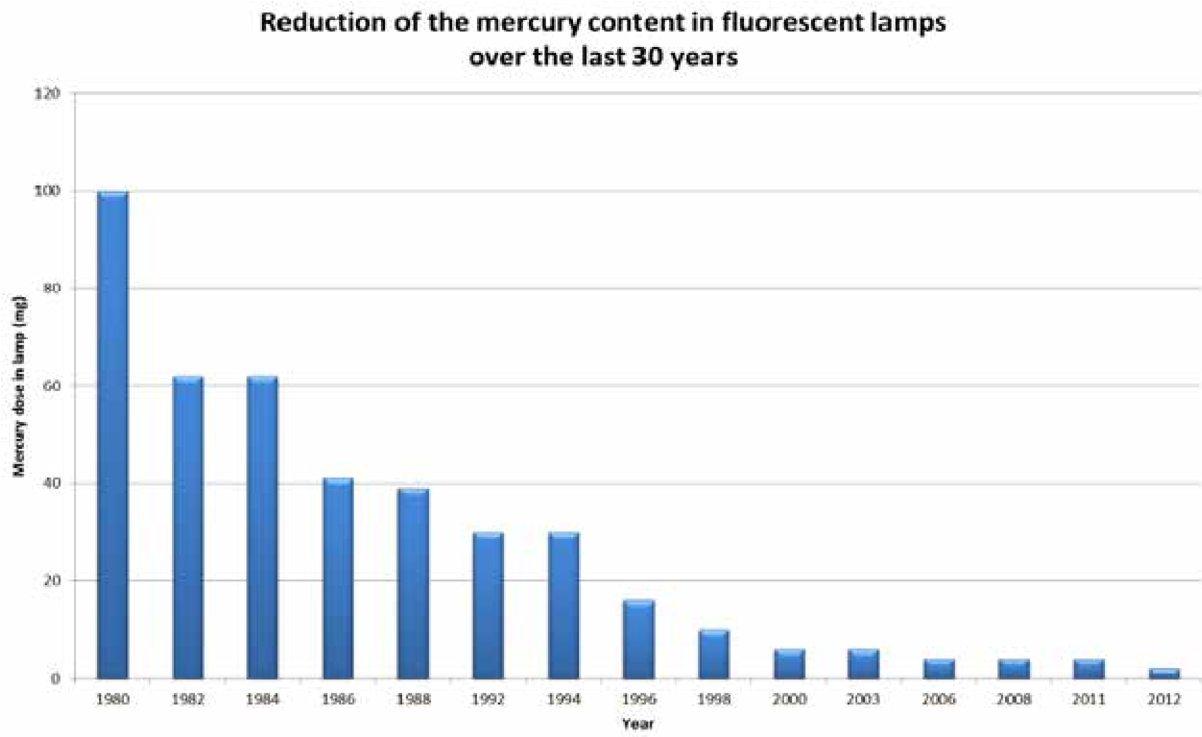
- The limited potential for reducing the amount of Hg dosed in lamps;
- The lack of substitutes for Hg in lamps covered by Ex. 1-4 (substance substitute);
- The limited applicability and product range of Hg-free lamps that may allow eliminating the use of Hg associated with Ex. 1-4, as well as possible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

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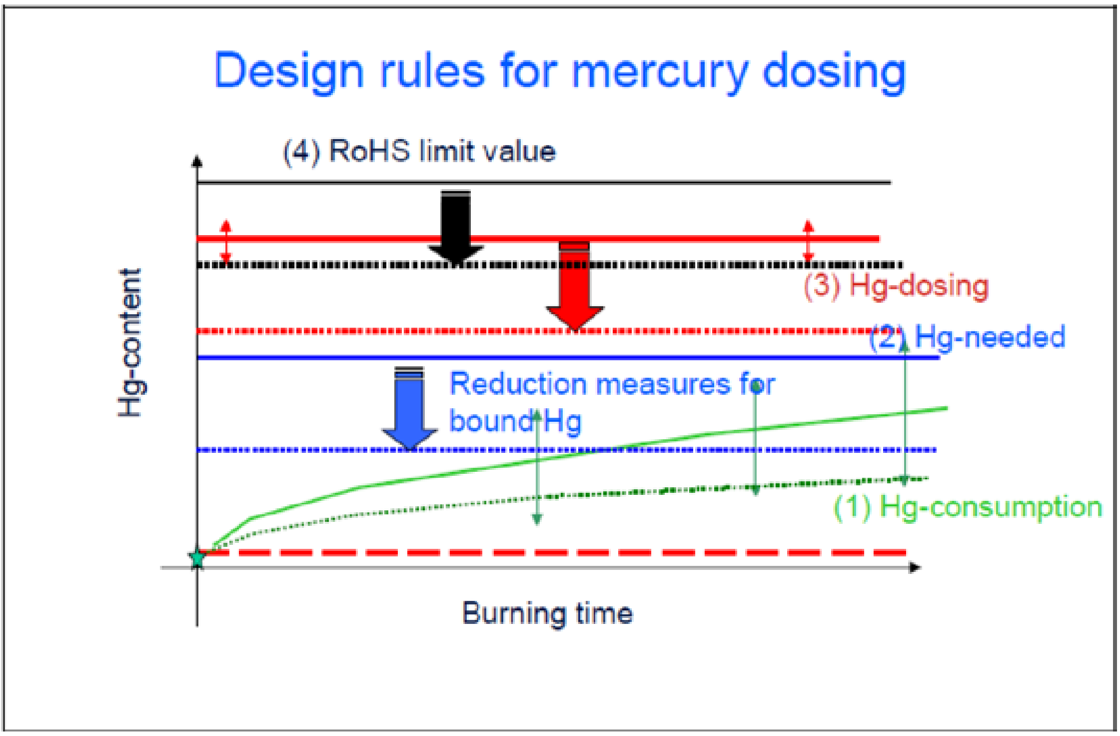
[11] Op. cit. LEU Ex. 1a (2015a)

- *"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.
Calculated Total				**2868 kg**	**100%**	LEU estimates that 45.7% of lamps are collected for recycling (see Figure 4-3).

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

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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

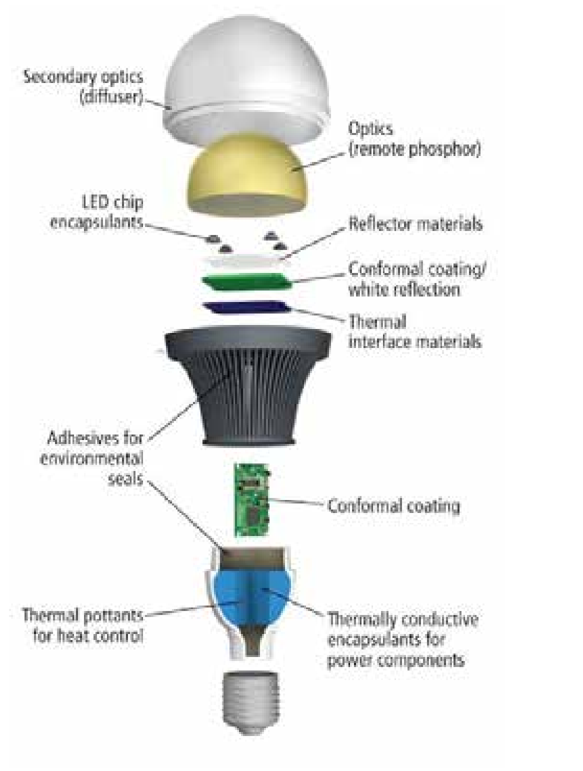
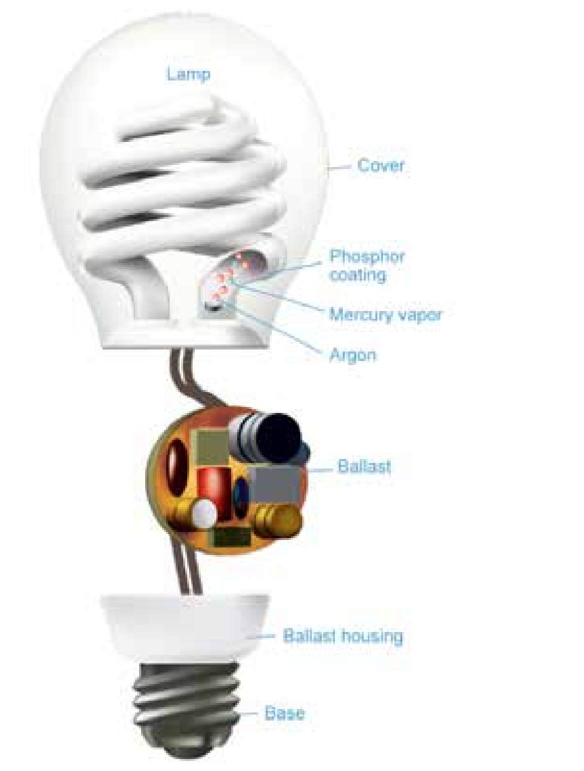
LEU[24] claims that concerning material composition it is also necessary to have a case by case view. Fluorescent lamps contain glass, metals, phosphors and mercury. These components can be effectively recycled. LED based alternatives contain electrical and electronic components such as a control gear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

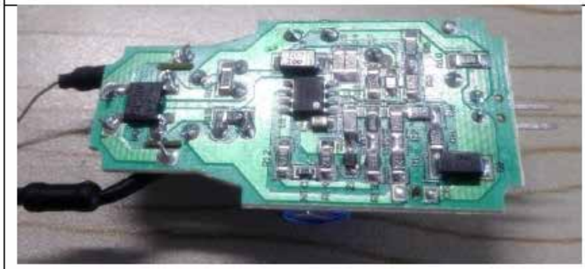
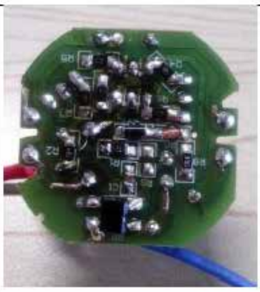
Table 4-2: General composition of LED and CFLi lamps

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

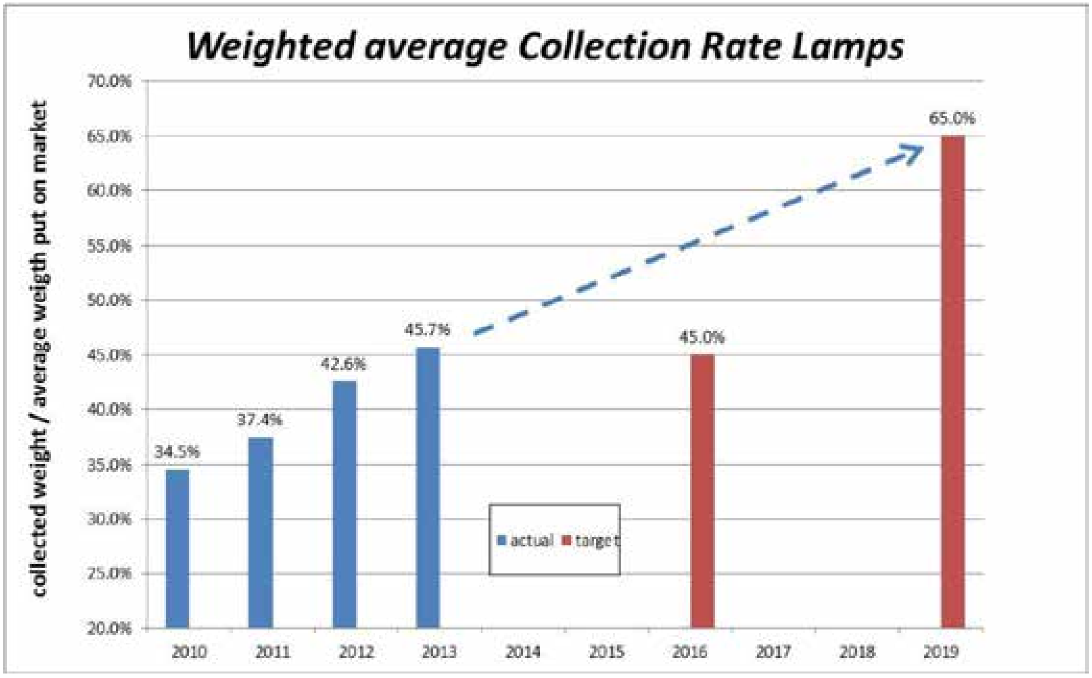
4.3.3.3 Waste management

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].

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[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

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[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

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

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

UNEP (2016) Minamata Convention on Mercury Website, http://www.mercuryconvention.org/Convention last accessed 4.3.2016

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

5.0 Exemption 1(a-e): "Mercury in single capped (compact) fluorescent lamps not exceeding (per burner)”

This review of Annex III exemption 1 covers the following exemption entries:

(a) For general lighting purposes < 30 W: 5 mg

(b) For general lighting purposes ≥ 30 W and < 50 W: 5 mg

(c) For general lighting purposes ≥ 50 W and < 150 W: 5 mg

(d) For general lighting purposes ≥ 150 W: 15 mg

(e) For general lighting purposes with circular or square structural shape and tube diameter ≤ 17 mm

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

B2B	Business to business
CFL	Compact fluorescent lamp
CFLi	CFL with integrated ballast
CFLni	CFL with non-integrated ballast
EEE	Electrical and Electronic Equipment
EM	Electromagnetic: lamp control gear based on a magnetic coil (= CCG)
HF	High frequency: lamp control gear based on high frequency (= ECG)
Hg	Mercury
LEU	LightingEurope
NARVA	NARVA Lichtquellen GmbH + Co. KG
EoL	End-of-life

5.1 Background

LightingEurope (LEU) and NARVA Lichtquellen GmbH + Co. KG (NARVA) have both applied for the renewal of Ex. 1, items a-e, of Annex III of the RoHS Directive. This exemption covers single capped (compact) fluorescent lamps.[55]

NARVA[56] explains that lamps falling under these exemptions are discharge lamps, which use mercury for the discharge process, arguing that there are no substitutes for Hg in discharge lamps.

In relation to substitutes, LEU[57] mentions that though more and more LED solutions come to the market, they cannot always serve as a fully compatible replacement for the huge variety of CFL lamps for consumers and professional end users.

Both applicants apply for the renewal of Ex. 1 entries a-e, with the current wording formulations listed in Annex III of the RoHS Directive and requesting the maximum available duration allowed (based on Art. 5(2) of the Directive).

5.1.1 Amount of Lead Used under the Exemption

To provide an estimation of the amount of Hg entering the EU through CFLs per annum, LEU[58] refers to the VHK report "Preparatory Study on Light Sources for Ecodesign and/or Energy Labelling, Requirements ('Lot 8/9/19'), Draft Interim Report, Task 2" [59] prepared for the EC. This report indicates a total volume of CFL lamps in EU 28 of 342 Mpcs in 2013, a volume, which includes all wattages. An external report indicating the exact wattage split is not available, however based on experience of the LEU members, an estimation is made as to the break-down of this number to various wattages. The assumption along with the estimated respective amounts of Hg to come on the EU market through the applications covered by each exemption entry is detailed in

Table 5-1.

[55] LEU Ex. 1a(2015a), LightingEurope, 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
[56] 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
[57] Op. cit. LEU Ex. 1a(2015a)
[58] Op. cit. LEU Ex. 1a(2015a)
[59] Quoted in LEU Ex. 1a(2015a) as: Preparatory Study on Light Sources for Ecodesign and/or Energy Labelling Requirements ('Lot 8/9/19'). Draft Interim Report, Task 2 by Prepared by VHK, in cooperation with VITO and JeffCott Associates Date: 19 November 2014, Table 1.

Table 5-1: Breakdown of total CFL market share according to wattages (RoHS exemption item) and respective Hg amounts

CFL Type[2]	EU market share of CFL	Calculated EU market volume in 2013[1]	Maximum allowed Hg	Hg brought on the market through application - worst case[4]
All	100 %[3]	342 Mpcs	-	945 Kg (100%)
Ex. 1(a): < 30 W	85 %	291 Mpcs	2.5 mg	727 kg (77%)
Ex. 1(b): ≥ 30 W and < 50 W	10%	34 Mpcs	3.5 mg	120 kg (13%)
Ex. 1(c): ≥ 50 W and < 150 W	3%	10 Mpcs	5 mg	51 kg (5%)
Ex. 1(d): >150 W	0.5%	2 Mpcs	15 mg	26 kg (3%)
Ex. 1(e): circular or square structural shape	0.5%	3 Mpcs	7 mg	21 kg (2%)

[1] Total sum according to LEU Ex. 1a(2015a), based on total market volume in pieces taken from VHK report for EU; exemption item specific data is calculated on that basis.
[2] Source for all other data is taken from LEU Ex. 1a(2015a), LEU Ex. 1b(2015a), LEU Ex. 1c(2015a), LEU Ex. 1d(2015a) and LEU Ex. 1a(2015a), respective to the relevant exemption item.
[3] According to LEU Ex. 1(2015b), 1% of this quantity is associated with lamps falling under Ex. 1(f).
[4] Shares are calculated and do not appear in source.

LEU further uses information from a McKinsey study quoted in the VHK report to forecast how the amount of Hg should change until 2020. The main reason for the reduction is explained to be the increased penetration of LED alternatives due to their expected decreasing price, improved availability and better suitability as replacements for the different CFL lamp types. LEU emphasizes that this is an estimation of the upper limit based on the threshold value of the Directive. In reality the amount entering the market is expected to be lower, as the average dose per lamp is most often below this threshold value (see Figure 4-2 in general chapter). LEU estimates that the average value is roughly 20% below the threshold value. This exercise is carried out for each of the Ex. 1 items and is summarised in

Table 5-2.

Table 5-2: Evolvement of Hg amounts to be placed on the EU market through exemption 1(a-e) between 2013 and 2020

Ex. 1 item	Share of all CFL lamps	Hg placed on EU market per annum						Comments
		2013		2016		2020		
All	100%	945 kg	342 Mpcs	615,5 kg	222 Mpcs	262,5 kg	93 Mpcs	All CFLs on the market - reference
a)	85%	727 kg	291 Mpcs	472 kg	189 Mpcs	198 kg	79 Mpcs	
b)	10%	120 kg	34 Mpcs	78 kg	22 Mpcs	33 kg	9 Mpcs	
c)	3%	51 kg	10 Mpcs	33 kg	7 Mpcs	14 kg	3 Mpcs	
d)	0.5%	27 kg	2 Mpcs	17 kg	1 Mpcs	7 kg	0.5 Mpcs	
e)	0.5%	21 kg	3 Mpcs	15.5 kg	1 Mpcs	10.5 kg	0.5 Mpcs	

Source of data is taken from LEU Ex. 1a(2015), LEU Ex. 1b(2015), LEU Ex. 1c(2015), LEU Ex. 1d(2015) and LEU Ex. 1a(2015), respective to the relevant exemption item. Lamp volumes for individual entries are calculated based on total and share data from source.

5.2 Description of Requested Exemption

Compact fluorescent lamps come in a wide variety of shapes, sizes and wattages. A few examples are given in Table 5-3. CFLs can have the electronic control gear integrated in the product (internal ballast/self-ballasted CFLs or CFLi's) or their control gear is separated from the lamp (external ballast / plug-in CFLs or CFLni's).

Table 5-3: Examples of CFL lamps

Source: Left image: Typical shapes and forms, taken from LEU Ex. 1a (2015a); Right image: Comparison of lamps of smaller wattages with lamps of higher wattages, taken from LEU Ex. 1(d)(2015a); Bottom image: examples of lamps falling under Ex. 1(e), taken from LEU Ex. 1d (2015a).

According to LEU[60], compact fluorescent lamps used in residential environments can be found in applications where they act as an energy saving solution for the now banned incandescent lamps. CFL lamps in professional applications are used as energy saving

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

solutions and are found in many down-lighters providing general lighting in for example shops, banks, schools, malls, hotels (reception, restaurants, bars, lobby, corridors, rest areas, conference rooms), galleries, offices (reception, lobby, meeting rooms, corridors, rest areas) and sporting facilities (gyms). Many luminaires have been specifically designed for the use of the CFL lamps.

Compact fluorescent lamps in category 1(a)(< 30 W) include lamps for residential and professional use.[61] Typical applications of the category 1(b)(≥ 30 W and < 50 W) are offices, public buildings, shops supermarkets and department stores, hotels, restaurants, industry, outdoors in residential areas and parks[62]. CFLs of categories 1(c and d)(≥ 50 W and < 150 W; >150 W) are mostly lamps for professional use.[63], [64] CFLs in category 1(e) (circular or square structural shape) include lamps for specific applications in residential and professional use.[65]

LEU[66] explains that for the current installed base of luminaires and lighting systems employing discharge lamps, replacement light sources based on discharge lamp technology will be needed for a long time. A typical refurbishment cycle in shops and offices is on average 7 and 12 years respectively and for street lighting it is even up to 30 years.[67]

Data are provided as to the various characteristics of CFL lamps falling under the various entries, as compiled in Table 5-4 below:

Table 5-4: Characteristics of CFL lamps falling under ex. 1(a-e)

CFL Type[1]	CRI	Colour temperature range	Light output range	Energy efficiency range	Lifetime range
Ex. 1(a): < 30 W	Above 80	warm white (2200K) to cool daylight (6500K)	150-2500 lm	50-80 lm/W	6000-20000 hours
Ex. 1(b): ≥ 30 W and < 50 W	Above 80	warm white (2700K) to cool daylight (6500K)	2000-4000 lm	70-80 lm/W	10000-20000 hours
Ex. 1(c): (≥ 50 W and < 150 W	Above 80	warm white (2700K) to cool daylight (6500K)	4000-12000 lm	70-80 lm/W	10000-20000 hours
Ex. 1(d): ≥ 150 W	Above 80	warm white (2700K) to cool daylight (6500K)	Typically above 12000 lm	70-80 lm/W	10000-20000 hours
Ex. 1(e):	80	warm white (2700K) to cool daylight (6500K)	Not specified	50-80 lm/W	6000-20000 h

[1] Source for further data is taken from LEU Ex. 1a(2015), LEU Ex. 1b(2015), LEU Ex. 1c(2015), LEU Ex. 1d(2015) and LEU Ex. 1a(2015), respective to the relevant exemption item.

[61] Op. cit. LEU Ex. 1(a)(2015a)
[62] Op. cit. LEU Ex. 1(b)(2015a)
[63] Op. cit. LEU Ex. 1(c)(2015a)
[64] Op. cit. LEU Ex. 1(d)(2015a)
[65] Op. cit. LEU Ex. 1(e)(2015a)
[66] Op. cit. LEU Ex. 1(a)(2015a)
[67] Op. cit. LEU Ex. 1(a)(2015a) and LEU Ex. 1(e)(2015a) – do not mention street lighting; LEU Ex. 1(b)(2015a); LEU Ex. 1(c)(2015a); LEU Ex. 1(d)(2015a)

LEU[68] refers to data from the VHK report[69] indicating a split between residential and non-residential used lamps in 2013 and a split into CFL integrated (CFLi) and non-integrated (CFLni) versions. These data indicate the following for the total CFL range in 2013 (all exemptions)[70]:

- **Residential:** 184 Mpcs (54%) of which 162Mpcs CFLi (~88% thereof) and 22 Mpcs CFLni (~12% thereof);
- **Non-Residential (Professional):** 158 Mpcs (46%) of which 108 Mpcs CFLi (~68% thereof) and 50Mpcs CFLni (~32% thereof).

The VHK[71] report provides an overview of 'stock', being the installed base of CFL lamps in 2013. This shows that in residential areas 2580 million CFL lamps are installed, of which 2296 million units are CFLi lamps (~89% thereof) and 283 million are CFLni versions (~11% thereof). The non-residential (professional) area consisted in 2013 of an installed park of 1881 million CFL lamps of which 1531 million pieces were CFLi (~81% thereof) and 350 million pieces CFLni (~19% thereof).

LEU[72] further explains that from a lamp-technical point of view CFLni's and CFLi's are not so different, except that the first use external ballasts (EM or HF) and have different caps. However, from a driver-technical point of view, the two groups (CFLni's and CFLi's) are quite different, i.e. in respect of the presence of a driver in CFLi's. CFLni's cannot be tuned for optimal cathode operation with a specific driver as it happens for CFLi's, which have specific ballasts for the lamp. The "ni" versions need to be designed for a variety of drivers available on the market which causes a lot of spread on the cathode condition. This is to a certain extent solved by using specific lamp bases (examples are provided in LEU Ex. 1(2015b)). Both lamp versions can be dimmable when specific designed ballasts are used. Inherent for the CFLi lamps is that lamps and ballasts are tuned to each other, whereas for the ni lamps again a range of ballast versions is available complicating the diversity even further. For both CFLi as well as CFLni types there are specific lamp-luminaire combinations. CFLni's in many cases are installed in luminaires containing 2-4 lamps, which implicates higher temperature of the lamp during burning. Typical examples of products are given in LEU's application document for Ex. 1c in Section 4.1.1., referenced as LEU Ex. 1(c)(2015a).

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[68] LEU Ex. 1(2015b), Lighting Europe, Answers to 1st Questionnaire Exemption Request No. 1(a-e), submitted 15.9.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_1_a-e_/Lighting_Europe/Ex_1_a_e__LightingEurope_1st_Clarification-Questions_final.pdf

[69] See footnote 59 for LEU reference of VHK study, Table 3 and Table 4.

[70] Data is udnerstood to represent new lamps placed on the market in 2013.

[71] 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

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

5.3 Applicant's Justification for Exemption

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

5.3.1 Possible Alternatives for Substituting RoHS Substances

LEU details some of the efforts in seeking an alternative for mercury in the discharge lamps, concluding that substitutes for Hg in the discharge technology are not available. Details can be found in the application documents as well as in part in Section 4.3.2.1 of this report.

5.3.2 Possible Alternatives for Eliminating RoHS Substances

In relation to the CFL lamps, LEU[73] mentions that a mercury free available technology is halogen. Halogen lamps can be a retrofit solution for some of the applications, but not for all. LEU[74] later refers to the stage 6 requirements of Commission Regulation EC/ 244/2009, which bans halogen bulb solutions and is to come into force in Sept 2018. Taking this ban into consideration, the estimated share of LED lamps sold from January 1 2019 is 100% if only Hg free technologies shall remain available on the market.

LEU[75] further provides detail about LED technologies which are rapidly developing and are considered an important alternative to discharge technology. It is explained that the lighting market is rapidly changing from discharge lamp technology to LED technology; however the change is explained mainly to be occurring in the new installation share of the market (new luminaires). Details can be found in the application documents and in Section 4.3.2.2 in general chapter. LEU reminds that CFL lamps are installed in a huge variety of types, shapes, sizes, wattages and colours, and claims that LED retrofit solutions are entering the market for just a few of these types. It is questionable if LED retrofit solutions will be developed for the total of this complex and scattered landscape with often small series per type. In relation to lamps of the specific entries, LEU also mentions the following points:

- More and more LED solutions come to the market; however they cannot always serve as a fully compatible replacement for the huge variety of CFL lamps falling under Ex. 1(a) (< 30 W) for consumers and professional end users.[76]

[73] Op. cit. LEU Ex. 1(a)(2015a)
[74] Op. cit. LEU Ex. 1(2015b)
[75] Op. cit. LEU Ex. 1(a)(2015a)
[76] Op. cit. LEU Ex. 1(a)(2015a)

- The main characteristics of lamps falling under Ex. 1(b) (≥ 30 W and < 50 W) is that they emit high lumen packages (2000 – 4000 lumen). Lamps falling under Ex. 1(c) (≥ 50 W and < 150 W) and lamps falling under Ex. 1(d)(≥ 150 W) are also explained to emit high lumen packages (4000 – 12000 lumen[77] and 12000 lumen[78] and more respectively). LEU explains that the development of LEDs with higher lumen packages (above 1500 lumen) is focussing on new luminaire solutions instead of retrofit CFL substitution. As a result, not many replacement solutions for this specific category in LED are available on the market.[79]
- Furthermore, most of the lamps falling under Ex. 1(d)(≥ 150 W) are self-ballasted, though both CFLi and CFLni versions are available. For CFLi (self-ballasted) lamps in high wattages (>150 W) no retrofit LED replacements are available on the market reaching the same lumen output.[80]
- Lamps in exemption 1(e) are clearly a different group of lamps than in the other exemption requests under exemption 1 because of their different shape and specific application. Lamps in this category can be with integrated driver (CFLi) or without (CFLni). The relative small volume of this application and the higher cost of a real replacement lamp (giving the same light characteristics) limit the number of alternative LED lamps offered on the market. LED technology developments are addressing one-on-one replacements for this segment (some examples are provided), but this will not result in a situation which would allow for full replacement of the current discharge lamps portfolio within the timeframe of the exemption. [81]

In this respect a few points are raised specifically related to the shortcomings of LEDs as replacements for CFL discharge lamps, including:

- CFL lamps are more of omnidirectional nature, while LEDs by nature emit their light more directionally, making one to one replacement difficult. [82]
- Luminaires are often dedicatedly designed for use of a high lumen CFL lamp. The size and shape of the reflector of the luminaire is fitted with the so-called Light centre length of the lamp to get the desired light distribution. Substitution of the lamp in such a luminaire by LED or HID is problematic as the Light centre and/or the direction of the light can differ significantly from the CFL lamp. Replacing an omnidirectional fluorescent lamp with a (bigger) directional LED lamp can result in reduced illuminance at the work place, changed uniformity ratios on floor and surroundings and even in unwanted

[77] Op. cit. LEU Ex. 1(c)(2015a)
[78] Op. cit. LEU Ex. 1(d)(2015a)
[79] Op. cit. LEU Ex. 1(b)(2015a)
[80] Op. cit. LEU Ex. 1(d)(2015a)
[81] Op. cit. LEU Ex. 1(e) (2015a)
[82] Op. cit. LEU Ex. 1(a)(2015a)

glare, sometimes requiring a new light plan design (renovation; installation of new luminaires). In street lighting the light distribution is bound by legal requirements, which can be a problem when installing a LED alternative in a CFL luminaire. On the right a 32 W CFL is shown next to a 25W LED bulb giving the same lumen output. The difference in size shows obvious problems when fitting in the CFL down light luminaires. [83]

Figure 5-1: Demonstrative comparisons of CFL lamps and LED alternative lamps

Referred Source in LEU Ex. 1a(2015a): http://www.energystar.gov/index.cfm?c=lighting.pr_what_are	*CFL 32W and LED 25W with same lumen package from LEU Ex. 1b(2015a)*	*CFL and LED in the same 6' and 10' down light fixture, from LEU Ex. 1b(2015a)*

- Where reflectors are used in installations, they are designed for the shape, dimensions and burning position of a CFL lamp to generate the desired light distribution. The more directional light of an LED will give a different light distribution in a CFL luminaire with reflector. This can result in reduced illuminance at the work place, changed uniformity ratios on floor and surroundings, unwanted glare and possibly require a new light plan design. [84]
- Some CFL luminaires are designed for 2 lamps. Differences in size of the LED alternatives can cause problems in fitting both lamps in the luminaire. [85]

[83] Op. cit. LEU Ex. 1(b)(2015a)
[84] Op. cit. LEU Ex. 1(a)(2015a)
[85] Op. cit. LEU Ex. 1(a)(2015a)

Figure 5-2: Demonstration of incompatibility of LED alternative lamps with luminaires designed for multiple lamps

Source: LEU Ex. 1a(2015a)

- The current lamp holders are designed to carry the weight of the existing CFL lamps. Safety standard for CFL lamps (EN60968) prescribes a maximum weight and bending moment to prevent a too high loading of the lamp holder. LED lamps can have a higher weight and bending moment than CFL lamps due to the necessary heat sink which needs to be close to the LEDs to remove the heat from the diodes. The weight of the LED solution often exceeds the values for CFL. [86]
- Luminaires for CFL are designed for the thermal properties of a CFL lamp and not to control the heat as required for dedicated LED fixtures. Direct application of LED replacement lamps instead of CFL can cause thermal problems in closed and/or narrow CFL luminaires. [87]
- The external lamp driver can be a conventional ballast or an electronic control gear. The market for new installations is moving toward electronic control gear due to new functionality (e.g. dimmability) and upcoming energy efficient legislation for the driver. Many CFL lamps used by professional end users are designed to be dimmable. Several modes of dimming (e.g. phase cutting) are present in the market. All modes of operation (EM, HF current controlled, power controlled, voltage controlled, preheat, non-preheat) have in common that the light source is expected to behave electrically as a standardised CFL lamp. The large diversity of drivers is not meant for an

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

electronically ballasted LED lamp. This makes it very difficult for a customer to know which ballast is used and which LED lamp to apply as a retrofit. [88]

- For many applications the prices of LED-based alternatives for CFL 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. [89]
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LEU[90] continues, that based on above arguments LightingEurope is of the opinion that suitable LED replacement lamps are not available for many CFL lamp types in many applications. Removing CFL lamps from the market would therefore force early refurbishment of the lighting systems or even new luminaire investments, which would unnecessarily and dramatically increase the waste. Furthermore, in the residential area, due to the higher product price of the LED alternative, giving the same energy efficiency, the consumer has to invest more to achieve the same amount of energy savings.

LEU[91] adds that aside from integrated LED solutions, the focus in the LED development is on reaching certain price points in the significant volume type of lamps and less on completing the total variety of lamp types available in conventional lamps. LEU also states that there is a focus on interesting high volume lamp types, ignoring many parts of the fragmented market. LEU expects the renewal of the exemption to have a positive effect on the efforts to further innovate in LED, as CFL is the benchmark to be outperformed by LED. It is explained that

> "*in the lighting industry a big fight for market share is ongoing in the LED arena. This fight is played along the price axis where performance is sacrificed to come to a lower price point (e.g. lifetime, efficacy, light output, size, lumen maintenance, colour quality). As long as there are alternative products on the market there is a 'threat', that users will buy the alternative when too much of the performance is sacrificed. So CFL will be the backstop for LED quality*."

5.3.3 The Minamata Convention

LEU states that during the 2013 UNEP Minamata Convention on Mercury in Japan agreements were made to limit mercury in various products, including compact fluorescent lamps. This treaty has been agreed upon and signed by 94 countries around the globe. The agreed mercury level for CFLs ≤ 30W is 5 mg, and is to be adapted until 2020 in countries that have signed the convention.

[88] Op. cit. LEU Ex. 1(a)(2015a)
[89] Op. cit. LEU Ex. 1(a)(2015a)
[90] Op. cit. LEU Ex. 1(a)(2015)
[91] Op. cit. LEU Ex. 1(2015b), also referring to VHK study referenced in footnote 59

5.3.4 Roadmap to Substitution

It can be understood that all efforts towards development of further substitutes are focused on LED technologies. 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.

In a later communication, LEU[92] states that there is no general roadmap to develop LED replacements for all existing CFL lamp types in the market (LEU is not entitled to share individual roadmaps of its member companies in relation to LEDs). McKinsey indicates in its report[93] that by 2020 still 48% of total general lighting will be in conventional technology. In relation to the breakdown of lamp sales to different technologies, data is provided from the VHK report as reproduced in Table 5-5, with shows CFL and LED sales in the context of other technologies.

Table 5-5: Technology breakdown of lamp sales, 2013

Lamp type	2013 sales in millions of units					
	Total		Residential		Non-residential	
	Mpcs	%	Mpcs	%	Mpcs	%
LFL	**344**	**20%**	**22**	**2%**	**322**	**45%**
CFL	**342**	**20%**	**184**	**18%**	**158**	**22%**
· **Retrofit CFLi**	271	16%	162	16%	108	15%
· **Non-Retrofit CFLni**	72	4%	22	2%	50	7%
Tungsten (HL)	**772**	**45%**	**617**	**61%**	**154**	**22%**
GSL	**159**	**9%**	**127**	**12%**	**32**	**4%**
HID	**33**	**2%**	**0**	**0%**	**33**	**5%**
LED	**82**	**5%**	**68**	**7%**	**14**	**2%**

Source: VHK study, see footnote 59 for reference, Compiled from Tables 1-4

5.4 Stakeholder Contributions

A number of contributions have been made by stakeholders. Comments of general nature have been summarised in Section 4.4 in the chapter regarding lamps in general. Comments regarding the lamp exemption Ex. 1(a-e) are summarised below:

The Belgian Federal Public Services for Health, Food Chain Safety and Environment (Health FGOV)[94], submitted comments regarding Hg in lamps, explained to specifically

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

[93] Quoted in LEU Ex. 1(2015b) as Lighting the way: Perspectives on the global lighting market – Second edition August 2012 by McKinsey & Company - Exhibit 27, page 52

[94] 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

target lamps falling under Ex. 1 (compact fluorescent lamps). Points raised regarding the fate of lamps and Hg and EoL are summarised in Section 4.4 above. Health FGOV recognize that alternative technologies to CFLs are already on the market and recommend an evaluation on the potential for substitution by these alternatives, relaying available data as to their possible limitations or deficiencies (including from a health perspective).

The Ministry of Environment and Food of the Danish Environmental Protection Agency (DEPA) [95] contributed a number of documents to the stakeholder consultation, which have been discussed in Section 4.4. In later correspondence additional detail was provided with specific relevance to Ex. 1(a-e) as follows[96]:

DEPA provides data from various surveys where consumers were asked to detail how many and what type of lamps they have in their homes. Results are compiled in Table 5-6 below. Though a general increase in the number of bulbs per household from 2010 to 2014 is observed in the data, during a discussion with DEPA it was explained that this change is probably explained in the different approaches of the surveys to data acquisition. It is thus assumed that total numbers have either remained similar of have changed less significantly.

[95] 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

[96] 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

Table 5-6: The number of the various bulb types in Danish households

	EPINION 2014 survey[1]		Danish Energy Agency 2010 Data[2]		Danish Energy Agency 2006 Data[3]	
	Average	**%**	**Average**	**%**	**Average**	**%**
Special bulbs (halogens or incandescent bulbs)	10.73	32%	10.2 (5.9+4.3)	50.6% (29.6%+21%)	15.13 (6.13+9)	68.25% (27.65%+40.6%)
Energy saving bulbs	9.72	29%	8.2	41%	4.64	20.93%
LED bulbs	8.84	26%	0.95	4.7%	0.44	1.98%
Fluorescent tube	4.4	13%	1.4	7%	1.96	8.84%
Crystal bulbs	-	-	0.25	1.2%	-	-
Total	**33.69**	**100%**	**19.91**	**100%**	**22.17**	**100.00%**

Source: 1 - EPINION, 2014, Kampagneevaluering elsparepærekampagne, Miljøstyrelsen (http://mst.dk/media/130867/forundersoegelse_sparepaerer.pdf)
2 - Danish Energy Agency, 2011, ELMODEL-domestic (http://statistic.electric-demand.dk/Files/2010_questionnaire_res.pdf)
3- 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

DEPA[97] refers to the EPINION survey of 2014, where consumers were asked as to their priorities when choosing lightbulbs for household use. The three most common aspects named were “saving energy and use as little current as possible” (53%); that lamps “have a long lifetime” (14%) the “Low price” (12%).

DEPA[98] refers to an assessment made in 2015 by FORCE Technology commissioned by the Danish EPA, in which a comparison of lumen/Watt for three randomly chosen LED bulbs and three energy saving bulbs was made. The result was that the LED lamps gave 24% more lumen for the same wattage. In Table 5-7 below a similar random comparison is made with 11 LED and 8 energy saving bulbs. Here the LED bulbs provide 26 % more lumen for the same wattage. DEPA states that these type of assessments are uncertain, however they are estimated to be in a realistic range, thus for further calculation the number was rounded to 25%.

[97] Op. cit. DEPA (2016a)
[98] Op. cit. DEPA (2016a)

Table 5-7: Lumen/Watt for randomly chosen bulbs

LED bulb			Brand	Energy saving bulbs			Brand
lumen	Watt	Lumen/Watt		Lumen	Watt	Lumen/Watt	
400	6,3	63	IKEA	550	11	50	Frostlight
600	10	60	IKEA	300	7	42	Frostlight
1000	13	77	IKEA	680	11	62	Frostlight
1000	14,2	70	IKEA	235	6	39	Osram
200	3,5	57	IKEA	430	9	48	Osram
200	3,0	66	IKEA	740	14	53	Osram
280	4	70	LED JemogFix	480	8	60	Phillips
290	4,2	69	LED JemogFix	425	8	53	Phillips
400	6	67	IKEA				
420	5	85	Opus				
2452	33	74	LG				
Average		69				51	

Source: DEPA (2016a)

DEPA[99] states that where omnidirectional light is required, many LED lamps are now available on the market which meet the requirements. DEPA provides a few examples in table form as presented below.

Figure 5-3: Examples of omnidirectional LED lamps

				
SunFlux krone LED E14 (greenline.dk)	SunFlux kultråds krone LED pære (greenline.dk)	Sunflux Kerte LED pære (greenline.dk)	Philips Inca LED Standard - E27 6w (Silvan.dk)	LED-PÆRE 6W E27 A60 KLAR (Harald-Nyborg.dk)

Source: DEPA (2016a)

Comments of the European Environmental Bureau (EEB), the Mercury Policy Project, and the Responsible Purchasing Network[100] are also summarised in part in Section 4.4 above. Regarding the Ex. 1 entries (a-e) EEB et al. explains that equivalent light emitting diode (LED) mercury-free products are not only widely available but are also more energy-

[99] Op. cit. DEPA (2016a)

[100] 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

efficient and have a longer rated life than CFLs. Such alternatives are rapidly becoming more cost competitive, especially when their long life and ability to cut energy, replacement, and waste disposal costs are considered. EEB et al. contest:

> "*LightingEurope's primary arguments against LEDs serving as a practical replacement to CFLs are based on their contention that LEDs cannot always serve as a fully compatible replacement for CFLs needed by consumers and professional users. LightingEurope presents this as their "opinion"*[101] *and has failed to substantiate the extent of this potential problem – if any. The crux of their argument lies in their contention that "LEDs in **many** [emphasis added] cases are not suitable drop-in replacements…so the availability of suitable discharge lamps needs to be secured to prevent a forced, early refurbishment resulting in extra costs and environmental burden."*[102] *While the issues they raised were a problem in the past, these concerns have largely been overcome by improved designs*."

EEB et al. further make recommendations regarding Ex. 1(a, b and e). In relation to CFLs, EEB et al. state that LEDs are a practical replacement that are more energy-efficient, more easily dimmable, and more cost-effective on a lifecycle basis (with a short payback of one year or less for most models).

- In particular, LEDs are explained to be a practical replacement for CFLs <30 Watts, where EEB et al.'s market survey shows a sufficient variety of both omni-directional LEDs and directional LEDs. "*Because a wide array of non-directional and directional LED lamps are available as practical and cost-effective replacements to CFLs <30 watts, we urge the EC to issue an expiry date on this exemption that is consistent with the phase out of inefficient halogen lamps: 1 September 2018*."
- Nonetheless EEB et al. state that "*according to our market research, most LED lamps are low-wattage models and could replace CFLs <30 watts*" (i.e., lamps falling under Ex. 1(a)). Though it is stated in relation to Ex. 1(b) that it is understood that the CFL variety in this category is much lower than in the *<30 watts* category, EEB et al. also state that they "*were able to identify far fewer LED lamps that appear to be direct replacements for CFLs in this category*". In this respect they propose reducing the threshold of Hg allowed for use in lamps falling under this exemption from 3.5 to 2.5 mg per burner. However, as their market survey revealed a few lamps with longer service lives with more than 2 mg of Hg, it is also recommended to consider adding new categories to the exemption for long-life CFLs.

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[101] Refered to in EEB et. al (2015) as: See page 6 of 35 of LightingEurope's exemption request.

[102] Refered to in EEB et. al (2015) as: 26LightingEurope, Request to Renew Exemption 1(a) under the RoHS Directive 2011/65/EU: Mercury in Single-Capped (Compact) Fluorescent Lamps Below 30W, January 15, 2015.

- In relation to Ex. 1(e), their position is similar. CFLs they have found on the market in this category show lower quantities of Hg, and on this basis EEB et al. proposes to lower the threshold in this category from 7 mg to 4 mg.

KEMI Kemikalieinspektionen, Swedish Chemicals Agency (KEMI)[103] mentions that new standards developed in the context of ecolabelling and public procurement criteria are based on the real market situation. KEMI concludes that the allowances permitted for Hg in lamps in most recent publications of this kind, for the Ex. 1(a-e) exemptions, show that it is possible to find low-energy light bulbs on the EU market with lower Hg-content than the current limit values prescribed in these RoHS exemptions. The following table is provided in this respect.

Table 5-8: Limit values for some light sources in RoHS compared with recommended mercury levels in EU GPP criteria for indoor lighting

	RoHS exemption request	Public procurement core criteria	Public procurement comprehensive criteria
Exemption 1(a-e) "Mercury in single capped (compact) fluorescent lamps not exceeding (per burner)":			
(a) For general lighting purposes < 30 W:	5 mg	2.5 mg	1.5 mg
(b) For general lighting purposes ≥ 30 W and < 50 W:	5 mg	3 mg	1.5 mg
(c) For general lighting purposes ≥ 50 W and < 150 W:	5 mg	3 mg	1.5 mg
(d) For general lighting purposes ≥ 150 W:	15 mg	3 mg	1.5 mg
(e) For general lighting purposes with circular or square structural shape and tube diameter ≤ 17 mm	7 mg		

Consultants Note: The Hg thresholds specified for Ex. 1(a-b) detailed above represent the levels allowed when the exemption was approved. The exemption however specified lower levels to come into force in 2011 and 2012 with the current allowances being as follows: 1(a): 2.5 mg; 1(b) 3.5 mg
Source: KEMI (2015a)

[103] 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

In respect with fluorescent lighting, the Polish Association of Lighting Industry (PZPO)[104] claim that fluorescent and LED lighting systems are not inter-compatible. "*Changing the fluorescent lamp-based systems to LED-based systems is associated with the need to replace the entire electrical system (power balance issues)… change the fixtures… number of lighting points… facility ceilings, as well as redesign the entire system and employ a sufficient number of designers and engineers*". This is also expected to generate WEEE.

5.5 Critical Review

5.5.1 Scientific and Technical Practicability of Substitution

LEU and NARVA request the renewal of Exemption 1, entries a-e, explaining that there are no substitutes on the market on the substance level, despite various research in this direction in the past. It is also explained that following the last review of Exemption 1 and its recommendations, industry has made an effort to reduce the levels of Hg in various lamps in this product range. This effort towards reduction among others allowed complying with the decreasing Hg allowances specified in Annex III for exemption 1(a, b and e).

The applicants argue that on the technical level, though Hg-free lamps are available, these also would not allow a phase-out of CFL lamps at present for various reasons. In theory these include incandescent light bulbs, halogens and LEDs, however as explained below, in some cases the availability of such alternatives is short-termed and in others the range of available products needs to be investigated (i.e. in the context of the various exemptions).

Halogens and incandescent lamps are explained to be a non-practical alternative as they consume significantly more energy during their use. The consultants agree with this point, which is also reflected in the European Commission's policy to phase out these lamps (based on non-compliance with minimum energy efficiency criteria of the EcoDesign Regulation).

As for LEDs, it is explained that the variety of CFLs on the market in relation to dimensions, wattages, luminous flux, efficacy etc. is very wide and that the parallel variety of LEDs is understood not to provide drop-in replacements for many of these lamps. LEU[105] quotes from the VITO & VHK study (Task 4) that

[104] 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

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

“in recent years, CFLi sales are decreasing, and the impression is that this regards in particular the sales in the low wattage range, where LED lamps are increasingly used.”

“CFLi’s are available up to 320 W (23000 lm) in cap E40 and 100 W (6365 lm) in cap E27. The maximum lumen output of LED retrofit lamps with integrated control gear is limited and high lumen output LED retrofit lamps are relatively more expensive. Consequently, direct LED retrofit solutions for high-capacity CFLi’s are expected to be scarce.”

“No LED retrofit lamps for CFLni have been found in the catalogues of major lighting manufacturers as Philips, Osram, General Electric, Havells Sylvania and Megaman. This is interpreted as a sign that this market is not sufficiently interesting, and that for many consumers the substitution of CFLni’s by LED retrofits may not be an attractive option.”

LEU contends that for an LED to be a retrofit solution for the total variety of CFL lamps, all the varieties have to be taken into account.

The VITO & VHK Task 4 report also states that for CFLni:

“…*there is a ballast problem: in most cases the existing ballast has to be removed or by-passed and a new LED control gear has to be installed (if not integrated in the lamp). The associated costs and luminaire safety certification problems might induce many consumers to stick with CFLni or to substitute the entire luminaire. However, technically there are no obstructions, because several smaller manufacturers are offering LED retrofit lamps for CFLni… Some are plug-and-play versions that can operate on existing ballast. However, when the ballast is not removed, their losses remain and these can be significant*.”[106]

In contrast to LEU, the consultants do not believe that LED substitutes need to be available for “the total variety of CFL lamps”, i.e., for each and every type of lamp. In the consultants’ view a substitute needs to provide the same function, in this case light with similar quality and in parallel a substitute should not create significant negative environmental or health related impacts, such as significant additional energy consumption or hazardous waste. In this respect the consultants contend that if the provision of light shows a high degree of similarity (e.g. above 90% in relation to for example luminous flux, light distribution) that this should be sufficient as long as from an environmental and health perspective the substitutes are at least comparable. Where substitutes show superiority in relation to environmental and health impacts, a larger difference in terms of light quality could also be considered. The consultants find this strategy is reflected in the various decisions of the EcoDesign Directive in relation to the banning of incandescent lamps and halogen lamps, which are understood to provide light of higher quality (e.g., “warm” light and higher colour rendering properties) but to

[106] Op. cit. VITO & VHK (2015)

have significantly higher energy consumption. In relation to CFLni the ECs decision in this respect can also be used as a basis to decide as to the applicability of substitutes. In the case of substitutes for halogen directional and non-directional lamps, exemptions from the phase-out of such lamps, were considered where the lamp fixture did not allow using alternatives within the same luminaires. In this sense, as long as plug-and-play alternatives are available, it can be understood that phase-out would be possible, with the provision of a sufficient transition periods. In the case of LEDs and CFLs, a further aspect that needs to be considered is the phase-out of mercury which goes hand in hand with the transition to LEDs.

In the consultants view, the information provided by LEU as to possible LED substitutes is very general in its nature. Many of the specific LED design limitations, raised as problems of LED technologies in the past review, are understood to now have been resolved, at least in many cases:

- As pointed out by some of the stakeholders who have made contributions[107] a growing variety of omni-directional LED lamps has become available.
- Furthermore, though indeed in the past the form and size of LED alternatives were problematic due to the use of large heat sinks, in recent years a decrease in the size of these components, as well as in the dimensions of LED lamps in general, is observed.[108] This is apparent from the amount of substitutes available for private consumers on the open market, which would clearly fit into standard installations. This trend towards a decrease in the size of heat sinks is also communicated for example in the DOE LCA[109], as early as 2012 as a trend expected to continue (see also Section 5.5.2 below). VHK & VITO[110] also state that in the small wattage range, lamps are available without a heat sink as other thermal dissipation techniques can be used. Impacts of heat sinks on weight are also understood to have decreased respectively and will not be relevant in the full wattage range. The evolving of heat sinks, in LED alternatives thus changes the significance of raised thermal incompatibility issues.
- LEU explains that some installations are particularly designed with reflectors to create a certain light distribution. Though it can be followed that in some cases LED lamps may not provide identical light distribution when used as substitutes, the consultants cannot follow that this aspect would result in insufficient light in most cases, particularly not in the lower wattage groups. In other words the consultants do not agree that light distribution is required to be identical, but only that a degree of similarity would be required.

[107] For example EEB et al. (2015a) and (DEPA 2016a)
[108] See for example EEB et al. (2015a)
[109] See DOE (2012a), DOE (2012b), DOE (2013a) and DOE (2013b) below.
[110] Op. cit. VHK & VITO (2015)

- LEU claims that LED alternatives are often not compatible with dimmers; however, as is also mentioned by some of the stakeholders[111], this claim was identified in the past as a problem of CFLs. LEU states in this respect that both CFLi and CFLni can be dimmable when specifically designed ballasts are used, however the consultants understand this to mean that this is not always the case. In other words, though information suggests that LEDs may not be compatible with all dimmers, information also suggests the same of CFLs. In the consultants' opinion, as seems to have been the case with CFLs, it can be expected that if LEDs are not compatible with all dimmers, that this would further develop in the coming years. Furthermore, at least some manufacturers are making information as to dimmer compatibility accessible to users on the internet. Information from Philips for example suggests that various LED models are compatible with a large variety of dimmers.[112] In contrast, from information on a Philips website for CFLs, only 5 CFLs out of 21 lamps can be dimmed.[113]
- LEU also raises concern as to the prices of LED alternatives, which are said in many cases to still be higher than the prices of CFLs. This aspect is particularly raised in relation to models of increased wattages, further stating that system energy efficiency and lifetime are in principal comparable. First of all, the consultants do not agree with the general statements as to energy efficiency and lifetime, as detailed in Section 5.5.2 below. The DOE LCA for example identified comparability in relation to the total life-cycle energy efficiency as early as 2012 and assumed that LEDs would significantly surpass their CFL counterparts in 2015. Other studies have also concluded that the longer-life and improved energy consumption of LEDs show that from a life-cycle-cost perspective, LEDs have a better "return on investment" due to reduced electricity costs. In relation to price, although cost aspects do not suffice to justify an exemption, in the consultants view, this aspect would possibly even justify revoking the exemption to some degree. Should LEDs indeed be more expensive than CFLs (with a sometimes more and sometimes less significant difference) the consultants assume that for some users the price at the time of purchase would actually delay the uptake of LEDs, despite the availability

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[111] For example see EEB et al. (2015a)

[112] See for example Philips dimmer compatability data from November 2015 for various LEDs, "KEY Consumer LED Mains Voltage range Recommended dimmer compatibility list for Mains Voltage Lamps", available under: http://download.p4c.philips.com/files/8/8718696481240/8718696481240_dmc_enggb.pdf

[113] See www.usa.philips.com/c-m-li/choose-a-bulb/latest#filters=STANDARD_BULB_SU%2CCANDLE_BULB_SU%2CSPOT_BULB_SU%2CREFLECTOR_BULB_SU%2CMINIREFLECTOR_BULB_SU%2CLUSTER_BULB_SU%2CGLOBE_BULB_SU%2CSPIRAL_BULB_SU%2CCAPSULE_BULB_SU%2CLINEAR_BULB_SU%2CCIRCULAR_BULB_SU%2CTUBULAR_BULB_SU%2CBENT_BULB_SU%2CSPECIALTY_BULB_SU%2CFK_BULBS_COMPACT_FLUORESCENT&sliders=&support=&price=&priceBoxes=&page=&layout=36.subcategory.p-grid-icon

of plug-and-play substitutes. This is particularly of concern in respect of older technologies, which are being phased out (for example halogens to phase out by September 2018) in light of their low energy efficiency. The consultants assume that users who have chosen CFLs in the past over the cheaper halogens (and incandescent) may be more aware to energy saving aspects and may thus also shift to LED when confronted with the purchase of a replacement lamp. However, for users who have retained the less efficient bulbs, despite the related costs of energy consumption, the availability of less expensive CFLs could create a shift towards these lamps when replacements are needed. This would not only reduce the potential for energy savings, but may also create a rebound effect in the trend away from Hg lamps explained to be underway relating to LED technology. This is understood to be particularly of importance in the residential market share, in which halogens still represented 61% in 2013, according to VHK & VITO data (See Table 5-5).

The consultants find it difficult to conclude as to two aspects raised by LEU as limitations of LED technology – the lack of plug-and-play substitutes for lamps with high lumen packages and the limited availability of plug-and-play substitutes for CFL with non-integrated ballasts (ni).

Regarding lumen packages, LEU states that the variety of LED alternatives for higher lumen packages is limited, of particular concern for exemption entries 1(b) through 1(d), which are specified with lumen packages between 2000 and 12000 lumen and above (see Table 5-4). This is also raised in the VHK & VITO study, though it also needs to be noted that in light of the generally lower variety of lamps placed on the market in these categories (particularly entry c and d) it is to be expected that the variety of CFLs shall also be smaller.[114] The consultants find it difficult to conclude as to the applicability of the range of available LEDs for the full range of higher lumen package CFLs. However, in contrast to LEU the consultants do not agree that in the case of lighting that substitutes need to be available for each and every lamp model. In the consultants' opinion, having alternatives that would be in the range of lumen output should be sufficient. Solutions need to be similar but not identical and a LED lamp providing a certain lumen flux can be expected to cover various CFLs exhibiting a range of luminous flux.

As regards CFLni, the consultants understand from the available information that there is limited availability of lamp replacement alternatives, particularly where plug-and-play substitutes are concerned, meaning that replacing a CFL could require conversion of installations due to driver incompatibility. LEU explains that 32% of lamps used for professional uses and 11% of lamps used for residential uses have non-integrated ballasts. When put into perspective of the breakdown of lamp sales according to different technologies (see Table 5-5) however, 11% of residential CFLs translates into 2% of all residential lamps, and 32% of non-residential (i.e. professional) ones into 7%. It

[114] Also stated in EEB et al. (2015a)

is thus observed that this aspect is of higher relevance for professional uses. Of further importance is that the ni lamps are often used in office lighting in arrays of luminaires, meaning that a lack of replacement lamps could have a more significant impact if replacements are not available for professional consumers as it may affect an array of luminaires and not a single installation. In such luminaires it is understood that lamps are often installed in twos and fours, meaning that where concern is raised as to early end-of-life (EoL) of luminaires, these numbers would actually be half or maybe even one third of lamp numbers (i.e., in reference to stock and not annual sales). In this respect, though the consultants can follow that the availability of LED substitutes for CFLni may be more limited (particularly where plug-and-play substitutes are concerned), this aspect is more of a concern for lamps used for professional uses. Though CFLni lamps may cover only 7% of the professional sector uses, it is possible that such uses are not distributed evenly between users; i.e. office lighting users may be affected to a higher degree than 7% of their lamps should the exemption be revoked. In this respect it should however also be noted that where (multiple) arrays exist within the same location (building), this will make the professional rewiring / conversion option more practical and shall increase the economic feasibility. The reason for this being, that for the conversion of a single lamp, technicians may charge a larger sum to include e.g., travel costs, etc. or the work may be refused completely. But as the number of lamps to be rewired or converted grows, the marginal cost for the repair of each additional one can be expected to decrease.

5.5.2 Environmental Arguments

5.5.2.1 Energy Savings

LEU[115] was asked to estimate the impacts to arise from a possible phase-out of the exemption over the next 10 years and explained that in relation to energy, the expected effect is minimal, because the efficacy of CFL is just a bit lower than LED. An impact such as that of the shift from incandescent lamps to CFLs (80% energy saving) is not anticipated as CFLs themselves are very energy efficient. In contrast, LEU says that energy savings can also be achieved through smart solutions with conventional lighting (e.g. dimming, presence detection, daylight link, etc.). It is further explained that lamps covered by the exemption for professional use are subject to application specific norms and requirements e.g. building norms for offices EN 12464-1. Replacing lamps in such installations so that they adhere to such norms may require a new lighting plan because e.g. the required illuminance levels can’t be reached with the same number of light points. This could influence the total energy use negatively.

In the consultants’ view it seems that statements raised by LEU in relation with energy savings overlook the fact that halogen lamps are to be phased out by September 2018 and, according to data from 2013 that such lamps still represent up to 45% of the total sales on the market. Even if LED energy efficiencies are only slightly superior to CFLs, the shift from halogens to LEDs could still be expected to result in a large energy savings with

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

the added values of the elimination of mercury. Furthermore, despite LEU's claims, at least in the lower wattages (Ex. 1(a)), comparisons of LEDs and CFLs currently on the market show that "the LED bulbs give 26 % more lumen for the same watt"[116]. Thus this argumentation cannot be followed and the consultants believe that significant energy savings could still to be expected, especially as further developments in the efficiencies of LEDs are expected, whereas for CFLs it is understood from LEU that industry is no longer focusing on further developments. Smart solutions raised by LEU are also relevant for LEDs and thus should not be understood to support further potential for energy savings through CFLs.

Even if LEDs and CFLS were still to be considered comparable in relation to energy savings, the fact that LEDs allow avoiding the use of mercury, which is a substance restricted not only under RoHS but also by the Minamata convention and other legislations, is of importance. As shall be raised in Section 5.5.3 despite the general reduction in the mercury quantities in CFLs, this substance is still of high concern, particularly where there is a risk of emissions to the environment. Thus promoting the shift from all conventional lamps to LEDs (and avoiding for example a shift from halogen to CFLs) is also understood to be of importance for reducing possible risks associated with mercury releases in various life cycle phases of lamps.

5.5.2.2 Life Cycle Aspects

Several stakeholders (e.g., LEU, EEB et al.) refer in their contributions to a study published in 2012 and 2013 by the U.S. Department of Energy. In the following this study will be summarised briefly against the background of the exemption evaluation at hand.

The U.S. Department of Energy (DOE) conducted a three-part study to assess the total life-cycle impact of LED screw-based replacement lamps in relation to two comparable lighting technologies used in residential homes: incandescent lamps and compact fluorescent lamps (CFLs). Taking this into account the scope that the study reflects is relevant to a large extent to exemption 1(a-e), with the exception of CFLs with an external ballast (CFLni). According to the principles of LCA, the DOE study regards not only use, but also manufacturing, transport, and disposal of the products under consideration. The DOE considers the LCA to be the most comprehensive study of its kind for LED products, breaking new ground in their understanding of how lighting affects the environment. In addition, it was the first public study to consider the LED manufacturing process in depth. The comparison looked at the LED lamp technology as available in 2012 and also projected what it might be in 2017, taking into account some of the anticipated improvements in LED manufacturing, performance, and driver electronics[117]. Part 1 of the study mainly includes an in-depth review of 10 existing LCAs on lighting products from various sources. As this review led to the conclusion, that most

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[116] Op. cit. DEPA (2016a)
[117] DOE (2013a), U.S. Department of Energy, Life-Cycle Assessment of Energy and Environmental Impacts of LED Lighting Products. Factsheet, April 2013

of the uncertainty concerning the life-cycle energy consumption of an LED lamp was found to be related to the manufacturing of the LED package, part 2 of the study focused specifically on this issue. Part 3 of the study takes the end-of-life disposal into consideration and presents a worst-case scenario regarding potentially toxic elements in hazardous waste from disassembly of lamps.

In respect to the exemption at hand the main findings of the study can be summarised as follows[118,119,120,121]:

- The "use" phase of all three types of lamps accounted for 90 percent of total life-cycle energy, on average, followed by manufacturing and transport.
- The average life-cycle energy consumption of LED lamps and CFLs was similar, and was about one-fourth the consumption of incandescent lamps.
- The efforts to further enhance the efficacy of LED are still ongoing. If LED lamps meet their performance targets by 2015, their life-cycle energy is expected to decrease by approximately one-half, whereas CFLs are not likely to improve nearly as much.
- Taking the environmental impacts into consideration, the LED lamp had a significantly lower environmental impact than the incandescent, and a slight edge over the CFL.
- The CFL was found to be slightly more harmful than today's[122] LED lamp in relation to all impact measures except hazardous waste landfill, because of the LED lamp's large aluminium heat sink. The heat sink is the main reason the LED currently exceeds the CFL in the category of hazardous waste to landfill, which is driven by the upstream energy and environmental impacts from manufacturing the aluminium from raw materials.
- As the efficacy of LED lamps continues to increase, aluminium heat sinks are expected to shrink in size—and recycling efforts could reduce their impact even further.
- The light source that performed the best was the LED lamp projected for 2017, whose impacts are expected to be about 50 percent lower than the 2012 LED lamp and 70 percent lower than the CFL.

Taking these results in to consideration in the context of exemption group 1, it can be concluded, that the environmental impacts caused by a substitution of CFL with LED

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[118] Op. cit. DOE (2013a)

[119] DOE (2013b), Life-Cycle Assessment of Energy and Environmental Impacts of LED Lighting Products. Part 3: LED Environmental Testing. March 2013

[120] DOE (2012a), U.S. Department of Energy, Life-Cycle Assessment of Energy and Environmental Impacts of LED Lighting Products. Part 1: Review of the Life-Cycle Energy Consumption of Incandescent, Compact Fluorescent, and LED Lamps. Updated version August 2012

[121] DOE (2012b), U.S. Department of Energy, Life-Cycle Assessment of Energy and Environmental Impacts of LED Lighting Products. Part 2: LED Manufacturing and Performance. June 2012

[122] The study estimated LED developments and thus the reference to today's LED technology is relevant for lamps assumed to be available by 2015 and thus also in 2016 – consultants note.

would not outweigh the total environmental benefits in relation to technologies on the market in 2012. Taking into account the increasing efficacy of LED, this conclusion can be expected to have increased in relevance; more than three years after the DoE published its results. Though from the total impact point of view equivalency and possibly superiority of LEDs is expected at present, for the heat sink factor the LEDs may have an environmental disadvantage where heat sinks are still used. Some LEDs, particularly in the low wattage range, shall no longer have an aluminium heat sink, removing the related environmental impact. VHK & VITO[123] state in this regard "*Efficacy improvements have a double positive effect: they also reduce the amount of heat produced. Some years ago, relatively low lumen LED bulbs (500-800 lm) had efficacies of 60-80 lm/W and a heavy and bulky heat sink, while recent LED filament lamps reach efficacies of 100-120 lm/W and are without heat sink*". This is explained not only to be due to efficacy improvements, but also to other dissipation methods, i.e. gas filling of the lamps. In other lamps, the heatsink may have already decreased in size and weight in comparison to what was common at the time of the DoE study, providing for a reduced environmental impact. In such cases, where the lamp is disposed of properly, the heat sink is expected to be recycled, alleviating the environmental disadvantage. Furthermore, the possible environmental impact related to the heat sink is one of 15 environmental indicators investigated and does not render the total environmental performance as inferior to CFLs. LEDs are still expected to show better performance when all indicators are considered.

5.5.3 Stakeholder Contributions

Various contributions have been made as specified in Section 5.4 and some of the aspects raised are already discussed in the sections above and thus not raised here again, however in the following some additional arguments raised by stakeholders are discussed.

As already mentioned in the general chapter, the consultants can follow concern raised by stakeholders that the risks of Hg emissions during the use phase (result of lamp breakage) and during the end-of-life phase (improper disposal, e.g. as municipal waste) may not be sufficiently controlled. Such risks shall prevail to some degree, despite the successful efforts of industry to communicate the risks of lamp breakage and how to handle such situations and despite the organisation, collection and recycling mechanisms as well as the communication of their availability to consumers. These concerns are of particular relevance to Ex. 1(a-e), as lamps covered by these exemptions are often used in households, where infants and elderly may be exposed in cases of breakage, and where behavioural habits concerning disposal can be more difficult to change.

DEPA provides results of a survey as to the total number of lamps in Danish households and the average shares for the various lighting technologies. The data is of particular

[123] Op. cit. VITO & VHK (2015)

interest to Ex. 1(a-e) as it shows that the number of CFLs has increased in the period between 2006 and 2014, whereas the number of halogens and incandescent lamps has decreased. Though the differences in the total number of lamps between the 2006/2010 data and the 2014 data suggest inconsistencies in the method of data collection, the consultants assume that these inconsistencies do not contradict this trend, though they may affect its intensity. In the consultants view this trend further supports concern as to the possible shift of consumers from halogens to CFLs, once the former are to be phased out in 2018. Additional data as to the average number of light sources per household and their breakdown across various technologies is presented in Appendix A.2.0.

DEPA also provides results of a survey, where Danish consumers were asked as to the main motivation for purchasing a lamp of a specific technology. Though results show that over 60% would buy a lamp because of its energy savings or its service life, for 12% the most important aspect is still price. If as LEU claims, the energy savings of CFL and LEDs are similar, than the fact that price still plays a role in consumer choice could mean that some consumers would prefer CFL over LED when replacing a halogen bulb.

EEB et al. criticizes LightingEuropes' argumentation, regarding the insufficient availability of LEDs as substitutes for CFLs, explaining that LEU fails to substantiate the extent and the potential of this problem and mainly raises issues that were a problem in the past, but that have for the most part been overcome with improved designs.

The consultants can follow the proposal of EEB et al. to specify an expiration date for Ex. 1(a), however do not agree with the proposed date, 1.9.2018. The consultants assume that EEB et al. are concerned that earlier expiration of this exemption could create a rebound effect of consumers purchasing halogens with higher energy consumption. However, should the exemption be revoked, a transition period of up to 18 months could be granted, at the earliest starting in 22.7.2016 and thus ending in 21.1.2018. Though a rebound affect may possibly occur in the time between January and September 2018, it is expected to be short termed, whereas as renewing the exemption with the expiration date of 1.9.2018 would enable stakeholders to request a renewal, at minimum resulting in an additional transitional period of 12 months.

EEB et al. further propose to reduce the Hg threshold allowances provided for Ex. 1(b) and for Ex. 1(e). The consultants do not disagree that some and possibly most CFLs available on the market could already be applying lower quantities of Hg. However, in the consultants' opinion, it can be followed that as claimed by the lighting industry, all current development efforts are directed towards LED solutions, which can be assumed to become the leading technology within the next few years. In this sense, it is clear that a reduction of thresholds shall not motivate manufacturers to change the application of Hg in their lamps, all the more so as it can be understood that the levels proposed by EEB are already applied in most lamps on the market. Though a reduction might "banish" models with more Hg from the market, the consultants assume that this shall not result

in a significant change, while communicating to industry that as long as lamps comply with the new threshold, market entry shall be allowed.

KEMI presents requirements of green public procurement initiatives, and proposes to align exemption Hg threshold allowances with the specified levels. LEU[124] responded to this proposal, explaining that the RoHS thresholds specified by KEMI have in some cases already decreased, as mentioned in the consultants note to Table 5-8. LEU further explains that for this reason the differences between the RoHS thresholds and the public procurement thresholds are not as significant and that it needs to be kept in mind that these are average levels, whereas there is a need to retain a margin above the average for the RoHS Directive thresholds. From the consultants experience with Green Public Procurement, threshold criteria are usually developed to create a preference for products that have a higher level of performance. Where such criteria have been developed, restricting the presence of hazardous substances, this is only done when the specified limits outperform restrictions already specified in legislation (e.g. in RoHS). Otherwise, there would be no need to specify the limit as all products are required to comply with legislation. With the current development strategy of the lighting industry, the consultants do not perceive a strategy of reducing Hg thresholds as preferable to other strategies in terms of the potential for creating environmental benefit.

5.5.4 The Scope of the Exemption

The exemption entries address CFLs, differentiating between lamp groups based on wattage groups and in the case of Ex. 1e based on shape and dimensions (e.g., tube diameter). In contrast, from the information provided by LightingEurope and the discussion of alternatives in the VHK & VITO report, different aspects appear to be of relevance in relation to the question of substitute compatibility.

A first differentiation regards the lumen packages of lamps. LEU explains that the development of LEDs with higher lumen packages (above 1500 lumen) is focussing on new luminaire solutions instead of retrofit CFL substitution. As a result, not many replacement solutions for this specific category in LED are available on the market. [125]

From independent market surveys, the consultants' are aware that the variety of available LED substitutes indeed decreases as lumen package increases. Nonetheless, the variety of CFLs in this area is also significantly lower than in lower lumen packages, and thus it follows that a lower variety of LED substitutes would also be expected. Though in theory it could be considered if future exemptions could be limited to lamps with higher lumen packages, available information to support the determination of a lumen threshold is not available in the public realm in a compiled form that would allow supporting a knowledgeable proposal.

[124] LEU (2015c), LightingEurope, Summary of critical observations to stakeholder submissions , Submitted per email on 18.12.2015
[125] Op. cit. LEU Ex. 1b(2015a)

A second aspect where a differentiation in the availability of substitutes is observed concerns the location of the ballast. In luminaires devised for CFLni's, the ballast is part of the luminaire and as such substitutes will either need to be plug and play for a consumer to be able to simply replace a lamp, or the ballast will need to be removed and the luminaire rewired. Though a lack of substitutes is observed in the product portfolios of major lighting manufacturers, it is also understood that several smaller manufacturers are offering LED retrofit lamps for CFLni, some being plug-and-play versions that can operate on existing ballast. This may make replacement less straightforward for consumers; however, on this basis the consultants find it difficult to follow LEU's general argumentation that there is a lack of alternatives.

In this sense, both of the aspects above do not assist in making a clearer demarcation as to the availability of LED substitutes for CFL lamps. The current differentiation, based on wattage and form, is also not optimal for such a demarcation. However, as shall be discussed below, against the background of market data and the knowledge of available LED substitutes, using this scope differentiation is understood to allow a gradual phase-out of CFL technologies and thus to still be useful.

5.5.5 Conclusions

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

- their **elimination or substitution** via design changes or materials and components which do not require any of the materials or substances listed in Annex II is scientifically or technically impracticable;
- the **reliability** of substitutes is not ensured;
- the total negative **environmental, health and consumer safety impacts** caused by substitution are likely to outweigh the total environmental, health and consumer safety benefits thereof.

The applicants put forward information that clearly shows that substitution on the substance level is not practical and that further reducing Hg amounts per burner is also not expected to result in significant environmental benefits.

The consultants can follow these points. A reduction has indeed taken place in the general Hg amounts. Though further reductions may be possible to some degree, the consultants also agree that the potential for this strategy has been realised to a large degree. As a shift towards LED technologies has become clear, the consultants further do not believe that a change in the Hg levels shall motivate manufacturers towards further reductions in actual lamps placed on the market. Though a decrease in levels could be proposed to allow the exemption to reflect the actual lamps on the market (or for example the best 80%), the consultants do not assume this to create a significant environmental benefit in comparison to scenarios where CFLs are substituted with LEDs, eliminating Hg completely.

In contrast, the statements made by the applicants regarding the availability of **LED substitutes** cannot be followed comprehensively. Statements are very general in nature

and the applicants do not provide data to substantiate various claims. Particularly for lamps of lower wattages such as those falling under Ex. 1(a), the various claims are also not supported by the range of LEDs available on the market that suggests that many of the problems raised were relevant in the past, but have been handled in newer products on the market.

Though for lamps of higher lumen packages there might be a lack of suitable alternatives, or a decreased variety thereof, the consultants are of the opinion that the general argumentation only holds true for some of the product range.

For lamps of lower wattages, there appears to be a large variety of substitutes of various sizes and various lumen packages. Such alternatives are understood to provide comparable performance in terms of energy efficiency and are in many cases understood to be more efficient than CFL counterparts on a lumen/watt basis, as well as having longer service lives. Many of the LED alternatives presented by the larger manufacturers (see footnote 112 as to dimmer compatibility of the Philips LED product range) are also understood to be compatible with a large variety of dimmers and information as to dimmer compatibility is provided by manufacturers for specific lamps and should sufficiently facilitate the correct choice of replacements. Even if the light distribution may differ, such lamps are understood to be sufficiently compatible in terms of light-output, with LEDs available in both direct versions (spot-lamp and omni-directional lamps). Arguments raised in relation to the size and weight of heat-sinks and possible thermal incompatibility are understood to have been of high concern in the past, but to have lost their relevance, at least in the lower wattage categories. The consultants also do not agree that the price of LED substitutes should be of concern in relation to the validity of the exemption – economical aspects do not suffice to justify an exemption from the RoHS Directive. Furthermore, though LEDs may be more expensive at the time of initial investment, the savings related to energy consumption are understood to return this investment quickly (lower life-cycle-costs) as compared with other lamp technologies.

For the higher lumen package categories, data suggests that the variety of substitutes in this area is more limited (as is also the variety of CFLs) and does not allow concluding whether the range of products sufficiently covers the CFL product range.

In this sense, the consultants conclude that there is a sufficient availability of substitutes for lamps of lower wattages, whereas in the higher wattage area, available data does not allow concluding whether the range of LED alternatives sufficiently covers the range of available CFLs.

To summarize, where substitutes exist, they are understood to have sufficient reliability and compatibility with **CFLi** installations (CFLni are discussed separately below), while also exhibiting superiority in terms of service life. The LED product range is developing considerably, with manufacturers quickly developing their product portfolios to expand the range of applicability. Though in areas of small market share, manufacturers can be expected to allocate lower priority to the development of a large variety of substitutes, in areas of larger market share the opposite is the case, as is clear from the larger variety of substitutes for Ex. 1(a).

Though LEU raises general argumentation as to the risk of negative environmental impacts related to early end-of-life of luminaire installations, the consultants do not agree that this argumentation is valid for CFLi lamps. For such lamps, a large variety of LED alternatives are available, which can be used as one-to-one, plug and play replacements, without a need for installation conversion. Though as explained above, for higher lumen packages (understood to fall under the higher wattage sub-categories) substitutes may not be available at present, it is understood that once they become available they also would be one-to-one / plug and play replacements. In this sense the consultants conclude that the only possible justification for an exemption for CFLi lamps is related to the lack of substitutes and this argumentation is only relevant for CFLi lamps of higher lumen packages, which also have higher wattages.

In contrast, there is concern as to the suitability of LED alternatives for substituting **CFLni**, where the ballast is not integrated in the lamp but rather part of the installation. Available information suggests, however, that smaller enterprises have brought LED alternatives to the market, which are compatible with installations. Compatibility in this case is either as plug-and-play substitutes or as substitutes requiring a conversion of the luminaire (rewiring of the ballast, etc.). The consultants can follow that such substitutes may be less straightforward for consumers as one-to-one replacements, since a larger effort shall be required to find a suitable substitute, possibly also requiring the conversion of the installation. However, from a technical perspective, the consultants do not agree that this can be understood as a lack of sufficient substitute availability. As is the case for CFLi, substitutes may be less available for lamps with higher lumen packages; however, in the lower lumen package categories in the consultants' opinion, from a technical point of view substitutes are available and when installed properly they are also expected to be reliable. In the case of retrofit lamps, when driver compatibility is assured, LED substitutes are expected to have higher energy efficiency. Though in some cases incompatibility with drivers may reduce the lamp efficiency, it is also expected that proper rewiring or conversion (performed by skilled personnel) shall prevent such decreases and that here too LED lamps shall be more efficient than CFLni's.

An important point raised by LEU in this respect regards the compatibility of installations with safety requirements and warranty conditions. Once a CFLni installation is rewired or converted to allow the use of an LED replacement, the responsibility for such aspects is said to shift from the manufacturer to the individual performing the conversion. Though this aspect does not necessarily change the actual safety of the installation, it is possible that it shall be more difficult to find professionals who are willing to perform such changes – this relating to the possible responsibility to faults in comparison to the possible profit from such conversions. Nonetheless in the consultants view, though this could make substitution more challenging in CFLni installations, it cannot be said that there is a lack of substitutes in this area. It can also not be said that such substitutes show lacking reliability, though it is possible that there is a lack in standardisation and in skilled employees willing to perform such conversions while ensuring sufficient reliability of installations. In such cases, early phase-out of CFLni's may result in early replacement of installations / luminaires, where the costs of conversion or the lacking guarantee of minimum reliability shall push consumers to replace CFLni installations with LED ones.

This could mean that some CFLni installations would reach end-of-life early, however a quantification of the actual environmental costs that could incur is not straightforward as installations will be in different life phases, and lamps still in use can also be expected to remain functional until they reach the end of their expected service life. To try to shed some light on the possible range of impacts that could be expected, it is important to note the share of CFLni's from the total CFL market, which is relatively small (~12% for residential uses and ~32% for non-residential). Put into the context of the total market share of lamps these numbers become even less significant (CFLni is 2% of residential uses and 7% of non-residential uses). LEU has further stated that some CFLni's are used in installations with 2 or 4 lamps. In this respect the stock of CFLni installations can be assumed to be smaller than the stock of CFLni lamps, meaning that impacts of early-end-of-life of installations would affect a smaller number of luminaires. As CFLni's are often used in arrays, for example in office lighting, it is assumed that costs related to installation replacement shall, however not be spread evenly across consumers, or at least not across non-residential consumers. Based on the available information it cannot be concluded how significant the described impacts could be. It is also not possible on the basis of the available information to conclude as to the actual relevance of CFLni's for the various Exemption 1 entries. Two strategies related to exemptions could be considered:

- The first following the logic of availability of LEDs for lower wattage categories, as from a technical perspective they can be used as replacements. In this case, CFLni's would be covered as was the case until now through exemption entries that are to remain valid, with the understanding that should certain entries not be renewed, that possible costs related to EoL of CFLni luminaires are acceptable.
- A second strategy would be based on an understanding that possible environmental impacts of EoL are of a range which would not be acceptable. In this case an exemption could be formulated specifically for CFLni lamps. Though the argumentation for this alternative is supported by the potential for environmental costs, the consultants' would like to note that such costs need to be observed in perspective. The fact that substituting a CFL with an LED eliminates the use of mercury in the product and thus also problems related to emissions of mercury at EoL shall to some degree off-set any environmental problems related to the early scrapping of luminaires. This is particularly relevant when one observes the current collection rates, which may comply with WEEE targets but are still below 50% (see further details below). It would also be false to expect the whole luminaire stock to be scrapped. Some plug-and-play substitutes are already available. Luminaire conversion is also possible, and when done properly results in reliable and more efficient lighting solutions. At least some luminaires are expected to be retrofitted or converted, with a rising trend in this direction as LED conversion kits could become more common and particularly in office lighting arrays, the larger number of luminaires to be converted shall affect the willingness of consumers to make an investment in conversion. Furthermore, some

luminaires are expected to be scrapped anyway due to age and also changing fashion trends. Against this background it is not to be expected that the total luminaire stock shall be scrapped subsequent to termination of the associated RoHS exemption, but only a certain percentage thereof. Finally, CFL luminaires, and with them also CFLni luminaires can still and are still placed on the market as new EEE. LEU states in this respect that "*luminaires for professional applications can exist for up to 30 years… it must also be clarified that it is allowed in the EU to sell and install new luminaires based on conventional technology*".[126] So any possible environmental impacts are not related solely to the current stock of luminaires, but rather to a stock that is still in growth. Due to the obvious lack of a clear roadmap towards phase-out of CFL lamps, the consultants believe that the continuous growth of the CFL luminaire stock needs to be considered in this context.
As shortly referred to above, despite the elaborate collection mechanism that has been established for lamps containing mercury, the actual estimated collection rates are still below 50%. The sound recycling of lamps not collected through this mechanism is not ensured and thus raises high concern related to possible mercury emissions associated with such lamps.

To summarize the above, the consultants believe that alternatives are sufficiently available for lower lumen packages. This includes lamps falling under Ex. 1(a), which are understood to have lumen packages up to 2500 lm. From surveys of various LED types it is also assumed that LEDs are available at lumen packages that would cover Ex. 1(b). For example, products presented on the German Eco-top-ten website[127] include two lamps (27 W) of 2800 lumen, one lamp (35 W) of 4000 lumen and one lamp (35 W) of 4160 lumen. Though the LED replacement variety in this category is not as large, the consultants believe that a long transition period (18 months) would suffice in this case for industry to develop further LED replacements to sufficiently cover the product range of both of these entries. As these two entries also cover the larger shares of the total CFL market (Ex. 1(a): 85% and Ex. 1(b): 10%), it can also be followed that industry is focusing on these areas in the current development of LED substitutes. As apparent from Table 5-1, this shall allow eliminating 90% of the mercury placed on the market through CFL applications. In the other three entries it is difficult to clarify the variety of LED

[126] Op. cit. LEU (2015b), Following this statement, LEU provides the following examples of luminaires based on conventional technologies:
(1) http://www.ecat.lighting.philips.nl/l/buitenverlichting/stads-en-straatverlichting/stads-en-straatverlichtingsarmaturen/metronomis/metronomis-torino-cds530-531/910502146918_eu/
(2) http://www.ecat.lighting.philips.nl/l/buitenverlichting/stads-en-straatverlichting/stads-en-straatverlichtingsarmaturen/iris/912300025697_eu/
(3) http://www.ecat.lighting.philips.nl/l/armaturen-binnenverlichting/downlights/fugato/fugato-performance-algemene-verlichting/910502488515_eu/

[127] See following link: http://www.ecotopten.de/beleuchtung/led-lampen?&&&field_10102_tid[0]=3850&&page=1

substitutes currently available. Though it can be assumed that some alternatives may be available, it cannot be dismissed that availability is not yet sufficient. As these three entries also cover relatively small shares of the total CFL market (Ex. 1(c): 3%; Ex. 1(d) and Ex. 1(e): 0.5%;), it is further assumed that developing a larger variety of substitutes in these categories is not a first priority for industry, and shall also have a much smaller contribution to the total amount of Hg placed on the market through lamps. Based on Table 5-1, this represents 10% of the Hg placed on the market through CFLs (excluding Ex. 1(f) CFLs). Renewing these three entries at present shall allow industry to focus its development efforts on then completing the substitute range for the other two entries, where environmental benefits of phase-out are expected to be more significant.

A three year exemption could allow evaluating the changed availability of substitutes in these three sub-categories in the short term, however assuming industry is to focus throughout the transition period on developing substitutes for the other two entries, it is possible that this period would not allow for a substantial change in substitute availability. In contrast, should a rebound effect of lamps falling under Ex. 1(c) and 1(d) being used to substitute lamps falling under Ex. 1(b)[128] become apparent (i.e. an increase in sales) a shorter transition period would allow identifying this trend earlier. Thus, though a longer period would support industry in terms of prioritisation of the development of LEDs, in the consultants' opinion a short termed exemption prior to next review would provide improved monitoring of changes within market trends, and thus is advised to be the preferable option.

5.6 Recommendation

Taking into account the availability of LED alternatives as explained in the conclusions the consultants recommend discontinuing exemptions for lower lumen packages covered by Ex. 1(a) and 1(b), while renewing Ex. 1(c), Ex. 1(d) and Ex. 1(e). The renewal is recommended for a period of three years, to allow following the development of substitutes more carefully, while also monitoring possible negative rebound affects. Should exemption 1(e) be renewed again after this period, the Hg threshold should be decreased to 5 mg, as specified in the Minamata Convention. For exemptions that are not to be renewed, a long transition period of 18 months should be granted, to allow industry additional time to further establish the availability of substitutes in relevant product categories.

For CFLni lamps it is possible that replacement of lamps with LEDs might be more complex and in some cases result in consumers deciding to replace luminaires in order to avoid such complications. Though this is understood to create an environmental impact, where lamps reach EoL early, prolonging exemptions for such lamps is not expected to allow reducing the impacts, as CFLni luminaires are still available on the market and have

[128] The availability of LED substitutes for CFLs under Ex. 1(a) is understood to suffice in terms of variety and prices are also lower than for higher lumen packages, so that a rebound trend would not be expected for this category.

in some cases expected service lives of up to 30 years. Such impacts also need to be observed in perspective of the relatively small share of the CFLni lamps in relation to the total CFL market and to the total lamp market. They shall further be off-set through the elimination of Hg and through application of retrofit and conversion substitution routes where this is possible. Thus, the consultants recommend not to provide an exemption specifically for CFLni lamps.

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 loophole for consumers seeking CFL replacements covered by entries to expire. If possible, the Commission should investigate limiting the sales of such lamps to a business-to-business basis to avoid such misuse.

<table>
<tr><th>Exemption 1</th><th>Scope and dates of applicability *</th><th>Comments</th></tr>
<tr><td colspan="3">Mercury in single capped (compact) fluorescent lamps not exceeding (per burner)</td></tr>
<tr><td>(a) For general lighting purposes < 30 W: 2.5 mg</td><td rowspan="2">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</td><td rowspan="2">The maximum transition period should be granted to other categories (18 months);
The COM should consider adopting measures to limit product availability to B2B transactions.</td></tr>
<tr><td>(b) For general lighting purposes ≥ 30 W and < 50 W: 3.5 mg</td></tr>
<tr><td>(c) For general lighting purposes ≥ 50 W and < 150 W: 5 mg</td><td rowspan="2">For Cat. 5: 21 July 2019
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</td><td></td></tr>
<tr><td>(d) For general lighting purposes ≥ 150 W: 15 mg</td><td></td></tr>
<tr><td>(e) For general lighting purposes with circular or square structural shape and tube diameter ≤ 17 mm</td><td>7 mg may be used per burner until 31.12.2019, 5 mg may be used per burner after 31.12.2019
For Cat. 5: 21 July 2019
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</td><td></td></tr>
</table>

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

5.7 References Exemption 1(a-e)

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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

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LEU Ex. 1b(2015a) LightingEurope, Request to renew Exemption 1(b) under the RoHS Directive 2011/65/EU Mercury in single-capped (compact) fluorescent lamps for general lighting purposes ≥ 30 W and < 50 W, submitted 15.1.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_1_a-e_/Lighting_Europe/1b_LE_RoHS_Exemption_Req_Final.pdf

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http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_1_a-e_/Lighting_Europe/1e_LE_RoHS_Exemption_Req_Final.pdf

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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

[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

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[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.

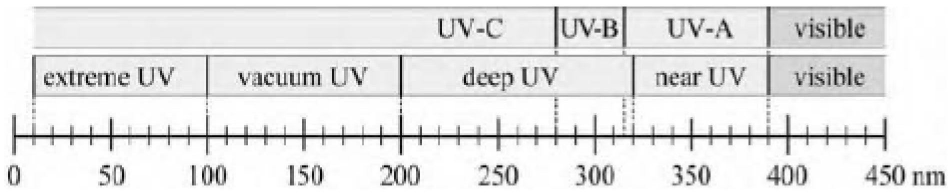
[146] Op. cit. Omnibus (2014)
[147] When a lamp is placed on the open market, the manufacture cannot guarantee that it shall only be installed in equipment for which it was designed. Nonetheless, the consultants expect that the lighting industry be able to detail the range of lamps covered by a certain 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

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[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

8.0 Exemption 2(a)(1-5): " Mercury in double-capped linear fluorescent lamps for general lighting purposes not exceeding (per lamp):" [various entries]"

This review of Annex III exemption 2(a) covers the following exemption entries:

(1) Tri-band phosphor with normal lifetime and a tube diameter < 9 mm (e.g. T2): 5 mg

(2) Tri-band phosphor with normal lifetime and a tube diameter ≥ 9 mm and ≤ 17 mm (e.g. T5): 5 mg

(3) Tri-band phosphor with normal lifetime and a tube diameter > 17 mm and ≤ 28 mm (e.g. T8): 5 mg

(4) Tri-band phosphor with normal lifetime and a tube diameter > 28 mm (e.g. T12): 5 mg

(5) Tri-band phosphor with long lifetime (≥ 25 000 h): 8 mg

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

CCG	Conventional control gear
CRI	Colour rendering index
ECG	Electric control gear
EEE	Electrical and Electronic Equipment
EoL	End-of-life
Hg	Mercury

LED	Light emitting diode
LEU	LightingEurope
LFL	Linear fluorescent lamps
NARVA	NARVA Lichtquellen GmbH + Co. KG

8.1 Background

LightingEurope (LEU) and NARVA Lichtquellen GmbH + Co. KG (NARVA) have both applied for the renewal of Ex 2(a) of Annex III of the RoHS Directive. LightingEurope[152] has applied for the renewal of items 1, 2, 3 and 5. NARVA[153] have applied for the renewal of items 1 through 5. This exemption covers double capped linear fluorescent lamps for general lighting purposes using tri-band phosphors as the fluorescing material.[154]

NARVA[155] explains that lamps falling under these exemptions are discharge lamps, which use mercury for the discharge process, arguing that no substitutes for the mercury are available. In relation to substitutes, LEU[156] mentions that though more and more LED solutions are coming onto the market, they cannot always serve as a fully compatible replacement for the huge variety of linear fluorescent lamps (LFLs) for consumers and professional end users.

Both applicants apply for the renewal of Ex. 2(a), entries (1, 2, 3 and 5), with the current wording formulations listed in Annex III of the RoHS Directive and requesting the maximum available duration allowed (based on Art. 5(2) of the Directive). NARVA also applies for entry 4, with the current wording formulation and requesting the maximum validity period, however did not provide specific information to justify this request.

[152] LEU Ex. 2(a)(1)(2015a), LightingEurope, Request to renew Exemption 2(a)(1) Under Annex III of 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

[153] 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_2_a__1-5_/NARVA/01_02_a__2b3_4a.pdf

[154] Op. cit. LEU Ex. 2(a)(1)(2015a)

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

[156] Op. cit. LEU Ex. 2(a)(1)(2015a)

8.2 Description of Requested Exemption

According to LEU, all lamps falling under Ex. 2(a)(1-3) are very economical and offer a good quality of light and excellent luminous flux. They are slim and compact with good average lifetime (entries 1, 2 and 3) or with long-lifetime (entry 5[157]) with suitable electronic control gear. Employing only limited componentry, fluorescent tubes are explained to be very resource efficient.[158]

The introduction of electronic ballasts for fluorescent lamps was important for improving lighting quality, especially regarding flicker. Today, most fluorescent lamps operate on either instant-start or rapid-start electronic ballasts, with the former using shunted lampholders (sockets) and the latter using unshunted lampholders - meaning there is no connection between the terminals. There is also still a substantial installed base of lamps operating on magnetic ballasts, which typically connect to unshunted sockets. Shunted sockets are usually recognizable because they have a connection terminal on only one side of the lampholder. When changing lamps - or retrofitting an existing luminaire with LED lamps - it is important to know the type of lampholder used, because the electrical paths are different. In general, there has been a shift to using linear fluorescent lamps with a colour rendering index (CRI) of at least 80 in typical applications, as opposed to a CRI of at least 70 in earlier LFL applications.[159]

For lamps covered by Ex. 2(a)(1) the maximum allowed mercury dose is currently 4 mg per lamp. T2 linear fluorescent lamps (LFL) [where the 'T' designates a tubular lamp and the numerical identifier represents the diameter in eights of an inch] are a small segment of energy efficient lamps required on the market. They are used in professional areas as well as in private homes (e.g. as furniture background lighting). According to LEU such lamps have a diameter of ca. 7 mm and different lengths. Due to the very wide range of applications LEU believes that there is still a market need for lamps covered by this exemption for 15-20 years for the existing applications, fixtures and equipment.[160]

For lamps falling under the scope of Ex. 2(a)(2) the maximum allowed mercury dose is currently 3 mg per lamp. Such lamps placed on the EU market have a diameter of ca. 16 mm and different lengths. The lamps are in use mainly in professional areas, such as offices, schools and industrial buildings, but also in residential homes. T5 are among the

[157] In later communication LEU states that some T8 lamps operating on conventional control gear (CCG) are also covered by this exemption. The consultants thus assume that this statement is made as lamps are understood to have a longer service life when operated on electric control gear (ECG) as compared to CCG.
[158] Op. cit. LEU Ex. 2(a)(1)(2015a); LEU Ex. 2(a)(2)(2015a); LEU Ex. 2(a)(3)(2015a); LEU Ex. 2(a)(5)(2015a)
[159] CALiPER (2014a), Pacific Northwest National Laboratory, Application Summary Report 21: Linear (T8) LED Lamps, Solid-State Lighting Program Building Technologies Offi ce Office of Energy Effi ciency and Renewable Energy U.S. Department of Energy, available under: http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/caliper_21_t8.pdf
[160] Op. cit. LEU Ex. 2(a)(1)(2015a)

most energy efficient lamps, reaching levels up to 115 lumens per watt and a lifetime of 20,000 hours for the regular lamps.[161]

In relation to T5 lamps, LEU further states that luminaire service lifetime can be estimated on different levels depending on the application, e.g. approximately 20 years for industry installations, 10-14 years for offices, 15-30 for outdoor. LEU notes that lamp service life is significantly lower than 20 yrs. So during these 20 years the luminaire has had several lamp replacements.[162]

T2 and T5 luminaires are operated nearly exclusively with electronic control gears (ECG) which have advantages over conventional control gears (CCG) regarding power consumption, lifetime, maintenance costs, temperature behaviour, switching, flicker, dimming etc.[163]

In lamps covered by Ex. 2(a)(3) the maximum allowed mercury dose is currently 3.5 mg per lamp. T8 lamps currently placed on the EU market usually have a diameter of ca. 26 mm and come in 16 different lengths. Linear T8 lamps for general lighting as covered by exemption 2(a)3 is a very big segment of all linear fluorescent lamps. They are among the most energy efficient lamps, reaching levels up to 100 lumens per watt and a lifetime of 20,000 hours for the regular lamps. LEU roughly estimates that ca. 60% of the installed T8 luminaires are using a CCG, elaborating that there are no statistical data available. [164] In contrast, the VHK & VITO[165] study states that available data are confusing, but the share of electronic ballasts in 2014 is expected to be around 75-80%.

[161] LEU Ex. 2(a)(2)(2015a), LightingEurope, Request to renew Exemption 2(a)(1) Under Annex III of the RoHS Directive 2011/65/EU 2(a) 2(a)Mercury in double-capped linear fluorescent lamps for general lighting purposes not exceeding (per lamp): 2(a)(2) Tri-band phosphor with normal lifetime and a tube diameter ≥ 9 mm and ≤ 17 mm (e.g. T5): 3 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/2a2_LE_RoHS_Exemption__Req_Final.pdf

[162] LEU Ex. 2(a)(2015b), LightingEurope, Response To Oeko-Institut regarding the 1st Questionnaire Exemption No. 2(a)(1-5) (renewal request), submitted 15.9.2015, available under:
http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_2_a__1-5_/Lighting_Europe/Ex_2a_1-5__LightingEurope_Clarifications_1st_round_final.pdf

[163] Op. cit. LEU Ex. 2(a)(1)(2015a) and LEU Ex. 2(a)(2)(2015a)

[164] LEU Ex. 2(a)(3)(2015a), LightingEurope, Request to renew Exemption 2(a)(3) under Annex III of 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)(3) Tri-band phosphor with normal lifetime and a tube diameter > 17 mm and ≤ 28 mm (e.g. T8): 3.5 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/2a3_LE_RoHS_Exemption__Req_Final.pdf

[165] 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

Both T5 and T8 lamps are said to be used in hundreds of millions of installed light points in many configurations. [166]

Notably, T8 lamps have supplanted T12 lamps - which have now been phased out of production - and offer substantially improved performance. T5 fluorescent lamps are not a direct replacement for either T12 or T8 lamps.[167]

Ex. 2(a)(5) covers long-life linear T5 (16 mm diameter) and T8 (27 mm) tri-band phosphor lamps with standardised dimensions and base. The maximum allowed mercury dose is currently 5 mg per lamp. Electrical characteristics of long life lamps are compatible to normal life lamps. LEU explains that lamps with long life time need more Hg compared to normal life time, but have environmental advantages compared to the standard types. The main reason for this is the relationship between Hg consumption and lamp life span. It is of course to be expected that lamps with a longer life span will mean fewer lamps throughout the life of a luminaire. So long-life lamps need less materials and the waste at end-of-life is reduced accordingly. Regarding mercury, the quantity required per 10,000 hours life span is significantly lower in long life lamps compared to the alternative. So a T8 with a 90,000 hour life span needs < 30% of the mercury per hour of life span compared to a 20,000 hour life span lamp. Examples as listed in Table 8-1 below show 46% reductions for a T5 HE 35W, and at least 11% reduction for a T5 HO lamp.[168]

[166] LEU Ex. 2(a)(2)(2015a); Ex. 2(a)(3)(2015a)
[167] Op. cit. CALiPER (2014a)
[168] LEU Ex. 2(a)(5)(2015a), LightingEurope, Request to renew Exemption 2(a)(5) 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)(5) Tri-band phosphor with long lifetime (≥ 25.000): 5 mg may be used per lamp after 31 December 2011, submitted 55.1.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_2_a__1-5_/Lighting_Europe/2a5_LE_RoHS_Exemption__Req_Final.pdf

Table 8-1: Comparison of resource efficiency and mercury content per 10.000 hours lifespan show significant advantages of linear T5 and T8 lamps with long life time compared to lamps with normal lifetime (examples)

Lamp type	T8 36W/840	T8 XT 36W/840	T8 XXT 36W/840	T5 HE 35W/840	T5 XT HE 35W/840	T5 HO 49W/840	T5 XT HO 49W/840
Length	1200 mm	1200 mm	1200 mm	1449 mm	1449 mm	1449 mm	1449 mm
Life span (B50)	20.000	50.000	90.000	24.000	45.000	24.000	45.000
Service life	18.000	42.000	75.000	19.000	30.000	19.000	30.000
Average mercury	2.5 mg	3.3 mg	3.3 mg	2.5 mg	2.5 mg	1.5 mg	2.6 mg
Mercury per 10.000 h life span (Hg/Life span*10.000) [mg]	1.25	0.66	0.37	1.04	0.56	0.63	0.56
Lamps required for 100.000 h life span	5,00	2,00	1,11	4,17	2,22	4,17	2,22

Note: In a later communication LEU[169] explains that:
Average rated lamp life (here referred to as Lifespan)(B50) is the average value of the life values of individual lamps operated under standardized conditions (50 % failure). In other words, this is the operation time at which for a standardized 3-hour switching cycle (165 minutes on/15 minutes off in accordance with IEC 60081 and IEC 60901) 50 % of a sample population of lamps have failed. See Fig. 27, Fig. 28, Fig. 29 and Fig. 30.
Service life time is the mathematical life time (maintenance multiplied with the % of failed lamps e.g. B10) for lamps in an installation after which the installation luminous flux (100 h value) decreased with 20 % (decrease in luminous flux and failed lamps) for indoor lighting.
See Fig. 27, Fig. 28, Fig. 29 and Fig. 30.
For further information, please consult http://catalog.myosram.com.
Source: LEU Ex. 2(a)(5)(2015a)

LEU[170] explains that for the purpose of Ex. 2(a)(5), long lifetime has been defined as *"≥ 25.000 hours where the installed luminous flux (lamp survival in % times lamp luminous flux in % or service life) is higher than 80% at 25.000 hours with an electronic ballast using the standardised 3 hour cycle*".[171] This definition is different to the widely used average (=median) life time, which is defined as the average value of the life values of individual lamps operated under standardized conditions (50% failure): i.e. the operation time at which for a standardized 3-hour switching cycle (165 minutes on/15 minutes off

[169] LEU (2016c) LightingEurope, Response to Clarifiction Questions Regarding Ex. 2(a)(5)", submitted 9.3.2016 per email
[170] Op. cit. LEU Ex. 2(a)(5)(2015a)
[171] Referenced in LEU Ex. 2(a)(5)(2015a) as: Final Report "The Adaptation to scientific and technical progress under Directive 2002/95/EC, Oeko-Institut, 20 Feb. 2009, http://ec.europa.eu/environment/waste/weee/pdf/rohs_report.pdf

in accordance with IEC 60081) 50% of a sample population of lamps have failed. According to these definitions service life as used for the purpose of this exemption is much more demanding than average or median life time as it also takes the luminous flux into account. Life time values of fluorescent lamps are different, depending on whether lamps are operated with magnetic ballast and starter (i.e. CCG) or with ECG.[172]

Long-life lamps are used in areas where lamp replacement is difficult and expensive due to high ceilings, when special luminaire design for critical application is required or when too much disturbance of running processes would occur during long operating hours. There is more Hg in the lamp since the process "consuming" mercury in the lamps is taking place for a longer time (see Section 4.3.1 in general chapter regarding Hg "consumption"). The product is different and more expensive to produce since for instance more rare earths are used in the phosphor to produce the lamps. In long life lamps, the corresponding mercury amount per lumen hour of operation is lower compared to lamps with lower lifetime. For example, one lamp with 50,000 hour lifespan and 4.5mg Hg can replace 2.5 lamps with 20,000 hour lifespan each containing 3mg (i.e. 2.5 × 3mg = 7.5 mg Hg).[173]

LEU provides typical parameters for each entry to further describe the range of lamps available on the market and covered by this exemption. The data is summarised in Table 8-2.

[172] Op. cit. LEU Ex. 2(a)(5)(2015a)
[173] 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 8-2: Typical parameters of lamps falling under Ex. 2(a)(1,2,3, and 5)

	Ex. 2(a)(1)	Ex. 2(a)(2)	Ex. 2(a)(3)	Ex. 2(a)(5)
Available Wattages (main types used in EU)	6 Watt, 8 Watt, 11 Watt, 13 Watt	4 - 80 W	10 - 70 W	10 - 70 Watt (W)
Typical lengths in mm		136; 212; 288; 517; 550; 850; 1150; 1.450;	330; 361; 438; 470; 691; 590; 720;742; 818; 895; 970; 1047; 1200; 1500; 1764;	
Available Colour Temperatures	2.700K up to > 6.500 Kelvin (K)	2.700K up to > 6.500K	2.700K up to > 6.500K	2.700 up to >6.500 K
Typical Colour Rendering Index (Ra)	70-79	80 - >90	80 - >90	80 - >90
Average Lifetime	8.000hrs (with preheat electronic control gear)*	Typically ca. 20.000hrs on an electronic control gear*	Typically 15.000 - 20.000hrs on an electronic control gear*	Typically 40.000 – 90.000 hrs (B50): Corresponding service life time: 30.000 h (T5 on ECG), up to 75.000 (T8 on ECG);
Base (standard designation)	W4.3 x 8.5d (IEC/EN60061)	G5 (bi-pin), (acc IEC/EN60061):	G13 (bi-pin), IEC/EN60061),	
Additional aspects mentioned:		Dimmable	Dimmable (with special electronic control gear)	Dimmable;

* Explained by LEU as: Average rated lamp life (B50) which is the average value of the life values of individual lamps operated under standardized conditions (50 % failure). In other words, this is the operation time at which for a standardized 3-hour switching cycle (165 minutes on/15 minutes off in accordance with IEC 60081 and IEC 60901) 50 % of a sample population of lamps have failed.

Source: Op. cit. LEU Ex. 2(a)(1)(2015a), LEU Ex. 2(a)(2)(2015a), LEU Ex. 2(a)(3)(2015a); LEU Ex. 2(a)(5)(2015a)

8.2.1 Amount of Mercury Used under the Exemption

LightingEurope explains that there are no specific sales data available for EU-28. However, it provides estimated data based on a rough estimation of the world market performed by a LightingEurope member. The various data are summarised in Table 8-3.

8.3 Applicant’s Justification for Exemption

LightingEurope claims that the replacement of mercury in LFLs is scientifically and technically impracticable. Currently there are no significant T2, T5 LED lamps available on the market, whereas the availability of T8 retrofit replacements is limited as shall be explained below. Argumentation is also raised as to the comparability of LED alternatives

in terms of efficacy and light distribution. Alternatively, installed luminaires can be replaced with very high socioeconomic impact by mercury-free fixtures. [174]

Table 8-3: Data regarding lamp sales and respective Hg quantities placed on the market

Entry		Lamp sales, million lamps unless otherwise noted					
		2009	2010	2011	2012	2013	2014
Ex. 2(a)(1) (T2 lamps) – global data.	Lamp sales - thousand	*n.s*	*n.s*	*n.s*	*n.s*	400	250–300
	Hg placed on market (kg)	*n.s*	*n.s*	*n.s*	*n.s*	1-1.2	0.75-0.9
	Average Hg per lamp (mg)	*n.s*	*n.s*	*n.s*	*n.s*	2.5-3	*n.s*
Ex. 2(a)(2) (T5 lamps) – EU 28 data.	Lamp sales - millions	57	68	76	81	76	*n.s*
	Hg placed on market (kg)	228	272	228	203	190	*n.s*
	Average Hg per lamp (mg)	4	4	3	2.5	2.5	*n.s*
Ex. 2(a)(3) (T8 lamps Tri-band) – EU 28 data.	Lamp sales - millions	175	216	254	261	247	*n.s*
	Hg placed on market (kg)	1604	1408	1097	815	751	*n.s*
	Average Hg per lamp (mg)	4	4	3.5	3	3	*n.s*
Ex. 2(a)(5) (Long-life lamps, T5, T8) – EU 28 data.	Lamp sales - millions	Statistic data is not collected separately for long-life T5 and T8 lamps, but included in data for normal lamps above.					8 – 10 Mio. T5 and T8 lamps
	Hg placed on market (kg)	*n.s*	*n.s*	*n.s*	*n.s*	*n.s*	40 Kg
	Average Hg per lamp (mg)	*n.s*	*n.s*	*n.s*	*n.s*	*n.s*	4 mg

Note: n.s = not specified

Source: LEU Ex. 2(a)(1)(2015a), LEU Ex. 2(a)(2)(2015a), LEU Ex. 2(a)(3)(2015a), LEU Ex. 2(a)(5)(2015a)

8.3.1 Possible Alternatives for Substituting RoHS Substances

LightingEurope explains that during the last decades several approaches have been made to design low pressure discharge lamps where the light producing element Hg is replaced by a less hazardous material. So far no approach yielded a result with comparable luminous efficacy, product cost and product availability as the (still state of the art) Hg low pressure discharge lamps. However, it is said that with the arrival of equally efficient LED light sources, research into alternative discharges has stopped at most companies and universities. Further details of such research efforts can be viewed in LEU's applications. Information is also provided as to the accomplishments in terms of Hg reduction, however it can be understood that the potential for this strategy has been implemented for the most part and that further research is focusing on the development of LED alternatives and not on Hg reduction.[175]

8.3.2 Possible Alternatives for Eliminating RoHS Substances

LEU states that lamps and luminaires based on LED technology show much more opportunities as substitutes and are rapidly entering the market. Correctly installed LED

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[174] Op. cit. LEU Ex. 2(a)(1)(2015a); LEU Ex. 2(a)(2)(2015a); LEU Ex. 2(a)(3)(2015a); LEU Ex. 2(a)(5)(2015a)
[175] Op. cit. LEU Ex. 2(a)(1)(2015a); LEU Ex. 2(a)(2)(2015a); LEU Ex. 2(a)(3)(2015a); LEU Ex. 2(a)(5)(2015a)

based luminaires are considered to be reliable; however, they have specific technical and performance characteristics that need to be considered and that prevent immediate change-over. Those will be discussed in this chapter in detail. It is explained that there are two key ways to use LED technology in order to substitute fluorescent lamps: (1) replacement lamps, (2) new installation (either in new buildings or refurbished areas).[176]

8.3.2.1 LED Replacement Lamps

LEU describes two routes for achieving replacement of an LFL with a LED tube:

- **Retrofit route:** A fluorescent lamp is substituted by a LED tube. The luminaire itself is not rebuilt and the control gear remains in the installation. Driver compatibility is assumed here. Such replacement is also called plug-and-play.
- **Conversion route:** Conversion route: the fluorescent 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.

Though various types of LED tubes are becoming available, LEU explains that such alternatives still show limitations as substitutes, both in terms of the range of products available (i.e. its coverage of the LFL product range) and in terms of the technical comparability. Safety aspects and lack of standards for using such lamps to replace LFLs is also explained to be a limiting factor.

In relation to product range, LEU explains that on the European market there are nearly no **T2** products available based on LED technology that allow a direct replacement of T2 lamps in existing applications.[177] There are also relatively few **T5** products available based on LED technology. Developing LED alternatives in this area requires efforts in electronics miniaturization and heat management, while meeting T5 energy efficiency standards at reasonable costs. According to LEU members this has not been broadly solved yet, and from the limited examples of such lamps available on the EU market, none can be considered fully compatible with existing applications.[178] According to LEU for T2 and T5, all alternatives require refurbishment (rewiring or complete luminaire replacement) of the existing fixture and the involvement of professional expertise.

In contrast **T8** LED based lamps, are available in both retrofit and conversion route options, however, in this area, LEU[179] explains that there are limitations in the technical compatibility. Currently the majority of T8 LED tube replacements are designed for CCG systems. T8 LED tube replacements for ECG systems require different technology to ensure electrical compatibility and are rare on the market (LEU members claim that only one of the key market players offers LED tubes for ECG). Typically CCG compatible lamps have single-ended electrical supply, where ECG compatible LED replacements require double ended electrical supply from the outside. Though the CCG systems can be

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[176] Op. cit. LEU Ex. 2(a)(1)(2015a); LEU Ex. 2(a)(2)(2015a); LEU Ex. 2(a)(3)(2015a); LEU Ex. 2(a)(5)(2015a)
[177] Op. cit. LEU Ex. 2(a)(1)(2015a
[178] Op. cit. LEU Ex. 2(a)(2)(2015a
[179] Op. cit. LEU Ex. 2(a)(5)(2015a)

recognized by the existence of a starter in the luminaire, it is not easy for a non-skilled customer to recognize the exact installation he has, without a broader technical knowledge. The starter is often not visible from the outside and the installation looks the same as an ECG system. In this respect, LEU further explains that the market is still in transition from CCG to ECG. The share of installations with ECG, from the total stock of LFL installations, is growing and they currently represent around 30% of the market. Furthermore, from April 2017, CCGs shall no longer be permitted on the EU market in light of Regulation 245/2009/EC (Ecodesign requirements for fluorescent lamps), so ECG market share shall grow. LEU explains that the average lifetime of an installed luminaire in office or industrial areas is typically 15 years[180], so it is expected that the replacement market will be completely ECG by 2035-2040. LEU contends that with the present installed base complexity, it is impossible to guarantee a full 100% coverage for both CCG and ECG systems compatibility. This could lead to situations where a customer opting for a retrofit lamp (assuming driver compatibility) is forced to use the conversion route in light of drivers not supported by retrofit alternatives. Furthermore, LEU explains that available LED retrofit tubes still do not cover the full product range of T8 lamps. LED retrofits are mainly available on the market in 3 lengths (600, 1200, 1500 mm) and only in the most common colour temperatures (not available in very cool (12000K) and warm (2700K) colours). In comparison, conventional T8 lamps offer more than 10 different lengths and even more wattage equivalents.[181]

As for the LFL long-life lamps, LEU states that T5 and T8 linear fluorescent lamps with long lifetime have advantages compared to LED retrofit and conversion lamps as well as LED based luminaires. Resource efficiency of fluorescent lamps is better due to comparable or longer lifetime (40,000 – 90,000 hours life span B50) compared to LED lamps (30,000 – 50,000 hours B50). Where LED retrofits are preferred, instead of only a lamp being replaced, the complete luminaire or set of luminaires has to be replaced at end of life creating more waste and resulting in higher costs.

On the technical level, LEU further explains that there are differences between LFLs and LED retrofits regarding light distribution and lumen output. LFLs are omnidirectional in light distribution, whereas LED packages emit light directionally. In an LED, it is difficult to achieve an omnidirectional luminous intensity distribution, while also meeting needs for thermal management and electrical regulation. As a result the emitting surface of linear LED lamps often covers only half of the surface area.[182]

Finally, LEU raises concern as to the problematic conformity of LED retrofits to safety certification requirements, of relevance to the conversion route:

[180] Referenced in LEU Ex. 2(a)(5)(2015a) as McKinsey – Lighting the way, http://www.mckinsey.com/~/media/mckinsey/dotcom/client_service/automotive%20and%20assembly/lighting_the_way_perspectives_on_global_lighting_market_2012.ashx

[181] Op. cit. LEU Ex. 2(a)(5)(2015a)

[182] Op. cit. LEU Ex. 2(a)(1)(2015a); LEU Ex. 2(a)(2)(2015a); LEU Ex. 2(a)(3)(2015a); LEU Ex. 2(a)(5)(2015a)

> "*Conversion of the luminaire shifts the responsibility for the technical and the safety consequences of the conversion to the party carrying out the conversion. There is no separate safety standard for the conversion of lamps. Converted luminaires must conform to the basic requirements of the Low Voltage Directive and the Electromagnetic Compatibility directive. A new conformity assessment is required for rebuilt luminaires used with conversion lamps, which needs to be carried on case-by-case basis.*"[183]

When a conversion is performed, legal and compliance requirements like conformity assessments, declaration, and labelling of the changed luminaire are necessary to establish the conformity of the changed installation with safety requirements. For conversion lamps there is no own safety standard available so far:

> "*For a modified luminaire, the manufacturer of the original luminaire will generally no longer be seen as responsible for the safety of the product. Any modifications made to the original luminaire may alter the characteristics of the original product e.g. safety aspects of the original luminaire, and hence risk assessment of hazards posed by the original luminaire may no longer be applicable to the modified luminaire. In this case, the modified luminaire would be considered as a new product.*"[184]

Although a standard covering double capped linear retrofit LED tube is in preparation (EN62776), until its approval manufacturers are recommended to use draft standard 34A/1642/CDV (ZVEI, 2014). For the electromagnetic compatibility of LED retrofit lamps an electromagnetic compatibility assessment is in preparation at IEC/CISPR (current draft CISPR/F/628/CDV). Requirements of the lamp components must be met, e.g. EN61347-2-13 for the control gear, etc. This aspect is understood to apply to any conversion, making the process more complicated and more costly.[185] However, in the case of emergency lighting applications, LEU states that no dedicated replacement solutions are available. Given that standards (of LFL emergency lighting applications) specify lamps that can be used as replacements, and that currently LED retrofit lamps are not specified, such replacements would currently be understood not to be permitted.[186]

8.3.2.2 LED New Instalations

According to LEU[187], Linear LED luminaires are providing a viable alternative to the traditional fluorescent tube with such features as: efficacy, energy efficiency, and design

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[183] Referenced in LEU Ex. 2(a)(1)(2015a) as ZVEI and VDE document LA-T 2012-025: "LED lamps as substitutes for fluorescent lamps", 2012 http://www.zvei.org/Publikationen/LED%20tubes%20-%202012-01-26%20english.pdf

[184] Referenced in LEU Ex. 2(a)(1)(2015a) as LVD ADCO Recommendation on "Safety of LED T-type replacement tubes and modified luminaires" http://ec.europa.eu/enterprise/sectors/electrical/files/lvd-adco/recomm-led-replac-tubes_en.pdf

[185] Op. cit. LEU Ex. 2(a)(1)(2015a); LEU Ex. 2(a)(2)(2015a); LEU Ex. 2(a)(3)(2015a); LEU Ex. 2(a)(5)(2015a)

[186] Op. cit. LEU Ex. 2(a)(5)(2015a)

[187] Op. cit. LEU Ex. 2(a)(1)(2015a); LEU Ex. 2(a)(2)(2015a); LEU Ex. 2(a)(3)(2015a); LEU Ex. 2(a)(5)(2015a)

flexibility and appearance. But the quality and performance of LED products varies among manufacturers. Many conformity and performance related issues are solved. Dedicated designed luminaires directly comply; a system with all safety and standardization legislations is tested and confirmed by the luminaire manufacturer. LED based luminaires so far do not reveal a clear general environmental benefit, e.g. energy efficiency is not higher than in conventional luminaires based on LFL lamps.

However, LEU argues that LED luminaires may have limitations in some cases, i.e. when a single luminaire in an array of luminaires malfunctions and needs to be replaced: If a luminaire is broken in an existing installation or a customer wants to refurbish an existing installation with built in, recessed luminaires in the ceiling, the replacement LED luminaire should be able to fit in the existing space and give the same light distribution. Described earlier challenges that customers might be confronted with (e.g. illuminance), will not be solved in many cases with one-to-one luminaire replacement. A customer will be forced to refurbish his ceiling and/or building, make a new lighting design and replace all existing luminaires, while many of them still operating properly.[188]

A growing market approach is the use of integrated LED luminaires requiring full luminaire replacement. This would lead to high investment and negative environmental impact, especially when the T2 luminaire is installed in furniture, vehicles, installations or other electrical and electronic equipment. There is a clear development in the lighting market for new installations towards LED technology, such as LED stripes in furniture. Correctly installed LED based luminaires are considered to be reliable.[189]

8.3.3 Environmental Arguments

LEU states that various LCA's show different results and are as such inconclusive regarding the comparison of LED technology versus conventional linear fluorescent technology on their total environmental impact. Non-renewal of this exemption will lead to unnecessary waste of luminaires that cannot be used, due to lack of a replacement lamps (premature refurbishment).[190]

The consultants would like to note in this respect that, though some information on LCA studies is provided in the Exemption 2 applications, comparative LCA studies relate to CFLs and LEDs and show equivalency as early as 2012. The consultants are not aware of comparative LCA studies of LFLs with LED alternatives.

Referring to various studies, LEU[191] explains that LED lamp product manufacturing uses considerably more energy than does the manufacturing of a T8 with comparable light

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[188] Op. cit. LEU Ex. 2(a)(1)(2015a); LEU Ex. 2(a)(2)(2015a); LEU Ex. 2(a)(3)(2015a); LEU Ex. 2(a)(5)(2015a)
[189] Referenced in LEU Ex. 2(a)(1)(2015a) as CALiPER, "Application Summary Report 21: Linear (T8) LED Lamps", p.6
[190] Op. cit. LEU Ex. 2(a)(2015b)
[191] LEU Ex. 2(a)(5)(2015a) refers to http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/caliper_21-4_t8.pdf

output[192]. However one must consider the improving LED alternative in the right perspective: according to reference[193] the LED sources are expected to have a real advantage in the total life cycle over time, at least if efficiency keeps improving at the same rate and given their relatively long life. Recent DoE research[194] illustrated that luminaires retrofitted with LED lamps performed in the same efficacy range as the fluorescent benchmarks, so it is not clear that they offer guaranteed energy savings when compared to fluorescent troffers (rectangular light fixtures) equipped with 25 or 28 W high-performance lamps and electronic dimming ballasts. Energy efficiency, or more specifically the total luminaire efficacy and lighting power density of a typical installation, is an important criterion for choosing a proper LED replacement in existing installations. In this regard, LEU states in a particular consultation submission the following, referring to a US DOE study:[195]

> "In 2013 the US Department of Energy analysed LED retrofit lamps and came to the conclusion: "*This report focused on the bare-lamp performance of 31 linear LED lamps intended as alternatives to T8 fluorescent lamps. Data obtained in accordance with IES LM-79-08 indicated that the mean efficacy of the group was slightly higher than that of fluorescent lamps (with ballast), but that lumen output was often lower. Along with a range of colour quality attributes, the luminous intensity distributions of the linear LED lamps varied substantially, with none truly comparable to a linear fluorescent lamp. (March 2014)*"."

In case T2 fluorescent lamps would no longer be available for existing installed lighting solutions, the impact would be significant. The need to replace or technically change the luminaires, control gears, equipment etc. results in high investments for private, commercial or public customers.

The lamps concerned in this exemption request are mainly for professional use (where certain application norms and requirements are in place), one-to-one (i.e., retrofitting) replacement should not always be taken into account. As explained in the exemption requests, change of a conventional application may require a new lighting plan adjusted to the need of the space, hence can influence the total energy use. The overall energy use will remain at a comparable level as today. Additionally it should be noted, that

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[192] LEU Ex. 2(a)(5)(2015a) refers to U.S. Department of Energy. (2012). Life-Cycle Assessment of Energy and Environmental Impacts of LED Lighting Products. Retrieved March 10, 2012 from – Study not found. It is possible that one of the CALiPER studies prepared for the DoE is meant.

[193] LEU Ex. 2(a)(5)(2015a) refers to Life-Cycle Assessment of Energy and Environmental Impacts of LED Lighting Products, The U.S. Department of Energy (DOE) building technologies office – report found under the following link http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/lca_factsheet_apr2013.pdf, however, with direct comparison of LEDs and LFLs.

[194] LEU Ex. 2(a)(5)(2015a) refers to http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/caliper_recessed-troffer_2013.pdf

[195] LEU Ex. 2(a)(5)(2015a) refers to http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/caliper_21-4_t8.pdf

energy savings can also be achieved through smart solutions with conventional lighting (e.g. dimming, presence detection, daylight link, etc.).[196]

8.3.4 The Minamata Convention

LEU states that during the 2013 UNEP Minamata Convention on Mercury in Japan, agreements were made to limit mercury in various products including linear fluorescent lamps. This treaty has been agreed upon and signed by 94 countries around the globe. The agreed mercury level for linear fluorescent is 5 mg and is to be adapted until 2020 in countries that have signed the convention. [197]

8.3.5 Road Map to Substitution

LightingEurope[198] is not able to share the individual road maps the member companies have planned for their LED portfolio. There is no general roadmap to develop LED replacements for all existing linear fluorescent lamp types in the market. McKinsey indicates in its report that by 2020 it shall still make up for 48% of total general lighting. Specific data per application is given, e.g. in Industry Lighting 75% and in Office Lighting 71% of the light sources will still be of conventional technology.

8.4 Stakeholder Contributions

A number of contributions have been made by stakeholders. Comments of general nature have been summarised in Section 4.4 in the Chapter regarding lamps in general. Comments regarding the lamp exemption Ex. 1(a-e) are summarised below:

Comments of the European Environmental Bureau (EEB), the Mercury Policy Project, and the Responsible Purchasing Network[199] are also summarised in part in Section 4.4 above. Regarding the Ex. 2(a) entries (a-e) EEB et al. explains that one area where there has been tremendous innovation over the past several years is in the development of LED tube lamps. According to a 2014 report by the International Energy Agency (IEA), LED tube lamps now have equivalent performance to even the most energy-efficient fluorescent tubes: T5s. EEB et al. quotes this report:

> "*In the domain of professional lighting, the T5 linear fluorescent lamp luminaire was the best rated product in 2009. In studies published in 2013, the T5 lamp*

[196] Op. cit. LEU Ex. 2(a)(2015b)
[197] Op. cit. LEU Ex. 2(a)(1)(2015a)
[198] Op. cit. LEU Ex. 2(a)(2015b)

[199] 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

> *remains the product with the lowest environmental impacts, but thanks to the advances of LED technology, LED tubes are nearly at the same level of performance*."[200]

EEB et al. recommend removing the words 'normal lifetime' from Ex. 2(a)(2) since from their research all T5s (covered by this exemption), meet the threshold of 3 mg, regardless of their lifetime. EEB et al. also recommend monitoring improvements in the performance of LED T5 tubes and their life-cycle price to allow understanding their practicability as substitutes in the future and subsequently the further need for the exemption.

In relation to T8 lamps, EEB et al. state that many European lamp manufacturers are now offering LED linear T8 lamps that are drop-in replacements for linear fluorescent T12 and T8 lamps, claiming that they are more energy efficient. Some of these products include an internal driver so that no additional wiring is required. Other products are compatible with either electronic or magnetic ballasts, or both. Some examples are given for T8 substitutes showing comparable lumen per watt performance and service lives of 40-50 thousand hours as well as plug-and-play alternatives for both magnetic and electric ballasts. EEB et al. expect LED tube lights to continue to improve over the next several years, and urges the European Commission to continue to monitor their advancements for performance and lifecycle costs and consider them for phase-out in the next review. The words 'normal lifetime' are proposed to be removed since T8s, no matter their lifetime, already meet these limits.

EEB et al. make recommendations regarding entry 4, which concerns T12 lamps, however as LEU has not requested the renewal of this lamp, it is assumed to have been phased out for the most part in light of availability of alternatives and is not discussed further.

Regarding the exemption entry for long-life lamps (Ex.2(a)(5)) EEB et al. recommends that this exemption be eliminated and that all T5 linear fluorescent lamps be included under Exemption 2(a)(2), which currently has a mercury limit of 3 mg, and that all T8 lamps be included under Exemption 2(a)(3), which currently has a mercury limit of 3.5 mg. In their research, long-life T2 and T12s were not found, e.g. in the GE and OSRAM catalogues. In case such types of lamps exist, the exemption should be rephrased accordingly to cover only those; the T5 and T8s should all meet 3 mg and 3.5 mg respectively, no matter the lifetime, as many already do. Examples are provided to demonstrate this.

KEMI Kemikalieinspektionen, the Swedish Chemicals Agency (KEMI)[201] mentions that new standards developed in the context of ecolabelling and public procurement criteria

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[200] Quoted as International Energy Agency, *Solid State Lighting Annex: Life Cycle Assessment of Solid State Lighting: Final Report*, 17 September 2014, http://ssl.iea-4e.org/files/otherfiles/0000/0068/IEA_4E_SSL_Report_on_LCA.pdf

are based on the real market situation. KEMI concludes that the allowances permitted for Hg in lamps in most recent publications of this kind, for the Ex. 2(a) exemption entries, show that it is possible to find LFLs on the EU market with lower Hg-content than the current limit values prescribed in these RoHS exemption entries. Table 8-4 is provided in this respect.

Table 8-4: Limit values for some light sources in RoHS compared with recommended mercury levels in EU GPP criteria for indoor lighting

	RoHS exemption request	Public procurement core criteria	Public procurement comprehensive criteria
Exemption 2(a)(1-5) "Mercury in double-capped linear fluorescent lamps for general lighting purposes not exceeding (per lamp):			
(1) Tri-band phosphor with normal lifetime and a tube diameter < 9 mm (e.g. T2):	5 mg		
(2) Tri-band phosphor with normal lifetime and a tube diameter ≥ 9 mm and ≤ 17 mm (e.g. T5):	5 mg	2.5 mg	2 mg
(3) Tri-band phosphor with normal lifetime and a tube diameter > 17 mm and ≤ 28 mm (e.g. T8):	5 mg	3.5 mg	4.5 mg
(4) Tri-band phosphor with normal lifetime and a tube diameter > 28 mm (e.g. T12):	5 mg		
(5) Tri-band phosphor with long lifetime (≥ 25 000 h):	8 mg		

Note: The RoHs Hg allowances for Exemption 2(a) entries decreased in December 2011 and are as currently follows: Ex. 2(a)(1) – 4mg; Ex. 2(a)(2) – 3mg; Ex. 2(a)(3) – 3.5mg; Ex. 2(a)(4) – 3.5mg; Ex. 2(a)(5) – 5mg;
Source: KEMI (2015)

In respect with fluorescent lighting, the Polish Association of Lighting Industry (PZPO)[202] claim that fluorescent and LED lighting systems are not inter-compatible. "*Changing the*

[201] KEMI (2015), 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

[202] PZPO (2015a), Polish Association of Lighting Industry, Comments to Annexes III and IV Directive 2011/65/EU (RoHS), submitted 5.10.2015, available under:

fluorescent lamp-based systems to LED-based systems is associated with the need to replace the entire electrical system (power balance issues)… change the fixtures… number of lighting points… facility ceilings, as well as redesign the entire system and employ a sufficient number of designers and engineers”. This is also expected to generate WEEE.

8.5 Critical Review

8.5.1 Scientific and Technical Practicability of Substitution

LEU explains that substitutes are not sufficiently available for LFLs. In terms of substance substitutes the consultants can follow that despite various research initiatives, results have not led to the development of Hg-free LFLs. As for the reduction of Hg in LFLs, it is also apparent that the potential for such benefits has been realised to a large extent. In light of the development of LED technologies, further potential for these strategies is understood to no longer be in the focus of development efforts. As for LED substitutes, LEU claims that at present, replacement products are lacking and that available substitutes often do not provide comparable performance. General statements are made, however, data as to availability of substitutes and their comparability has been found in various studies performed over the last few years.

The VHK & VITO[203] study states that for T8 LFLs, a broad range of LED retrofit tubes is available on the market from all major lighting manufacturers and many new companies entered this market. According to the results of their study, the majority of the LED retrofit tubes found on the market today require a rewiring of the existing luminaire to by-pass the existing ballast. However, it is also mentioned that recently so called plug-and-play lamps have come to the market that can directly replace an LFL T8 in the existing configuration without any further action. Some of these LED lamps have control gears that will automatically detect the type of ballast installed and shall “behave” accordingly. These lamps can operate on a wide range of existing ballasts, including magnetic and electronic ballasts. Other plug-and-play lamps have been specifically designed for operation on instant-start electronic ballasts, for example. The plug-and-play lamps have the control gear integrated in the tube. This implies that a small part of the tube length is occupied by the control electronics and hence may not be available for light emission. The integrated solution is also more challenging when additional functions have to be integrated in the control gear, such as 0-10 V dimming, a DALI interface, or a wireless receiver. In addition the location of the control gear inside the tube can pose specific thermal management problems. External control gears offer

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http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_1_a-e_/Directive_RoHs_-_PZPO_comments_05_10_15_eng.pdf

[203] Op. cit. VITO & VHK (2015)

advantages from these points of view.[204] The study lists some of the variety of LED T8 alternatives and it is observed that in this category most alternatives are for lamp lengths of 120 or 150 cm, with few alternatives for other lengths. Only a few models are said to be dimmable, though LEU reported that this aspect is not a concern. Furthermore, VHK & VITO states that many of the listed tubes have a tested CRI below 80 (usually between 70 and 80), implying that they do not meet the requirements from regulation 1194/2012. The VHK & VITO study states that, some manufacturers offer T5 (16 mm) LED tubes with G13 cap and efficiencies up to 141 lm/W[205] (G13 is typical for T8 as opposed to T5 usually equipped with a G5 base). LED luminaires for upgrading the efficiency of existing installations are also available and offer similar efficacies as retrofit tubes (100-143 lm/W) 177, though VHK & VITO identify various reasons for favouring luminaire replacement with LED over lamp replacement (required electrical modifications of luminaire, change on lighting plan, etc.). VHK & VITO list the following as shortcomings of LED retrofits: relatively low lumen output, low CRI, not suitable for direct-indirect lighting applications, and potential dimming problems, however expect shortcomings to be resolved within 2 to 3 years.

In contrast to the T8 lamps, the VHK & VITO study states LED retrofit tubes for substitution of LFL T5 are available on the market, but the choice is limited as compared to LED retrofit tubes for LFL T8. In addition, major (LED) lighting manufacturers as Philips, Osram, General Electric, Havells-Sylvania, Megaman and CREE, do not have LED tubes with G5 cap in their catalogues. This is explained in part by the number of T5 lamps being replaced per annum to be is considerably smaller than the number of T8 lamps being replaced (market is less interesting). The improvement potential of LED tubes with respect to LFL T5 is also said to still be too small, also considering the price difference. The study further refers to alternatives to T12 lamps, however as LEU did not request the renewal of that exemption these are not mentioned here. As for further types (including for example T2), the VHK & VITO study did not specifically research the availability of such types, however it is assumed that such retrofits will generally not exist.

A factsheet published by the US DoE[206] with the purpose of providing guidance when deciding on an LED upgrade for a fluorescent system confirms some of the arguments made by LEU. It is understood that the conclusions are based on studies of alternatives for T8 LFLs. The US DoE states that most products marketed as retrofit lamps require further modifications to the luminaire, and will have labour costs similar to products marketed as retrofit kits (upgrade expected to require electrical modifications). For

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[204] Op. cit. VITO & VHK (2015)
[205] Referenced in VITO & VHK (2015) as http://www.narvabel.de/clicksystem/csdata/download/1/de/leaflet_sl_t5_linear_lens_technology__spt_narva_en_1436.pdf
[206] DoE (2014), US Department of Energy – Building Technologies Office, Solid State Lighting Technology Fact Sheet, Published Jnauary 2014, avaialbe under http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/led_troffer-upgrades_fs.pdf

retrofit projects that retain the existing number of luminaires and control scheme, energy costs depend on the wattage of the luminaire with the new components installed relative to the existing luminaire. In some cases, the retrofit products offering the greatest wattage reductions also deliver much less light than the existing system. A recent CALiPER[207] project found that some LED replacement lamp products provided little to no reduction in wattage; in one case also increasing the system wattage. Based on efficacy data from CALiPER, LED Lighting Facts[208], and other programs, new LED luminaires are said to generally provide the greatest energy savings for equal luminaire output, followed by LED retrofit kits. Many of the LED options produce different distribution characteristics than typical fluorescent troffers. In addition to increasing the chance for glare from the luminaire, this altered distribution also may result in uneven light levels in task areas and reduced light on the walls. LED options are available for lighting systems requiring dimming capability, although dimmable products in the replacement lamp category were very rare at the time of publication. Some combinations of LEDs, drivers, and dimmers can produce noticeable flicker. All of the LED categories offer products with a selection of correlated colour temperatures (CCT), and all offer products with colour rendering index (CRI) values in the 80s and higher, though LED products with poor colour quality are also available, often at low cost.

The CALiPER[209] study on recessed troffer lighting (recessed luminaires) procured and tested twenty-four pairs of 2×2 and 2×4 troffers for photometric and electrical performance, including installation in a mock-up space for testing. Three of the pairs were T8 fluorescent benchmark products, 12 were dedicated LED troffers, five were fluorescent troffers modified for LED lamps (sometimes referred to as “tubes”), and another four troffers were modified with LED retrofit kits. Summarised findings include:

- **LED luminaire replacements:** Dedicated LED troffers are ready to compete with fluorescent troffers in terms of efficacy (lumens per watt [lm/W]), and also in terms of many lighting quality issues such as glare, light distribution, visual appearance, and colour quality. That is not to say that each one is stellar, but each one tested in this CALiPER study bested the fluorescent benchmarks in terms of efficacy, and almost all were rated highly in several categories—only one luminaire of twelve performed consistently poorly. One area of concern is that one third of the dedicated LED troffers were equipped with 0-10V dimming drivers that caused the LEDs to exhibit flicker when dimmed. It is important for the lighting industry to develop, adopt, and apply

[207] Referenced in DoE (2014) as: Exploratory Study on Recessed Troffer Lighting", March 2013 (revised June 2013), http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/caliper_recessed-troffer_2013.pdf.
[208] Referenced in DoE (2014) as: http://www.lightingfacts.com/
[209] CALiPER (2013), Exploratory Study on Recessed Troffer Lighting", March 2013 (revised June 2013), available under: http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/caliper_recessed-troffer_2013.pdf

standards to limit flicker that may contribute to health concerns and reduced task performance.

- **LED lamp replacements:** Luminaires retrofitted with LED lamps performed in the same efficacy range as the fluorescent benchmarks, so it is not clear that they offer guaranteed energy savings when compared to fluorescent troffers equipped with 25 or 28 W high-performance lamps and electronic dimming ballasts. The colour quality from these LED lamps ranged widely from very poor (CRI in the 60s) to very good (CRI in the upper 80s, which is slightly higher than typical high-performance T8 fluorescent lamps), so specifiers need to exercise care to ensure the new lamps are not reducing colour quality compared to the incumbent fluorescent. LED lamps that have exposed rows of bright LEDs are more likely to produce objectionable stripes and patterns in existing troffers than LED lamps that have a diffuse finish on the luminous half of the tube. Even diffuse LED lamps produced a more "stripey" troffer appearance and increased perceived glare, compared to fluorescent lamping. This was true whether K12 lensed troffers or parabolic louvered troffers were retrofitted.
- **LED kit replacements:** LED retrofit kits hold some promise, but also face challenges. Each one of the four kits in this CALiPER study had issues:
    - different colours delivered from the same fixture specification,
    - odd or distracting brightness patterns produced on the lens,
    - a poor-quality appearance,
    - greater glare, and/or
    - flicker when dimmed.

  However, these are engineering issues that can be solved by manufacturers, and a retrofit kit avoids some of the safety concerns associated with LED lamps. Kits also offer the chance to provide a fresh appearance to the luminaire, rather than retaining the original lens or louver.

Though this information is understood to sufficiently portray the status of LED substitutes for lamps with normal service-life, there is no specific information for alternatives for long-life LFLs. In general, the consultants can follow that alternatives for T5 lamps falling under this category shall also not be available. As for T8 lamps, though availability may be larger, it can be understood that such lamps shall be comparable with lamps of normal service life, and thus it is assumed that they shall not perform as well when compared to long life lamps. As such lamps are understood to be a potential substitute for T5 and T8 lamps, additional information as to such lamps follows:

When asked about the types of long-life lamps which are covered by Ex. 2(a)(5), LEU[210] confirmed that the following three types exist:

- T5 lamps with electronic control gear (ECG) and a lifetime of 30,000h;

[210] Op. cit. LEU Ex. 2(a)(2015b)

- T8 lamps with ECG and a lifetime up to 75,000h; and
- T8 Long Life lamps that can be operated with a conventional gear (CCG) – these are understood to comply with the lifetime threshold of the exemption of 25,000h.

LEU[211] further explains that, at present, the lifetime of T8 lamps has been standardised only for the use on a conventional control gear (magnetic ballast, IEC60081). A large variation on lifetime will exist depending on the operating conditions of the ECG driver (e.g. cold start versus warm start, see manufacturers' product pages for reference). These lifetimes are usually significantly higher. Therefore, the preferred definition for lifetime of the lamps is the one according to IEC60081. This means lifetime evaluation for T8 lamps is recommended to be made for 50% point at a standardized 3-hours cycle on a CCG (not like suggested on ECG one). In that case for certain long-life lamp types the lifetime will be still below 30,000h. Hence proposal is to keep the defined lifetime target at ≥ 25,000h. LEU recommends referencing EN60081 for the measurements of lifetime and lumen maintenance, which are the basis for the service life, in the wording of the exemption:

> *"Tri-band phosphor with long lifetime (≥25,000h service life, EN60081) and a tube diameter ≥9 mm: 5 mg"*

8.5.2 Environmental Arguments

Though LEU provides information as to LCA studies to show that there are uncertainties in the comparison of LFLs and LED replacements, most of their references regard LCAs comparing other fluorescent technologies (e.g. CFLs) with LEDs, results of which are discussed in the review of Ex. 1(a-e) in Section 5.5.2.2. Despite an effort to identify LCA studies comparing LFLs with their LED replacements, there is little information available of such studies in the public realm.

A study from 2014 prepared by Tähkämö et al.[212], and published by "International Energy Agency 4E Solid State Lighting Annex", states the following:

> "*In the domain of professional lighting, the T5 linear fluorescent lamp luminaire was the best-rated product in 2009. In studies published in 2013, the T5 lamp remains the product with the lowest environmental impacts, but thanks to the advances of LED technology, LED tubes are nearly at the same level of performance… It should be noted that the comparison of LED-based products with conventional lighting technologies is not always in favour of solid-state lighting.*

[211] Op. cit. LEU Ex. 2(a)(2015b)

[212] Tähkämö et al. (2014), Tähkämö, L., Martinsons, C., Ravel, P., Grannec, F., and Zissis, G., Life Cycle Assessment of Solid State Lighting, Final Report, International Energy Agency 4E Solid State Lighting Annex (4E), pg. 2, pg. 31, available under http://ssl.iea-4e.org/files/otherfiles/0000/0068/IEA_4E_SSL_Report_on_LCA.pdf

> *In professional indoor lighting (tertiary, offices, etc.), the T5 linear fluorescent lamp luminaire was the best-rated product (DEFRA 2009)*".

However Tähkämö et al. also note that:

> "*this is one of the first studies for this technology area. We need to remind readers that performance has changed much since*".

In this sense, the consultants conclude that though studies performed in the past may have shown superiority of LFLs, at least for T5, such analysis has been carried out a few years ago and is assumed to be based on older data sets. Though 5 years may not be a long time for some technologies, in the case of LEDs it is understood to be substantial due to rapid developments in this market, and in this respect it can currently not be concluded whether LFLs still retain their advantage or whether this has changed.

8.5.3 Stakeholder Contributions

Various contributions have been made as specified in Section 8.4.

EEB et al. argue that substitutes for LFLs are available for T2, T5 and T8. However examples with actual specifications are only provided for substitutes available for T8 models and no evaluation is made as to their actual comparability when used as a retrofit substitute. On the basis of the data provided, EEB et al. urge the Commission to continue monitoring the comparability of substitutes, which can be understood to mean that EEB et al. are not yet confident if the product range of LFLs is sufficiently covered for various lamp types. EEB et al. further proposes to merge long-life and normal life lamps for T5 and T8, prescribing the Ex. 2(a)(2 and 3) Hg thresholds for each lamp type. In the situation where long-life lamps now fulfil normal life Hg restrictions, omitting this distinction seems plausible. However, the consultants cannot agree to this proposal. For these lamp types it is understood that the lamps are similar in terms of the use of resources, and that the amount of Hg and phosphor used may differ. However this small difference provides service lives that are significantly longer than the normal life counterparts, particularly against the background of how long-life is defined for this exemption (see Section 8.2). LEU has been asked about the differences and whether the Hg allowance could be lowered, and responded "*In order to achieve higher lifetimes different design changes are required. One of them is an up to 3 times higher amount of phosphor containing in addition a higher amount of rare earth metals. Further measures are optimized electrode and emitter design, higher filling pressure to extend lifetime of the electrode. The higher amount of phosphor is needed in order to compensate lower efficiency of this design. Mercury is consumed over lifetime. This consumption is also dependant on the nature and amount of materials in the discharge tube… The RoHS value is a maximum value every single lamp has to meet. Published values are average values where the dosing units can have variances of +/-10-20%… A limit value of 3.5 mg would definitively be the end of certain lamp types, especially those with the highest lifetimes and best mercury per lifetime ratio leading to higher mercury usage and lower*

resource efficiency."[213] On this basis it would thus appear not possible to lower the RoHS limit threshold. As the lamps are otherwise very similar, the consultants believe that it would be preferable from a resource efficiency perspective to require all lamps to be long-life, according to the more stringent definition:

> *"≥ 25,000 hours where the installed luminous flux (lamp survival in % times lamp luminous flux in % or service life) is higher than 80% at 25,000 hours with an electronic ballast using the standardised 3 hour cycle*".[214]

KEMI presents requirements of green public procurement initiatives, and proposes to align exemption Hg threshold allowances with the specified levels. LEU[215] responded to this proposal, explaining that the RoHS thresholds specified by KEMI have in some cases already decreased, as also noted. LightingEurope further explains that for this reason the differences between the RoHS thresholds and the public procurement thresholds are not as significant and that it needs to be kept in mind that these are average levels, whereas there is a need to retain a margin above the average for the RoHS Directive thresholds.

As explained in Section 4.5.7, differences between RoHS thresholds and public procurement ones are generally acceptable. All the more so, as in light of the valid RoHS thresholds, the only difference is in this case of Ex. 2(a)(2), which is not as far from the public procurement levels.

8.5.4 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.

As explained above, it can be followed that Hg-free LFL substitutes are not available and that the potential for further Hg reductions has been realised to a large degree.
In contrast, LED alternatives are understood to be developing rapidly, both as retrofit lamp replacements and as luminaire replacements. Information is available from various

[213] LEU (2016b), LightingEurope, Response to Clarifiction Questions Regarding Ex. 2(a)(5)", submitted 7.3.2016 per email

[214] Referenced in LEU Ex. 2(a)(5)(2015a) as: Final Report The Adaptation to scientific and technical progress under Directive 2002/95/EC, Oeko-Institut Freiburg, Feb. 19, 2009, http://ec.europa.eu/environment/waste/weee/pdf/rohs_report.pdf

[215] LEU (2015c), LightingEurope, Summary of critical observations to stakeholder submissions , Submitted per email on 18.12.2015

studies performed in the past, however only a few are more recent (2013 and on) and have been presented above. On the basis of these studies, it can be concluded that LED replacements are available for T8 LFLs, however their comparability on the component level (lamp) and the system level (after installed in LFL luminaire as replacement) can have various shortcomings, expected to be resolved within a few years. Furthermore it appears that most alternatives are sufficient for a few of the LFL length range, while for other lengths only few or no alternatives were reported. For other LFL types (T2, T5), the availability of LED replacement lamps is understood to be very limited and where existing, performance advantages are currently not observed.

It is understood that most of the studies have compared LFLs with “normal” lifetimes to LED alternative options, and it is thus expected that where long-life LFLs are available, that such lamps might still have advantages over LED alternatives, in light of their extended performance time. Though LED alternatives are understood to have longer lives in comparison with “normal” LFLs, it can be expected that service-lives shall be comparable with long-life LFLs (particularly in lamps operating on electric ballast which are understood to have longer service lives). Where it can be understood that LED replacement tubes are starting to be comparable with LFLs with “normal” service lives, it can be expected that “long-life” LFLs shall still show a higher comprehensive performance. In this sense, despite a possible availability of LED replacements with long-life, these are still not assumed to have larger benefits in terms of environmental and health impacts, in light of some of the limitations mentioned above.

There is understood not to be a reliability problem with LED alternatives where these are properly installed, however LightingEurope raises concern that a lack of sufficient LED retrofit substitutes shall push consumers to replace lamps prior to actual end of life (EoL). In light of the current limitations related to LED replacement lamps, the consultants can follow that this concern may be justified for T2 and T5 lamps and to some degree also for T8 lamps. The concern of possible significant environmental costs of early EoL of LFL luminaires, may justify a slower shift towards LED alternatives, however the consultants observe that “substitutes” in the form of long-life LFLs would have environmental benefits in comparison with normal LFLs and should be considered in relation to the justification of the exemptions.

Long-life LFL models are available for T5 and T8 lamp types and are understood to be a preferable substitute in light of the clear environmental benefit over normal life lamps in the form of resource savings. The still very high sales volumes of such lamps, as well as continued sales of new LFL designed luminaires, plus statements (from LightingEurope) that such replacements could be needed for many years to come, further support a shift from normal life to long life. Such a shift shall reduce sales, and in this sense also the use of resources needed for manufacturing new lamps, while also preventing accelerated waste of luminaires. This shall also allow industry to further develop LEDs to their full potential and compatibility over the next few years. In contrast, since both types of substitutes are understood not to exist for T2 models, the renewal of the exemption for these lamps could be justified. This is further supported by the understanding that the sales of such lamps have significantly decreased. In both cases, although LightingEurope

states that replacement lamps shall be needed for many years (10-20 and longer), the consultants do not agree that this should justify continuation of exemptions for many years. This statement is understood in part to be related to the fact that new LFL luminaires are still coming onto the market; in this sense, extending the exemptions shall mainly delay the point in time at which such luminaires and lamps are to be phased out.

8.6 Recommendation

The consultants recommend granting a renewal for the specific exemption for T2 lamps. Alternatives are understood not to be available as replacement lamps and replacement luminaires would cause environmental costs in the form of luminaires reaching EoL early (waste). Sales of such lamps also suggest that this technology is rapidly headed towards phase-out, but shall still be needed where luminaires are still in use.

The consultants recommend revoking specific exemptions for T5 and T8 lamps as substitutes, either in the form of long-life lamps or in the form of LEDs are available. A longer transition period could be granted, as manufacturers may need to establish long-life alternatives for some specific models (combinations of wattages, lengths and diameters).

As an exemption was not requested for entry 4 (T12 lamps) by LightingEurope, it is assumed that such lamps have phased out. It is thus also recommended that this exemption be revoked. In light of the expected phase-out, a short termed transition period is expected to suffice.

As LED alternatives are not understood to be preferable to long life LFL lamps (possibly also exhibiting environmental or performance disadvantages for T8 models and not available for T5 models), it is recommended to extend the exemption for long-life lamps.

Exemption 2(a)	Duration*
Mercury in double-capped linear fluorescent lamps for general lighting purposes not exceeding (per lamp)	
1) Tri-band phosphor with normal lifetime and a tube diameter < 9 mm (e.g. T2): 4 mg	For Cat. 5, 8 & 9: 21 July 2021
	For Sub-Cat. 8 in-vitro: 21 July 2023
	For Sub-Cat. 9 industrial: 21 July 2024
(2) Tri-band phosphor with normal lifetime and a tube diameter ≥ 9 mm and ≤ 17 mm (e.g. T5): 3 mg ***(3) Tri-band phosphor with normal lifetime and a tube diameter > 17 mm and ≤ 28 mm (e.g. T8): 3.5 mg*** ***(4) Tri-band phosphor with normal lifetime and a tube diameter > 28 mm (e.g. T12): 3.5 mg***	For Cat. 8 & 9: 21 July 2021
	For Sub-Cat. 8 in-vitro: 21 July 2023
	For Sub-Cat. 9 industrial: 21 July 2024
(5) Tri-band phosphor with long lifetime (≥ 25 000 h): 5 mg	For Cat. 5, 8 & 9: 21 July 2021
	For Sub-Cat. 8 in-vitro: 21 July 2023
	For Sub-Cat. 9 industrial: 21 July 2024

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

8.7 References Exemption 2(a)(1-5)

CALiPER (2013) Exploratory Study on Recessed Troffer Lighting", March 2013 (revised June 2013), available under: http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/caliper_recessed-troffer_2013.pdf

CALiPER (2014a) Pacific Northwest National Laboratory, Application Summary Report 21: Linear (T8) LED Lamps, Solid-State Lighting Program Building Technologies Offi ce Office of Energy Effi ciency and Renewable Energy U.S. Department of Energy, available under: http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/caliper_21_t8.pdf

DoE (2014) US Department of Energy – Building Technologies Office, Solid State Lighting Technology Fact Sheet, Published Jnauary 2014, available under http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/led_troffer-upgrades_fs.pdf

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

KEMI (2015) 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. 2(a)(1)(2015a) LightingEurope, Request to renew Exemption 2(a)(1) Under Annex III of 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

LEU Ex. 2(a)(2)(2015a) LightingEurope, Request to renew Exemption 2(a)(1) Under Annex III of the RoHS Directive 2011/65/EU 2(a) 2(a)Mercury in double-capped linear fluorescent lamps for general lighting purposes not exceeding (per lamp): 2(a)(2) Tri-band phosphor with normal lifetime and a tube diameter ≥ 9 mm and ≤ 17 mm (e.g. T5): 3 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/2a2_LE_RoHS_Exemption__Req_Final.pdf

LEU Ex. 2(a)(3)(2015a) LightingEurope, Request to renew Exemption 2(a)(3) under Annex III of 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)(3) Tri-band phosphor with normal lifetime and a tube diameter > 17 mm and ≤ 28 mm (e.g. T8): 3.5 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/2a3_LE_RoHS_Exemption__Req_Final.pdf

LEU Ex. 2(a)(5)(2015a) LightingEurope, Request to renew Exemption 2(a)(5) 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)(5) Tri-band phosphor with long lifetime (≥ 25.000): 5 mg may be used per lamp after 31 December 2011, submitted 55.1.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_2_a__1-5_/Lighting_Europe/2a5_LE_RoHS_Exemption__Req_Final.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. 2(a)(2015b) LightingEurope, Response To Oeko-Institut regarding the 1st Questionnaire Exemption No. 2(a)(1-5) (renewal request), submitted 15.9.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_2_a__1-5_/Lighting_Europe/Ex_2a_1-5__LightingEurope_Clarifications_1st_round_final.pdf

LEU (2015c) LightingEurope, Summary of critical observations to stakeholder submissions, submitted per email on 18.12.2015

LEU (2016b) LightingEurope, Response to Clarifiction Questions Regarding Ex. 2(a)(5)“, submitted 7.3.2016 per email

LEU (2016c) LightingEurope, Response to Clarifiction Questions Regarding Ex. 2(a)(5)“, submitted 9.3.2016 per email

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_2_a__1-5_/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

Tähkämö et al. (2014) Tähkämö, L., Martinsons, C., Ravel, P., Grannec, F., and Zissis, G., Life Cycle Assessment of Solid State Lighting, Final Report, International Energy

Agency 4E Solid State Lighting Annex (4E), pg. 2, pg. 31, available under http://ssl.iea-4e.org/files/otherfiles/0000/0068/IEA_4E_SSL_Report_on_LCA.pdf

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

9.0 Exemption 2(b)(3): "Mercury in other fluorescent lamps not exceeding (per lamp): (3) Non-linear tri-band phosphor lamps with tube diameter > 17 mm (e.g. T9)”

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

CCG	Conventional control gear
ECG	Electric control gear
EEE	Electrical and Electronic Equipment
EoL	End-of-life
Hg	Mercury
LED	Light emitting diode
LEU	LightingEurope
LFL	Linear fluorescent lamps
NARVA	NARVA Lichtquellen GmbH + Co. KG

9.1 Background

LightingEurope (LEU)[216] and NARVA Lichtquellen GmbH + Co. KG (NARVA) [217] have both applied for the renewal of Ex 2(b)(3) of Annex III of the RoHS Directive. This exemption covers non-linear triband phosphor fluorescent lamps for general lighting, explained to be a small group of energy- and resource-efficient lamps required in the EU market.[218]

NARVA[219] explains that lamps falling under this exemption are discharge lamps, which use mercury for the discharge process, arguing that no substitutes for the mercury are available. In relation to substitutes, LEU[220] also states that the replacement of mercury in non-linear fluorescent lamps is scientifically and technically impracticable. Currently there are no significant LED retrofit lamps available in the market. Alternatively installed luminaires can be replaced with very high socioeconomic impact by installations using mercury-free lamps.

Both applicants apply for the renewal of the exemption, requesting the current wording formulation as listed in Annex III of the RoHS Directive and the maximum available duration allowed (based on Art. 5(2) of the Directive).

9.2 Description of Requested Exemption

LEU explains that Exemption 2(b)(3) covers mercury in non-linear fluorescent tri-band phosphor lamps for general lighting purposes with normal lifetime and a tube diameter > 17 mm (e.g. circular T9 or T12 lamps or U-shaped T8 lamps, see Figure 9-1. The maximum allowed mercury dose is currently 15 mg per lamp. Non-linear fluorescent lamps always need more mercury compared to linear lamps. The main reason for this effect lies in the production process. Lamp production starts with a linear glass tube, to which coatings on glass are applied as well as the phosphor layer. After these processes the tube is brought in a circular, U-form or other non-linear structural shape. This process has influence on the coating and phosphor layers as small cracks are created where the glass is bent. For that reason more mercury diffuses into the glass tube during

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[216] LEU Ex. 2(a)(1)(2015a), LightingEurope, Request to renew Exemption 2(b)(3) Under Annex III of the RoHS Directive 2011/65/EU 2(b) Mercury in other fluorescent lamps not exceeding: 2(b)(3) Non-linear tri-band phosphor lamps with tube diameter > 17 mm (e.g. T9): 15 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_b__3-4_/Lighting_Europe/2b3_LE_RoHS_Exemption__Req_Final.pdf

[217] 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_2_a__1-5_/NARVA/01_02_a__2b3_4a.pdf

[218] Op. cit. LEU Ex. 2(b)(3)(2015a)

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

[220] Op. cit. LEU Ex. 2(b)(3)(2015a)

operational lamp life meaning more mercury is necessary in order to provide the functionality of these lamps over the lamp lifetime. [221]

The majority of lamps falling under this exemption currently put on the EU market by LEU members are T9 circular or T8 U-shaped lamps with standardised dimensions and base. These lamps with a diameter of ca. 26 mm (T8) or 29 mm (T9) are very economical, offer a good quality of light having a very good luminous flux. They are compact with good average lifetime and have suitable electronic control gear. In contrast, in other parts of the application, LEU states that non-linear tri-band phosphor lamps with tube diameter > 17 mm can be used with conventional control gear (CCG) as well as with electronic control gear (ECG). Lamps are in use mainly in professional areas (public buildings, restaurants, industry, shops, supermarkets; department stores, street and city lighting), but sometimes also in private homes. [222]

Figure 9-1: Drawings/pictures of T9 circular and T8 U-shaped lamps

Source: LEU Ex. 2(b)(3)(2015a)

[221] Op. cit. LEU Ex. 2(b)(3)(2015a)
[222] Op. cit. LEU Ex. 2(b)(3)(2015a)

LEU provides typical parameters for each entry to further describe the range of lamps available on the market and covered by this exemption. The data is summarised in Table 9-1.

Table 9-1: Typical parameters of lamps falling under Ex. 2(b)(3)

	U-shaped T8	Circular T9
Available types and wattages (main types used in EU):	18, 36, 58 Watt	22, 32, 40 Watt
Available Colour Temperatures: 2.700K up to 6.500K	2.700 - 6.500K	
Typical Colour Rendering Index (Ra):	80- >90	
Base (standard designation): G13 (bi-pin), IEC/EN60061),	2G13	G10q
Typical average Lifetime[2]	13.000h	7.500h
Dimmable	yes	

*

Source: Op. cit. LEU Ex. 2(b)(3)(2015a)

9.2.1 Amount of Mercury Used under the Exemption

There are limited statistical data available for non-linear T8 or T9 lamps. T12 lamps are considered to have a niche market only. Specific market data is not available for the lamps covered by this exemption. As an indication, LEU explains that data for the EU-28 of lamps covered by the exemptions 1(e), 2(b)(2), 2(b3), 2(b)(4) and 4(a), show a decrease in market sales from 2009 to 2013. For lamps under all of these exemptions, in 2013 ca. 19 Mio. pcs. non-linear and special purpose lamps were marketed[223]. The overall roughly estimated annual mercury input decreased between 2009 and 2013 from circa 510 kg to 190 kg (total decrease of -63%, average decrease per lamp of -33%). Data for the various years can be viewed in Table 9-2.[224]

Table 9-2: Market and mercury content of lamps covered by the Exemptions 1(e), 2(b)(2), 2(b)(3), 2(b)(4) and 4(a) of RoHS Annex III

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

Note: Data represent sales in EU-2814. Mercury content has been estimated by LightingEurope.
Source: Op. cit. LEU Ex. 2(b)(3)(2015a)

[223] Referenced in LEU Ex. 2(b)(3)(2015a) as Preparatory Study on Light Sources for Ecodesign and/or Energy Labelling Requirements ('Lot 8/9/19) Draft Interim Report, Task 2, Nov.2014, VITO, VHK
[224] Op. cit. LEU Ex. 2(b)(3)(2015a)

9.3 Applicant's Justification for Exemption

LEU claims that the replacement of mercury in non-linear fluorescents is scientifically and technically impracticable. Currently there are no significant non-linear LED lamps available on the market. Argumentation is also raised as to the comparability of LED alternatives in terms of efficacy and light distribution. The alternative of a continuation of this exemption would be to bring about replacement of installed non-linear fluorescent luminaires with LED luminaires. [225]

9.3.1 Possible Alternatives for Substituting RoHS Substances

LEU explains that during the last decades several approaches have been made to design low pressure discharge lamps where the light producing element Hg is replaced by a less hazardous material. So far no approach yielded a result with comparable luminous efficacy, product cost and product availability as the (still state of the art) Hg low pressure discharge lamps. However, it is said that with the arrival of equally efficient LED light sources, research into alternative discharges has stopped at most companies and universities. Further details of such research efforts can be viewed in LEU's applications.[226]

Information is also provided as to the accomplishments in terms of Hg reduction, however it is explained that the potential for this strategy has been implemented for the most part and that further research is focusing on the development of LED alternatives and not on Hg reduction.[227]

LEU members producing these lamps have reduced the mercury content within most lamp models in the past years. The point is made that there is not an "average lamp", but that they take all manner of different wattages, phosphors, sizes and forms. LEU emphasizes that some lamps on the market have a value exceeding the 10 mg average and that the current limit should thus not be changed. Publicly available data only reveals the mercury content of lamps for general lighting. But exemption 2(b)(3) also covers special purpose lamps. Therefore LEU recommends not changing the limit as it would in practise only have impact in very small amounts, but probably with the consequence that for some lighting or non-lighting[228] applications, lamps would no longer be available.[229]

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[225] Op. cit. LEU Ex. 2(b)(3)(2015a)
[226] Op. cit. LEU Ex. 2(b)(3)(2015a)
[227] Op. cit. LEU Ex. 2(b)(3)(2015a)
[228] The consultants understand this to mean EEE of other categories (not Cat. 5) in which an Ex. 2(b)(3) lamp is integrated, where the main purpose of the equipment is not lighting. For example furniture with lighting would be considered a non-lighting application.
[229] LEU Ex. 2(b)(3)(2015b), LightingEurope, Response To Oeko-Institut regarding the 1st Questionnaire Exemption No. 2(b)(3) (renewal request), submitted 15.9.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_2_b__3-4_/Lighting_Europe/Ex_2b3_LightingEurope_1st_Clarification-Questions_final.pdf

9.3.2 Possible Alternatives for Eliminating RoHS Substances

LED lighting is understood to comprise the candidate substitutes for non-linear fluorescent lamps. LED lighting is a very innovative technology offering a high variety of new functionalities, high and still increasing energy efficiency and overall performance in nearly all areas. However, at present no significant trend for nonlinear LED based replacement lamps is visible. They have a relatively small market, with diverse portfolio, hence LED penetration might be slower (on lamp level). [230]

LEU states that there are two key ways to use LED technology in order to substitute fluorescent lamps: 1) replacement lamps (retrofit/ conversion), or 2) new installations (for example in new buildings or in refurbished areas). Currently LightingEurope is not aware of any relevant nonlinear T8 or T9 LED replacement lamps being available on the EU market. However, in other parts of the application document, LEU states that the non-linear LED replacement market is in its very initial stage. To the best knowledge of LEU members, only limited examples of such lamps can be found on the European market and none of them can be considered as fully compatible with existing applications.[231]

New circular or U-bent LED lamps would have to be developed. So far there is no market justifying the effort to develop these lamps and make them available for the EU market. It is also much easier to produce different fluorescent lamp types and wattages due to the big similarity of phosphors and components compared to development and production of the full range of lamps in LED technology.[232]

Installation of replacements mostly requires involvement of people with professional expertise due to the following issues: [233]

- Electrical compatibility: A LED tube has to operate on the installed control gear without any problems. It can require technical changes to the luminaire (rewiring), especially in luminaires equipped with electronic control gears.
- Applicable legal and compliance requirements like conformity assessments, declaration, and labelling of the changed luminaire are needed.
- Different light distribution: LED has typically unidirectional optical characteristics vs. more omnidirectional distribution from fluorescent lamps[234].
- LED lamps do contain electronic components as well as materials which like nearly all other electronic equipment use the RoHS regulated substance lead in applications exempted by Annex III of the Directive.

[230] Op. cit. LEU Ex. 2(b)(3)(2015a)
[231] Op. cit. LEU Ex. 2(b)(3)(2015a)
[232] Op. cit. LEU Ex. 2(b)(3)(2015b)
[233] Op. cit. LEU Ex. 2(b)(3)(2015a)
[234] The consultants interpret this statement to be in relation to the different light distribution, where LED is typically non-directional vs. fluorescent lamps which are typically of an omnidirectional nature.

Further detail as to these aspects is available in the application document and can also be observed in Section 8.3.2 related to substitutes for LFLs, in light of the similarities.

LEU summarises that only few nonlinear LED replacements are available, hence reliability cannot judged. However, correctly installed LED based luminaires are considered to be reliable.

Another growing market approach is the use of integrated LED luminaires, but this requires full luminaire replacement including the additional high investment and negative environmental impact. There are no data available about number of luminaires, equipment and fixtures using non-linear lamps. With a conservative assumption 500€ per luminaire including installation would be needed for replacement creating 5-10 kg WEEE for each still functional and energy efficient equipment. LEU further contends that LED based luminaires so far do not reveal a clear general environmental benefit, for example due to higher energy efficiency during the use phase. [235]

LEU summarised that for non-linear T8, T9 and T12 lamps no significant LED retrofit solutions are currently available on the EU market, which can be used in respective fluorescent lamp luminaires. Those lamps which are available often need technical changes in the luminaire. Instead new LED solutions are replacing non-linear fluorescent lamps in new products, such as LED street lighting systems.

9.3.3 Environmental Arguments

LEU explains that there are several external [understood to mean independent – consultant's comment] LCA's performed regarding lighting. There is general agreement, that the main environmental impact is created during the use phase, meaning through electricity consumption when burning the lamp[236]. This means that currently the efficacy of the lamp is the determining parameter. The environmental and economic performance comparison of various lamp types is difficult, due to lack of established rules for the LCA of light sources. As a result, it creates distortion and makes it difficult to numerically compare the results of the LCAs. LEU explains that comparing non-linear fluorescent lamps and LED lamps with LCA is even more challenging due to the various-shaped LED light sources. LED technology provides new possibilities for manufacturers to design luminaires, lamps, components and packages containing LED chips, thus the question on which basis those should be compared remains.[237, 238]

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[235] Op. cit. LEU Ex. 2(b)(3)(2015a)
[236] Referenced in LEU Ex. 2(b)(3)(2015a) as Enlighten report, Section 5, Ch. 3 fig. 4 & 5
[237] Referenced in LEU Ex. 2(b)(3)(2015a) as Life cycle assessment of light sources – Case studies and review of the analyses Leena Tähkämö, Aalto University publication series DOCTORAL DISSERTATIONS 111/2013, p. 17-18
[238] Op. cit. LEU Ex. 2(b)(3)(2015a)

9.3.4 Road Map to Substitution

Lamps covered by exemption 2(b)(3) cover a small market segment. Developing retrofit or conversion lamps takes as much time as other comparable electrical and electronic equipment. A prerequisite for the development of such products is market demand. This market demand could only be sufficient for a positive marketing decision for the lamp types with the highest volume. Currently for lamps under this exemption, LEU states that there is no positive business case. This is said to remain valid even if the lamps would be prohibited in certain cases. [239]

9.4 Stakeholder Contributions

A number of contributions have been made by stakeholders raising general points in relation to discharge lamps. Such contributions are summarised in Section 4.5.7 of the general lamp chapter.

The European Environmental Bureau (EEB), the Mercury Policy Project and the Responsible Purchasing Network[240], submitted comments specifically in relation to Ex. 2(b)(3). They argue that "*the example of T9 lamps may not be correct. T9s are halophosphate. Even ELC[241] at the 2009 submission was talking about halophosphate lamps in relation to the T9s. Therefore the example there should rather be T8 and the limit should be reduced since U-shaped T8s can meet this lower limit… The mercury limit for non-linear tri-band phosphor lamps with tube diameter > 17 mm, including the U-bent T8s, should be lowered to 8 mg from the current limit of 15 mg*."

9.5 Critical Review

9.5.1 Scientific and Technical Practicability of Substitution

LEU explains that substitutes are not sufficiently available for non-linear fluorescent lamps. In terms of substance substitutes the consultants can follow that despite various research initiatives, results have not led to the development of Hg-free LFLs. As for the reduction of Hg in LFLs, it is also apparent that the potential for such benefits has been realised to a large extent. Though LEU admits that many lamps covered by this exemption use less than 10 mg, they also explain that some lamps with special purposes

[239] Op. cit. LEU Ex. 2(b)(3)(2015b)
[240] 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
[241] ELC is the European Lamp Companies Federation, who participated in the 2008/2009 review of the exemption – consultants comment.

require more mercury. Due to the development of LED technologies, further potential for these strategies is understood to no longer be in the focus of development efforts.

As for LED substitutes, LEU claims that at present, replacement products are lacking and that available substitutes often do not provide comparable performance. In general it is explained that the small market segment of Ex. 2(b)(3) lamps means that that very few replacement LEDs are available, and that they would all require conversion of existing luminaires. LED luminaires are available, however LEU is neither aware of their market uptake, nor whether their efficiency can be considered comparable to non-linear fluorescent lamps or not. LEU states that new installations can be applied in new buildings or in refurbished areas of buildings, however in the consultants view this limitation would only be relevant to luminaires applied in arrays such as in office lighting. However, from the examples provided by LEU (see Figure 9-1) it seems that lamps relevant for this exemption are used in "stand-alone" luminaires as well as luminaires used for street lighting. It cannot be assumed from this information that such lamps are applied as luminaire arrays for office lighting and thus this limitation could only be relevant for some luminaires if at all.

To support statements related to LED alternatives, LEU does not submit any data and it is difficult to estimate to what degree these statements are correct.

The VHK & VITO[242] study also does not address such lamps specifically. Circular (T9 or T12) lamps are explained to be covered in the information provided for T5 LFL lamps, from which it can be understood that there is a lack in replacement substitutes. Though VHK & VITO explain some replacements to be available from the smaller manufacturers for T5 lamps, the variety is said to be small among others as "*The number of T5 lamps being replaced in a year is considerably smaller than the number of T8 lamps being replaced, so the market is less interesting*". This statement is assumed to be of higher relevance for circular lamps, which are understood to have a much smaller market share. U-shaped T-8 lamps are assumed to be addressed by VHK & VITO under "*LFLs, other types*", specifically said to include for example "*special fluorescent lamps, e.g. circular T9*" as well as other T-classifications. It is explained that "*No specific research on the availability of LED retrofit lamps was performed, but considering the situation for the LFL T5 base case discussed…, it is assumed that such retrofits will generally not exist*." As for how the market is expected to develop, the study states "*In the residential sector it is expected that most people will switch to dedicated LED luminaires, in particular for portable applications. In the tertiary sector, strict safety regulations apply for emergency lighting and exit signs, which might induce a choice for the lamps with exactly the same specifications as those issued with the luminaire. In general a natural phase-out of LFL X lamps is expected, in favour of LED solutions*".

Where LED luminaires shall be chosen as replacements, it is understood that they would be reliable. Though there is no information as to their efficiency, the consultants assume

[242] Op. cit. VITO & VHK (2015a)

that as with any type of technology, that some would be more efficient than others. LED solutions are however generally understood to provide good efficiencies as well as a large flexibility in terms of producing lighting solutions in a variety of shapes and sizes.

9.5.2 Environmental Arguments

Though LEU provides information as to LCA studies to show that there are uncertainties in the comparison of LFLs and LED replacements, most of their references regard LCAs comparing other fluorescent technologies (e.g. CFLs) with LEDs, results of which are discussed in the review of Ex. 1(a-e) in Section 5.5.2.2.

The consultants are not aware of comparative LCAs in the public realm of relevance to non-linear fluorescents and their LED replacements. However it is considered plausible that comparisons of non-linear fluorescents and possible LED replacements may be more challenging in this case due to a lack of products which are sufficiently comparable (dimensions, wattage, luminous flux etc.).

9.5.3 Stakeholder Contributions

For the discussion of general aspects raised by stakeholders, please see Section 4.5.7 of the general chapter.

As for the specific aspects raised by EEB et al., the consultants do not recommend following the approach proposed by the applicants. To begin with, assuming that T9 circular lamps are only produced with halo-phosphate phosphors, they would not benefit from the current exemption wording, which limits its applicability to tri-band phosphors.

Furthermore, if indeed T9 circular lamps are not produced with tri-band phosphors, lowering the current mercury limit may be possible, however as EEB et al. states, U-shaped T8 lamps already comply with the proposed lower limit. This strategy is thus not assumed to result in a change in articles on the market and thus also not in respective environmental benefits. In contrast, should T9 circular lamps produced with tri-band phosphors be marketed, it cannot be concluded that such lamps would not need the current mercury limit. The consultants further believe that enforcing a mercury reduction at this point of development of LED technologies would give an unhelpful signal to industry on where R&D efforts are best spent, which might delay further developments of substitutes.

9.5.4 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.

As explained above, it can be followed that Hg-free LFL substitutes are not available and that the potential for further Hg reductions has been realised to a certain degree.

LED alternatives are understood to be developing rapidly, however from available information it still seems that LED replacements are limited in their variety and possibly also in their compatibility as retrofit replacements. It is apparent that LED luminaires are available and that this technology opens a large degree of flexibility in terms of creating various shapes and sizes. VHK & VITO estimate that private consumers shall shift towards LED luminaires and this is understood as a natural phase-out, which is possibly already underway to some degree. In contrast, the same study assumes that in the tertiary sector, stricter regulations may hinder such a phase-in, particularly should emergency lighting and exit signs be relevant for this exemption. However, LEU has not specified such examples to be relevant to the scope of this exemption. As the conclusions of the VHK & VITO study apply to a wider range of lamps, and not just to non-linear lamps, it is possible that this aspect is not relevant to this exemption.

A further aspect of interest in this regard is the possible size of this exemptions' market segment. LEU specifies sales of 19 million lamps for the following exemptions: 1(e), 2(b)(2), 2(b3), 2(b)(4) and 4(a). This information is said to originate in the VHK & VITO szudy. It is assumed that this data is taken from the first version of the Task 2 report[243], however in the final version from May 2015 according to Table 1, 19 million lamps were placed on the market for all other LFLs (including T5 old types 4 -13 Watt and special FL), excluding T2, T5 and T8 types for which specific data is provided. This would mean that lamps for Ex. 1(e) and Ex. 4(a) are not included in this count. Furthermore, Ex. 2(b)(1) expired in 2012 and Ex. 2(b)(2) is to expire on 13 April 2016, and it is thus assumed that the sales of such lamps in 2013 would have been negligible. It is not clear how 19 million lamps would be distributed between Ex. 2(b)(3) and Ex. 2(b)(4), however it is possible that the number of lamps related to Ex. 2(b)(3) is not negligible.

Despite LEU explaining that there is a wide variety of lamps that require substitutes, it appears that the factor that is of the largest importance for substitutes is dimensions. LEU has specified that all lamps are either T8 (U-shaped) or T9 (circular), meaning that the diameter is standardized. In parallel, it can be understood that other dimensions may vary. From manufacturer catalogues it is observed that U-shaped lamps come in a relatively small variety of overall lengths: 310; 601-607; 570; 765[244]. It is possible that a

[243] VHK & VITO (2015b), Preparatory Study on Light Sources for Ecodesign and/or Energy Labelling Requirements ('Lot 8/9/19') - Draft Interim Report, Task 2 (revision 1): Markets, Prepared for the European Commission, DG ENER.C.3, pg. 2-15, Table 1.

[244] Based on Data from Osram: http://www.osram.de/appsinfo/pdc/pdf.do?cid=GPS01_1027909&vid=PP_EUROPE_DE_eCat&lid=DE

few further lengths exist, however the consultants assume that most further variance is in terms of the lumen package and the wattage. According to one internet supplier[245], 48 different lamps were available from 6 suppliers, in 6 different lumen groups and 12 different wattage types. The consultants believe that as long as substitutes would be available for each of the different dimension groups, that a forced phase-out, leading to early end-of-life (EoL) of luminaires would be avoidable, possibly requiring luminaire conversions in order to "accept LED replacements".

As for circular lamps, from data available from the same supplier[246], 50 lamps are available from 6 manufacturers in 6 lumen groups and in 4 different watt types. According to one source[247] for such T9 tubes, outside diameters of 6½", 8", 12", or 16" are available. In this sense, here too, the dimension variety and the wattage variety clarify that were a small number of alternatives available in terms of dimensions, that these should suffice to enable substitution.

As it is understood form the applicant that lamps have different types of drivers, it is possible that at present alternatives do not provide sufficient compatibility on this respect. However data to substantiate such claims has not been provided.

Against this background, it is difficult to determine the availability of substitutes in terms of their coverage of non-linear lamp dimensions and their electric compatibility with existing luminaries. In parallel it can be understood that substitutes on the system level (luminaires) are available and phase-out is assumed to have begun in this direction.

Because of the lacking data related to replacement lamp availability, the consultants would recommend a short term renewal. This period should allow industry to bring a few LED substitutes on to the EU market[248] and to compile data so as to clarify if indeed a substitution problem exists that could create substantial waste from early EoL of luminaires should this exemption be allowed to expire.

9.6 Recommendation

As explained above, it seems that substitutes are available on the system level (LED luminaires). However the range of substitutes on the component level (replacement LEDs) and their compatibility with existing installations is yet to be verified in terms of dimensions and electric compatibility. Only with this information would it be possible to understand the range of potential environmental costs of early EoL of luminaires and subsequently their acceptability in comparison to the potential for Hg saving. The

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[245] http://www.mercateo.com/kw/leuchtstofflampe%2820%29u%282d%29form/leuchtstofflampe_u_form.html

[246] http://www.mercateo.com/kw/leuchtstofflampe%2820%29ringform/leuchtstofflampe_ringform.html?ViewName=live&wortFilter=G10Q

[247] https://sizes.com/home/fluorescents.htm

[248] It can be understood that a few substitutes are available on non-EU markets such as the US market, however from an initial survey similar lamps were not found on the EU market.

consultants thus recommend a short (three year) exemption to allow for the bringing of substitutes onto the market and for data to be compiled regarding LED coverage of the non-linear product range.

Exemption 2(b)(3)	Duration*
2(b) Mercury in other fluorescent lamps not exceeding (per lamp)	
(3) Non-linear tri-band phosphor lamps with tube diameter > 17 mm (e.g. T9)"	For Cat. 5: 21 July 2019
	For Cat. 8 & 9: 21 July 2021
	For Sub-Cat. 8 in-vitro: 21 July 2023
	For Sub-Cat. 9 industrial: 21 July 2024

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

9.7 References Exemption 2(b)(3)

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

LEU Ex. 2(a)(1)(2015a) LightingEurope, Request to renew Exemption 2(b)(3) Under Annex III of the RoHS Directive 2011/65/EU 2(b) Mercury in other fluorescent lamps not exceeding: 2(b)(3) Non-linear tri-band phosphor lamps with tube diameter > 17 mm (e.g. T9): 15 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_b__3-4_/Lighting_Europe/2b3_LE_RoHS_Exemption__Req_Final.pdf

LEU Ex. 2(b)(3)(2015b) LightingEurope, Response To Oeko-Institut regarding the 1st Questionnaire Exemption No. 2(b)(3) (renewal request), submitted 15.9.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_2_b__3-4_/Lighting_Europe/Ex_2b3_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_2_a__1-5_/NARVA/01_02_a__2b3_4a.pdf

VHK & VITO (2015b) Preparatory Study on Light Sources for Ecodesign and/or Energy Labelling Requirements ('Lot 8/9/19') – Draft Interim Report, Task 2 (revision 1): Markets, Prepared for the European Commission, DG ENER.C.3, pg. 2-15, Table 1.

10.0 Exemption 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

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

CCG	Conventional control gears
CFL	Compact fluorescent lamp
CRI	Colour Rendering Index
DBD	Dielectric barrier discharge
ECG	Electronic control gears
EEE	Electrical and Electronic Equipment
EoL	End of Life
LED	Light Emitting Diode
LEU	LightingEurope
R&D	Research and Development
UV	Ultraviolet (subtypes UVA, UVB, UVC)

10.1 Background

LightingEurope (LEU)[249] has submitted a request for the renewal of the above mentioned exemption.

LEU states that due to a vast variety of parameters relevant for lamps falling under Ex. 2(b)(4), such lamps cannot be easily replaced with LED alternatives (e.g. form factor, length, spectrum etc.).

The applicant applies for the renewal of Ex. 2(b)(4), with the current wording formulation listed in Annex III of the RoHS Directive and requesting the maximum available duration allowed.

10.2 Description of Requested Exemption

According to LEU[250], lamps in the scope of Ex. 2(b)(4) are in a wide variety of different lamp families with mercury content from < 2 mg and up to 15 mg. They are mainly niche products with low market shares compared to the other fluorescent lamps, and have a vast variety of parameters (form, factor, length, spectrum, colours, and technologies – e.g. induction, external ignition etc.). [251] Specific market data is not available for the lamps covered by this exemption.

In general, LEU explains that fluorescent lamps are very energy- and resource efficient lamps. They contain a small amount of intentionally added mercury in the discharge tube, which is essential to convert electrical energy into light. There are no specific market data and mercury content available for the lamps covered by this exemption.

There is a growing market for mercury-free lamps based on LED technology with features such as energy efficiency and design flexibility. At present to the best knowledge of LEU none of the key players on the market offer LED-based alternative solutions for most of the lamps covered by Ex. 2(b)(4).

For most of the lamps covered by this exemption there is currently no significant availability of LED retrofit or conversion lamps.

Against this background, LEU does not expect LED alternatives to allow for a full phase-out of Ex. 2(b)4 lamps within the coming 5 years, and thus requests a renewal of the exemption with the following wording:

> *"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"*

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[249] LEU Ex. 2(b)(4) (2015a), LightingEurope, Request to renew Exemption 2b(4) under Annex III of the RoHS Directive 2011/65/EU Lamps for other general lighting and special purposes (e.g. induction lamps): 15 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_b__3-4_/Lighting_Europe/2b4_LE_RoHS_Exemption__Req_Final.pdf

[250] Op. cit. LEU 2(b)(4)- (2015a)

[251] Op. cit. LEU 2(b)(4)- (2015a)

10.1 Applicant's Justification for Exemption

LEU[252] explains that the scope of exemption 2(b)(4) includes all other fluorescent lamps for general lighting and special purposes, which do not belong to any other exemptions in Annex III:

- Compact fluorescent lamps (Exemptions 1(a)-1(f));
- Double-capped linear triband phosphor lamps for general lighting (2(a)(1) – 2(a)(5));
- Linear and non-linear halophosphate lamps (2(b)(1) – 2(b)(2));
- Non-linear triband phosphor lamps (2(b)(3));
- Cold cathode fluorescent lamps (3(a) – 3(c)).

Fluorescent lamps are low-pressure discharge lamps containing a phosphor coating. Low- pressure discharge lamps without a fluorescent phosphor layer (e.g. UV-lamps) as well as medium and high pressure discharge lamps are covered by exemptions 4(a) – 4(f). Thus exemption 2(b)(4) includes an inhomogeneous group of lamps with amongst others different:[253]

- Form factors and bases, e.g. linear, circular, square shape;
- Technologies e.g. induction, external ignition;
- Colours, e.g. white, coloured, black light; blue light; and
- Applications and purposes, e.g. general lighting, colour, explosion protection, tanning, horticultural lighting, colour comparison, medical use;

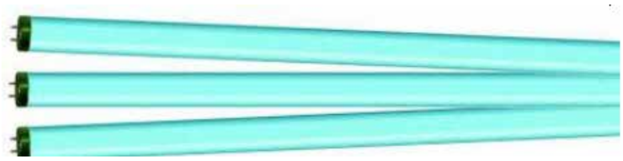
A non-exhaustive selection of lamps falling under 2(b)(4) is listed in Table 10-1.

Table 10-1 Non-exhaustive list of fluorescent lamps falling under Ex. 2(b)(4)

Lamps and applications	Example
Chip control **Lamps without UV- and blue spectrum (below 500 nm) through special coating, yellow light Applications: semiconductor industry (wafer), printing industry, (lithography);**	 
Colour proof lamps Printing industry, graphic workshops, photographic laboratories, industrial inspection and colour	[No visual example provided]

[252] Op. cit. LEU 2(b)(4)- (2015a)
[253] Op. cit. LEU 2(b)(4) (2015a)

Lamps and applications	Example
matching facilities, **industry**, shops, incoming goods inspection;	
High colour rendering index lamps **Very good colour rendering group: 1A (Ra: ≥ 90);**	[No visual example provided]
High colour temperature lamps **Colour temperatures > 6500K range;**	[No visual example provided]
T12 lamps with external ignition strip improved ignition at low ambient temperatures **Applications: street lighting, industry, outdoor applications (only in suitable luminaires);**	 **T12 lamps for explosion proof luminaires** Applications: Industry, places with a heightened risk of fire or explosions, oil rigs; Product features Fa6 base for explosion-proof fixtures; Operation without starter; 
Coloured lamps **Cost-effective creative illumination and decoration, uniform light along the entire length of the lamp;** **Areas of application: Decorative applications: shops supermarkets and department stores, restaurants, hotels, accent lighting;**	
Blacklight & Blue fluorescent lamps **Lamps that emit long wave (UV-A) ultraviolet light and not much visible light.** **Applications: Curing large areas of plastic, hardening paints, lacquers and modern adhesives, artificial, material aging, exposure of diazo film material and print masters, fluorescence excitation (with black glass filters);**	

<table>
<tr><th>Lamps and applications</th><th colspan="2">Example</th></tr>
<tr><td>Tanning lamps
Cost-effective creative illumination and decoration[254], uniform light along the entire length of the lamp;</td><td colspan="2"></td></tr>
<tr><td>Induction lamps
Electrodeless lamps, very long life time (ca. 100.000hours), 70 – 150 Watt) Wherever relamping is expensive;
- Outdoor lighting, tunnel lighting and factory lighting
- Street and city lighting
- Sports grounds and outdoor facilities
- Marine lighting
- Outdoor applications only in suitable luminaires</td><td></td><td>Medical, Therapy lamps
Special spectra for medical applications
</td></tr>
</table>

Source: taken from LEU Ex. 2(b)4 (2015a)

Moreover, LEU states[255] that some of the 2(b)(4)- lamps can be used with conventional control gears (CCG) as well as with electronic control gears (ECG). There are numerous different control gears available on the market offering various functionalities. For more details in this regard, see also Section 8.2. They are used depending on customer requirements, such as dimming or temperature range. LEU highlights that due to international safety standards, it is essential that only suitable combinations of lamps and luminaires are installed and maintained. These lamps can operate on a wide range of existing ballasts, including magnetic and electronic ballasts. For further information on ballasts in fluorescent lamps please refer to Section 8.3.2.1.

10.1.1 Possible Alternatives for Substituting RoHS Substances

LEU[256] explains that during the last decades several approaches have been made to design low pressure discharge lamps where the light producing element Hg is replaced by a less hazardous material. So far no approach yielded a result with comparable

[254] The consultants would like to note that tanning lamps are not understood to be used for decorative purposes, however the text is copied from LEU's application as is. It is assumed that this aspect could be a result of a typing mistake.
[255] Op. cit. LEU 2(b)(4)- (2015a)
[256] Op. cit. LEU 2(b)(4)- (2015a)

luminous efficacy, product cost and product availability similar to that of the still state of the art Hg low pressure discharge lamps. However, it is said that with the arrival of equally efficient LED light sources, research into alternative discharges has stopped at most companies and universities.

LEU claims[257] that non-linear fluorescent lamps always need more mercury compared to linear lamps. The average amount of mercury in lamps falling under Ex. 2(b)(4) on the market is about 8.0 mg Hg. Higher mercury consumption of Ex. 2(b)(4) fluorescent lamps as compared to normal linear fluorescent lamps is mainly caused by special phosphors and additives in the fluorescent powder and their life expectancy. Many of the lamps are produced on the same production lines as general lighting. The difference in Hg content between linear and non-linear lamps in many cases is quite small. Furthermore, in most cases, significant reductions of mercury content have already been realised, likely of a similar order to the mercury reductions implemented in linear fluorescent lamps for general lighting (as presented in 8.2.1). However, the current 15 mg limit is said to be needed due to the large variety of different lamps and functions, and their high variance in relation to different factors. Thus according to the applicant Ex. 2(b)(4) should still be specified with a maximum limit of 15 mg.

Further reduction of mercury might technically be possible with high economic effort and research and development (R&D) resources. But these would require financial and human resources, which are needed for the investments in the production process and transfer to LED technology. Moreover it is explained that the potential for Hg reduction has been implemented for the most part and that further research is focusing on the development of LED alternatives and not on Hg reduction

10.1.2 Possible Alternatives for Eliminating RoHS Substances

According to the applicant[258] there is a growing market for mercury-free lamps based on LED technology with features such as energy efficiency and design flexibility.

At present, to the best knowledge of LEU, there is no manufacture of LED based alternative solutions for most of the lamps covered by Ex. 2(b)(4). The Ex. 2(b)(4) lamp portfolio addresses fragmented, specialized applications. LEU states that these applications cannot be easily replaced by LED in all situations, since in some cases the functional objective of the special lighting application might not be met in terms of technical comparability. It must be decided case by case, if the LED based solution can be an effective replacement for the existing fixture and situation. It mostly requires involvement of people with professional expertise due to the following issues (see also the general chapter, Section 4.3.2.2.

1) Electrical compatibility: LED tube has to operate on the installed control gear without any problems. It is essential to know what kind of control gear is present

[257] Op. cit. LEU 2(b)(4)- (2015a)
[258] Op. cit. LEU 2(b)(4)- (2015a)

in the luminaire. It can require technical changes to the luminaire (rewiring), especially in luminaires equipped with an electronic control gear. Full compatibility with all installed conventional or electronic control gears is not possible.

2) Applicable legal and compliance requirements like conformity assessments, declaration, and labelling of the changed luminaire, fixture or other electrical or electronic equipment are needed. Safety aspects and lack of standards for using such lamps to replace LFLs is also explained to be a limiting factor.
3) Different light distribution: due to the LED tubes, changed optical characteristics vs. the existing lamp, the light plan can no longer be optimized for the application.
4) Restricted choice in the LED based lamps, only a fraction of the existing lengths are available, not all colours are available, for example no direct replacements are available for emergency lighting.

When asked for clarification as to lamps covered by this exemption and their availability of substitutes, LEU explained[259] that it is currently not possible to demonstrate an overview of lamps being easily replaced with LED alternatives. Only within the group of coloured lamps for non-professional purposes may LED T8 retrofit lamps be available.

10.1.3 Environmental Arguments

LEU explains[260] that comparing non-linear fluorescent lamps and LED lamps (regarding the specific characteristics and requirements) with LCA is especially challenging due to the various-shaped LED light sources for lamps falling under Ex. 2b(4). The applicant advocates carrying out further research into the overall substance effect of LED lamps in comparison with fluorescent lamps. LEU is not aware of such LCAs[261]

Other environmental arguments are general in nature. Please refer in this respect to Section 4.3.3 of the general chapter.

10.1.4 Socio-economic Impact of Substitution

A growing market approach is the use of integrated LED luminaires, but this requires sufficient time for a full luminaire replacement including an additional high investment (in the luminaire) for private, commercial or public customers. It is also said to lead to

[259] LEU Ex. 2(b)4 (2015b), LightingEurope, Response to Oeko-Institut regarding the 1st Questionnaire Exemption No. 2(b)4 (renewal requests) Mercury in other fluorescent lamps not exceeding (per lamp): (4) Lamps for other general lighting and special purposes (e.g. induction lamps): 15 mg per lamp", submitted 25.9.2015, available under: *http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_2_b__3-4_/Lighting_Europe/Ex_2b4_LightingEurope_1st_Clarification-Questions_final.pdf*

[260] Op. cit. LEU 2(b)(4)- (2015a)

[261] Op. cit. LEU 2(b)(4)- (2015a)

potential increased environmental impact (assuming the original installation is not yet at end-of-life), without a mitigating improvement in safety or socio-economic factors.

According to the applicant[262] a conservative assumption is that 500€ per luminaire including installation would be needed for replacement, creating 5-10 kg of WEEE for each still functional and energy efficient installation. For special EEE using lamps covered by this exemption, figures are assumed to be much higher.

10.1.5 Road Map to Substitution

LEU[263] is not able to share the individual road maps that its member companies have planned for their LED portfolio. There is no general roadmap to develop LED replacements for all existing linear fluorescent lamp types on the market (see also Section 4.3.5 in the general chapter. Regarding lamps covered by Ex. 2(b)(4) the applicant further emphasizes the market segment of lamps covered by this exemption, with a vast variety of parameters and small market shares for lamp types of relevance.

According to the applicant, currently the market demand for the development of substitutes for specific lamp types is low[264], so the efforts would result in higher costs for the manufactures. LEU[265] states in this respect that it is much easier to produce different fluorescent lamp types and wattages compared to development and production of the full range of lamps in LED technology.

10.2 Stakeholder Contributions

A number of contributions have been made by stakeholders, all of a general nature. Such aspects are summarised in Section 4.4 of the general chapter.

10.3 Critical Review

10.3.1 Scientific and Technical Practicability of Substitution

LEU explains that several approaches have been investigated to design fluorescent lamps where the light producing element Hg is replaced by a less hazardous material. So far no approach yielded a result with comparable luminous efficacy, product cost and product availability to that of the still state-of-the-art Hg low pressure discharge lamps. With the arrival of equally efficient LED light sources, research into alternative discharges has been discontinued. Further details of such research efforts can be viewed in LEU's application document. Information is also provided as to the accomplishments in terms of Hg reduction; however, it can be understood that the potential for this strategy has

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262 Op. cit. LEU 2(b)(4)- (2015a)
263 Op. cit. LEU 2(b)(4)- (2015a)
264 The consultants interpret this to mean that the general market demand for lamps covered by this exemption is low and thus there is no motivation to develop substitutes.
265 Op. cit. LEU 2(b)(4)- (2015a)

been implemented for the most part. Further research is focusing on the development of LED alternatives and not on Hg reduction.

The current threshold specified in the exemption in the form of a 15 mg limit, leaves a wide range allowance for using Hg. Examples of lamps falling under this exemption show that in some cases the limit is needed but that in other cases a far lower threshold could be applied. But according to the applicant it is not practical to address certain sub-groups of lamps in relation to the actual use of Hg applied.

Based on the latter point, it becomes obvious that where no sub-groups can be specified, it is difficult to propose a new threshold lower than 15mg. The consultants however assume that a reduction could be specified if sub-groups could be identified. Without further information and data as to the parameters, market sales and possible overlaps with other exemptions listed in Annex III, such a specification is difficult.

LED is a very innovative technology offering a high variety of new functionalities, high and still increasing energy efficiency, and overall high performance in nearly all areas relating to light sources emitting in the wavelength of visible light. However, at present to the best knowledge of the applicant there is no manufacture of LED based alternative solutions for most of the lamps covered by Ex. 2(b)(4). Moreover, Ex. 2(b)4 applications have a relatively small market, with diverse portfolio; hence LED penetration might be slower compared to general lighting applications. LEU states that there are two key ways to use LED technology in order to substitute fluorescent lamps:

- Replacement lamps (retrofit/ conversion); or
- New installations.

LEU claims that "*Even if retrofit solutions would be developed it must be verified case by case for every application whether the lamp can technically replace the fluorescent lamp with all required specified parameters. Therefore LEU is not able at the moment to give a detailed overview".* Only for T8-lamps are there LED retrofit tubes available. The VHK & VITO[266] study also supports this statement.

The consultants understand from these statements that where LED alternatives shall not enable substitution within existing installations, there is no intention of developing other alternatives. This is further supported by the applicants' statement that it is much easier to produce different fluorescent lamp types and wattages compared to development and production of the full range of lamps in LED technology. The consultants interpret this to mean that currently, very limited development of alternatives is being undertaken, and it seems that there is no roadmap towards substitution of Ex. 2(b)4 applications, or at least not one which is in the public realm.

The statements made by the applicant regarding the availability of LED substitutes cannot be followed comprehensively, because the applicant did not provide specific information in relation to all sub-groups of this exemption to justify its request. Such

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[266] Op. cit. VITO & VHK (2015)

information is not provided, neither in relation to the availability of existing LED substitutes for specific applications, nor in relation to the difficulty or limitations of developing such substitutes.

In the consultants view, the information provided by LEU as to possible LED substitutes is very general in its nature. Such arguments are discussed in the chapter regarding Exemption 1a-e or 2a (see Section 5.5.1and 8.5.1). 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. 2(b)4 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, or why they could not be implemented for such applications.

In the following, the various sub-groups understood to fall under Ex. 2(b)(4) are discussed.

T12 lamps with external ignition, with improved ignition and for explosion proof luminaires: LEU mentions certain T12 lamps that are explained to be covered by Ex. 2(b)(4), e.g. T12 lamps with external ignition strip and improved ignition at low ambient temperatures and T12 lamps for explosion proof luminaires that operate without a starter. Though it can be followed that such lamps may have different electrical characteristics, it has also been explained for lamps used for general purposes that they have a wide variety of electrical configurations. It is not explained why the light produced by such lamps would be understood to be relevant for special purpose applications and why it would not be covered by general purpose exemptions. In this respect it is not sufficiently clear why such lamps would not fall under the exemptions specified for T12 lamps in Annex III, namely 2(a)(4) and Ex. 2(b)(1). As applications for the renewal of these exemptions were not submitted, it is understood that such lamps have been phased out for general purposes. Thus without a comprehensive explanation why remaining T12 lamps would be considered as special purpose lamps, it cannot be established whether they would indeed be covered by Ex. 2(b)(4) and why an exemption for their further use is to be understood as justified. In this respect it should also be mentioned that T12 lamps are understood to have been phased out, as they were not efficient and thus do not comply with the Ecodesign Regulation for lamps. Understanding why such lamps could still be placed on the EU market thus needs to be clarified from a technical perspective in relation to the Ecodesign limitations.

Lamps with high colour rendering, with high colour temperature and coloured lamps: The consultants regard colour lamps mentioned in relation to this exemption similarly; these being lamps with high colour rendering (Ra: ≥ 90), lamps with high colour temperature > 6500K, and coloured lamps for creative illumination and decoration. LEU does not provide specific information or data to explain why such lamps would fall under Ex. 2(b)4. It is not explained why such lamps would not fall under exemptions for lamps used for general purposes, which do not limit the colour of lamps, their colour temperature or their colour rendering. Such lamps are understood to be of use for general purposes and it thus cannot be understood why they would fall under Ex.

2(b)(4). For example, coloured lamps can be applied for decorative purposes by residential consumers, lamps with CRI above 90 are considered as general purpose lamps under Ex. 4(b), etc. There are LEDs available in many colours such as red, green, yellow or blue[267]. LEU states only that due to the fact of restricted choice in the LED based lamps, only a fraction of the existing lengths are available, not all colours and for example no direct replacement in emergency lighting. However no details are provided to substantiate this claim and detail is not provided as to for what type of applications available substitutes are relevant. On the basis of the provided information it is thus not possible to conclude neither whether such lamps would fall under this exemption nor what the status of available substitutes is in this respect.

Induction lamps are also mentioned and explained to have a long lifetime. It is understood that most of the studies that have compared fluorescent lamps and LED lamps have investigated fluorescents with "normal" lifetimes. Thus it is expected that where long-life fluorescent lamps are available, that such lamps could still have advantages, or at least be comparable to LED alternatives, due to their extended performance time. However, LEU does not provide information to substantiate its statement or to allow an understanding as to how such lamps compare with possible LED alternatives. It can thus not be concluded neither if LED substitutes are sufficiently available nor if they are comparable in their performance or not.

Lamps for emergency lighting: LEU mentions that lamps for emergency lighting applications in the application for this request, but does not provide any detail as to such lamps and whether they would indeed fall under this exemption in terms of their characteristics. It is thus possible that lamps used for emergency lighting are covered by other exemptions, particularly where lamp output and dimensions could be provided by other lamps, for example, by the use of linear fluorescent lamps (LFL). In relation to lamp replacement, the consultants agree that there may be limitations as to lamps that could be used for this purpose. Where addressing substitutes for LFLs, VHK & VITO state in this respect "In the tertiary sector, strict safety regulations apply for emergency lighting and exit signs, which might induce a choice for the lamps with exactly the same specifications as those issued with the luminaire."[268] The consultants can thus follow that for existing luminaires, that safety regulations and standards might restrict the use of lamps in such installations to discharge lamps for which the luminaire was originally designed. In contrast, a lack of LED alternatives on the system level cannot be followed without a better understanding of the type of light that such lamps would need to provide.

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[267] http://www.osram.com/osram_com/news-and-knowledge/led-home/professional-knowledge/led-basics/light-colors/index.jsp

[268] VHK & VITO (2015), VITO in cooperation with VHK, 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, available under http://ecodesign-lightsources.eu/sites/ecodesign-lightsources.eu/files/attachments/LightSources%20Task4%20Final%2020151031.pdf

UV lamps: 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, it can also be followed that such developments shall be slower than for other lamp applications with larger market shares. As detailed in Section 7.4.1 of the report for Ex. 1(f) LED alternatives currently do not provide sufficient performance in terms of spectral output and in terms of wall-plug efficiency and can thus not be viewed as a practical substitute for UV lamps falling under Ex. 2(b)(4).

10.3.2 Environmental Arguments

The environmental performance comparison of various lamp types is difficult, due to lack of established rules for the LCA of light sources. Though LEU provides information as to LCA studies to show that there are uncertainties in the comparison of fluorescent lamps and LED replacements, their references regard LCAs comparing other fluorescent technologies with LEDs, results of which are discussed in the review of Ex. 1(a-e) in Section 5.5.2.2

Regarding other environmental arguments (inter alia: the use of materials and hazardous substances; the health and safety impact of substitutes; aspects related to the waste stream and recycling) please also refer to section 4.5.3 of this report.

10.3.3 Stakeholder Contributions

There were no specific contributions submitted regarding the exemption at hand, for the discussion of general aspects raised by stakeholders, please see Section 4.5.7.

10.3.4 The Scope of the Exemption

Regarding RoHS legislation, problematically, there is in general no official definition for the term ‘special purposes’ at the current time and an overview of which lamps are covered by exemptions 1(f), 2(b)(4), 4(a) and 4(f) is not available. An attempt is made in the exemption request of the applicant to clarify the scope of each of these exemptions, however the consultants are not confident that explanations sufficiently clarify that overlaps do not occur. In some case it is also not clear that lamps explained to fall under these exemptions would not also be covered by other exemptions for general purpose lamps. Though exemptions should be clearly defined to avoid possible overlaps, available information does not allow a clear demarcation of all lamps covered by these exemptions, and establishing the availability of substitutes for various applications is thus also difficult.

The scope of exemption 2(b)(4) is said to include all other fluorescent lamps for general lighting and special purposes, which do not belong to any of the Annex III exemptions of the RoHS Directive. Furthermore it was stated by the applicant that lamps covered by Ex. 2(b)(4) have specific special purposes. The consultants thus conclude from this statement that this exemption does not cover lamps for general lighting purposes, which are already regulated in other exemptions of Annex III.

- In this respect, single capped lamps would be expected to fall under Ex. 1, with lamps used for general lighting falling under Ex. 1(a-e) and lamps used for special purposes falling under Ex. 1(f).
- Double-capped lamps for general purposes would be expected to fall under Ex. 2(a). The wording of Ex. 2(b)(1-3) does not limit their applicability to general purpose lamps and thus halophosphate phosphor lamps (Ex. 2(b)(1-2)) and tri-band phosphor non-linear lamps (Ex. 2(b)(3)) for both general and special purposes would be expected to be covered by these exemptions.
- Thus Ex. 2(b)(4) could only cover double capped fluorescent lamps used for special purposes as well as other than single and double capped fluorescent lamps (e.g. bayonet capped lamps, induction lamps).

10.3.5 Exemption Wording Formulation

LEU[269] does not have a proposal for a wording describing lamps falling under Ex. 2(b)(4). *"LEU is of the opinion that a split would increase complexity of the exemptions and it make already difficult for authorities act appropriately regarding market surveillance. Thus the benefit of yet another category is nearly zero as specialty lamps are by their nature sold in small numbers".*

In the consultants' opinion, the current wording with "general lighting and special purpose" however, leaves areas of uncertainty and overlap with other exemptions as mentioned in Section 10.3.4. Moreover according to the applicant, lamps covered by Ex. 2(b)(4) usually have a specific special purpose. Thus general purpose lamps should be excluded from this exemption altogether.

The consultants further do not believe that a differentiation, based on wattage, form, bases or colour, would allow a clear demarcation of lamps actually covered by this exemption.

Furthermore, in terms of the technical availability of substitutes, argumentation for justifying the exemption can only be followed in support of the lack of substitutes for applications in the non-visible range and in part for lamps used for emergency lighting. The consultants' thus recommend a distinction between visible and non-visible light as well as further provision of the exemption for emergency lamps, where safety regulation does not permit the use of other than discharge lamps. The definition for the initial scope of non-visible light in the draft[270] for the new Ecodesign Regulation for lamps refers to *"mainly visible optical radiation in a wavelength of 380-780 nm".*

[269] Op. cit. LEU 2(b)(4)- (2015b)

[270] COMMISSION REGULATION (EU) …/ of XXX implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for lighting products

10.3.6 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.

LEU provides no estimation as to how much time is needed for a replacement of the existing 2(b)(4)-lamps, explaining that due to the low market segments and the vast variety there is no general roadmap to develop LED alternatives for all lamps covered by this exemption.

In contrast to LEU, the consultants do not believe that LED substitutes need to be available for “the total variety of 2(b)4 lamps”, i.e. for each and every type of lamp. In the consultants’ view a substitute needs to provide the same function, in this case light with similar quality and in parallel a substitute should not create significant negative environmental or health related impacts, such as significant additional energy consumption or hazardous waste.

It can be followed that Hg-free fluorescent substitutes are not available and that the potential for further Hg reductions has been realised to a certain degree.

LED alternatives are understood to be developing rapidly, however from available information it still seems that LED replacements are limited in their variety and possibly also in their compatibility as retrofit replacements for all applications of Ex. 2(b)(4).

For lamps such as induction lamps, tanning, black light, blue light, medical lamps, lamps for colour comparison, lamps with high colour rendering index, T12 lamps for areas with explosion protection or with external ignition strips, LEU is not aware of existing replacement lamps. Parameters are not provided in most of these cases to clarify on what basis a substitute should be compared to establish comparable performance. Against this background, it is not possible to determine the availability of substitutes in terms of their coverage of other fluorescent lamp functionalities, their dimensions and their electric compatibility. LEU also does not provide information to substantiate why such substitutes are lacking from a technical perspective (i.e. why they could not be produced on the basis of current LED technology). In this sense, and as it is stated that there is no roadmap to develop alternatives for all of the lamps covered by this exemption, it cannot be concluded for most of the application range if the lack of substitutes is due to the limited economic motivation to develop substitutes or due to actual technology limitations.

Against this background, the consultants are of the opinion that there is no justification why the formulation of Ex. 2(b)4 should remain general in nature, creating a “blanket”

exemption that is open to applications covered by other exemptions of Annex III. Broad and unspecific wording formulations do not conform to the requirements of the recast Directive (RoHS 2), which requires limiting exemptions in their scope (see Recital 19). In contrast to LEU, the consultants do not believe that the current exemption wording covers only “other fluorescent lamps” which are understood to be Ex. 2(b)4 special purpose lamps. It is concluded that Ex. 2(b)(4) could only cover double capped fluorescent lamps used for special purposes as well as other than single and double capped fluorescent lamps. In this respect, technical justification as to the lack of substitutes can only be followed for UV lamps and in part for lamps used in emergency lighting.

In relation to the exemption mercury allowance, examples of lamps falling under this exemption show that in some cases the limit is needed but that in other cases a far lower threshold could be applied. Nonetheless, the consultants do not believe that leaving the threshold at its current level would motivate the development of new lamps taking advantage of the allowance and propose not to change the threshold.

10.4 Recommendation

In light of the lacking data related to replacement lamp availability, the consultants would recommend a short term renewal for most applications. This period should allow industry to compile data so as to clarify if indeed a substitution problem exists that could create substantial waste resulting from early EoL of luminaires, as well as allowing a demarcation of lamps actually requiring the availability of this exemption. The consultants would further recommend cancelling the exemption, should industry fail to provide substantiated information in this respect in the future. For this purpose the consultant proposes a 3 year exemption. This short period is recommended as it can be understood that stakeholders must only compile information as to current applicatons, which should thus be available. The consultants can follow that other applications may exist relevant for the scope of this exemption, however information has not been provided to clarify why such applications would indeed be covered by Ex. 2(b(4), nor to justify the renewal of the exemption on the basis of Article 5(1)(a) for such cases.

The only exceptions to this rule are the cases of emergency lighting lamps, for which replacement lamps are specified in safety regulation and standards, and UV lamps for which technical information is available to support why LED alternatives currently do not provide comparable performance. An exemption of the maximum permissible 5 year duration is recommended for such lamps.

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.

Exemption 2(b)4	Duration*
(I) Lamps for other general lighting and special purposes (e.g. induction lamps); 15 mg may be used per lamp after 31 December 2011	For Cat. 8 & 9: 21 July 2021 For Sub-Cat. 8 in-vitro: 21 July 2023; For Sub-Cat. 9 industrial: 21 July 2024
(II) Lamps emitting light in the non-visible spectrum: 15 mg per lamp	For Cat. 5: 21 July 2021
(III) Emergency lamps: 15 mg per lamp	For Cat. 5: 21 July 2021
(IV) Mercury in other fluorescent special purpose lamps not specifically mentioned in this Annex: 15mg per lamp	For Cat. 5: 21 January 2019

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

10.5 References Exemption 2(b)4

LEU Ex. 2(b)(4) (2015a) LightingEurope, Request to renew Exemption 2b(4) under Annex III of the RoHS Directive 2011/65/EU Lamps for other general lighting and special purposes (e.g. induction lamps): 15 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_b__3-4_/Lighting_Europe/2b4_LE_RoHS_Exemption__Req_Final.pdf

LEU Ex. 2(b)4 (2015b) LightingEurope, Response to Oeko-Institut regarding the 1st Questionnaire Exemption No. 2(b)4 (renewal requests) Mercury in other fluorescent lamps not exceeding (per lamp): (4) Lamps for other general lighting and special purposes (e.g. induction lamps): 15 mg per lamp", submitted 25.9.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_2_b__3-4_/Lighting_Europe/Ex_2b4_LightingEurope_1st_Clarification-Questions_final.pdf

VHK & VITO (2015) VITO in cooperation with VHK, 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, available under: http://ecodesign-lightsources.eu/sites/ecodesign-lightsources.eu/files/attachments/LightSources%20Task4%20Final%2020151031.pdf

11.0 Exemption 3(a-c): "Mercury in other fluorescent lamps not exceeding (per lamp): (3) Non-linear tri-band phosphor lamps with tube diameter > 15 mm (e.g. T9)”

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

Cat. 5	Lighting equipment
Cat. 8	Medical devices
Cat. 9	Monitoring and control instruments
CCFL	Cold cathode fluorescent lamps
EEE	Electrical and Electronic Equipment
EEFL	External electrode fluorescent lamps
EoL	End-of-life
Hg	Mercury
IMCI	Industrial monitoring and control instrument
LED	Light emitting diode
LEU	LightingEurope

11.1 Background

LightingEurope (LEU)[271] has applied for the renewal of Ex 3(a-c) of Annex III of the RoHS Directive. This exemption covers cold cathode fluorescent lamps and external electrode fluorescent lamps (CCFL and EEFL) for special purposes, explained to be a small group of lamps required on the EU market.[272]

LEU[273] explains that lamps falling under exemptions 3(a-c) *"are mostly used for applications for backlighting of liquid crystal displays such as in computer displays and monitors. These lamps are described in the ruling provided on March 13, 2014 in Annex IV to Directive 2011/65/EU under point 35[274] . While not all applications are specifically known to us some special lighting applications in equipment, displays and indicator panels, are replaced professionally, as these lamps are usually custom sizes and colours and are not made with typical lamp end caps that fit into standardized lamp sockets. While many new designs have already been changed to LEDs there are products made, although in very limited usage, that have not yet been redesigned. Based on the prior submission by The Test and Measurement Coalition, the subsequent Oeko recommendations and the EU adoption of the Category 35 exemption we respectfully amend the proposal for application in Category 5 and request consideration under Category 9 to allow for the continued limited use in these products where the change in technology has not yet been adopted*."

LEU applies for the renewal of the exemption, requesting the current wording formulation as listed in Annex III of the RoHS Directive and the maximum available duration allowed (based on Art. 5(2) of the Directive):

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[271] LEU Ex. 3(a-c)(2015a), LightingEurope, Request to renew Exemption 3(a-c) Under Annex III of the RoHS Directive 2011/65/EU Mercury in cold cathode fluorescent lamps and external fluorescent lamps (CCFL and EEFL) for special purposes not exceeding per lamp: 3(a) Short length ≤ 500mm 3.5mg/lamp; 3(b) Medium length (> 500mm and ≤1500mm) 5mg/lamp; 3(c) Long length (> 1500mm) 13mg/lamp, submitted 15.1.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_3__a-c_/3a_3b_3c_LE_RoHS_Exemption_Req__Final.pdf

[272] Op. cit. LEU Ex. 3(a-c)(2015a)

[273] LEU Ex. 3(a-c)(2015b), LightingEurope, Response To Oeko-Institut regarding the 1st Questionnaire Exemption No. 3, submitted 21.10.2015, available under http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_3__a-c_/LE_Ex_3_abc__1st_Clarification-Questions_final.pdf

[274] Referenced in LEU Ex. 3(a-c)(2015b), as http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:32014L0075

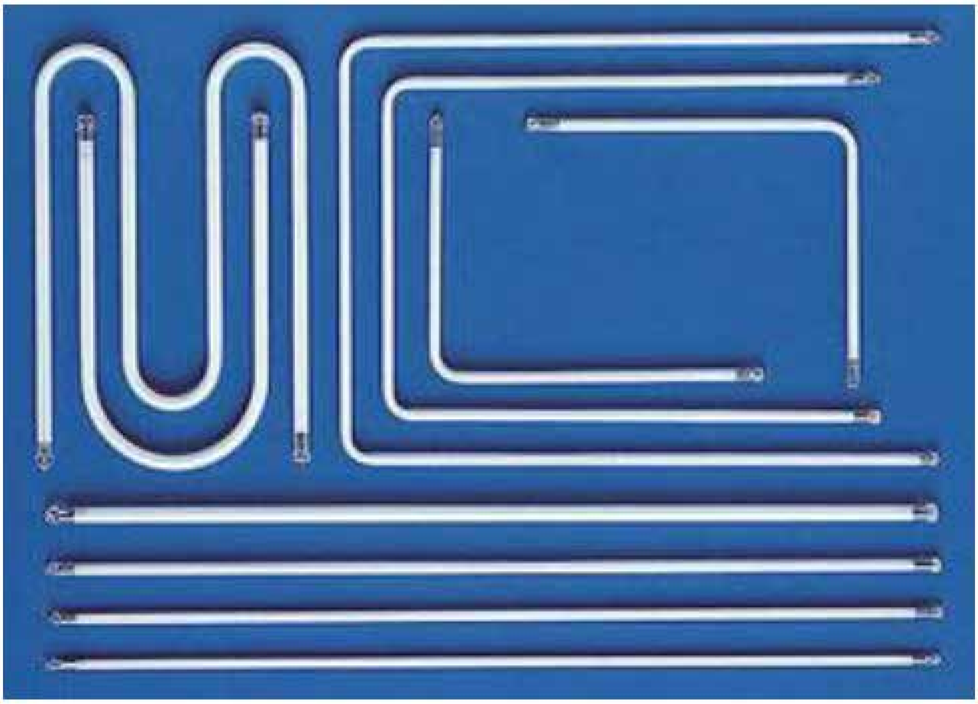
	Exemption	Scope and dates of applicability
3	Mercury in cold cathode fluorescent lamps and external electrode fluorescent lamps (CCFL and EEFL) for special purposes not exceeding (per lamp):	
3(a)	Short length (≤ 500 mm)	No limitation of use until 31 December 2011; 3,5 mg may be used per lamp after 31 December 2011
3(b)	Medium length (> 500 mm and ≤ 1 500 mm)	No limitation of use until 31 December 2011; 5 mg may be used per lamp after 31 December 2011
3(c)	Long length (> 1 500 mm)	No limitation of use until 31 December 2011; 13 mg may be used per lamp after 31 December 2011

11.2 Description of Requested Exemption

LEU[275] explains that there is a continued use of CCFL, otherwise known as sub-miniature cold cathode fluorescent lamps, for illuminating the backlight of a liquid crystal display, or in other equipment for such use as medical, inspection and professional equipment, backlit display, laptop computer displays and computer monitors. These lamps tend to have an extremely long effective life under normal use with typical rated life times at 25,000 hours or more. The lamps are not fitted with an industry standard end cap or termination and are typically hard wired into the appliance or connected via snap in terminals. These lamps are not typically used in general lighting applications and are not intended to be replaced by the user. Replacements are typically made by the equipment manufacturer or repair facility and the spent lamps would be required to be recycled. Examples of lamps covered by this exemption are shown in Figure 11-1.

[275] Op. cit. LEU Ex. 3(a-c)(2015a)

Figure 11-1; Examples of lamps covered by Ex. 3(a-c)



Source: LEU Ex. 3(a-c)(2015a)

LEU[276] elaborates that fluorescent lamps are low-pressure discharge lamps containing a phosphor coating. They contain a small amount of intentionally added mercury in the discharge tube, which is essential to convert electrical energy to light. Lamps in the scope of exemption 3(a)(b)(c) are in a variety of lamp families with mercury content from 3.5 mg up to 13 mg. They are mainly niche products with extremely low market size compared to the other fluorescent lamps.

LEU[277] details a few definitions appearing in other regulations for the term special purposes and proposes the following definition:

> "*Special purpose lamps have documented and communicated application-specific features. They [are] generally manufactured in accordance with general-purpose lamp making technology. The use of special design, materials and process steps provide their special features*."

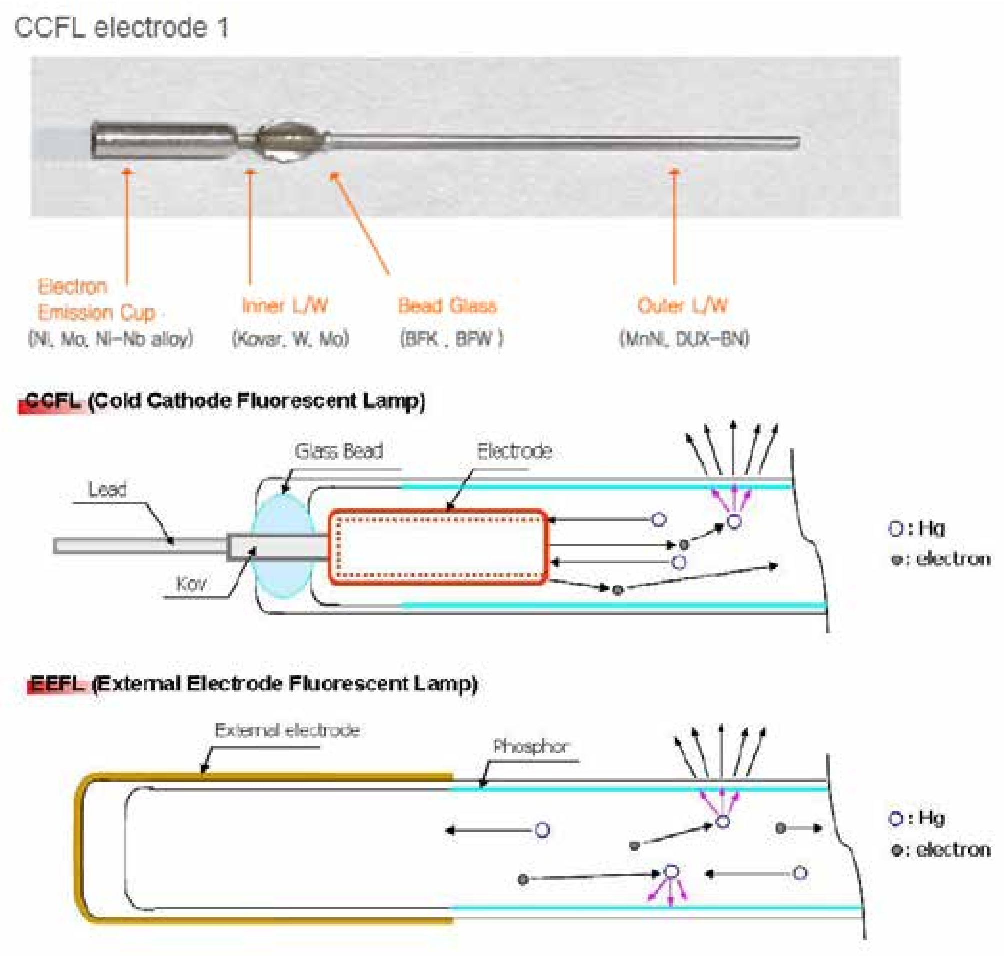
LEU[278] specifies various examples of lamps considered to be special purpose lamps (see application cited above as LEU Ex. 3(a-c)(2015a)) and contends that Ex. 3(a-c) includes an inhomogeneous group of lamps falling under most of the mentioned examples. CCFL and

[276] Op. cit. LEU Ex. 3(a-c)(2015a)
[277] Op. cit. LEU Ex. 3(a-c)(2015a)
[278] Op. cit. LEU Ex. 3(a-c)(2015a)

EEFL fluorescent lamps are always components of a lighting system. They reveal amongst others different:

- Form factors and bases, e.g. linear, circular, square shape;
- Technologies e.g. induction, external ignition;
- Phosphor types;
- Mercury content, from < 2 mg up to a maximum of 13 mg.

Figure 11-2: Technical schematic of CCFL and EEFL Lamps



Source: LEU Ex. 3(a-c)(2015a)

11.2.1 Amount of Mercury Used under the Exemption

Lamps covered by exemption 3(a)(b)(c) are a very small segment of all fluorescent lamps. Although this data is not formally collected, the total mercury content of lamps in this class are estimated at less than 1% of the total [not specified as total of what – consultants comment]. LEU provides representative data from 2009 to 2013 as to the number of produced lamps and the corresponding mercury amount put on the EU (plus Switzerland, plus Norway) market of all lamps falling in the current exemptions 1(e), 2(b)(2), 2(b3), 2(b4), 3(a)(b)(c) and 4(a) of Annex III, RoHS Directive (all non-linear lamps and all lamps for special purposes). The data shows a decreasing market from 2011 to

2012. In 2013 ca 17.3 million non-linear and special purpose lamps have been marketed. The overall roughly estimated yearly mercury input decreased from 2009 to 2013 from ca 437 kg to 174 kg. Based on this estimate the total mercury content placed on the market through Ex. 3(a-) in 2013 was less than 2kg. [279]

11.3 Applicant's Justification for Exemption

LEU states that while many new designs have already been changed to LEDs that these lamps do not lend themselves to retrofit. This is explained to be since neither form, fit nor function are adequate and the entire electrical/electronic control gear is different for a cold cathode fluorescent lamp. Any substitute of the cold cathode fluorescent lamp with an LED would require multiple changes to the equipment to enable proper function as explained below. Replacements and repairs using LEDs therefore would not be practical.[280]

11.3.1 Possible Alternatives for Substituting RoHS Substances

LightingEurope explains that during the last decades several approaches have been made to design low pressure discharge lamps where the light producing element Hg is replaced by a less hazardous material. So far no approach yielded a result with comparable luminous efficacy, product cost and product availability as the (still state of the art) Hg low pressure discharge lamps. However, it is said that with the arrival of equally efficient LED light sources, research into alternative discharge technologies has stopped at most companies and universities. Further details of such research efforts can be viewed in LEU's applications. [281]

Information is also provided as to the accomplishments in terms of Hg reduction. In lamps falling under Ex. 3(a-c) special phosphors and additives cause higher mercury consumption. Furthermore, non-linear fluorescent lamps (such as those falling under this exemption) always need more mercury compared to linear lamps. For such lamps it was necessary to implement a reduction to a range of 3.5 – 13 mg coming in force in 2012. Only a part of the lamps had to be changed. Most of them already had significantly lower mercury content as similar reduction measures, applied in other fluorescent lamp types used for general lighting, could be realized in such lamps as well. Dosage possibilities for the CCFL are lower than those of other specialty fluorescent lamps indicated for example in 2(b)(4). Further reduction of mercury might technically be possible with high economic effort and R&D resources. But these financial and human resources are needed for the investments and the running transfer to LED technology. The major part of development resources of lighting companies have already been allocated to LED based alternatives. On the other hand the lamps are required for the existing base of

[279] Op. cit. LEU Ex. 3(a-c)(2015a)
[280] Op. cit. LEU Ex. 3(a-c)(2015b)
[281] Op. cit. LEU Ex. 3(a-c)(2015a)

fixtures systems and luminaires, which are also highly efficient and have a long life time.[282]

11.3.2 Possible Alternatives for Eliminating RoHS Substances

LEU explains that there are two key ways to use LED technology in order to substitute fluorescent lamps can be distinguished: (1) replacement lamps, (2) new installations.[283] LEU[284] explains that, while many new designs of displays and control panels have already been redesigned to function with LEDs, there are products, although in very limited usage, that have not yet been redesigned.[285] Currently LEU has no reliable market data about LED retrofit/conversion lamps, which could be used as substitutes for lamps falling under Ex. 3(a-c). Many existing and new lamp manufacturers are working on new products. Standards are in preparation in order to address above mentioned technical challenges. [286]

LEU[287] explains that there is a growing market for mercury-free lamps based on LED technology with features such as energy efficiency and design flexibility as an array of LEDs on a printed circuit board. However, based on numerous performance criteria LED tubes, strips, strings or arrays are not fully equivalent to fluorescent lamps; hence cannot generally replace them in their broad usage base. It must be decided case by case, if the LED based solution can be an effective replacement for the existing device and situation. It mostly requires involvement of people with professional expertise due to the following issues (aspects raised have been mentioned in relation to other exemptions, see for example report for Ex. 2(b)(3) and are thus only summarised below):

- Electrical compatibility;
- Applicable legal and compliance requirements like conformity assessments, declaration, and labelling of the changed luminaire are needed;
- Different light distribution;
- Restricted choice in the LED based lamps;
- LED lamps contain components using materials such as the RoHS regulated substance lead in applications exempted by Annex III of the Directive.

LEDs do not lend themselves to retrofit since neither form, fit nor function, is adequate and the entire electrical/electronic control gear is different for a cold cathode fluorescent lamp vs. an LED. Any substitute of the cold cathode fluorescent lamp with an LED would require a complete change of the power supply and control gear. In addition the light dispersion is different in a cold cathode fluorescent lamp than an LED and

[282] Op. cit. LEU Ex. 3(a-c)(2015a)
[283] Op. cit. LEU Ex. 3(a-c)(2015a)
[284] Op. cit. LEU Ex. 3(a-c)(2015b)
[285] Op. cit. LEU Ex. 3(a-c)(2015b)
[286] Op. cit. LEU Ex. 3(a-c)(2015a)
[287] Op. cit. LEU Ex. 3(a-c)(2015a)

would require a change in the light guides[288] to provide even light distribution. Replacements and repairs using LEDs therefore would not be practical. [289]

Linear LED luminaires are providing a viable alternative to the traditional fluorescent tube with such features as: efficacy, energy efficiency, and design flexibility and appearance. But the quality and performance of LED products varies among manufacturers. Many conformity and performance related issues have been solved. Dedicated designed luminaires directly comply as a system with all safety and standardization legislations which are tested and confirmed by the luminaire manufacturer. New installations might be especially relevant for exemption 3(a-c) as LED luminaires can offer many different optical and performance characteristics. Especially the new functionalities of LED solutions (colour changing, flexible form factors, tailor made sizes etc.) could lead to new lighting options and extension of the use of these products. [290]
LEU summarises that there is a fast increase in the use of LED based technologies. On the other hand LED retrofit or conversion lamps replacing lamps covered by Ex. 3(a-c) are nearly not available on the EU market.

11.3.3 Environmental Arguments

There are several external LCA's performed regarding lighting. There is general agreement, that the main environmental impact is created during the use phase, meaning through electricity consumption of the lamp. This means that currently the efficacy of the lamp is the determining parameter in regard to the total environmental performance. On the other hand, LEU states that for lamps covered by the exemption 3(a-c) the specific purpose is essential. It only makes sense to perform an LCA comparing it with a lead- and mercury-free lamp if the specific characteristics and requirements to the fluorescent lamp are met. LEU is not aware of such LCAs. [291]

11.3.4 Roadmap to Substitution

In new equipment, integrated LED solutions are rapidly entering the market. In existing equipment, however, replacing CCFLs/EEFLs with LED lamps is still problematic, as retrofit LED lamps are not available for the whole range of products. Since the equipment is diverse and not manufactured by the lighting companies, LEU cannot provide an accurate time line as to when such equipment shall be replaced (eliminating the need for replacement lamps). Stopping replacement (i.e., with CCFLs/EEFLs) would

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[288] According to AVAGO Technologies (2006), Light Guide Techniques - Using LED Lamps, Application Brief I-003, available under http://www.avagotech.com/docs/5988-7057EN: „A light guide is a device designed to transport light from a light source to a point at some distance with minimal loss. Light is transmitted through a light guide by means of total internal reflection.“
[289] Op. cit. LEU Ex. 3(a-c)(2015b)
[290] Op. cit. LEU Ex. 3(a-c)(2015a)
[291] Op. cit. LEU Ex. 3(a-c)(2015a)

render otherwise well-functioning equipment useless, and would lead to unnecessary waste. [292]

11.4 Stakeholder Contributions

A number of contributions have been made by stakeholders raising general points in relation to discharge lamps. As none of these raise aspects specifically of relevance for this exemption, the information is not reproduced here, but can be viewed in Section 4.4 of the general lamp chapter.

11.5 Critical Review

11.5.1 Scientific and Technical Practicability of Substitution

From the information provided by LEU it can be understood that CCFLs and EEFLs are used as lights sources of various EEE equipment, for example in the lighting of displays, control panels etc. In many cases, such equipment has been redesigned and new models placed on the market at present use LED light sources. From the information provided, it is assumed that this is the case for most new EEE placed on the market, though there could be a very small amount of products that are yet to be redesigned.

In this respect, it can be followed that LEU requests the renewal of the exemption to allow further use of CCFLs and EEFLs for repair of equipment already on the EU market. It could be considered that parts needed for repair of equipment would benefit from the Article 4(f) provision, which allows the use of RoHS restricted substances in cables or spare parts for repair of EEE, which benefited from an exemption and which was placed on the market before that exemption expired, as far as the specific exemption is concerned. Assuming a lamp used in a display unit could be defined as a spare part, this article may apply. This aspect was dicussed in the evaluation of a request for exemption submitted by the Test and Measurement Coalition in 2011 as detailed below:

> *"The possibility of using non-compliant spare parts and components can be summarized as follows:*
>
> *Article 4(4)(e) provides an exclusion from the RoHS stipulations for cables and spare parts needed for repair, reuse, updating and upgrading of sub-category 9 industrial products placed on the market before July 2017. If the displays (containing the non-compliant CCFLs) can be considered to be spare parts, this exclusion would apply. However, it is unclear if components can be understood to be spare parts.*
>
> *Article 3(27) defines spare parts as:*
>
>> *'a separate part of an EEE that can replace a part of an EEE. The EEE cannot function as intended without that part of the EEE. The functionality of EEE is restored or is upgraded when the part is replaced by a spare part;'*

[292] Op. cit. LEU Ex. 3(a-c)(2015b)

Components are not specifically defined in the Directive, though they are mentioned in the stipulations made concerning cases in which exemptions may be justified, in the context of obtaining an exemption for "materials and components of EEE".

The EU Commission RoHS FAQ Document[293] *provides some further insight as to the definition and use of components. Components, can 'be separated and used as fully functional separate products'. The relation between spare parts and components remains unclear, though the FAQ document also details when components need to be RoHS compliant and when not:*

> *'Since equipment consists of different components, the EEE itself can only meet the substance requirements if all its components and parts meet the substance restriction requirements of RoHS 2… Therefore components being used in finished EEE or for repair or upgrade of used EEE, which is in the scope of RoHS 2 must meet the substance restrictions according to Art. 4 but do not need CE marking.'*

However, the document also makes a distinction to this avail, between the use of non-compliant components in products already in the scope of RoHS and between products that are excluded from scope – whether per directive exclusion or per exemption:

> *'Components… if produced to be used in a product benefiting from an exclusion do not have to be CE marked and do not have to comply with the substance requirements.'*

This clarifies, that if the 5mg mercury CCFL based displays are to be seen as components, they could be used in products benefiting from an exclusion, i.e., in sub-cat. 9 industrial products placed on the market before 22.7.2017. It is however unclear, if non-compliant components are further excluded for repair, reuse etc. in such products after this category comes into scope. To summarize:"

- *if the displays and the lamps fall under the definition of spare parts, their use benefits from a further exclusion, so that the exemption would not be needed;*
- *if they fall under the definition of components, it must be clarified:*
  - *whether components fall under the definition of spare parts, in which case an exemption is again not needed; or*
  - *if components are not covered by this exclusion, as it is unclear if non-compliant components can further be used for the repair of products placed on the market during the exclusion period, an exemption may be needed. This would require the fulfilment of one of the Article 5(1)(a) criteria for justifying an exemption."*

[293] Referenced as: EU COM, 2012, ROHS 2 FAQ Guidance Document, updated 12.12.2012, Q7.1 & Q 7.3; available under http://ec.europa.eu/environment//waste/rohs_eee/pdf/faq.pdf, accessed 16.5.2013

As the exemption recommended for the TMC evaluation was granted, it is understood that the EC concluded that a lamp (or at least a lamp used as part of a display) was not to be understood to fall under the scope of the term spare part.

It should further be noted that should an exemption not be granted, with the understanding that the application would be covered as a spare part benefiting from Article 4(f), that this could raise a general question as to when a lamp installed in an EEE is to be understood as a spare part.

In equipment already on the market using CCFLs or EEFLs in displays, there is little knowledge of the availability of LED replacements and it is explained that such replacements shall have difficulty in providing comparability with Ex. 3(a-c) lamps. Reasons for this include, among others, the large variety of CCFL/EEFL dimensions and forms, difficulties in electric compatibility, and differences in light distribution. LEU was thus asked if the exemption could be limited to use in EEE placed on the market in the past and if specific product sub-groups could be specified in which such lamps are still needed for new products to be placed on the market in the coming 5 years. LEU stated in response "Yes we agree that we can limit the use of these lamps as stipulated in Exemption request 20a of 2012 Consultation 4".

The request mentioned was submitted by the Test and Measurement Coalition in 2011. TMC explained that the mercury allowance of Ex. 3(a) would be limited to 3.5 mg after 31.12.2011, whereas for industrial monitoring and control instruments (IMCI) still not in the scope of RoHS at the time of this change, in some equipment, lamps with 5mg would still be needed. It was established that the exemption was only needed for IMCI to be placed on the market before 21.7.2017, as lamps in such equipment used up to 5mg. An exemption was thus recommended, limiting its scope to equipment placed on the market before this date. The recommendation was followed and Ex. 35 was thus added to Annex IV and reads as follows:

> "*Mercury in cold cathode fluorescent lamps for back-lighting liquid crystal displays, not exceeding 5 mg per lamp, used in industrial monitoring and control instruments placed on the market before 22 July 2017*"

The consultants thus conclude that if exemption 3(a-c) should be renewed, that it could be limited in a similar manner, as shall be discussed in Section 11.5.4 below.

11.5.2 Environmental Arguments

There are currently no LCA-studies available in relation to the application of CCFL and EEFL in the context of the exemption at hand. Taking into account the above mentioned situation that the scope of the exemption could be limited to EEE placed on the market in the past, the same environmental arguments, which were relevant with respect to Ex. 35 of Annex IV could be taken into account:

> "*If such replacement is not allowed, once a malfunction occurs in a relevant device, in cases where display substitutes are not drop-in, devices will not be repairable and thus shall have to be scrapped….Furthermore, the premature disposal of devices is perceived as negative from an environmental standpoint.*

Though a comprehensive comparison has not been made, the consultants can follow that favouring the replacement of displays with non-compliant units with up to 5 mg mercury per CCFL, over replacement of the whole device, would be in-line with the RoHS Directive intentions. In particular when referring to Item 20 of the RoHS 2 legal text, which states that '...product reuse, refurbishment and extension of lifetime are beneficial.'[294]... In this sense, not recommending an exemption would promote the early disposal of such devices before they have reached their full service potential, contributing to the production of more waste."

11.5.3 Stakeholder Contributions

There were no specific contributions submitted regarding the exemption at hand, for the discussion of general aspects raised by stakeholders, please see Section 4.5.7 of the general chapter.

11.5.4 Scope

As explained above, it can be understood that the scope of the requested exemption could be limited to use in EEE placed on the market before a certain date. It is understood that this was the situation already in October 2015, when LEU approved that this strategy was practical. In parallel, the current exemption is scheduled to expire on 21.7.2016, and it is thus assumed that manufacturers would be expected to consider that beyond this date the exemption could change. As manufacturers could be expected to prepare for a situation in which the exemption was no longer available, it is concluded that a renewal of the exemption could be limited to EEE placed on the market by the date of the EC decision on this exemption renewal.

In parallel, it is understood that there may be equipment for which redesign has not been completed yet, and for which new EEE placed on the market may still require an exemption in order to use CCFLs and EEFls currently addressed by Ex. 3(a-c). Despite being asked, LEU did not specify particular groups of such equipment. However, as their answers were part of the information submitted for this request to stakeholder consultation, manufacturers would have been expected to participate in the stakeholder consultation were this to be relevant for their equipment. The only EEE for which this may not be the case is equipment falling under Cat. 8 (medical devices) and Cat. 9 (monitoring and control instruments), for which the exemption is understood to remain available.

In the consultants view CCFLs and EEFLs are lamps, which as such, are understood to fall under Cat. 5 (lighting equipment). In this sense, the consultants would recommend providing an exemption for Cat. 5 lamps. This is understood not to limit the possibility of installing such lamps as components in equipment of other categories, as long as the

[294] See Directive 2011/65/EU (RoHS 2), item 20.

exemption wording does not limit its applicability to specific types of equipment and/or categories.

A further aspect to be considered in this respect is the current Ex. 35 listed under Annex IV. As explained above, equipment falling under other categories such as IMCI of Sub-Cat. 9 industrial, would still benefit from an exemption for lamps of Cat. 5, as long as such equipment was included in the scope of the exemption. It is thus recommended that the EC consider the possible merits of merging Ex. 35 of Annex IV with Ex. 3. This would require transferring Ex. 35 to Annex III and limiting its applicability to lamps of Cat. 5, used in IMCI of Sub-Cat. 9 industrial.

11.5.5 Conclusions

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

- their **elimination or substitution** via design changes or materials and components which do not require any of the materials or substances listed in Annex II is scientifically or technically impracticable;
- the **reliability** of substitutes is not ensured;
- the total negative **environmental, health and consumer safety impacts** caused by substitution are likely to outweigh the total environmental, health and consumer safety benefits thereof.

It can be followed that substitutes in the form of LED have become available, and that they are used as lighting sources in new equipment coming on the market. However, it is also understood that it is not feasible to use LED lamps as replacement for the repair of EEE originally designed with CCFL/EEFL light sources. Due to the expected variety of CCFL and EEFL lamps in terms of form, electrical configuration and light distribution, it can be followed that LED replacement lamps for such equipment may be lacking and/or may be non-comparable. Should an exemption be denied under such circumstances, it is possible that in some cases LED replacements would become available. However in others, it can be followed that replacements would either not be sufficiently reliable or that they would not be available. In such cases, the relevant component (display, control panel) and possibly the complete equipment would be scrapped as it would no longer function properly. As CCFLs and EEFLs are understood to have a wide variety, it is assumed that this scenario is relevant for a wide range of EEE placed on the market before 22.7.2016.

11.6 Recommendation

As explained above, it can be understood that LED replacements for CCFLs and EEFLs in EEE of Cat. 1-7 and 10, placed on the market before July 2016 (or before the EC's decision date on this exemptions renewal), are for the most part either lacking or not compatible. It is thus recommended to renew the exemption, while limiting its scope to such equipment. It is further recommended to merge Ex. 35 of Annex IV with this exemption, so that all exemptions for CCFL and EEFL are located under the same entry of one annex. Though it is possible that other equipment of Cat. 8 and Cat. 9 may also be

coming on the market with LED alternatives, Article 5(2) provides other duration periods of the current exemption for these categories. In this respect, in future evaluations, consideration could be given to the further need of the exemptions for these categories.

Exemption 3	Duration*
Mercury in cold cathode fluorescent lamps and external electrode fluorescent lamps (CCFL and EEFL) for special purposes not exceeding (per lamp):	
(a) Short length (≤ 500 mm), 3.5 mg may be used per lamp	For Cat. 8 & 9: 21 July 2021; For Sub-Cat. 8 in-vitro: 21 July 2023; For Sub-Cat. 9 industrial: 21 July 2024
(b) Medium length (> 500 mm and ≤ 1 500 mm), 5 mg may be used per lamp	
(c) Long length (> 1 500 mm) 13 mg may be used per lamp	
(d) Short length (≤ 500 mm), 3.5 mg may be used per lamp in EEE placed on the market before 22 July 2016*	For Cat. 5: 21 July 2021
(e) Medium length (> 500 mm and ≤ 1 500 mm), 5 mg may be used per lamp in EEE placed on the market before 22 July 2016*	
(f) Long length (> 1 500 mm) 13 mg may be used per lamp in EEE placed on the market before 22 July 2016*	
(g) For back-lighting liquid crystal displays, not exceeding 5 mg per lamp, used in industrial monitoring and control instruments placed on the market before 22 July 2017	Alternative a: For Cat. 5: 21 July 2021; or Alternative b: For Sub-Cat. industrial: 21 July 2024

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

11.7 References Exemption 3(a-c):

LEU Ex. 3(a-c)(2015a) LightingEurope, Request to renew Exemption 3(a-c) Under Annex III of the RoHS Directive 2011/65/EU Mercury in cold cathode fluorescent lamps and external fluorescent lamps (CCFL and EEFL) for special purposes not exceeding per lamp: 3(a) Short length ≤ 500mm 3.5mg/lamp; 3(b) Medium length (> 500mm and ≤1500mm) 5mg/lamp; 3(c) Long length (> 1500mm) 13mg/lamp, submitted 15.1.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_3__a-c_/3a_3b_3c_LE_RoHS_Exemption_Req__Final.pdf

LEU Ex. 3(a-c)(2015b) LightingEurope, Response To Oeko-Institut regarding the 1st Questionnaire Exemption No. 3, submitted 21.10.2015, available under http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_3__a-c_/LE_Ex_3_abc__1st_Clarification-Questions_final.pdf

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

Declaration

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

Acronyms and Definitions

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

12.1 Background

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

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

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

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

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

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

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

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

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

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

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

[299] Op. cit NARVA (2014a)

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

12.2 Description of Requested Exemption

According to LEU[301], such lamps are produced with similar manufacturing techniques as fluorescent lamps, but are used in highly specific applications to produce light in the ultra-violet C (UVC) region. *"The lamps are not phosphor coated and do not produce visible light nor are they intended for illumination purposes. Unlike general visible lighting lamps or specialty lighting lamps, which may be produced with soda-lime glass, which intentionally blocks UVC transmission, these lamp types will allow the transmission of light in the deep UVC region of 185-254nm. The practical uses of these lamps are for ultraviolet germicidal or bacterial disinfection of: fluids such as drinking water; waste water; water for food, beverage, pharmaceutical preparation; aquaculture; fish farming; semiconductor manufacturing; surface disinfection; air disinfection. The lamps are installed in equipment for industrial, commercial and residential applications and the use of these is growing as they have been accepted by Environmental Agencies worldwide to kill many forms of bacteria including, but not limited to giardia and cryptosporidia[302]. These low pressure gas discharge lamp types can be T5, T6, T8, T10 and T12, which are industry standards, but can also include other tubular lamp types outside dimensions or compact Hg discharge lamp shapes like single ended bended or bridged 2, 4, or 6 legged lamps. Due to their highly specialized use, the lamps may be double ended with standard lighting end caps or may be single ended with standard or custom end cap configurations. Lamps may also be made in custom sizes and lengths and power levels. Power ranges for these lamp types can vary from 1W/5W to 1000W and are typically dimmed in operation. The operating environment of these lamps varies greatly. The operating temperature range can potentially be 0˚C to 100˚C. They may be operated directly in air, in a sleeve in air, or in a sleeve in water. Thermal control may become a necessity for these lamp types especially in higher powered lamp types."*

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

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

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

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

[302] So-called "Cryptosporidium"

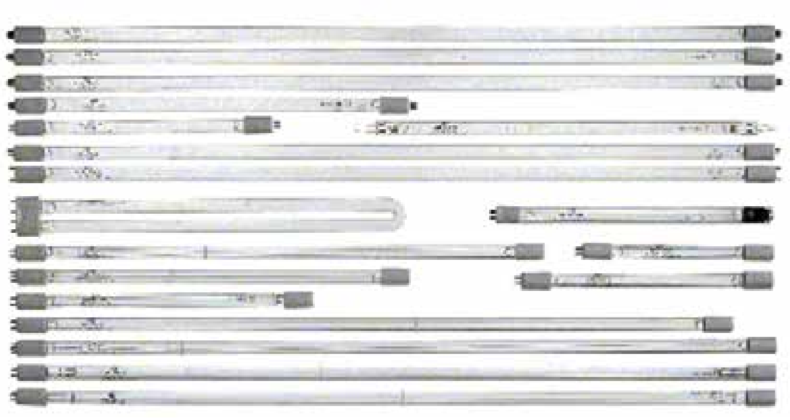
[303] NARVA (2015): NARVA Lichtquellen GmbH + Co. KG, Additional information provided after first questions for clarification Date of submission: August 24, 2015, available under http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_4_a_/NARVA/Ex._4_a__Narva_Answers_2_Clarification_Questions_24.8.2015.JPG

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

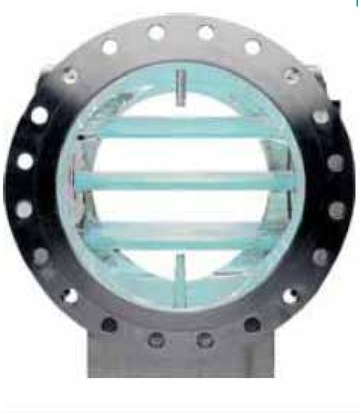
In the following table a non-exhaustive selection of lamps falling under Ex. 4(a) is listed.

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

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

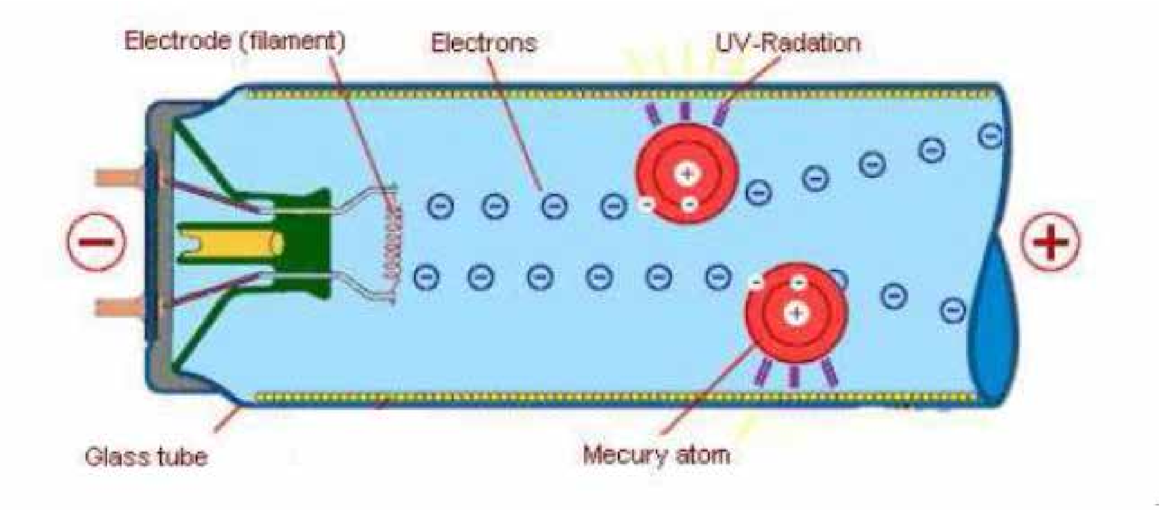
Lamps and applications	**Example**
Lamps types	
Ultraviolet lamps	
CFL UVC lamps	 

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

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

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

Figure 12-1: Function of mercury in lamps



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

12.2.1 Amount of Mercury Used under the Exemption

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

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

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

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

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

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

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

12.3 Applicant's Justification for Exemption

LEU claims[309] that at present *"there is no available LED that can produce light in the 185-254nm range of the UVC spectrum or other lighting technology that may use less mercury, or can be used as a substitute for these lamps. There are UVC producing LEDs which are in the early stages of development and use, at the higher wavelengths of the UVC spectrum i.e. 365-405nm, however these would not perform the same germicidal function as the lamps covered under this request. It is estimated by the LED manufacturers that deep UVC LEDs will not be available for five to ten years due to the high power and long life requirements that are available with low pressure gas discharge lamps."*

12.3.1 Possible Alternatives for Substituting RoHS Substances

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

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

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

12.3.2 Possible Alternatives for Eliminating RoHS Substances

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

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

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

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

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

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

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

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

12.3.3 Road Map to Substitution

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

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

12.4 Stakeholder Contributions

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

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

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

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

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

12.5 Critical Review

12.5.1 Scientific and Technical Practicability of Substitution

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

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311 Op cit LEU Ex. 4a (2015a)

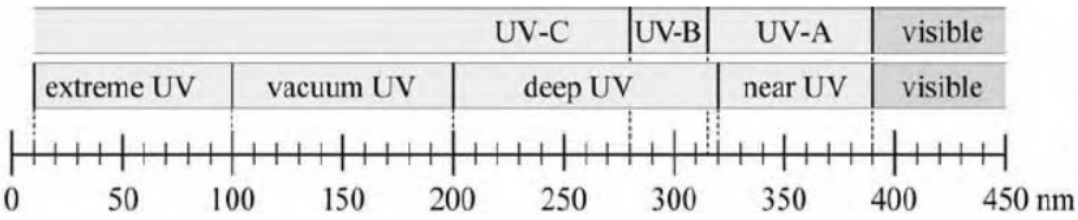
312 JBCE (2015a): Japan Business Council (JBCE), Comment on public consultation of 4(a): "Mercury in other low pressure discharge lamps (per lamp) in 2015 Consultation submitted 14 October 2015, available under http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_4_a_/Comment_on_public_cousulation_of_Exemption_request_2015-2_4_a_.pdf

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

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

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

Figure 12-2 Classification of UV radiation



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

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

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

12.5.2 Environmental Arguments

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

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

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

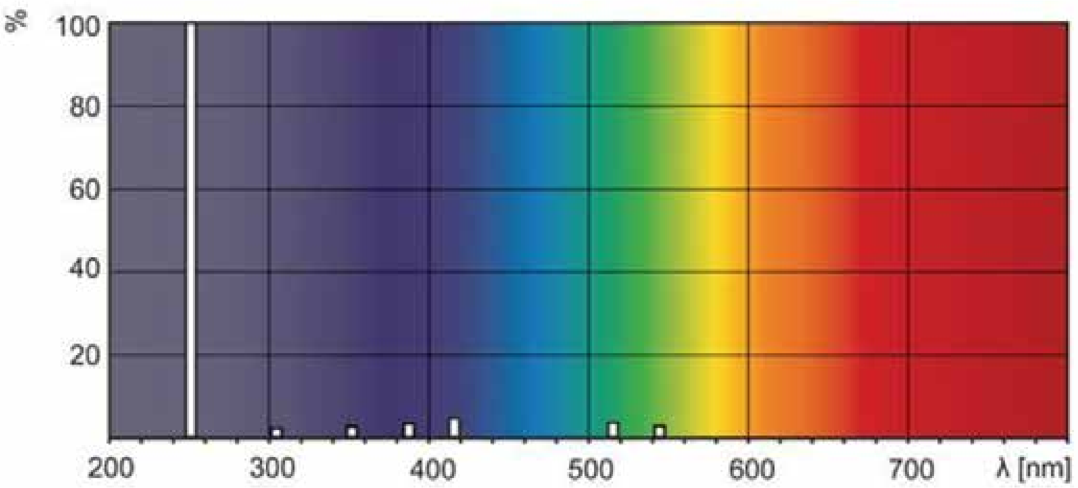
12.5.3 The Scope of the Exemption

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

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

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

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



Source: LEU Ex. 4a (2015b)

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

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

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

12.5.4 Exemption Wording Formulation

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

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

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

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

12.5.5 Conclusions

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

- their **elimination or substitution** via design changes or materials and components which do not require any of the materials or substances listed in Annex II is scientifically or technically impracticable;
- the **reliability** of substitutes is not ensured;
- the total negative **environmental, health and consumer safety impacts** caused by substitution are likely to outweigh the total environmental, health and consumer safety benefits thereof.

Such lamps are understood to be produced with similar manufacturing techniques as fluorescent lamps, but to be used in highly specific applications where UVC light enables the main function. They are understood to be used for bacterial disinfection of air, water or other liquids, solids, or UV curing of surfaces, print media and the like which use UVC radiation to dry the imprinted surface.

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

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

12.6 Recommendation

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

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

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

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

12.7 References Exemption 4(a)

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

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

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

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

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

NARVA (2015) NARVA Lichtquellen GmbH + Co. KG, Additional information provided after first questions for clarification Date of submission: August 24, 2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_4_a_/NARVA/Ex._4_a__Narva_Answers_2_Clarification_Questions_24.8.2015.JPG

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/

13.0 Exemption 4(b)(I-III): " Mercury in High Pressure Sodium (vapour) lamps for general lighting purposes not exceeding (per burner) in lamps with improved colour rendering index Ra > 60”

This review of Annex III exemption 4(b)(I-III) covers the following exemption entries:

I) P ≤ 155 W
II) 155 W < P ≤ 405 W
III) P > 405 W

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 lamp
EEE	Electrical and Electronic Equipment
Hg	Mercury
HID	High intensity discharge lamps
HPS	High pressure sodium (vapour)
LED	Light emitting diode
LEU	LightingEurope
LFL	Linear fluorescent lamps
PCA	Poly-crystalline alumina
SDW	SDW lamps are lamps in the HPS family with a very high red rendering warm colour and a lifetime of 15000 hours.

13.1 Background

LightingEurope (LEU)[315] has applied for the renewal of Ex 4(b)(I-III) of Annex III of the RoHS Directive. This exemption covers mercury in high pressure sodium (vapour) lamps (HPS) with improved colour rendering, used for general lighting purposes.[316]

LEU explains that reduction or omission of mercury in these lamps inevitably leads to loss of their specific colour rendering properties. It is further stated that there are currently no substitutes – in the form of LED modules or otherwise - that can replace the products of exemption 4(b) with an alternative that realizes the same colour specification. [317]

The applicant thus requests the renewal of the exemption with the current wording formulation as listed in Annex III of the RoHS Directive and the maximum available duration allowed (based on Art. 5(2) of the Directive):

	Exemption	Scope and dates of applicability
4(b)	Mercury in High Pressure Sodium (vapour) lamps for general lighting purposes not exceeding (per burner) in lamps with improved colour rendering index Ra > 60:	
(I)	P ≤ 155 W	No limitation of use until 31 December 2011; 30 mg may be used per burner after 31 December 2011
(II)	155 W < P ≤ 405 W	No limitation of use until 31 December 2011; 40 mg may be used per burner after 31 December 2011
(III)	P > 405 W	No limitation of use until 31 December 2011; 40 mg may be used per burner after 31 December 2011

13.2 Description of Requested Exemption

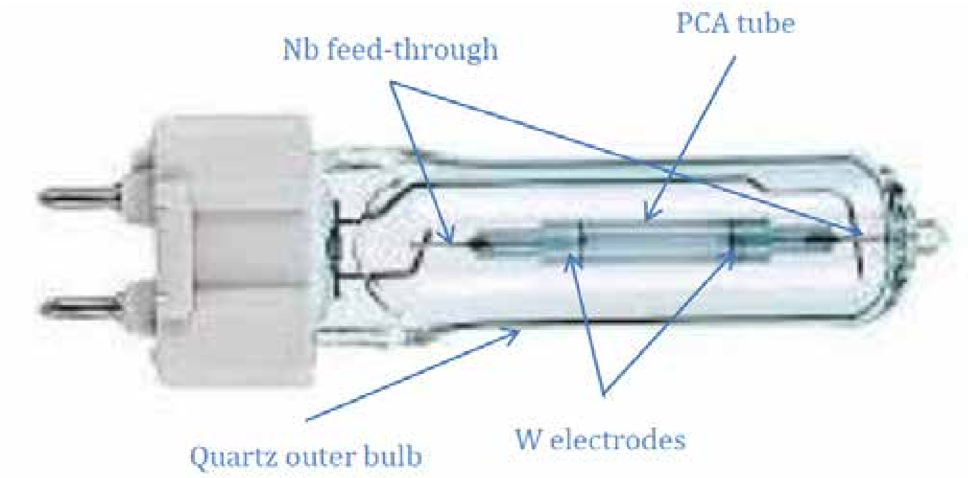
High pressure sodium lamps with increased colour rendering index are explained to fall under the High Intensity Discharge Lamps (HID) group. The HPS family includes lamps designed for different purposes in the professional market. HPS lamps are handled by technically skilled installers and sold by specialized distributors or as part of lighting equipment. The customers are for example governments, installers, specialized wholesalers, designers of lighting equipment etc.[318]

HPS lamps consist of a cylindrical discharge tube made of poly-crystalline alumina (PCA), in which two electrode assemblies are mounted at each side (Figure 13-1). The

[315] LEU Ex. 4(b)(I-III)(2015a), LightingEurope, Request to renew Exemption 4(b) under the RoHS Directive 2011/65/EU: Mercury in High Pressure Sodium lamps, submitted 15.1.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_4_b__I-III_/4b_LE_RoHS_Exemption_Req_Final.pdf
[316] Op. cit. LEU Ex. 4(b)(I-III)(2015a)
[317] Op. cit. LEU Ex. 4(b)(I-III)(2015a)
[318] Op. cit. LEU Ex. 4(b)(I-III)(2015a)

electrodes are made of tungsten and consist of a rod with, in some cases, coiled windings. The tungsten electrodes are welded to niobium tubes that serve as the electrical feed-through. The discharge tubes are sealed with a sealing frit which is designed such that it has the same expansion coefficient as PCA and niobium. This way there are no thermal stresses during the heating and cooling cycles present during starting and shut-down. The discharge tube is mounted in a vacuum quartz bulb in order to insulate it thermally.[319]

Figure 13-1: Construction of a HPS lamp with increased colour rendering



Source: LEU Ex. 4(b)(I-III)(2015a)

Inside the discharge tube xenon is present as a buffer gas. Mercury is dosed in the discharge tube during lamp manufacturing as sodium mercury. The amount of mercury dosed per lamp depends on aspects like lamp power and optical performance. For high pressure sodium lamps in the scope of Ex. 4(b)(I-III) the maximum dosed mercury amounts vary between 3 and 40 mg. Mercury and sodium are dosed as an amalgam of mercury and sodium in the form of a pill.[320]

Upon starting, a high voltage pulse is supplied to the electrodes and this breaks down the xenon gas allowing a current to flow through the resulting plasma. After ignition the heat released by the discharge warms up the discharge tube and evaporates part of the sodium and mercury. A liquid pool of sodium-mercury amalgam remains at the coldest spot in the discharge tube during operation. The HPS types with increased colour rendering index (CRI) have a higher sodium pressure. The increase in sodium pressure can be obtained by an increase in cold spot temperature of the saturated lamp and/or by an increase in the sodium to mercury ratio of the amalgam.[321] Increasing the arc tube

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[319] Op. cit. LEU Ex. 4(b)(I-III)(2015a)

[320] Op. cit. LEU Ex. 4(b)(I-III)(2015a)

[321] Referenced in LEU Ex. 4(b)(I-III)(2015a) as: Schmidt, K., Radiation characteristics of high pressure alkali metal discharges, Proc. 6th Int. Conf. On Phenomena in Ionized Gases, Paris, vol. 3, p. 323 (1963); and

diameter also contributes to a higher CRI.[322] There are two types of lamps covered under this exemption:[323]

- A lamp family with colour rendering index of 60, correlated colour temperature of 2200 K and luminous efficacies between 53 and 90 lm/W has successfully been introduced on the market in the range 150W-400 W. Some manufacturers also offer this lamp type for mercury retrofit applications. With improved colour rendering at low colour temperature and fairly high efficacies, these lamps find their application in outdoor situations where a better colour rendering is needed or in indoor applications where a good luminous efficacy is more important than high quality colour. Examples are parking lots and warehouses.
- The second type is used for high quality indoor lighting. With colour rendering index of 85, correlated colour temperature 2500-2700 K and luminous efficacies of 40-50 lm/W, this lamp is used as an incandescent lamp replacement with improved efficacy. Specifically, these lamps are used in applications where a very good rendering of red colours is required. The available wattage range is 35 W to 100 W This lamp family is often referred to as "White HPS". Electronic stabilisation is needed in order to minimise colour temperature, system-to-system variation and colour shift over life.

High Pressure Sodium lamps with increased colour rendering are characterized by long life-time (15,000 to 24,000 hours[324]), good luminous efficiency (from 40 to 92 lm/W) and good to very good colour rendering (Cri of 60 for the first type and 80+ for the second type). The High Pressure Sodium lamps with CRI 60 mostly are single-capped with Edison screw caps (E27 and E40 for Europe). The European types of CRI 80 are marketed with G12 and PG-12 bi-pin caps. All HPS lamps can only operate on designated drivers that switch the lamp on and regulate their power. These drivers are electro-magnetic ballast (inductive/capacitive load) used to stabilize the lamp current in combination with a high voltage pulse generator (ignitor) to ignite the lamp, or electronic power supplies that regulate the power and also provide the required ignition pulse.[325]

Mizuno, H., Akutsu, H. and Watarai, Y., New high pressure sodium lamp with higher colour rendition, CIE 17th Session, Barcelona, P. 71.14 (1971)

[322] Refferenced in LEU Ex. 4(b)(I-III)(2015a) as: Akutsu, H., Watarai, Y., Saito N. and Mizuno H., A new high-pressure sodium lamp with high color acceptability, J. of the IES, 13, no.4, p. 341-349 (1984)

[323] Op. cit. LEU Ex. 4(b)(I-III)(2015a)

[324] According to LEU Ex. 4(b)(I-III)(2015b), in this context, The term “long life” refers not to another HPS product but to the alternative lamp that will give the same functionality to the end user. For SDW lamps (lamps with a very high red rendering warm colour and a lifetime of 15000 hours), the only existing alternatives are halogen of normal incandescent lamps with lifetimes below 4000 hours. The HPS with colour rendering of approximately 60 gives a warm white light and has a lifetime of 24000 hours. There is no product yet that gives the same light from a compact luminaire. The CFL-ni lamps come close, but have a higher colour temperature (and better CRI). Their lifetime is shorter than the 24000 hrs of HPS CRI=60.

[325] Op. cit. LEU Ex. 4(b)(I-III)(2015a)

Figure 13-2: Different formats of HPS lamps with increased colour rendering: Edison

Source: LEU Ex. 4(b)(I-III)(2015a)

The product characteristics make HPS lamps with increased colour rendering a suitable choice for applications that require very good colour rendering with emphasis on warm colours. Typical applications for the CRI 60 types are outdoor applications where colour rendering matters, like city centres and parking lots where they provide a typical city atmosphere. The CRI 80+ types are mostly used indoors in shops where objects like red meat, breads or furniture have to be displayed. For these kinds of applications these lamps are the only energy efficient option since no other light sources but incandescent are capable of delivering the kind of red saturation that is required.[326]

In HPS lamps Hg has a number of roles:[327]

- The main role of mercury is to tune the resistance of the plasma in such a way that the efficiency of the combination lamp and driver functions in an optimal way. High Intensity Discharge lamps generate light in a compact plasma arc with a high brightness. After the lamp is started by a voltage pulse the initial noble gas discharge heats the lamp and evaporates part of the sodium/mercury amalgam pill. At first it is mainly the mercury that goes into the vapour phase. The increasing mercury vapour pressure increases the electrical resistance in the discharge which allows for putting more power into the discharge. As a consequence of more power coupled into the discharge, the discharge tube wall will heat up causing sodium and mercury to evaporate further until a state of equilibrium is established between the electrical power supplied to the discharge, the heat conducted to the surroundings and the radiation emitted from the discharge. The lamps are designed such that the optimal efficiency is reached at this equilibrium. The mercury is not consumed over life. However, the sodium in the discharge tube does chemically react with the PCA wall and the electrode emitter. As a

[326] Op. cit. LEU Ex. 4(b)(I-III)(2015a)
[327] Ibid.

consequence the fraction of mercury in the amalgam becomes higher and this raises the lamp voltage. At a certain point in time the lamp voltage becomes so high that the mains voltage can no longer sustain the arc and the lamp extinguishes. This is the end of the lamp life. For a given sodium consumption, a certain amalgam dose is required to reach the specified life. If the dose is too small, the ratio of mercury in the amalgam rises rapidly and so does the lamp voltage, leading to a premature end of life.

- The mercury in the plasma of a High Pressure Sodium lamp does not directly contribute to the spectrum of the lamp because the arc temperature is too low to excite the interesting (optical) energy levels of the mercury atom. However, there is a very significant indirect contribution of the mercury atoms: the proximity of mercury atoms shifts the energy levels of sodium and creates a very large broadening of the sodium resonance line in the red part of the spectrum. It is this red broadening of the sodium spectral resonance line that gives the High CRI HPS lamps their excellent red rendering properties. It is possible to shift the colour point for a given sodium pressure towards the black body locus by tuning the sodium to mercury ratio. Too low Hg content gives the lamp a greenish colour; too much Hg however, shifts the colour point to the pinkish side of the black body locus.
- The presence of the mercury vapour also greatly reduces the thermal conduction of the sodium-mercury-xenon plasma. As a consequence, there is less heat loss from the plasma to the discharge tube wall. The efficiency of the lamp is thereby greatly improved by the mercury pressure.
- The high pressure of mercury limits evaporation of the hot tungsten electrode. The low evaporation helps to maintain the light flux over lifetime, a high evaporation rate of tungsten will lead to blackening of the arc tube and a reduced transmission of light.

For classes (i.e. entries – consultants comment) I and II the amalgam dose increases with lamp power (=lamp size).

LEU was asked to explain how the two types of lamps and the mercury contents of lamps on the market refer to the three entries of the exemption. LEU[328] stated that:

- In **category I:** for lamps with a power below 155W both families are still available;
- In **category II**: lamps with a power 155W<P<405W, only one family is available (lamps with colour rendering > 60); and

[328] LEU Ex. 4(b)(I-III)(2015b), LightingEurope, Response To Oeko-Institut regarding the 1st Questionnaire Exemption No. 4(b)(I-III), submitted 15.9.2015, avaialble under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_4_b__I-III_/Ex_4b__I-II-III__LightingEurope_1st_Clarification-Questions_final.pdf

- In **category III**: lamps with a lamp power >405W, no lamps are available anymore. This category could be eliminated completely since the industry does not produce lamps falling under this category anymore.

13.2.1 Amount of Mercury Used under the Exemption

The lamps have to be replaced about every 2 to 3 years. The estimated European market for these lamps cannot be disclosed publicly, thus the total amount of mercury brought on the European market through lamps of Ex. 4(b) could not be estimated.[329]

In a later communication LEU[330] provided a rough estimation that the total amount of mercury put on the market per annum through this application is in the range of 5-10 kg. They also explain that the boundaries on the mercury content in the exemption can be differentiated based on 60 < CRI < 80 or CRI >80. The lamps with CRI>80 are made with another technology and use less mercury.

13.3 Applicant's Justification for Exemption

LEU claims that the replacement of mercury in non-linear fluorescents is scientifically and technically impracticable and that currently there are no significant LED lamps available on the market with comparable CRI.[331]

13.3.1 Possible Alternatives for Substituting RoHS Substances

LEU states that it is the presence of mercury that broadens the sodium resonance line dramatically into the red part of the spectrum (see also Figure 13-3). There are no other elements known that have the same influence on the spectrum of an HPS lamp. Replacing the mercury pressure by xenon (see also Figure 13-4) broadens the spectrum on both sides of the Na resonance line 24 and hence does not have the effect of a warm colour, high CRI lamp. Moreover, to have a similar effect with Xe as with Hg on the red side, the Xe pressure would have to be so high that ignition with existing ignitor systems would not be possible. LEU concludes that mercury is essential for high CRI HPS lamps and that without mercury they completely lose their properties.[332]

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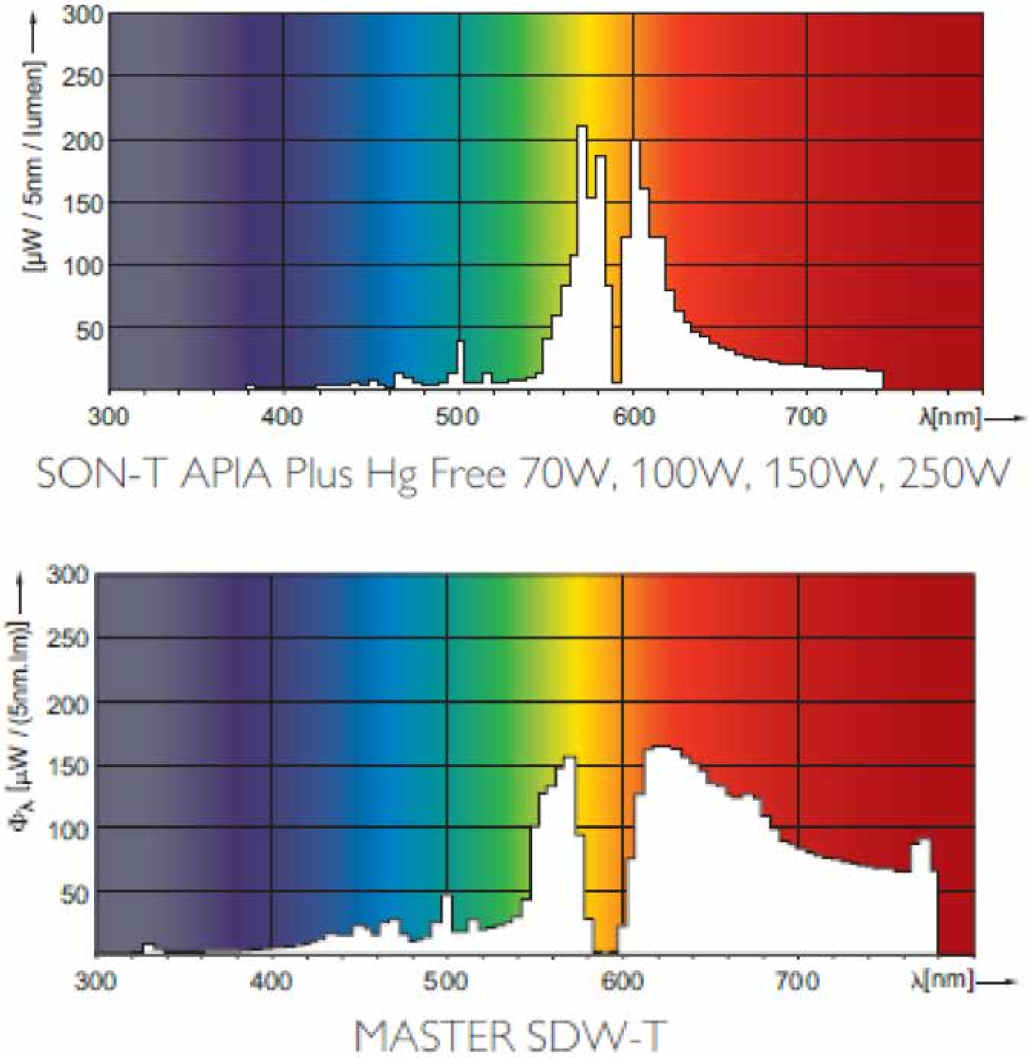
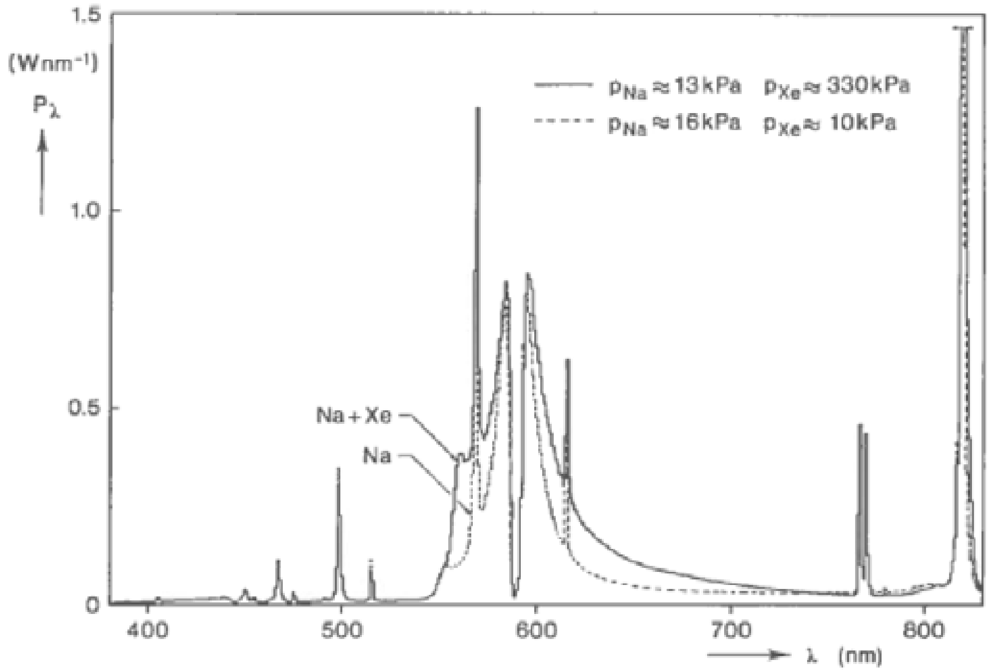
[329] Op. cit. LEU Ex. 4(b)(I-III)(2015a)
[330] Op. cit. LEU Ex. 4(b)(I-III)(2015b)
[331] Op. cit. LEU Ex. 4(b)(I-III)(2015a)
[332] Op. cit. LEU Ex. 4(b)(I-III)(2015a)

Figure 13-3: Spectra of an Hg-free and an improved CRI HPS lamp



Source: LEU Ex. 4(b)(I-III)(2015a)

Figure 13-4: Spectra of an Hg-free HPS lamp with increased Xe pressure



Source: Refered to in LEU Ex. 4(b)(I-III)(2015a) as Woerdman, J.P, Schleyen, J., Korving, J., Van Hemert, M.C, De Groot. J.J. and Van Hal, R.P.M., Analysis of satellite and undulation structure in the spectrum of Na+Hg continuum emission, J. Phys. B: At.Mol.Phys., vol.18, pp4204-4221 (1985)

LEU further explains that ever since the introduction of the HPS lamp in the 1960's, the possibility of operating this lamp in an unsaturated vapour mode -just as high pressure mercury lamps- has been suggested and discussed. In this mode all the Hg/Na amalgam is vaporised during operation, in contrast to the standard HPS types where only a fraction of the amalgam dose is vaporised. The unsaturated vapour mode offers a number of advantages over the saturated lamp: better voltage and power stability, no cycling at end-of-life, substantially reduced Hg dose and faster warm-up. However, the very low sodium dose (20-100µ g) makes this lamp extremely vulnerable for sodium loss reactions. HPS lamps with increased colour rendering operate at increased PCA wall temperature in order to realize the necessary Na pressure. At this PCA temperature the sodium reactions within the wall cause a rapid depletion of the sodium in the discharge tube. This reduction causes the colour point of the lamp to shift and also raises the lamp voltage with premature failure following. Hence, LEU concludes that reduction of mercury to unsaturated dosage is not possible.

13.3.2 Possible Alternatives for Eliminating RoHS Substances

LEU explains that there are no replacement lamps for the colour improved HPS family available, and assume that revoke of the exemption would subsequently result in a "loss of applications":

- On the component level (lamp replacement – retrofit/conversion): LED replacement lamps for HPS are proposed by a large variety of suppliers.

However, specific replacements for colour improved HPS that mimic its unique colour properties are said to be not yet available.

- LED replacement luminaires (system level): LED luminaires that mimic the unique colour properties of colour improved HPS lamps are also said not available yet.

LEU[333] later explains that several attempts were made to develop LED lamps with a similar colour impression like the SDW classification of lamps [SDW understood to be solely a coding system and not an acronym – consultants comment]. The main barrier is the emission of saturated red light. One way to produce this light is with quantum dots. "*The application for the best quantum dots (that use cadmium) is not granted yet and generates not enough red light.*[334] *This means that no breakthrough is ready at present. Research is ongoing for other options like phosphors, quantum dots or direct red light emission from the LED. The red light on itself is highly appreciated in all lighting applications. It is difficult to generate efficiently, so the granting of the exemption 4b will not limit the efforts to find a good solution for good red light emission since the solution will provide a competitive advantage*. "

13.3.3 Environmental Arguments

LEU explains that specific LCA's of high colour rendering HPS lamps are not publicly available. LEU discusses results of three public LCA's published for general HID lamps[335] and makes a comparison between results of these studies related to ceramic metal halide lamps in comparison with LEDs. However, LEU explains that the comparison made is not a suitable comparison for HPS, as according to LEU there would be no retrofit replacements for HPS lamps. A true comparison would need to assume that the luminaire is replaced and not just the lamp.

As the referenced studies are from 2009-2011, and it is possible that available LED alternatives have developed (i.e. results outdated), the discussed results are not reproduced here and can be viewed in the applicants document.

[333] Op. cit. LEU Ex. 4(b)(I-III)(2015b)

[334] Referred to in LEU Ex. 4(b)(I-III)(2015b) as "Cadmium in color converting II-VI LEDs (< 10 µg Cd per mm2 of light-emitting area) for use in solid state illumination or display systems" (Request for renewal of Exemption 39 of Annex III of Directive 2011/65/EU) http://rohs.exemptions.oeko.info/index.php?id=182

[335] Referenced in LEU Ex. 4(b)(2015a) as:

- Department for Environment Food and Rural Affairs (DEFRA). Life Cycle Assessment of Ultra-Efficient Lamps. Navigant Consulting Europe Ltd. 2009
- AT. Dale.MM. Bilec,J. Marriott, D. Hartley,C.Jurgens,E. Zatcoff Preliminary comparative life-cycle impacts of streetlight technology. Journal of Infrastructure Systems193— 199,(2011).
- Preparatory Study for Eco-Design Requirements of EuP, Lot 9, Public Street Lighting, P. Van Tichelen, T. Geerken, B. Jansen , M. Vanden Bosch (Laborelec), V. Van Hoof, L. Vanhooydonck (Kreios), A. Vercalsteren

13.3.4 Road Map to Substitution

LEU claims that no solution (i.e. alternative) for the deep red rendering typical of colour improved HPS has been proposed yet. It is very probable that solutions will appear in the coming years but the timing and the performance/cost specifics are not known at this point in time.

13.4 Stakeholder Contributions

A number of contributions have been made by stakeholders raising general points in relation to discharge lamps. Such contributions are summarised in Section 4.4 of the general lamp chapter.

The European Environmental Bureau (EEB), the Mercury Policy Project and the Responsible Purchasing Network[336], submitted comments specifically in relation to Ex. 4(b) and 4(c), explaining that LEDs are increasingly being made to replace HPS lamps and are expected to increase for this application. EEB et al. recommend the Commission to monitor improvements in the availability, performance and price of LED replacements, to consider when an expiry date may be practical. EEB et al. present information showing that HPS lamps with lower mercury contents are available on the market. Such information is not reproduced here as such examples are understood to have relatively low CRI (<25) and are thus understood to only be relevant for Ex. 4(c). EEB et al. also claim that many companies offer a variety of drop-in LED replacements for HPS lamps, and it is further explained that the benefits of LEDs over HPS lamps are many:

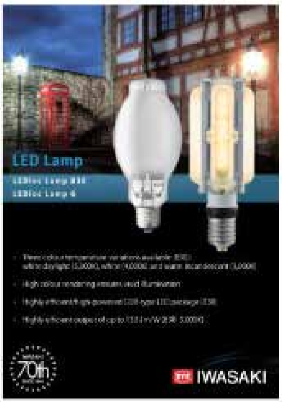
- LED lamps are much more energy efficient than HPS lamps.
- LEDs also have a longer rated life, which reduces their replacement and installation costs as well as their lifecycle environmental impacts.
- LEDs emit a higher quality of light, which is white rather than the yellow light that is emitted from HPS lamps.
- LED lamps do not cycle on and off.
- LEDs are mercury-free unlike HPS lamps.

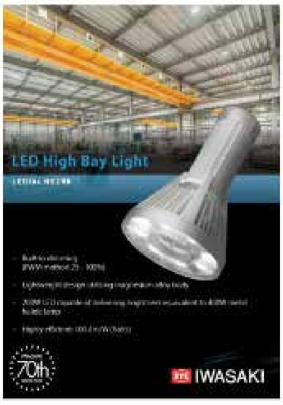
EEB et al. present a few LED examples to demonstrate their suitability:

[336] 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

- GE's LED Replacement for a 400-Watt HID lamp uses 50% less energy for a similar light output (approximately 200 watts for the LED), it lasts at least twice as long as an equivalent HID lamp (50.000 hours for the LED versus 24.000 for the HID lamp), and improved light quality (its Colour Rendering Index is 73, compared to 22 for a typical HPS HID lamp).[337]

- Other EU-based lighting equipment distributors sell LED drop-in retrofit products that can directly replace HID lamps. One example is Eye Lighting Company, which offers a variety of exterior and high-bay/interior LED lamps that can replace high-pressure sodium and metal halide HID lamps, which are often used to light gymnasiums, streets, pedestrian walkways, stadiums, and more[338]. Referenced LED lamps (left image) come in a CRI of 75 or 85. The right hand example is stated as an alternative for metal halide lamps and has a CRI of 65 or 80.





13.5 Critical Review

13.5.1 Scientific and Technical Practicability of Substitution

From the information that LEU provides it can be followed that eliminating mercury in HPS lamps with improved colour rendering is not practical. The presence of Hg allows broadening the spectrum of such lamps into the red part of the spectrum. Other substances that have been investigated such as xenon are understood not to allow a

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[337] Referenced in EEB et al. (2015a), GE Lighting Company, LED Replacement Lamp for 400 Watt HID, GE webpage accessed 06 October 2015, http://www.gelighting.com/LightingWeb/na/solutions/led-lamps-and-modules/led-replacement-for-hid/

[338] Referenced in EEB et al. (2015a), as Eye Lighting Company, Iwasaki LED Lighting Brochures , 2014, http://www.eyelighting.co.uk/public/images/pdf/brochures/LEDleaflets2014.pdf

comparable performance in this respect as well as requiring a high ignition not compatible with current systems.

It can further be followed that reducing the amount of mercury in lamps is not practical. Investigations into unsaturated vapour modes for these lamps, in which all sodium and mercury would be in a vapour state when the lamp is operated, did not result in products with reduced Hg. Though such lamps have several advantages, it is also understood that the low dose of sodium would result in the colour point of the lamp shifting throughout the life of the lamp as well as in premature failure. A further aspect that shows that a reduction of Hg limits would not necessarily be needed is related to the dosing of Hg. It is explained that Hg is not "consumed" throughout the lifetime of the lamp. In this sense, in contrast with fluorescent lamps such as CFL and LFL for example, it is assumed that the Hg dosing in HPS lamps is in relation to the actual level of Hg needed for operation of the lamp and the dosing does not include additional Hg to ensure the lamp lifetime. This is also supported by the understanding that too little mercury results in a green light, whereas to much would result in a pinkish tone.

LEU explains that there are no LED alternatives that provide sufficient colour rendering properties. This is explained to be of relevance both for replacement lamps in existing HPS installations (retrofit/conversion) and for replacement luminaires (i.e., new LED installations). However examples provided by EEB et al. show that there are LED lamps on the market providing higher colour rendering, i.e. lamps with CRI of 65, 73, 75, 80, 85. LEU explained that Ex. 4(b) covers both lamps with CRI between 60-80 as well as lamps with CRI above 80. In this respect, at least the former group appears to be covered by such examples. Such lamps could thus replace HPS lamps at least to some degree when used in new installations (luminaire replacement). However, the consultants understand there to be technical limitations to replacing lamps in existing installations.

LEU provides a few examples of lamp data sheets in which HPS dimensions relevant for this exemption can be found. Example sizes in mm are 103,110 and 143 for the full length of the lamp and 20 and 32 for the diameter.[339] In comparison the examples provided by EEB et al. show dimensions of 155, 200 and 201 mm for the full length of the lamp and 70, 73 and 90 for lamp diameter[340]. It is therefore concluded that the difficulty of substitution is related to the dimensions of LED substitutes, which would probably not be compatible as replacement lamps in existing installations. In this respect, the problem of substitution appears to be related to replacement lamps but not necessarily to replacement luminaires.

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[339] See Examples from Philips: http://download.p4c.philips.com/l4bt/3/323010/master_sdw-tg_mini_323010_ffs_nld.pdf and http://download.p4c.philips.com/l4bt/3/322803/master_sdw-t_322803_ffs_nld.pdf

[340] See Examples of Iwasaki Eyelighting under http://www.eyelighting.co.uk/public/images/pdf/brochures/LEDleaflets2014.pdf

13.5.2 Environmental Arguments

Though LEU mentions LCAs that could be used to provide an indicative comparison of HPS and LED alternatives, this information is explained not to compare the LED in a way that would represent an actual substitution situation. The reports are furthermore outdated and thus this information has not been evaluated. Further aspects raised are of general nature and are discussed in the general chapter under Section 4.5.3.

13.5.3 Stakeholder Contributions

For the discussion of general aspects raised by stakeholders, please see Section 4.5.7 of the general chapter. As for information provided by EEB et al. specifically for HPS lamps, it concerns both Ex. 4(b) and Ex. 4(c). Thus, not all aspects are understood to be relevant for this exemption. However, EEB et al. present a few examples of LED alternatives with CRI's that are comparable to lamps falling under Ex. 4(b). As the dimensions of such lamps are larger, it is understood that they currently would probably not be suitable for use as lamp replacements in existing HPS installations. However, it is concluded that such lamps could provide substitutes on the system level for use in new LED installations. The consultants thus agree with EEB et al. that the Commission should further monitor the development of such alternatives. This would allow understanding when the size of LED alternatives ceases to limit their applicability in existing luminaires, as well as observing the progress in the shift from HPS luminaires to LED alternative luminaires.

13.5.4 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.

It can be followed that Hg cannot be substituted in HPS lamps with high colour rendering as investigations into such lamps show that alternatives did not provide the relevant red part of the spectrum. It can also be understood that reducing the amount of mercury would not be possible as this would result in colour shifting and premature failure of the lamps (unsaturated vapour mode) or in a change in the spectral output colour should Hg amounts in the current technology be increased.

Though LEU claims that LED alternatives are not available on the market, information provided by EEB et al. shows that alternatives providing CRIs of up to 85 are available. Such alternatives are understood to allow substitution at the system level in new installations. However, such lamps are larger in dimensions and are expected not to be

compatible with existing installations. Thus on the component level, lamps of Ex. 4(b) would still be needed to allow lamp replacement and thus to prevent early end-of-life of existing luminaires. Though a shift to LED luminaires can be expected, the consultants would recommend renewing the exemption and monitoring the development both of additional LED alternative lamps and of the shift in the luminaire stock from HPS to LED. This would allow understanding at what point environmental costs related to early end-of-life of luminaires would be acceptable to allow the elimination of Hg brought on the EU market through this exemption.

13.6 Recommendation

Though substitutes are understood to be available on the system level (for use in new LED luminaires), such substitutes are too large to allow their application as substitutes in existing HPS luminaires (component replacement). It is assumed that the shift of the luminaire stock from HPS to LED is still at its beginning and that an early phase-out could result in an early end-of-life of HPS luminaires. It is thus recommended to renew the exemption for a further 5 years. Furthermore, as raised by the applicant, this renewal should only apply to items I and II of the exemption as item III has become obsolete since manufacturers no longer place such lamps on the market.

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.

Exemption 4(b)	Scope and dates of applicability
Mercury in High Pressure Sodium (vapour) lamps for general lighting purposes not exceeding (per burner) in lamps with improved colour rendering index Ra > 60:	
(I) P ≤ 155 W; 30 mg may be used per burner	For Cat. 5, 8 & 9: 21 July 2021; For Sub-Cat. 8 in-vitro: 21 July 2023; For Sub-Cat. 9 industrial: 21 July 2024;
(II) 155 W < P ≤ 405 W; 40 mg may be used per burner	
(III) P > 405 W; 40 mg may be used per burner	For Cat. 8 & 9: 21 July 2021; For Sub-Cat. 8 in-vitro: 21 July 2023; For Sub-Cat. 9 industrial: 21 July 2024;

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

13.7 References Exemption 4(b)(I-III):

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

LEU Ex. 4(b)(I-III)(2015a) LightingEurope, Request to renew Exemption 4(b) under the RoHS Directive 2011/65/EU: Mercury in High Pressure Sodium lamps, submitted 15.1.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_4_b__I-III_/4b_LE_RoHS_Exemption_Req_Final.pdf

LEU Ex. 4(b)(I-III)(2015b) LightingEurope, Response To Oeko-Institut regarding the 1st Questionnaire Exemption No. 4(b)(I-III), submitted 15.9.2015, avaialble under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_4_b__I-III_/Ex_4b__I-II-III__LightingEurope_1st_Clarification-Questions_final.pdf

14.0 Exemption 4(c)(I-III): "Mercury in other High Pressure Sodium (Vapour) Lamps for General Lighting Purposes not Exceeding (Per Burner):”

This review of Annex III exemption 4(c)(I-III) covers the following exemption entries:

I) $P \leq 155$ W
II) 155 W $< P \leq 405$ W
III) $P > 405$ W

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

CRI	Colour rendering index
EEE	Electrical and electronic equipment
EoL	End of life
ErP	The European Directive ErP (Energy related Products) 2009/125/EC also known as EcoDesign
Hg	Mercury
HID	High intensity discharge lamps
HPMV	High Pressure Mercury Vapour
HPS	High pressure sodium (vapour)
LED	Light emitting diode
LEU	LightingEurope
PCA	Poly-crystalline alumina
WEEE	Waste electrical and electronic equipment

14.1 Background

LightingEurope (LEU)[341] has applied for the renewal of Ex 4(c)(I-III) of Annex III of the RoHS Directive. This exemption covers mercury in other high pressure sodium (vapour) lamps (HPS) used for general lighting purposes, i.e. it does not cover HPS with improved colour rendering, which would fall under Ex. 4(b)(I-III).[342]

LEU explains that reduction or omission of mercury in these lamps inevitably leads to loss of efficacy. On the component level (replacement lamps) the applicant further explains that replacing HPS lamps by LED retrofit lamps with conservation of the specification is not possible and is not expected anytime soon due to thermal limitations and compatibility issues. Though on the system level (installations), substitution of HPS installations with LED installations is explained to be underway, this is expected to require another 15-25 years or to result in WEEE prematurely (early end-of-life) if phase-in is forced.[343]

The applicant thus requests the renewal of the exemption with the current wording formulation as listed in Annex III of the RoHS Directive and the maximum available duration allowed (based on Art. 5(2) of the Directive):

	Exemption	Scope and dates of applicability
4(c)	Mercury in other High Pressure Sodium (vapour) lamps for general lighting purposes not exceeding (per burner):	
(I)	P ≤ 155 W	No limitation of use until 31 December 2011; 25 mg may be used per burner after 31 December 2011
(II)	155 W < P ≤ 405 W	No limitation of use until 31 December 2011; 30 mg may be used per burner after 31 December 2011
(III)	P > 405 W	No limitation of use until 31 December 2011; 40 mg may be used per burner after 31 December 2011

14.2 Description of Requested Exemption

High pressure sodium lamps are explained to fall under the High Intensity Discharge Lamps (HID) group. The HPS family includes lamps designed for different purposes in the professional market. HPS lamps are handled by technically skilled installers and sold by specialized distributors or as part of lighting equipment. The customers are for example governments, installers, specialized wholesalers, designers of lighting equipment etc. [344]

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[341] LEU Ex. 4(c)(I-III)(2015a), LightingEurope, Request to renew Exemption 4(c) under the RoHS Directive 2011/65/EU: Mercury in High Pressure Sodium lamps, submitted 15.1.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_4_c__I-III_/4c_LE_RoHS_Exemption_Req_Final.pdf
[342] Op. cit. LEU Ex. 4(c)(I-III)(2015a)
[343] Op. cit. LEU Ex. 4(c)(I-III)(2015a)
[344] Op. cit. LEU Ex. 4(c)(I-III)(2015a)

HPS lamps covered by Ex. 4(c)(I-III) are similar in structure and function to those covered by Ex. 4(b)(I-III). A short summary with some specific details is provided here, while additional details can be viewed in Section 13.2 of the Ex. 4(b)(I-III) chapter. HPS lamps consist of a cylindrical discharge tube made of poly-crystalline alumina (PCA), in which two electrode assemblies are mounted at each side (Figure 14-1). The electrodes are made of tungsten (W) and consist of a rod with coiled windings containing a mix of oxides, called the emitter. These oxides reduce the work function of the tungsten and hence reduce also the temperature of the electrodes during operation, thereby greatly improving the life time of the lamps. The tungsten electrodes are welded to niobium (Nb) tubes that serve as the electrical feed-through (Figure 2). The discharge tubes are sealed with a sealing frit which has the same expansion coefficient as PCA and niobium, to prevent thermal stresses during the heating and cooling cycles (start-up / shut-down). Inside the discharge tube xenon is present as a buffer gas, at a pressure of some 20-500 mbar, under room temperature conditions.[345]

Figure 14-1: Construction of a high pressure HPS lamp

Source: LEU Ex. 4(c)(I-III)(2015a)

HPS lamps are characterized by very long life (30,000 to 50,000 hours) and very high luminous efficiency (from 80 lm/W to 150 lm/W). They also typically have a lumen maintenance of more than 80% at end of life (EoL). Their ability to render colours is low (CRI around 20). The majority of HPS lamps are single-capped with Edison screw caps (E27 and E40 for Europe) but there exists also a double-capped range with R7s and Rx7s caps. Figure 14-2 shows different formats. Most manufacturers have both lamps in tubular clear glass format and in ovoid shape with a light diffusing coating. The wattage range is 35W to 1000W. [346]

[345] Op. cit. LEU Ex. 4(c)(I-III)(2015a)
[346] Op. cit. LEU Ex. 4(c)(I-III)(2015a)

Figure 14-2: Different formats of HPS lamps: tubular clear, ovoid coated and clear double-ended

Source: LEU Ex. 4(c)(I-III)(2015a)

HPS lamps can only operate on designated drivers that switch the lamp on and regulate the power. These drivers can be an electro-magnetic ballast (inductive/capacitive load) to stabilize the lamp current in combination with a high voltage pulse generator (ignitor) to ignite the lamp. Nowadays, also electronic drivers are used to stabilize the lamp at the correct power.[347]

LEU states that the product characteristics make HPS lamps a suitable choice for applications that require long life, high efficacy and very good lumen maintenance, but where colour rendering is less important. Typical applications are outdoor lighting: street lighting, parking's, city squares, flood lighting of buildings. Sometimes these lamps are also used indoors, like in warehouses where colour rendering is not important.[348]

14.2.1 Amount of Mercury Used under the Exemption

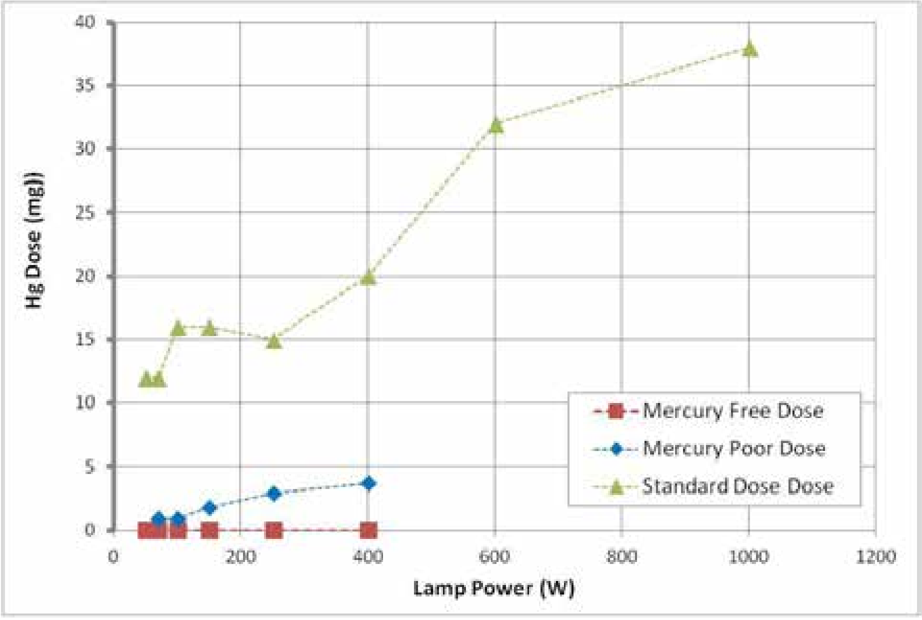
"*Mercury is dosed in the discharge tube during lamp manufacturing as sodium/mercury amalgam with an Hg/Na fraction of 75-97%. The amount of mercury dosed per lamp depends on aspects like lamp power and optical performance. For high pressure sodium lamps in the scope of the Exemptions 4(c) the dosed mercury amounts vary between 1 and 40 mg. There are three types of HPS lamps on the market*":[349]

- Standard dosed: HPS lamps with saturated amalgam dose (i.e. only part of the mercury and sodium is vaporized in the operational lamp) and optimized to yield the highest possible efficacies.
- Mercury poor: Lamps with an unsaturated amalgam dose (i.e. all the mercury and (almost) all the sodium is evaporated in the operational lamp). These lamps are mostly marketed in the USA.
- Mercury Free: Lamps without dosed mercury.

[347] Op. cit. LEU Ex. 4(c)(I-III)(2015a)
[348] Op. cit. LEU Ex. 4(c)(I-III)(2015a)
[349] Op. cit. LEU Ex. 4(c)(I-III)(2015a)

For the first two types listed above, the amalgam dose increases with lamp power (=lamp size). Figure 14-3 shows the dose versus the lamp power.

Figure 14-3: Amalgam doses of different types of HPS lamps on the market



Source: LEU Ex. 4(c)(I-III)(2015a)

The total amount of mercury brought on the European market in HPS lamps is calculated in the following way: an estimated 23 million HPS lamps will be brought onto the European market in 2016. The highest volumes are sold in 70W and 150W Standard dose lamps. The volumes of Mercury Free are low and the Mercury Poor lamps are not on the market in Europe (because of non-compliance with ErP[350] regulation). LEU estimates an average of 15 mg per lamp. Hence, LEU estimates that the total amount of mercury brought on the European market by new lamps of Ex. 4(c) is 345 kg per year. It is estimated that about 46% of the mercury brought onto the European market is recycled. Hence, the net amount brought onto the European market is 186 kg.[351]

LEU[352] mentions the VHK and VITO[353] study, which uses data, available from a report by McKinesy[354], EuroStat Data and LEU statistics (confidential), to develop a self-consistent overview of the EU28 market size and evolution for all lamp technologies. In the

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[350] ErP - European Directive ErP (Energy related Products) 2009/125/EC, also known as EcoDesign
[351] Op. cit. LEU Ex. 4(c)(I-III)(2015a)
[352] Op. cit. LEU Ex. 4(c)(I-III)(2015a)
[353] Quoted in LEU Ex. 4(c)(I-III)(2015a) as: Preparatory Study on Light Sources for Ecodesign and/or Energy Labeling Requirements (‘Lot 8/9/19’), Prepared by VHK, in cooperation with VITO and JeffCott Associates, 19 November 2014. Available from http://ecodesign-lightsources.eu/documents
[354] Quoted in LEU Ex. 4(c)(I-III)(2015a) as: Lighting the way: Perspectives on the global lighting market, McKinsey 2012 second edition

derivation of this data several assumptions had to be made by the study team and the number of lamps sold are finally tabulated (Table 57 in the report) for two different assumptions for the Average Selling Price (ASP) in the EU28 (low and high ASP). In LEU's application document, these two results are interpreted as confidence intervals and the average of the two is used. Further explanations and results are given in Table 14-1. From the results derived by this procedure it is clear that despite the fact that some new HPS applications are still installed, the installed base is decreasing rapidly in EU28: from 72 million in 2016 to 37 million in 2020. Also the number of HPS replacement lamps will drop drastically between 2016 and 2020: from 23 million to 12 million. The largest part of these lamps is nowadays replacement of lamps for existing luminaires.

Table 14-1: World and European market trend (in million pieces) for HID and HPS lamps according to VHK & VITO report

Source	Category	2011	2012	2016	2020
VHK & VITO	HID TOTAL	54	63	60	30
	LED TOTAL	30	72	407	634
	New	1075	1158	999	878
	Replacement	2817	2572	1399	728
	LAMPS TOTAL	3892	3730	2397	1606
LE Statistics	HPS/HID Ratio	35%	35%	39%	39%
This work	HID NEW	15	19	18	7
	HID Replacement	39	44	42	22
	HPS NEW	5	6	7	3
	HPS REPLACEMENT	14	15	16	9
	HPS TOTAL	**19**	**22**	**23**	**12**
	HPS INSTALLED BASE	**60**	**68**	**72**	**37**

The upper part of the table gives the sales numbers as derived by VHK & VITO for LED and HID as well as the division of all sold lamps over new installations (lamp in a newly installed fixture) and lamp replacements (a new lamp replacing an old one in an existing fixture). Confidential statistical data on lamp sales of LEU members shows that the percentage of HPS lamps in HID sales has been around 35% in the last 4 years and seems to be stable. We assume that this fraction can be extrapolated from LEU members to the whole EU28 sales. Knowing that High Pressure Mercury Vapour lamps will be banned in 2015 and assuming that these lamps will be replaced by a different technology than HID (mainly LED) we obtain that the ratio of HPS to HID sales in the EU28 will be 39% after 2015. The 2nd part in the table gives the projected HPS to HID ratio derived in this way. The division of HID over new and replacement is calculated from the division for all lamps given by VHK & VITO in the following way: assuming that all LED sold until 2020 are new installations and that the new to replacement ratio is the same for all conventional technologies, the total number of HID lamps can be split in new and replacement (third part in table). Using the HPS to HID ratio's obtained the number of new and replacement HPS lamps are then calculated. Finally, assuming a 4-year replacement cycle for HPS lamps, LEU derives the installed base of HPS light points in the EU28.

Source: LEU Ex. 4(c)(I-III)(2015a)

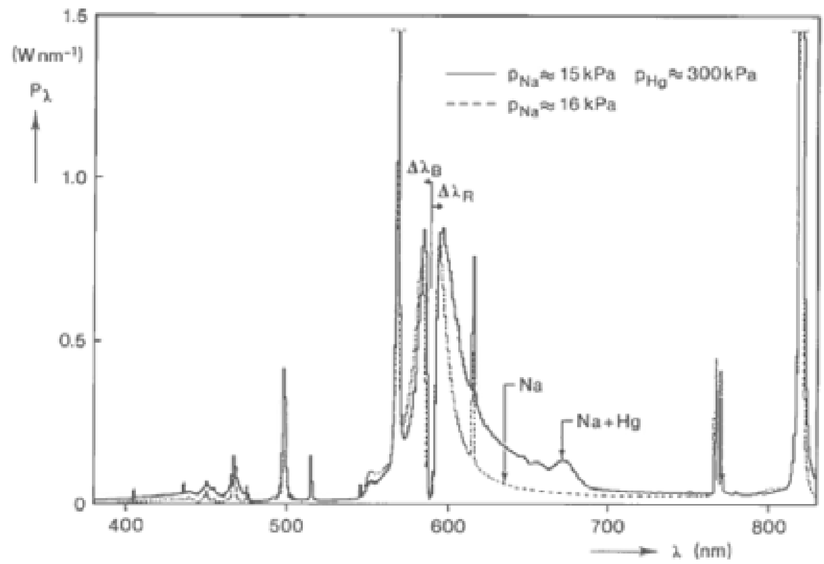
14.3 Applicant's Justification for Exemption

LEU[355] argues that the exemption is still needed as eliminating mercury is not possible and reducing mercury dose per lamp would not allow producing lamps of comparable performance. LEU states that alternatives are becoming more common, but are explained not to be suitable as lamp (component level) replacements in existing installations.

14.3.1 Possible Alternatives for Substituting RoHS Substances

If a sodium discharge lacks mercury, the energy radiated is considerably lower. The lamp with mercury radiates more between 600 and 700 nm and the lamp also produces more light in the blue range (Figure 14-4). The decrease in visible radiation in a lamp without mercury is due to the higher thermal losses of the Na-plasma as compared to an Na-Hg plasma. The loss of luminous efficacy is about 14 lm/W.[356]

Figure 14-4: Spectra of a Hg-containing and a Hg-free HPS lamp



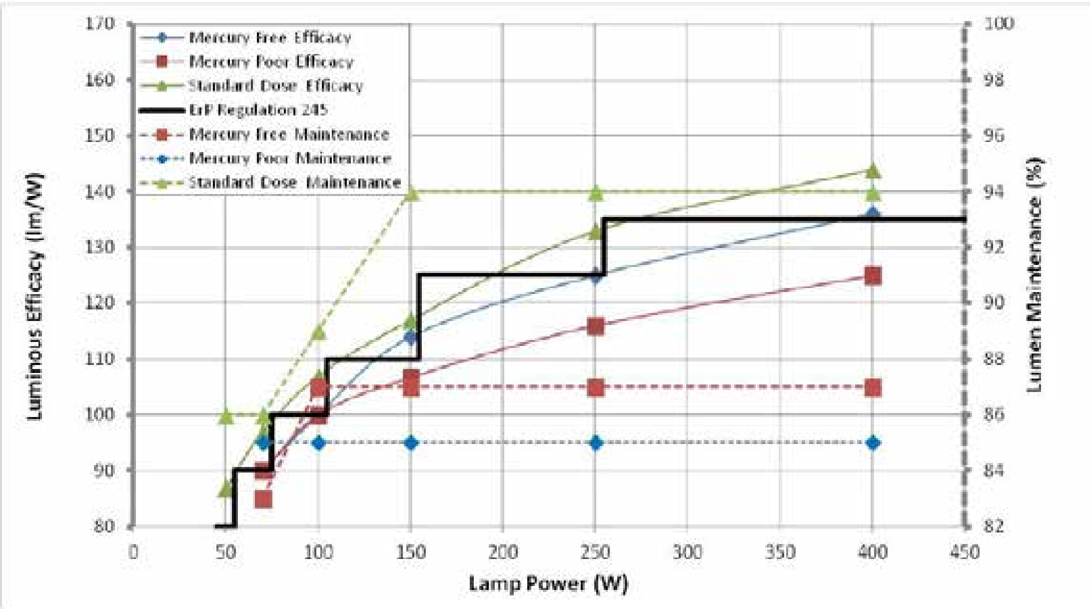
Source: Referred to in LEU Ex. 4(c)(I-III)(2015a) as Department for Environment Food and Rural Affairs (DEFRA), Life Cycle Assessment of Ultra-Efficient Lamps. Navigant Consulting Europe Ltd. 2009

By replacing the mercury pressure with an equivalent xenon pressure, the thermal losses can be kept constant. However, because the electrical conductivity of xenon is higher than that of mercury, a longer and narrower arc tube is required to bring the lamp voltage back to the specified value. The use of this type of tube decreases the luminous efficacy as compared to the standard lamps. Mercury is condensed in the amalgam when

[355] Op. cit. LEU Ex. 4(c)(I-III)(2015a)
[356] Op. cit. LEU Ex. 4(c)(I-III)(2015a)

the lamp is cold. Ignition of this lamp requires a relatively low peak voltage pulse (2 kV). As xenon is not condensed when the lamp is switched on, starting a lamp with a high xenon pressure is more difficult. A higher voltage pulse is needed to cause breakdown in the high pressure xenon and this voltage pulse alone is not enough: a special antenna needs to be provided to enhance the electric field during ignition. Even with the antenna, the pressure of xenon, which can be used, is limited by the requirement that ignition on all installed conventional ballasts is guaranteed.[357] To reach equivalent lumen output a higher sodium pressure would be required but the high temperature needed to evaporate the sodium limits the lifetime of the lamp. In practice the mercury free lamps are approximately 5% less efficient, have a reduced lumen maintenance (-5%) and a shorter lifetime (4 years of operation instead of 6 years), see also Figure 14-5.

Figure 14-5: Luminous efficacy and lumen maintenance of three types of HPS lamps



Source: LEU Ex. 4(c)(I-III)(2015a)

The luminous efficacy and lumen maintenance of mercury free and mercury poor HPS lamps are currently still lacking versus the standard dosed types. Mercury poor lamps are also not compliant with ErP Regulation 245/2009. While progress in efficiency, reliability and lumen maintenance has been made, the mercury containing counterparts have seen the same trend. It is not expected that Hg-free or mercury poor HPS will catch up on the performance of the highest performing Hg-containing HPS products, especially since R&D resources are increasingly dedicated to LED developments.

[357] The consultants understand this to refer to the need for such lamps to be electrically compatible with existing installation to allow their use as replacement lamps.

The Preparatory Study for Eco-Design Requirements of ErP's for Public Street Lighting[358] shows that there is an almost linear relationship between environmental impact and energy efficiency (p. 212) of different lighting scenarios. The authors conclude that due to the lower efficiency of mercury free HPS lamps the studied scenario of replacing all installed HPS lamps with mercury free HPS has a negative overall environmental impact (p. 227) and is therefore not recommended.

14.3.2 Possible Alternatives for Eliminating RoHS Substances

LEU distinguishes in their application between the availability of LED alternatives on the component level (lamp replacement) and on the system level (luminaire/installation replacement.

14.3.2.1 LED Replacement Lamps

LEU explains that numerous LED replacement lamps for HPS are proposed by a large variety of suppliers. However, substitute comparability hinders acceptable retrofitting:

- The lumen output of the substitute is much lower than the HPS lamp it should replace (in the order of 25% of the HPS luminous flux);
- The replacement lamp is much larger than the HPS lamp and will not fit in the vast majority of the luminaires;
- The optical characteristics of the substitute lamp are completely different leading to distorted beam patterns of the luminaires.

A typical example of advertised "retrofit" solutions is given in Figure 14-6.

[358] Quoted in LEU Ex. 4(b)(I-III)(2015a) as Preparatory Study for Eco-Design Requirements of EuP, Lot 9, Public Street Lighting, P. Van Tichelen, T. Geerken, B. Jansen , M. Vanden Bosch (Laborelec), V. Van Hoof, L. Vanhooydonck (Kreios), A. Vercalsteren

Figure 14-6: Typical advertised LED retrofit lamp for HPS lamp replacement

Source: LEU Ex. 4(c)(I-III)(2015a)

In street lighting applications the light levels are strictly regulated and replacement with lamps with much lower luminous flux can cause dangerous situations in traffic. So at least for these regulated applications the use of these LED “retrofits” is not possible.

HID lamps are compact and are in general high power lamps. In the application it is required that HID lamps operate in closed luminaires. Since over 90% of the power supplied to the HID lamp leaves the burner as radiation (visible light, infrared radiation and some UV) the temperature of the luminaire and the lamp is stabilized without the need for heat sinking. The glass surface of the outer bulb of the lamp is heated by conduction of the heat generated in the burner (10% of total supplied power) and by absorption of about half of the infrared radiation from the burner. In total the glass envelope is heated by approximately 40% of the lamp power.

For a currently available 120 lm/W LED lamp the power that is transformed into light is about 40% and there is no IR or UV. So 60% of the power is transformed into heat that has to be removed by convection/radiation to the surrounding air in the closed luminaire. LEU gives an example of a future LED lamp with an efficiency of 150lm/W. To generate the same amount of light this lamp requires only 80% of the power of the 120 lm/W HPS (120/150*100%). For this LED the radiation is now 50% of the input power and the heat generation is the other 50%. So, the heat that needs to be removed by convection/radiation is now 40% of the input wattage to the 120 lm/W HPS.

Since a typical HPS lamp of intermediate power also has an efficacy of 120 lm/W, the power to be removed is now almost equal to the heat loss from the current HPS glass bulb. So for this hypothetical, very efficient LED lamp that might exist in the future, the envelope temperature will be approximately the same as for the current HID lamp. The question is thus whether this efficient LED lamp can operate in the hot lamp envelope? LED lamps can have a long lifetime, above 25000 hrs, as long as the junction temperature of the LED is not above 100°C. As argued above the heat loss to the envelope of 150lm/W LED and for a HPS lamp are the same. So measurement of the envelope temperature of the HPS lamps in a luminaire will predict the temperature of the envelope of the future LED lamp with the same size. Since the transport of heat in a lamp via the lamp base is limited, the only path for the heat to disappear is via conduction to the air surrounding the lamp. In a closed luminaire, warm air limits the transport, but even if the lamp would operate in open air, the compact size needed to fit as a retrofit lamp in the closed luminaire limits the cooling opportunities. On the basis of data concerning the measured surface temperature of HPS lamps of different power, LEU assumes that LED retrofit lamps (reaching at least the same temperature) will have a surface temperature from 160-400°C. This is much higher than the optimal LED junction temperature of 100°C, meaning that LED replacement lamps with the same size as the current HPS lamps cannot exist in the coming decades or that the emitted light flux is lower and/or the lifetime is limited.

It is also explained that should LED lamp replacement alternatives become available, that their use in existing installations would require rewiring of the luminaire.

LEU summarises that LEDs have insufficient performance. Whether it is mostly because of light output or dimensional depends on the approach: more light can be provided by making the lamps bigger, but the HPS specification is never reached and it makes the lamp even more out of dimensional specification. In practise, these lamps are only used in cases where the luminaires are oversized, where there are no requirements on light level and distribution and where it is acceptable to reduce the light level drastically. These conditions represent a very small fraction of the installations as the majority of HPS lamps are used in public lighting conditions where there are strict legal requirements for the lighting provided.[359]

14.3.2.2 LED Replacement Installations

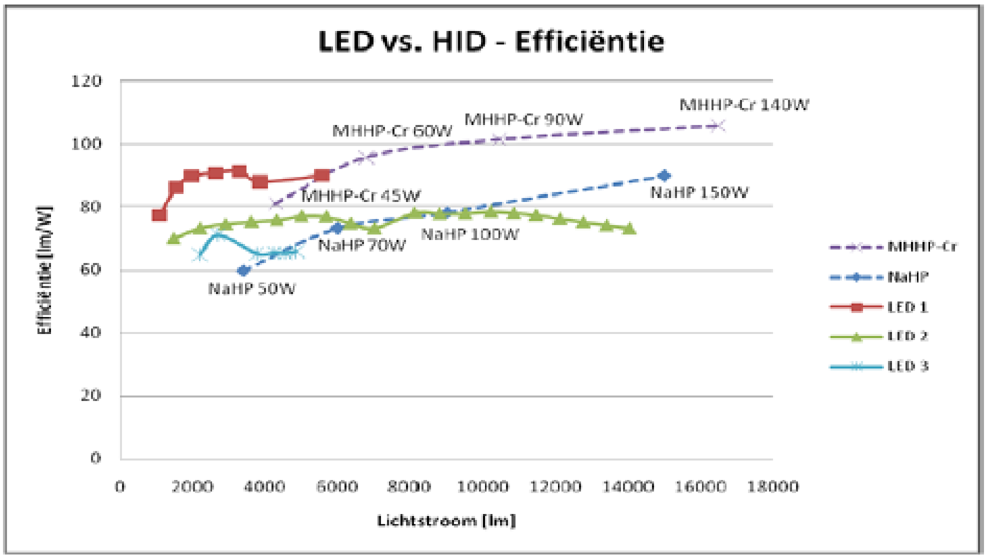
According to LEU[360], LED solutions are entering the market rapidly. McKinsey[361] shows that on the world level LED is competing mainly in the initial market of new luminaires. It is reasonable to state this is also true in Europe.

[359] LEU Ex. 4(c)(I-III)(2015b), Response To Oeko-Institut regarding the 1st Questionnaire Exemption No. 4c(I-III) (renewal request), submitted 15.9.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_4_c__I-III_/Ex_4c_LightingEurope_1st_Clarification-Questions_final.pdf

[360] Op. cit. LEU Ex. 4(c)(I-III)(2015a)

In principle, it is technically possible to replace the complete HPS installation by an LED solution. While this replacement has many advantages there are also significant drawbacks and challenges. A study[362] from the Renselaer Polytechnic Institute in Troy, NY, comparing street layouts with several HPS and LED light points found that, in order to guarantee uniformity and sufficient illuminance levels in accordance with the relevant regulations, the poles on which the fixtures are mounted have to be replaced and the spacing changed (more poles required). The reason for this is basically that LED luminaires are efficient or available below 6000 lumens only. LED streetlight layouts on average resulted in a slightly lower power demand than the average HPS streetlight layouts. The LED layout with the lowest power demand had 81% of the power demand of the HPS layout with the lowest power demand. However, the power demand per kilometre of street for individual layouts varied significantly.[363]

Figure 14-7: Luminaire efficiency of HPS (NaHP), ceramic metal halide (MHHP-Cr) and LED



Note: Efficientie = efficacy, Lichtstroom = Lumen output
Source: Quoted in LEU Ex. 4(c)(I-III)(2015a) as EANDIS presentation at Energiedag VVSG Openbare Verlichting - J. Delandtsheer and K. Putteman, Energiedag VVSG Openbare Verlichting, 19 march 2013. Available from http://www.vvsg.be/Omgeving/Documents/AV%20d4906_VVSG_Energiedag2013_S26_OpenbareVerlichting_JeroenDelandtsheer.pdf

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[361] Quoted by LEU Ex. 4(c)(I-III)(2015b) as: Lighting the way: Perspectives on the global lighting market, McKinsey 2012 second edition
[362] Quoted in LEU Ex. 4(c)(I-III)(2015a) as: [1] National Lighting Product Information Programme. 2010. Streetlights for Collector Roads. Rensselaer Polytechnic Institute. Available from http://www.lrc.rpi.edu/programs/NLPIP/PDF/VIEW/SRStreetlights.pdf (August 2011); and
[2] National Lighting Product Information Programme. 2011. Streetlights for Local Roads. Rensselaer Polytechnic Institute. Available from http://www.lrc.rpi.edu/programs/NLPIP/PDF/VIEW/SR_StreetlightsLocal.pdf (August 2011)
[363] Op. cit. LEU Ex. 4(c)(I-III)(2015a)

In a later communication, LEU confirms however that the feasibility for replacement of the luminaire with LED luminaires has improved over the last years. However, the light plan with the new luminaires on existing poles still has to be adapted to provide the required legal light fluxes. The characteristics of replacing an HPS (and more generally an HID) luminaire with an LED luminaire in 2015 are described in the draft interim Preparatory Study on Light Sources for Ecodesign and/or Energy Labeling Requirements[364] prepared by VITO and VHK, see par. 5.17.4. The report states that the LED luminaires nowadays need about 20% less lumen to provide the same lighting. However the cost of LED luminaires is still significantly higher than that of an HID luminaire, especially for the higher lumen packages. In paragraph 5.18.2 the report predicts that, nevertheless, the replacement of HID luminaires with LED luminaires will be common practise in the following years: “Considering current trends in street lighting and considering the advantages of LED luminaires over LED retrofit lamps, this is expected to be a frequently used option, in particular for low wattage HPS-lamps at the end of the luminaire life time (30 years).”[365]

It is not always commercially feasible for the owners of these professional lighting systems to invest in new LED luminaire solutions when lamps need to be replaced. Such a change requires not only changing the light source but the whole lighting system including luminaire, its optics and magnetic or electronic driver system.[366]

14.3.3 Environmental Arguments

LEU discusses results of three public LCA’s published for general HID lamps[367] and makes a comparison between results of these studies related to ceramic metal halide lamps in comparison with LEDs. However, LEU explains that the comparison made is not a suitable comparison for HPS, as according to LEU there would be no retrofit replacements for HPS lamps. A true comparison would need to assume that the luminaire is replaced and not just the lamp.

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[364] Referenced in LEU Ex. 4(c)(I-III)(2015a) as Preparatory Study on Light Sources for Ecodesign and/or Energy Labelling Requirements (‘Lot 8/9/19) Draft Interim Report, Task 4(Technologies), May.2015, VITO, VHK http://ecodesign-lightsources.eu/sites/ecodesign-lightsources.eu/files/attachments/LightSources_Task4_may2015_Draft.pdf

[365] Op. cit. LEU Ex. 4(c)(I-III)(2015b)

[366] Op. cit. LEU Ex. 4(c)(I-III)(2015a)

[367] Referenced in LEU Ex. 4(b)(2015a) as:

- Department for Environment Food and Rural Affairs (DEFRA). Life Cycle Assessment of Ultra-Efficient Lamps. Navigant Consulting Europe Ltd. 2009
- AT. Dale.MM. Bilec,J. Marriott, D. Hartley,C.Jurgens,E. Zatcoff Preliminary comparative life-cycle impacts of streetlight technology. Journal of Infrastructure Systems193— 199,(2011).
- Preparatory Study for Eco-Design Requirements of EuP, Lot 9, Public Street Lighting, P. Van Tichelen, T. Geerken, B. Jansen , M. Vanden Bosch (Laborelec), V. Van Hoof, L. Vanhooydonck (Kreios), A. Vercalsteren

As the referenced studies are from 2009-2011, and it is possible that available LED alternatives have developed (i.e. results are now outdated), the discussed results are not reproduced here and can be viewed in the applicants document.

In the case of a ban on mercury containing replacement lamps a huge investment into LED replacement luminaires will have to be made in the short time span of the replacement cycle of an HPS lamp (4 years). The environmental impact of early end-of-life for millions of still operational HID installations, to LEU's knowledge, has not been quantitatively assessed. However, it is reasonable to assume that the total negative environmental impact caused by this forced substitution is likely to outweigh the total environmental benefits. In view of the natural life of HPS installations, natural replacement of end-of-life installations by LED solutions will take 15 to 25 years.

14.3.4 Road Map to Substitution

LEU explains that, in reference to lamps for new installations, mainly LED luminaires solutions are used. Most of the currently produced HPS lamps are used in existing installations. For this market the LED solutions are not suitable and LEU estimates that the installed base of HPS lamps will be replaced by LED in a time frame of 12 years, i.e. by 2027. In view of the uncertainty involved in this extrapolation a period of 10-15 years seems the best estimate.[368]

14.4 Stakeholder Contributions

A number of contributions have been made by stakeholders raising general points in relation to discharge lamps. Such contributions are summarised in Section 4.4 of the general lamp chapter.

The European Environmental Bureau (EEB), the Mercury Policy Project and the Responsible Purchasing Network[369], submitted comments specifically in relation to Ex. 4(b) and 4(c), explaining that LEDs are increasingly being made to replace HPS lamps and are expected to increase for this application. EEB et al. recommend the Commission to monitor improvements in the availability, performance and price of LED replacements, to consider an expiry date as practical. It is explained that HPS lamps are rapidly being replaced by other technologies because:

- of their poor colour quality – they appear yellow because their CRI is typically in the 20s;
- they cycle on and off, which causes maintenance problems; and

[368] Op. cit. LEU Ex. 4(c)(I-III)(2015b)

[369] 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

- because of their relatively short life.

EEB et al. explain that some HPS lamps have already been phased out from the market due to energy efficiency under the ErP Directive. For those that remain, HPS lamps with a lower mercury content and more-efficient ceramic metal halide lamps, which also have a lower mercury content than equivalent HPS lamps, are widely available as practical drop-in replacements. A few examples are detailed:

- GE Lighting has a line of low-CRI (<25) Lucalux Standard High Pressure Sodium Lamps (in both tubular and elliptical shapes) in a wide array of common wattages including 70W, 100W, 150W, 250W, 400W and 1000W that can meet the following lower mercury levels through the use of amalgam technology:
    - P < 155 W = 20 mg per burner;
    - >155 W < P < 405 W = 20 mg per burner;
    - P > 405 W = 25 mg per burner.

  The datasheet for this product, which uses ceramic technology, explains that these products are easy drop-in replacements for standard HPS lamps. It states: *"Lucalox™ XO Superlife lamps comprise a sodium discharge system operating at a high pressure within a ceramic arc tube which is mounted in an outer glass bulb. These lamps offer outstanding luminous efficacy, lumen maintenance thus reducing energy and maintenance costs....Easy replacement of standard HPS lamps, fits standard HPS sockets – no new wiring, ballast or fixture are required"*[370]. From the referenced datasheet the consultants observe that lamp dimensions are 156/211/260/283 mm (lengths) by 39/48 mm (diameter) for tubular modules and 156/186 mm (length) by 72/76 for elliptical shapes, depending on wattage.

  Philips MASTER SON-T APIA Plus Xtra High Pressure Sodium Lamps, which contain a ceramic discharge tube, are this manufacturer's most energy-efficient and long-lasting HPS lamps (with rated lifetimes that range from 38.000 to 45.000 hours). It is promoted as *"the longest life, most reliable"* and *"most cost-effective solution in road lighting. All of the HPS lamps in this family of products, which include common HPS wattages of 50W, 70W, 100W, 150W, 250W and 400W) can meet our proposed limits."*[371] From the referenced data sheet the consultants observe that lamp dimensions are 156/210/257/283 mm (lengths) by 36/48 mm (diameter) for tubular modules, depending on wattage.

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[370] EEB et al. (2015a) refers to the following data sheet: http://www.gelighting.com/LightingWeb/emea/images/HPS_Lucalox_XO_Superlife_Lamps_Data_sheet_EN_tcm181-12784.pdf

[371] EEB et al. (2015a) refers to the following data sheet: Philips Company, Data Sheet for MASTER SON-T APIA Plus Xtra High Pressure Sodium Lamps, 3 July 2015, http://download.p4c.philips.com/l4bt/3/344247/master_son-t_apia_plus_xtra_344247_ffs_eng.pdf

EEB et al. thus recommend reducing the Hg allowance of lamps with P ≤ 405 W (Ex. 4(c)(I and II)) to 20 mg and lamps with P > 405 W of Ex. 4(c)(III) to 25 mg. They propose these reductions to take affect by 1 September 2018 at the latest

EEB et al. also claim that many companies offer a variety of drop-in LED replacement lamp for HPS lamps, and it is further explained that the benefits of LEDs over HPS lamps are many. For details please see Section 13.4 of chapter 13.0 (Ex. 4(b)).

14.5 Critical Review

14.5.1 Scientific and Technical Practicability of Substitution

From the information that LEU provides it can be followed that eliminating mercury in HPS lamps is not practical. Though HPS lamps without mercury are said to exist, it can be understood that they require a different ignition, and it is thus assumed that such lamps would not be practical as replacements in existing installations. Information also shows that HPS lamps with lower mercury levels exist. Some of these, termed poor-mercury-HPS, are said to have a lower efficacy and not to comply with the ErP regulation. In this respect it is understood that they are not available on the EU market and would thus not be practical as substitutes. However the data comparing such lamps to standard dosed HPS (see Table 14-2) suggests that the efficacy differences are between 5-17 lm/W. Information was not provided as to the difference in Hg dosing, however in the consultants opinion against such efficacy differences (ca. 5-12 % less efficient), it may make sense to integrate the Hg trade-off into considerations whether HPS-Hg-poor lamps should be prohibited on the EU market or not. Arguing as to which lamps should be prohibited under ErP and which should not is however beyond the consultants' mandate. In this context HPS-Hg-poor lamps can at present not be considered as a substitute.

Table 14-2: Comparative data for Hg-free, Hg-poor and standard dosed HPS lamps, related to efficacy and lumen maintenance

Wattage	*Mercury Free Technology*		*Mercury Poor Technology*		*Standard Dose Technology*		ERP Efficacy
	Mercury Free Efficacy	Mercury Free Maintenance	Mercury Poor Efficacy	Mercury Poor Maintenance	Standard Dose Efficacy	Standard Dose Maintenance	
50					83	85	80
70	90	83	90	85	95	89	90
100	100	87	100	85	107	90	100
150	114	87	106.7	85	117	91	110
250	125	87	116	85	130	92	125
400	136	87	125	85	142	92	135
600					150	88	135
1000					130	80	-

Values averaged over published values of main European suppliers

Source: Quoted in LEU Ex. 4(c)(I-III)(2015b)

In contrast, information from EEB et al. shows that there are HPS lamps on the market with significantly lower amounts of Hg, which could support a reduction of Hg allowances specified in Ex. 4(c).

Where LED alternatives are concerned, it can be understood that a distinction must be made between replacement of lamps on the component level (retrofit lamps) and on the system level (installation replacement). LEU explains that on the system level, LED alternatives are numerous; however it is argued that such replacements do not necessarily provide benefits in terms of energy efficiency, particularly for higher lumen output lamps. This argumentation is however substantiated with reports that may be outdated and LEU later confirms that the feasibility for replacement of the luminaire with LED luminaires has improved over the last years. Though current alternatives may show some drawbacks (e.g., lumen output, higher investment costs), LEU admits that the shift towards LED installations has already begun and that HPS lamps are mainly needed to allow lamp replacement in existing HPS installations. The consultants thus conclude that regardless of possible drawbacks, LED alternatives are already perceived on the market as an acceptable alternative.

Where LED alternatives are discussed as replacement lamps in existing HPS installations, it can be understood that alternatives have various limitations. The understanding that most alternatives have dimensions that would prevent their use as alternatives in existing installations clarifies that such lamps would not be practical as retrofit substitutes. Furthermore, as it is explained by LEU that most installations are closed, it can also be followed that the thermal incompatibility of LED alternatives would affect their service life, which would also make substitution with such lamps impractical.

14.5.2 Environmental Arguments

Though LEU mentions LCAs that could be used to provide an indicative comparison of HPS and LED alternatives, this information is explained not to compare the LED in a way that would represent an actual substitution situation. The reports are furthermore outdated and thus this information has not been evaluated.

LEU raises concern that an early phase-out of HPS lamps could result in early-end-of-life of HPS installations which would need to be scrapped, at the latest 4 years after the last HPS replacement was available. Assuming that replacement lamps shall not be available that would be compatible with existing installations, this can be followed in relation to an installed base of 72 million in 2016. In this respect it can be followed that LED alternatives are not a compatible replacement in most cases, supporting this argument. However, it cannot be concluded that other lamps, either Hg-free HPS, HPS-poor HPS, HPS with lower amounts of Hg or metal halide alternatives could not be used as replacements should the Hg allowances be reduced or should the exemption not be renewed. Of the installed stock, it is also assumed that some installations are already approaching EoL and shall be replaced with LED alternatives as a result of the trend in this direction. In this sense, this estimation is considered to be higher than the impacts that could actually be expected.

Further aspects raised are of general nature and are discussed in the general chapter under 4.5.3.

14.5.3 Stakeholder Contributions

For the discussion of general aspects raised by stakeholders, please see Section 4.5.7. As for information provided by EEB et al. specifically for HPS lamps, it concerns both Ex. 4(b) and Ex. 4(c). Thus, not all aspects are understood to be relevant for this exemption. EEB et al. present a few examples of HPS alternatives with lower amounts of mercury, in support of a reduction of the hg allowances of the exemption at hand. As some of these lamps are HPS lamps, their compatibility with current installations is assumed. The differences in Hg doses are understood to be considerable in some cases (for example for entry III the proposal is a reduction of 15 mg). It is also understood that replacement lamps could be needed for existing HPS installations for up to 12 years due to the lack of suitable LED alternatives. In this sense, the consultants agree that a reduction in Hg levels would be beneficial, even if this would mean that replacements are not available for a certain part of the product range (i.e. where Hg doses are above recommended levels). Though EEB et al. also provide examples of LED alternatives, as discussed in Section 13.5.3 of Chapter 13.0 regarding Ex. 4(b), it can be followed that such lamps would not be compatible with current installations due to their dimensions and also because of possible heat dissipation issues.

14.5.4 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.

On the luminaire level it can be understood that a trend is already underway towards LED alternatives. Despite arguments raised by LEU that such installations have drawbacks in relation to lamps with higher lumen outputs as well as requiring higher investments, such alternatives are understood to be acceptable as LED installations are being placed on the market, among others to replace HPS ones. This is also supported by LEU's statements that most HPS lamps placed on the market are used as replacements in existing installations.

In contrast, on the level of lamp replacement/retrofit, LED alternatives are understood not to be sufficiently available. Though in some cases it is explained that they could be used (oversized luminaires and where there is acceptability of changes in light level and distribution), in most cases their dimensions would not allow their use. Thermal and

electrical incompatibility with existing HPS installations are also understood to limit their applicability at present.

It can further be followed that though Hg-free HPS lamps are available, that they would not be suitable as retrofit replacements in most HPS installations as their ignition is different and thus lamps would not be electrically compatible. It is also understood that despite the existence of Hg-poor HPS lamps, that these are prohibited by ErP and can thus not be considered as an available substitute in the EU. In contrast, it is observed that there are standard-dosed HPS lamps with lower amounts of Hg that would support a reduction of the Hg allowances currently specified in the exemption entries. In this respect, the proposal submitted by EEB et al. to reduce the Hg allowance of lamps with P ≤ 405 W (Ex. 4(c)(I and II)) to 20 mg and lamps with P > 405 W of Ex. 4(c)(III) to 25 mg, can be followed.

14.6 Recommendation

Though substitutes are understood to be available on the system level (for use in new LED luminaires), such substitutes are too large to allow their application as substitutes in existing HPS luminaires (component replacement). It is assumed that the shift of the luminaire stock from HPS to LED is already underway, but that a phase-out could result in an early end-of-life of existing HPS luminaires (i.e. in waste and potential overall environmental dis-benefit). It is thus recommended to renew the exemption for a further 5 years. However, as proposed by EEB et al., as alternatives with reduced mercury are available in different shapes and for different wattages, it is recommended to reduce that amounts of Hg currently specified in the exemption entries. LEU estimates that the installed base of HPS lamps will be replaced by LED in a time frame of 12 years, i.e. by 2027.[372] Considering the long period understood to be needed to allow the shift from HPS luminaires to LED luminaires, an Hg reduction is perceived as beneficial for the environment.

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

[372] Op. cit. LEU Ex. 4(c)(I-III)(2015b)

Exemption 4(c)	Scope and dates of applicability
Mercury in other High Pressure Sodium (vapour) lamps for general lighting purposes not exceeding (per burner):	
(I) P ≤ 155 W; 25 mg may be used per burner after 31 December 2011	For Cat. 5: 31 August 2018; For Cat. 8 & 9: 21 July 2021; For Sub-Cat. 8 in-vitro: 21 July 2023; For Sub-Cat. 9 industrial: 21 July 2024;
(II) 155 W < P ≤ 405 W; 30 mg may be used per burner after 31 December 2011	
(III) P > 405 W; 40 mg may be used per burner after 31 December 2011	
(IV) P ≤ 405 W; 20 mg may be used per burner	For Cat. 5: from 1 September 2018 until 21 July 2021
(V) P > 405 W; 25 mg may be used per burner	

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

14.7 References Exemption 4(c)(I-III):

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

LEU Ex. 4(c)(I-III)(2015a) LightingEurope, Request to renew Exemption 4(c) under the RoHS Directive 2011/65/EU: Mercury in High Pressure Sodium lamps, submitted 15.1.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_4_c__I-III_/4c_LE_RoHS_Exemption_Req_Final.pdf

LEU Ex. 4(c)(I-III)(2015b) Response To Oeko-Institut regarding the 1st Questionnaire Exemption No. 4c(I-III) (renewal request), submitted 15.9.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_4_c__I-III_/Ex_4c_LightingEurope_1st_Clarification-Questions_final.pdf

15.0 Exemption 4(e): "Mercury in Metal Halide Lamps (MH)”

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.

Abbreviations

CRI	Colour rendering index
EEE	Electrical and electronic equipment
EoL	End of life
Hg	Mercury
HID	High intensity discharge lamps
HPMV	High pressure mercury lamps
IR	Infra-red
LED	Light emitting diode
LEU	LightingEurope
MH	Metal halide
WEEE	Waste electrical and electronic equipment

15.1 Background

LightingEurope (LEU)[373] has applied for the renewal of Ex 4(e) of Annex III of the RoHS Directive.

This exemption covers mercury in metal halide lamps (MH). LEU explains that MH lamps are very compact and used in (parabolic) reflectors where the compact light source needs to be at the exact position in the focal point to get the right light beam. MH lamps have long lifetimes, high light fluxes and high efficacy. LEU continues to explain LED alternatives that are compatible with MH luminaires and provide similar performance are currently not available on the market. The lifetime of MH professional luminaires is long (15-25 years) and thus the exemption shall be needed for many years.[374]

The applicant thus requests the renewal of the exemption with the current wording formulation as listed in Annex III of the RoHS Directive and the maximum available duration allowed (based on Art. 5(2) of the Directive):

> "*Mercury in metal halide lamps (MH)*"

15.2 Description of Requested Exemption

Exemption 4(e) covers High Intensity Discharge Lamps (HID) containing Metal Halides (MH). As detailed bellow, a distinction is observed in metal halide between the use of a ceramic discharge tube and a quartz discharge tube as well as between different metal halide salts within the discharge tube.

Figure 15-1: Metal halide lamps

Source: LEU Ex. 4(e)(2015a)

[373] LEU Ex. 4(e)(2015a), LightingEurope, Request to renew Exemption 4(e) under the RoHS Directive 2011/65/EU: Mercury in metal halide lamps (MH), submitted 15.1.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_4__e_/4e_LE_RoHS_Exemption_Req_Final.pdf

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

The light in the HID lamp is generated by metal atoms, in metal halide lamps the metal atoms are transported into the arc as metal halide molecules. The name MH lamp refers to these molecules. LEU provides a description of the different families of lamps covered by Ex. 4(e), together with an indication of the efficiency of the lamps, the range of lamp powers available, colour properties and the lifetimes (see Table 15-1).

Table 15-1: Lamp types and properties

Lamp type (Application)	Metal halide salt fill	power range [W]	η (lm/W)	Ra	T_c (K) [K]	lamp life [kHr]
Shop lighting Ceramic Discharge tube	Na–Tl–(Ca,Ce)– Dy–Ho–Tm iodide	20 – 400	90-120	>85	3000-4200	12 – 20
Shop lighting Quartz Discharge tube	Na–Tl–Dy–Ho–Tm iodide	70 – 250	80	85	3000-4200	10
Outdoor Lighting HPI	Na–Tl–In iodide	250 – 2000-45kW *	80	67	4500	20
Outdoor Lighting Sodium Scandium	Na–Sc iodide	70 – 2000	85	65	4000	20
Entertainment Quartz Discharge tube	Dy–Ho–Tm–Cs iodide & bromide	400 – 2500-25kW	85-90	>90	5500	0.75-1.5

Source: LEU Ex. 4(e)(2015a)

Metal halide salts used by different manufacturers differ and are detailed in Table 15-1. In Table 15-2, the acronyms used for MH lamps by manufacturers are also given.

Table 15-2: MH abbreviations

Metal halide lamp	Names used:
Ceramic discharge tube (low-medium power)	CMH CDM HCI
Quartz discharge tube (Low power)	MHN ARC HQI MH
Quartz discharge tube (Medium-high power)	MVR MH HPI

Source: LEU Ex. 4(e)(2015a)

HID lamps generate light in a compact plasma arc with a high brightness. It is this brightness that enables the luminaire to gather the generated light efficiently into a broad or narrow beam of light with only a small reflector. After the lamp has started by a voltage pulse, the initial noble gas discharge heats the lamp and evaporates the condensed mercury. The increasing mercury vapour pressure increases the electrical resistance in the discharge which allows for putting more power into the discharge. As a consequence of more power coupled into the discharge, the discharge tube wall will heat up and the metal halide salts are evaporated. Once all mercury has been evaporated and the metal halides have entered the discharge, a state of equilibrium is established between the power entering the discharge and the light emitted from the discharge. The optimal efficiency is reached at this equilibrium. In contrast to low pressure fluorescent lamps, mercury is not consumed over the life time of MH lamps. Its initial amount is instrumental over life.

The metal halide family is a diverse family with lamps designed for different purposes in the professional market. MH lamps are designed for specific applications (lighting for cities, shops, roads, theatres, disco's, outside sports, etc.) and the shape and size varies from the lowest power 20 Watt in shop lighting to above 2000 W in sports lighting and lighting stages for concerts. These lamps are handled by technically skilled installers and sold by specialized distributors or as part of lighting equipment. The customers are for example institutions, governmental projects, municipalities, retail chains, sports facilities, designers of lighting equipment etc. The installation of the lamps requires knowledge how to handle these lamps that require special driving gear including igniters that generate high voltage pulses.[375]

The efficiency of MH light sources varies from good (80 lm/W) to highly efficient (120 lm /W). The ability to render colours ranges from good enough in street lighting, to excellent for lighting fashion shops or TV broadcasting. This broad range of lamp powers and spectral demands has led to a wide range of lamps each designed for its own field of use.[376] MH lamps can only operate on designated control gear that switch the lamp on, and regulate its power. Lamps of different MH families have dedicated control gear. These lamps can produce UV radiation and the lamps become very hot during operation.[377]

15.2.1 Amount of Mercury Used under the Exemption

Mercury is dosed in the discharge tube during lamp manufacturing as liquid metal. The amount of mercury dosed per lamp depends on aspects like lamp power and optical performance. For metal halide lamps in the scope of Ex. 4(e) the dosed mercury amounts mainly vary between 3 and 30 mg. Since the dosing determines the lamp voltage and the colour properties, the dosing process has to be performed accurately. For higher power lamps with a discharge tube with a larger volume the amount of mercury needed to realise the same pressure increases. The distribution of mercury dose is not Gaussian: the 10% lower boundary is at 3 mg, the median dose is 4.7 mg, the mean dose is at 11 mg and the 90% upper bound is at 28 mg. [378]

The lowest amount of mercury is used in low power lamps that have a discharge tube with a small volume. The higher power lamps used for instance in soccer stadia use almost 200 mg. These lamps have an operating power of 1.8 kW and generate 155000 lumen.[379]

Some of the Ex. 4(e) lamps are very high power lamps, designed for projection equipment, enabling extremely high lumen flux of daylight, essential for studios, theatre, and the movie industry. In such lamps more mercury is used. These lamps need a certain

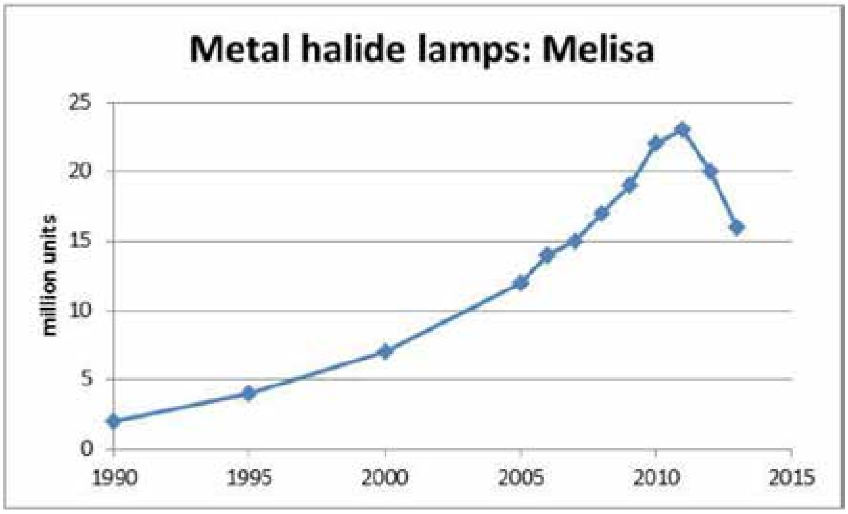
[375] Op. cit. LEU Ex. 4(e)(2015a)
[376] Op. cit. LEU Ex. 4(e)(2015a)
[377] Op. cit. LEU Ex. 4(e)(2015a)
[378] Op. cit. LEU Ex. 4(e)(2015a)
[379] Op. cit. LEU Ex. 4(e)(2015a)

lamp volume to prevent that the heat generated in the discharge melts the wall of the discharge vessel. If the same high power lamp is used for projection the arc must be very compact. This requires a very high mercury pressure. The combination of a very high pressure and a large discharge volume leads to the necessity of a large amount of mercury (up to 2 gram) compared to the other types of MH lamps. These high power lamps for entertainment consist of less than 0.05 % of the total market.

The total amount of mercury brought on the European market in the MH lamps is calculated in the following way: The database of one of the manufacturers is used to find the number of lamps sold in 2013 and the used mercury amount per lamp produced. Based on the estimated market share of this manufacturer in the different lamp families the total amount of mercury entering the European market is estimated to be around 16 Million lamps*11mg (mean dose)= 176 kg.

The market for MH lamps is slowly shrinking due to the fact that LED solutions are replacing MH lamps. The biggest part of the market is however the replacement of failed lamps. The installed luminaire stock is big and the lifetime of these professional luminaires is long. An indication of the European market size and the historical sales can be found in Figure 15-2, on the basis of the VHK & VITO study. The graph indicates that the fast growth of metal halide lamps is levelling off and even decreasing.

Figure 15-2: Historical sales of metal halide lamps, EU28 all sectors



Source: Referenced in LEU Ex. 4(e)(2015a) as "Preparatory Study on Light Sources for Ecodesign and/or Energy Labelling Requirements" Draft Interim Report, Task 2 Markets, pag. 2-14, 19-November-2014. http://ecodesign-lightsources.eu/sites/ecodesign-lightsources.eu/files/attachments/LightSources_Task2_nov2014_Draft.pdf

15.3 Applicant's Justification for Exemption

LEU[380] argues that the exemption is still needed as eliminating mercury is not possible and reducing mercury dose per lamp would not allow producing lamps of comparable performance. LED alternatives are becoming more common, but are explained not to be suitable as lamp (component level) replacements in existing installations.

15.3.1 Possible Alternatives for Substituting RoHS Substances

LEU explains that for MH lamps several attempts were performed to replace mercury. The alternatives used are: [381]

- Zinc, but these lamps show severe loss of light over life;[382]
- A high rare earth pressure, but these lamps contain very narrow arcs due to arc contraction. This results in visual flicker of the light, due to movement of the arc and might lead to short lamp life when the hot arc touches the wall of the discharge vessel; [383]
- Xenon that reduces the thermal losses but gives a very low lamp voltage. Therefore a different operation mode is needed and the pressure makes the lamp difficult to ignite; [384]

In the SCHELP project, co-funded by the Belgium government (IWT), Philips attempted to replace each function of mercury with a separate substance.[385] The project led to reasonable efficacies for cool white light, however for the warmer colour impression no efficient solution was found. Apart from the problems mentioned above, several others occurred: problems occurred with ignition on existing driver systems due to the halogens[386], and severe chemical reactions occurred with the reactor vessel with new chemistries[387]. The study concluded that operation of the lamps on existing lamp driver

[380] Op. cit. LEU Ex. 4(e)(2015a)
[381] Op. cit. LEU Ex. 4(e)(2015a)
[382] Referenced in LEU Ex. 4(e)(2015a) as M. Born. Untersuchungen zum Ersatz des Quecksilbers in keramischen Hochdruckgasentladungen mit Hilfe von metallischem Zink. ISBN: 3-89653-788-1, 2000 ; Born. Mercury free high pressure discharge lamps. In Proc. 9th Int. Symp. Sci. and Technol. of Light Sources, page 43, 2001; M. Born, H. Giese, and I. Niemann. Abschlusbericht BMBF-Projekt 13N8264, 2005
[383] Referenced in LEU Ex. 4(e)(2015a) as M. Käning, L. Hitzschke, B. Schalk, M. Berger, St. Franke and R. Methling, Mercury-free high pressure discharge lamps dominated by molecular radiation, J. Phys. D: Appl. Phys. 44 (2011) 224005
[384] Referenced in LEU Ex. 4(e)(2015a) as C. Stewart, M. Duffy, J.Dakin, V. Roberts,S-A El-Hamamsy, H. Witting,L. Inouye, K. Shimizu, K. Araki, Inductively Coupled HID Lighting System, The 6th International Symposium on the Science and Technology of Light Sources, Budapest, 1992
[385] Referenced in LEU Ex. 4(e)(2015a) as Rijke, A.J. (2013, Oktober 16). The power balance of ceramic metal-halide high intensity discharge lamps. TUE : Technische Universiteit Eindhoven (235 pag.) (Eindhoven: Technische Universiteit Eindhoven). Prom./coprom.: prof.dr.ir. M. Haverlag, prof.dr.ir. G.M.W. Kroesen & dr.ir. S. Nijdam.
[386] Referenced in LEU Ex. 4(e)(2015a) as E G Estupinan, R Pereyra, Y-M Li and W P Lapatovich The effect of hydrogen iodide on the ignition of Hg-free metal–halide lamps,J. Phys. D: Appl. Phys. 44 (2011) 224004
[387] Referenced in LEU Ex. 4(e)(2015a) as R. Hilbig, A. Koerber, S. Schwan and D. Hayashi, Novel molecular

systems was judged to be impossible if no concession could be done to the efficiency or lifetime of the mercury free lamps. The project did not lead to a mercury free lamp, or to an alternative lamp reduced in mercury, as a retrofit on existing lamp driver systems. [388]

In relation to mercury reduction in MH lamps, LEU explains that the presence of Hg is important to fulfil a few certain functions typical of MH lamps (or at least of some types of MH lamps):

- **Warm colour:** Due to the broadening process of the atomic sodium radiation by mercury atoms the yellow sodium line is broadened towards the red part of the spectrum. This red radiation is responsible for the good colour rendering in many metal halide lamps, but also for the low correlated colour temperature, for instance in 3000K ceramic metal halide lamps. Without mercury this warm colour is not possible. (This property is not valid for the high colour temperature lamps (>5000K) which do not have sodium in the discharge.)
- **Efficiency:** The most efficient radiating atom in the HID lamp is sodium: it radiates two yellow lines close to the maximum eye sensitivity. However this radiation would be absorbed in the colder regions of the plasma. Collisions of the radiating atom with other sodium atoms and mercury broaden the emission lines allowing the light to escape from the plasma. The efficiency of the lamp would thus be lower, were mercury not present. Mercury is very important for the lamp efficiency, not only for lamps with sodium but also for other radiating atoms like rare earth atoms. (This property is not valid for the small group of high colour temperature lamps (>5000K) that do not have sodium in the discharge.)
- **Lifetime:** The heavy mercury atoms move only slowly in the high temperature plasma. Therefore the heat flux lost from the centre of the arc tube by thermal convection and conduction is low. Much of the power remains inside the plasma and can only escape as visible radiation or as infra-red (IR) radiation. This improves the efficiency of the plasma in generating visible light. The reduced conduction of heat also protects the material of the discharge tube from overheating. The high pressure of mercury limits evaporation of the hot Tungsten electrode. This helps to maintain the light flux over lifetime, as a high evaporation rate of tungsten would lead to blackening of the arc tube and a reduced transmission of light. Replacement by a noble gas could help limiting the diffusion, but will increase the demands on the igniter.
- **Switch on:** Ignition of high pressure lamps is enabled by a short pulsed voltage of 3-5 kV. This is possible because the high pressure of mercury is absent when the cold lamp starts. Upon replacement of mercury by other

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discharge light sources, J. Phys. D: Appl. Phys. 44 (2011) 224009

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

gases, for instance Xenon, the high buffer gas pressure is already present in a cold lamp. This makes the lamp difficult to ignite and pulses certainly over 10 kV, but more typically 25-60 kV are needed. Such high voltages would require special electrical isolation measures and new lamp holder base designs to prevent discharges outside the lamp. These measures prohibit the use of such lamps in existing installations. In MH lamps the salts react with the oxygen impurities that are inevitable in the lamp production process. This reaction results in the formation of iodine molecules. These are volatile at room temperature and effectively prohibit the lamp igniting (the molecules bind the mobile free electrons). When mercury is present in the lamp the iodine will react with mercury to the much less volatile mercury iodide that does not hinder ignition.

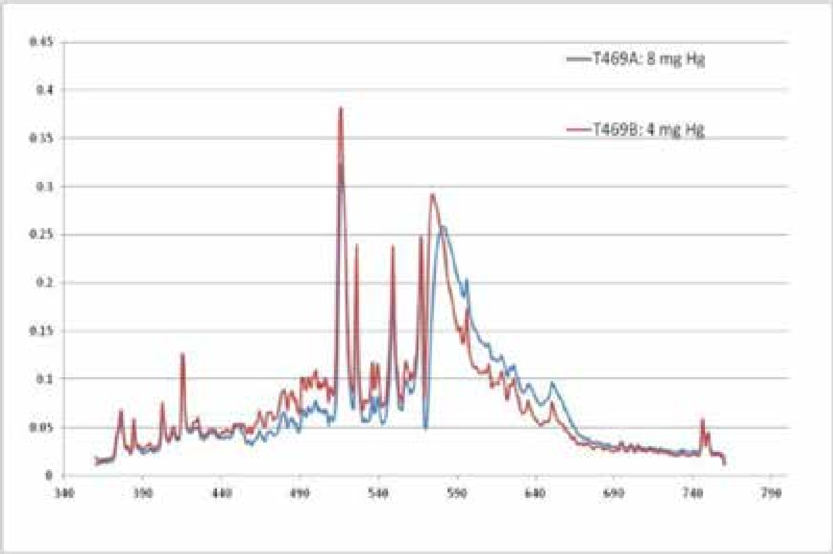
- **Stable operation:** The HID lamps are operated on alternating current. Each period when the current becomes zero, the radiation plasma cools down and the charge carriers disappear. The electrical resistance increases and the driver will encounter difficulties in keeping the lamp burning. The high density of mercury has enough heat capacity to keep the plasma warm enough for a short time. Eliminating the mercury makes the plasma extremely difficult to operate. The driver would need to supply very high voltage just after the current zero moment. The need for such a new driver effectively prevents the lamp [i.e. Hg-free lamps – consultant's comment] to be used as a replacement in an existing luminaire. Again a high noble gas pressure can have the same function, but these lamps cannot be started with the current igniters on the market.

Though some of these functions are understood to only be relevant for MH lamps containing sodium, LEU explains why mercury is also necessary for sodium-free MH lamps. Lamps with high colour temperature (>5000K) are mainly used in projection systems. The amount of red radiation needed is not large at these high correlated colour temperatures (but important for the colour rendering). Since these lamps are used in optical systems the brightness of the arc is the most important lamp property. This means that the lamp has a short electrode distance and needs a high mercury pressure to get a high enough lamp voltage. So also in the case of high colour temperature lamps a high mercury pressure is needed.

LEU explains that the main role of mercury is to make sure the lamp operates at the right power and to optimize the efficiency of the combination lamp and driver. Dosing less mercury will lead to lamps that will not perform the task they are designed for. Reduction of mercury first leads to a low lamp voltage. This will lower the power supplied by the driver to the lamp. This results in a lower light flux. As a secondary effect the lower power will reduce the temperature of the lamp causing reduced vapour pressure of the light emitting atoms in the discharge. This again leads to a change in light colour since not all metals have the same temperature dependence of the vapour

pressure and in many cases a reduced colour rendering, since part of the spectrum is not filled. An example of the effects on the spectrum is illustrated in Figure 15-3. In this case the red radiation is dramatically reduced.[389]

Figure 15-3: Spectrum change with mercury content



Note: Labels were not included in original. It is assumed that the X axis represents spectral output wavelength, while the y axis is assumed to represent lamp pressure.
Source: LEU Ex. 4(e)(2015a)

With the lower mercury dose the discharge tube needs to become longer to reach the same lamp voltage. This results in different colours when the lamp is used in different burning positions (for instance horizontal or vertical). To reduce this dependence, the physics of this process has been studied in a space station. Gravity is the driving force for the de-mixing that occurs in the lamp resulting in colour differences in different operating positions. No technical solution was found for this issue. [390]

Due to the nature of the lamp and driver combination a reduced lamp voltage leads to an increased current in the current limiting ballast. This will reduce the lifetime of the reactor ballast and can even lead to overheating. This limits the opportunity to design lamps with less mercury that can retrofit broken lamps in existing installations. Although a reflector, designed for efficient collection of light, demands a short arc (and high mercury pressure), in some cases of MH street lighting lamps the mercury dose is low. This is possible since the optical demands are such that a longer arc tube is not a disadvantage: the light has to be distributed over a long stretch of road and a longer arc is beneficial in this case. Moreover, these lamps are mainly used in horizontal burning position, such that the longer arc tube is no issue in this street lighting application. The

[389] Op. cit. LEU Ex. 4(e)(2015a)
[390] Op. cit. LEU Ex. 4(e)(2015a)

colour rendering however falls below CRI 70, due to the low mercury dose, but for outdoor lighting this is good enough. [391]

15.3.2 Possible Alternatives for Eliminating RoHS Substances

LEU distinguishes in their application between the availability of LED alternatives on the component level (lamp replacement) and on the system level (luminaire/installation replacement.

According to LEU, LED cannot replace MH lamps on a one to one replacement basis when a lamp has failed because of the following reasons:[392]

- MH lamps are compact and are in general high power lamps.
- The optics in the luminaires are designed to operate efficiently when the compact light source (MH lamp) is in the optimal focal point. This limits the possibilities for creating retrofit LED lamps, as the LED lamps cannot be too big and the cooling fins must also not be in the optical path.
- MH lamps operate in closed luminaires. Since over 90% of the power supplied to the MH discharge vessel leaves the discharge as radiation (visible light, infrared radiation and some UV) the luminaire and the lamp do not become too warm. Over 33% of the energy is transformed into visible light. An LED replacement bulb will need to be operated in the existing luminaire and thus also needs to get rid of the excess heat. The MH lamp envelope is heated by the non-radiative losses (10%) and by the UV and infrared radiation absorbed by the glass envelope. The total heat flux to the glass is about 40% of the power supplied to the MH lamp. In efficient LED lamps over 35% of the power is transformed into light, while the other 65% is to be removed as heat. This means that the heat flux from an LED is currently 1.5 times the heat from an HID lamp. Modern LED's can operate at junction temperatures close to 100°C, higher temperatures lead to reduced efficiency, shorter lifetimes and might even damage the device. At 100°C a lifetime of close to 25,000 hours is possible. Since the transport of heat from a lamp to the luminaire via the lamp base is limited, the only path for the heat to disappear is via conduction and convection to the air surrounding the lamp, and possibly by radiation if the lamp is hot. In a closed luminaire, warm air limits the transport, but even if the lamp would operate in open air, the compact size needed to fit as a retrofit lamp in other closed luminaires limits the cooling opportunities. With a hypothetical LED that is even 25% more efficient than the MH lamp, the heat loss would not be 1.5 times higher than for MH lamps, but would about the same. The reduction is due in part because the LED uses now 25% less power, and furthermore the non-radiative losses decrease. The bulb temperature of the replacement LED lamps will then come close to the

[391] Op. cit. LEU Ex. 4(e)(2015a)
[392] Op. cit. LEU Ex. 4(e)(2015a)

temperature of the MH lamps. Measurements of the glass bulb of existing MH lamps (Table 15-3) demonstrate the common temperatures of relevance. The bulb is much warmer than the required temperature of the LED junction of retrofit lamps. (400°C >> 100°C). Therefore retrofit lamps of the same size as MH lamps cannot be made now, at least as long as the efficiency of the LED's is not much larger than that of the current MH lamps[393].

- The last design obstacle is of electrical nature: MH lamps are operated on electrical systems that generate high voltage pulses to ignite the lamps. These ignition pulses are typical 3,500V, but can reach 5,000V or even 60,000 V in systems with a called hot-restrike facility. These igniters have to be taken out of the system (if not integrated in the electronic driver) and rewiring of the luminaire is needed if LED's would be designed to replace the failed HID lamps.

To support their argumentation, LEU provides some details as to typical diameters, power ratings and temperatures of MH lamps when operating. These are reproduced in Table 15-3.

Table 15-3: Temperature measurement of common metal halide lamps

Lamp type	Bulb diameter [mm]	Power [W]	Twall [°C]	stdev [°C]
Ceramic metal halide	19.0	70	394	4
	19.0	150	525	5
	14.0	70	580	10
	13.3	50	490	10
Quartz metal halide	46.6	400	560	10
Studio Stage lamp	30	575	650	15

Source: LEU Ex. 4(e)(2015a)

Further data is provided to support argumentation related to differences in lamp dimensions, is reproduced in Table 15-4.

[393] Consultant's comment: Although unclear from LEU's information, this conclusion may relate to the greater proportion of power converted to light within a more efficient LED (and more importantly to visible light). This would reduce the loss to heat. It is thus possible that LEU's statement is meant to reflect that once lamps are more efficient, the waste heat would be lower, the heat sink could be smaller and so the lamp could be smaller and thus possibly fit in existing luminaires.

Table 15-4: Examples of an LED replacement and MH lamps illustrating the problems with lamp size

Lamp type	Picture	Diameter	Length
LED		120 mm	300 mm
Ceramic Metal halide		14 mm	40 mm
Quartz Metal halide lamp		20 mm	117 mm

Source: LEU Ex. 4(e)(2015b) - The table shows the replacement lamp used in the VHK/VITO study (ref 2 task 4 page. 138) and possible metal halide alternatives.

In contrast, LEU explains that on the system level there are LED luminaires that can replace the HID system; examples are seen in luminaires for lighting fashion shops and even LED solutions are found for lighting tennis fields and soccer stadia. [394]

In a later communication, LEU[395] confirms that LED luminaire alternatives for MH luminaires can match the efficacy, life, CRI, light flux, and colour temperature of MH lamps.

15.3.3 Environmental Arguments

LEU mentions two public LCA's which have been published for HID lamps[396], however explains that in applications where directional lighting is involved an appropriate LCA is difficult, since both systems need to be compared on an equal basis [i.e. functional equivalence – consultant's remark]. In this respect, LEU raises aspects of light distribution of street lighting that make the comparison difficult. LEU explains that both, the LED and MH lamp efficiency are improving but perhaps "*to a lesser extent the HID efficiency/maintenance has been improved in the time since the publication of the studies. The HID efficiency is improved to from 90 lm/W to over 115 lm/W and the light flux over life stays above 90% at the end of life for some families*". LEU also explains that the comparison made is not a suitable comparison for MH and LED, as according to LEU

[394] Op. cit. LEU Ex. 4(e)(2015a)
[395] Op. cit. LEU Ex. 4(e)(2015b)
[396] LEU Ex. 4(c)(e)(2015a)

there would be no retrofit replacements for MH lamps. A true comparison would need to assume that the luminaire is replaced and not just the lamp.[397] LEU states that a definitive conclusion on the basis of the LCA's cannot be made at this time, at least not on the basis of the information that is publicly available.

In light of this last comment and as the referenced studies are from 2009-2011, and LEU itself claims that both MH and LEDs have improved, the discussed results are not reproduced here and can be viewed in the applicants document.

MH lamps are in the scope of EU Directives 2002/96/EC - WEEE and 2012/19/EU– WEEE Recast. Take back systems are installed in all EU Member States to facilitate the collection and recycling of lamps. The recycling percentage for the combination of household and non-household lamp waste combined is 45%[398] and is audited each year. LEU assumes that the return percentage is the same for all categories, also for MH lamps, and thus estimate 46% of 176 Kg (see Section 15.2.1) to mean that 81 Kg is recovered, or about 100 kg enters the environment. [399]

Substitution of mercury would inevitably lead into the changeover to a new light source technology, like LED. Since there are no LED replacement lamps for MH luminaires, as a consequence existing installations and drivers would need to be replaced completely resulting in high investments for customers and governments while the installed equipment is still capable to be used for many years should replacement lamps remain available (typical life cycle for professional luminaires is around 10-15 years for indoor use and 25-30 years in outdoor). This would create additional waste from the installations scrapped before end-of-life (EoL). The total installed number of luminaires with MH lamps installed is estimated to be about 500 million globally or approximately 150 million in Europe. [400]

15.3.4 Road Map to Substitution

LEU is not able to share the individual roadmaps the member companies have planned for their LED portfolio. There is no general roadmap to develop LED replacements for all existing applications. The expectation is that the penetration of LED's in the market of MH lamps will happen via the route of new luminaires. There are no MH retrofit lamps on the horizon yet. The market for MH lamps is declining. However since the existing professional luminaires are fully functional and have a long lifetime the customer needs replacement lamps on a regular basis. The MH lamps are also needed for customers with luminaires for high pressure mercury lamps (HPMV). These lamps are banned from the

[397] Op. cit. LEU Ex. 4(e)(2015a)
[398] This figure is elsewhere stated as 46%. The consultants assume that it is rounded here to 45% or that it is a typing mistake.
[399] Op. cit. LEU Ex. 4(e)(2015a)
[400] Op. cit. LEU Ex. 4(e)(2015a)

market [consultants comment – through the EcoDesign Directive due to their lower efficiencies]. The energy saving replacement lamps (i.e. MH) cannot be banned.[401]

15.4 Stakeholder Contributions

A number of contributions have been made by stakeholders raising general points in relation to discharge lamps. Such contributions are summarised in 4.4 of the general lamp chapter.

The European Environmental Bureau (EEB), the Mercury Policy Project and the Responsible Purchasing Network[402], submitted comments specifically in relation to Ex. 4(e). EEB et al. recommend the exemption to be limited after 1 September 2018, to ceramic MH for lamps with a wattage below 250 watts, whereas no limitation apply above this level. Ceramic MH lamps are explained to have less mercury, a higher efficiency and a longer rated life-time than quartz metal halide lamps. Ceramic metal halides are widely available up to 250 watts.

EEB et al. provide a few examples to support that quartz metal halide lamps – particularly low-wattage models – can be readily replaced with more energy-efficient ceramic metal halide (CMH) lamps, which have less mercury and longer rated life-time:

- Osram's 100-watt Powerstar HQI quartz metal halide lamp has a mercury content of 11,2 mg, while its 100-watt Powerball HCI ceramic metal halide lamp has a mercury content of only 8,5 mg and has a longer rated life of 12,000 hours. In addition, the quartz MH lamp is less energy-efficient (Class A) than the ceramic MH (Class A+). [403]
- GE manufactures both, quartz and ceramic double-ended MH lamps in equivalent wattages. Its 150-watt Arcstream Double-Ended Quartz MH Lamp[404] has a mercury content of 14.5 mg, while its 150-watt ConstantColor

[401] Op. cit. LEU Ex. 4(e)(2015b)

[402] 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

[403] EEB et al. (2015a) refers to: Osram, Data Sheet for Powerstar HGI Quartz Metal Halide Lamps, 30 September 2015, http://www.osram.com/osram_com/products/lamps/high-intensity-discharge-lamps/metal-halide-lamps-with-quartz-technology/powerstar-hqi-e-coated/index.jsp; and Osram, Data Sheet for Powerball HCI Ceramic Metal Halide Lamps, 30 September 2015, http://www.osram.com/osram_com/products/lamps/high-intensity-discharge-lamps/metal-halide-lamps-with-ceramic-technology/powerball-hci-ep/index.jsp

[404] EEB et al. (2015a) refers to: GE Lighting Company (Europe), Arcstream Double Ended Quartz Metal Halide Lamps with UV Control, November 2013, http://www.gelighting.com/LightingWeb/emea/images/Metal_Halide_Arcstream_Double_Ended_Lamps_Data_sheet_EN_tcm181-12560.pdf

Ceramic MH Lamp[405] has a mercury content of only 10 mg. Moreover, while the quartz MH lamp has a Class A rating and a rated life of 12,000 hours, the equivalent ceramic MH lamp has a Class rating of A+ and a rated life of 15,000 hours.

- Philips offers a wide array of ceramic MH lamps. Its 250-watt MASTER Plus CityWhite Tubular Ceramic Metal Halide lamp contains only 25.3 mg of mercury and has a Class A+ rating and a rated life of 27,000 hours.[406] In contrast, its equivalent 250-watt quartz MH lamp (MASTER HPI-T Plus Quartz Metal Halide Lamp contains 36 mg of mercury and has a Class A+ rating, also, but a shorter rated life of 20,000 hours.[407]

EEB et al. argues that since quartz and ceramic MH lamps are very often available in the same shape and type of lamps and bases, they are almost always interchangeable. Therefore, offering the RoHS Exemption on the ceramic models only would result in use of these easy, drop-in replacements with multiple environmental benefits, including significant mercury reduction as well as energy savings.

15.5 Critical Review

15.5.1 Scientific and Technical Practicability of Substitution

From the information that LEU provides it can be followed that eliminating mercury in MH lamps is not practical. Though available information shows that various investigations have been carried out into the possible replacement of mercury with other substances (e.g. zinc, rare earth, xenon, etc.), it is understood that none of these resulted in lamps coming on the market that could replace MH lamps.

A reduction of Hg in MH lamps is also understood not to be practical. As explained by LEU, mercury is important for facilitating various functions within MH lamps, including lamp power rating, lamp life and light flux. Reducing the mercury dose can affect the size of the lamp, when the lamp voltage is to be retained at a specified level. The changes in mercury pressure when the lamp is cold (not in use) and warm (operative) are of importance for enabling an ignition of the lamp with short pulsed voltages that are lower than for example required for igniting xenon lamps for which additional measures are needed to ensure ignition. In lamps with sodium, mercury is particularly understood to

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[405] EEB et al. (2015a) refers to: GE Lighting Company (Europe), ConstantColor CMH TD Double Ended Ceramic Metal Halide Lamps: 35W, 70W and 150W, August 2013, http://www.gelighting.com/LightingWeb/emea/images/ConstantColor_CMH_TD_Double_Ended_Lamps_Data_sheet_EN_tcm181-12599.pdf

[406] EEB et al. (2015a) refers to: Philips Company (UK), MASTER CityWhite Ceramic Metal Halide Lamps, 28 August 2013, http://download.p4c.philips.com/l4bt/3/322972/master_citywhite_cdo-et_322972_ffs_eng.pdf

[407] EEB et al. (2015a) refers to: Philips Company (UK), MASTER HPI-T Plus Quartz Metal Halide Lamps, 29 August 2015, http://download.p4c.philips.com/l4b/9/928481300098_eu/928481300098_eu_pss_enggb.pdf

be of importance to ensure for example warmer colours and lamp efficiency. LEU also explains that the mercury is not consumed over the lifetime of the lamp, but rather that the dosed amount remains instrumental throughout life. As the amount of mercury is also understood to be related to the pressure that needs to be obtained in the lamp throughout operation, it is understood that the dose for each lamp needs to be accurate and cannot be increased or decreased without changing the characteristics of the lamp.

In relation to differences between ceramic and quartz MH discharge tubes, EEB et al. propose a phase-out of MH lamps with a quartz discharge tube, in favour of the more efficient ceramic ones. From information provided by EEB et al. specifically for this exemption, the examples of ceramic and quartz MH lamps are understood to show that ceramic lamps may have lower mercury amounts, at least in some cases. This would in general support measures to promote the substitution of quart MH lamps with ceramic ones in some cases.

VHK and VITO[408] also explain in this regard that "*the more recent ceramic arc tube allows higher operating temperatures, which also implies higher efficacies, especially when combined with the 'unsaturated' working conditions, that avoid the presence of halide salts in the liquid phase, even when the lamp is dimming down to 50% of its rated power. Considering that unsaturated ceramic arc tube MH-lamps have higher efficacies, it has been proposed to raise the minimum efficacy requirements in the regulations, thus effectively phasing-out the quartz versions. Stakeholders (LightingEurope, IALD) have warned against this, because in their opinion the ceramic version cannot replace the quartz version in all applications: the difference in size of light source area would compromise the optical performance of many fitting types*."

LEU[409] further provided the following input in this respect:

> "*The mercury content depends on the design parameters of the arc tube (electrode gap, volume of the arc tube, Metal Halide salt composition), so ceramic MH lamps do not systematically have a lower mercury content.*
>
> *There are examples for ceramic lamp families with a very low mercury amount like the CosmoPolis lamp family (1-2 mg)… But there are also some examples where the ceramic lamp contains more mercury. For instance the Osram HQI-TS Excellence 150 W NDL has with 12,3 mg less mercury than the HCI-TS 150 W/NDL with 18,2 mg. Likewise the quartz lamps HQI-T 250W D and HQI-T 250W/N Plus lamps contain 18 mg mercury whereas the two comparable ceramic lamps (they have the same socket and bulb but differ in the Light centre and/or the colour temperature) the HCI-TT 250W/942 and the HCI-TT 250W/830 do have 30,5 mg resp. 27,3 mg.*

[408] 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.

[409] LEU Ex. 4(e)(2015c), LightingEurope, RoHS, Summary of Critical Observations to the EEB Submission of 16.10.2015, submitted per email on 30.11.2015

Certain colour temperatures (daylight, cool daylight) of quartz MH lamps which have a wide distribution in the market do not have an equivalent in ceramic MH lamps. Customers cannot buy the desired light colours any more. There is no ceramic MH replacement for the 250 W (Fc2 socket) quartz MH lamps by any of the big manufacturers. There are quartz MH lamps with special properties like low ignition voltage or that lamps can be operated in open fixtures which have no equivalent as ceramic MH lamps. Again the whole luminaires have to be replaced with high costs and here also the functionality is not available any more…

Shapes are different between several quartz MH and Ceramic MH lamp types… The G12 socketed Quartz MH lamps for instance are considerably shorter than the ceramic counterpart, the different values are part of the standard for metal halide lamps. (IEC 61167 Edition 3 2015-01 "Metal halide lamps – Performance specification") see Figure 15-4*.*

A luminaire adjusted to the shorter length cannot accommodate the longer replacement and would have to be replaced entirely at higher costs. Similarly the shape of the double ended HQI Excellence allows for smaller reflector openings where a double ended ceramic MH cannot fit any more. Either the reflector or the entire luminaire would have to be exchanged at higher costs.

Many double-ended quartz MH lamps are not suitable for hot restrike (instant re-ignition after switch-off through higher ignition voltage). This is commonly not permitted for ceramic MH lamps, so the respective luminaires cannot be used anymore and the functionality cannot be replaced by ceramic MH lamps.

The optical properties differ between quartz MH lamps and ceramic MH lamps. The transparent burner of the quartz MH lamp allows precise projection of the arc while the translucent ceramic arc tube will scatter the light from the arc. The resulting light intensity distribution and beam control may be influenced undesirably. Uniformity and minimum illuminance levels may not be achieved anymore."

Figure 15-4: Illustration of possible ceramic vs quartz lamp size differences

Note: Quartz MH lamps with G12 base have as defined per standard IEC 61167 a maximum length of 76 mm for both 70 W and 150 W while MH lamps with ceramic arc tube and a G12 base have a maximum length of 90 mm until 70 W lamp power and 100 mm for 100 W and 150 W.

Source: LEU Ex. 4(e)(2015c)

To conclude, though it can be followed that in some cases, ceramic MH lamps would have lower doses of mercury, it cannot be concluded that this would always be the case. It can also not be concluded whether ceramic MH lamps could replace quartz MH lamps in luminaires, or whether this would require technical adjustments or replacement of the luminaire.

In relation to alternatives that could allow elimination, a distinction can be made between the component level (replacement lamps) and the system level (luminaire/installation replacement). Various LEDs are understood to have been developed that may supply sufficient light when used in a compatible luminaire. However, it can be followed that such lamps have various limitations for use in MH luminaires.

VHK & VITO[410] provide a comparison of various HID lamps (also including some MH examples), which is reproduced below (see Table 15-5). From the table it is understood that LED lamps are becoming comparable with MH lamps in terms of efficacy. Further detail is provided as to MH lamps on the market in Table 15-6. From these two tables it can be concluded that MH lamps and LEDs currently have similar efficacies.

LED alternatives are also understood to have larger dimensions that would prevent their use in MH luminaires which are explained to be very compact. The light distribution of such alternatives and measures applied for heat dissipation can also make the application of such alternatives in MH luminaires impractical, as these installations are specifically designed optically for MH lamps. A significant drawback is the understanding that most existing MH luminaires are compact and closed, and it is expected that this would result in the heating up of the internal environment of the lamp to above 100°C. As it is understood that the lamp life decreases when the LED junction is operated above this temperature, it can be followed that using LED alternatives as replacements would result in decreased lamp life. Furthermore, as mentioned for other discharge technologies, existing installations are understood not to be electrically compatible with LED alternatives, particularly requiring the ignition to be disconnected to allow LED use.

In parallel, it can be understood that alternative LED luminaires are coming onto the market and gradually replacing existing MH luminaires. This is reflected in the decreasing numbers of MH lamps sold on the EU market (see Figure 15-2) and also confirmed by LEU who estimates that most MH lamps sold are used to replace malfunctioning lamps in existing installations.

[410] Op. cit. VHK & VITO (2015)

Table 15-5: Examples of HPM reference lamps, HPS- and CMH-substitutes, and LED retrofit lamps

Description	W	lm	lm/W class	CCT	CRI	Dimming	L (mm)	D (mm)	Life (kh)	Price (€)	Note
HPM lamps (ref)											
Philips HPL N 100W E26 A23 HG	100	4400	44	3700	45		138	73	24000		1
Philips HPL N 250W E39 HG CL 211 91	250	11500 12000	46	5800 4100	20 40		211	91	24000		1
Philips HPL N 400W E39 HG	400	21000	52	4200	50		290	122	24000		1
Non-LED retrofits											
Havells-Sylvania Relumina 85W WDL E27 (CMH)	85	7500	88 A+	3000	84		178	62	18000		2
Havells-Sylvania Relumina 170W WDL E40 (CMH)	170	15000	88 A+	3000	84		228	87	18000		2
Philips SON H 110W E27 (HPS retrofit)	110	8000-9600	84	2000	25	no	156	71	28000		3
Philips SON H 220W E40 (HPS retrofit)	220	19000	87	2000	25	no	227	91	26000	19.49	3
Philips SON H 350W E40 (HPS retrofit)	350	34000	98	2000	25	no	290	122	26000	20.99	3
Philips SON APIA Plus Xtra 100W E40 (HPS BAT)	100	10000	100 A+	1950	25		186	76	40000	(60)	4
Philips SON APIA Plus Xtra 250W E40 (HPS BAT)	250	31300	120 A+	1950	25		227	91	45000	(60)	4
Philips SON APIA Plus Xtra 400W E40 (HPS BAT)	400	55400	136 A++	1950	25		290	122	45000	(60)	4
LED retrofits											
Saled BS-S HP	27 54	3240 6480	120	3000/ 4000	>80		197 258	93x 107	50000		5
CroLED E40 80/100/120W	80 100 120	7200 9000 10800	90 A	6500			280 300 340	120		75 93 104	6
MLLG-GI-LED-RETRO from 35 to 400W	65 150 400	6000 13500 38000	92-95	4100-5500	>75	Yes	119 264 320	58/119 38/122 76/240	70000 (L70)		7

1 http://download.p4c.philips.com/l4bt/3/332443/mercury_vapor_standard_332443_ffs_aen.pdf

2 http://www.havells-sylvania.com/media/Sylvania%20Lamps/English/Relumina%20-%20English.pdf These are CMH lamps with integrated starter specifically intended for HPM retrofit. Works on existing HPM control gear. Available from Q3 2014

3 http://download.p4c.philips.com/l4bt/3/323223/son_h_323223_ffs_aen.pdf These are HPS lamps specifically intended for HPM retrofit. Works on existing HPM control gear. https://www.lampdirect.be/nl/philips-son-h (for prices)

4 http://download.p4c.philips.com/l4bt/3/344246/master_son_apia_plus_xtra_344246_ffs_aen.pdf This has been identified as a BAT HPS solution to replace HPM. In this case, starter and ballast also have to be replaced. Price estimated by study team as lamp 22+ballast 18+starter 20 euros. Installation costs have to be added.

5 http://www.saled.nl/nl/catalogus/led-straatverlichting-lichtbron/bs-s-hp/ Available in powers of 27, 36, 45 and 54 W. Lamps have an integrated gear. Existing gear to be removed or bypassed.

6 http://www.amazon.de/Leuchtmittel-Hochleistung-Beleuchtung-AC100-240V-Strahler/dp/B00M7YK63I/ref=sr_1_1?ie=UTF8&qid=1429712506&sr=8-1&keywords=100+W+E40+led+lampe (and similar) for Indoor use only (?)

7 http://www.myledlightingguide.com/ledretrofit.aspx (see links to LED retrofit kits for various powers) These lamps are not bulb-like, but flat with E26/E39 cap or mounting bracket. The existing control gear has to be removed and replaced by the LED control gear (optionally dimmable).

VHK & VITO note: The LED-lamps are intended as HID-lamp replacements, not specifically for HPM.

Source: VHK &_ VITO (2015)

Table 15-6: Efficacies of MH lamps existing on the market, compared to the minimum efficacies requested by regulation 245/2009 (EcoDesign) from April 2017.

Metal-halide lamps existing on the market				Required efficacy (lm/W), regulation 245/2009, table 10, clear lamps, from April 2017
Lamp wattage (W)	CRI	CCT (K)	Efficacy (lm/W)	
20 *(cap G8.5)*	87	3000	102	≥ 70 lm/W (for power ≤ 55 W)
45	66	2800	110	
50	89	2800	104	
50	90	4200	100	
60	73	2700	120	≥ 80 lm/W (55 W ≤ power ≤ 75 W)
60	81	4000	107	
70	87	3000	105	
70	87	4200	101	
140	66	2800	118	≥ 85 lm/W (75 W ≤ power ≤ 255 W)
150	90	3000	100	
315	90	3100	115	≥ 90 lm/W (255 W ≤ power ≤ 405 W)
315	90	4200	109	

Source: VHK & VITO (2015)

15.5.2 Environmental Arguments

Though LEU mentions LCAs that could be used to provide an indicative comparison of HPS and LED alternatives, this information is explained not to compare the LED in a way that would represent an actual substitution situation. The reports are furthermore outdated and thus this information has not been evaluated.

LEU argues that an early phase out of MH lamps (should the exemption be revoked) could lead to a large amount of waste from luminaires to be scrapped before end-of-life in lack of sufficient replacement lamps. The consultants would like to note that it is not that the amount of waste would change, but rather that end-of-life of such articles would be accelerated. In this respect it is important to take into consideration that for example, in street lighting though in some cases the whole luminaire (the pole and lamp head) would be replaced, that there is a trend towards only the lamp head being exchanged[411]. Furthermore, the materials used in lamp heads, for the most part, are understood to include various metals: "The waste typically consists of a conventional control gear (1 kg Iron and copper) and a luminaire (1 kg aluminium)."[412] For such metals, recycling practices in the EU are well established and return a large amount of secondary material to the market.

Further aspects raised are of general nature and are discussed in the general chapter under Section 4.5.3.

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[411] Please see for example: http://www.dotlux.de/strassenlaternen-und-strassenlampen-mit-dotlux-auf-led-umruesten/ last accessed 03.04.2016

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

15.5.3 Stakeholder Contributions

For the discussion of general aspects raised by stakeholders, please see Section 4.5.7 . As for EEB et al.'s proposal to phase-out quartz MH lamps in favour of ceramic ones, please see the discussion in Section 15.5.1.

15.5.4 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.

As explained above, despite various efforts to develop such alternatives, it can be followed that Hg cannot be substituted with another substance within MH lamps. It can also be followed that reducing (and also increasing) the amount of mercury would affect the function and performance of the lamp and probably also its lifetime. In this sense alternatives are understood not to be available on this level. Though it may be possible to make a distinction in the future between certain MH sub-groups in relation to the amount of Hg required for proper function, this is not expected to create actual environmental benefits. Due to the rising use of LED technology it is assumed that the lighting industry is no longer developing MH technology, so reductions in Hg amounts are not expected. In parallel, the current lack of an Hg allowance is understood not to be of concern as increasing the amount of Hg in a specific lamp would affect the lamp function negatively.

On the component level, various limitations of LED alternatives for MH lamps are apparent, particularly regarding larger dimensions of lamps, differing optical design and consequences of overheating on the LED lamp-life. These aspects among others render current LED alternative lamps as non-compatible in existing MH installations and it can be followed that an early phase-out of MH lamps would thus result in the early EoL of existing installations or at least of the luminaire heads. In relation to replacement lamps, due to the limitations explained above and as LED efficacies are currently only understood to be comparable, and not superior to those of MH lamps, it is difficult to determine whether a phase-out is recommended at this stage. On the one hand, a phase-out may accelerate the production of waste, while on the other hand it would eliminate the use of mercury and help to avoid diffuse mercury emissions from EoL. Further factors relevant to such a comparison are discussed in Section 4.5.3.2 of the general chapter. A detailed investigation is not in the scope of this review and thus it is not possible to conclude at what point early EoL of MH luminaires could be viewed as acceptable in light of the elimination of Hg and in light of possible energy savings.

Though LED alternative installations are gradually entering the new installations market, the large number of existing MH installations that would lack replacement lamps should the exemption expire would result in a large amount of waste, i.e. in a negative environmental impact.

On the system level it can be understood that a trend is already underway towards LED alternatives. Such alternatives are understood to be acceptable as the volume of MH lamps placed on the market is already decreasing and it is understood that such lamps are used mainly as replacements in existing installations. Thus it is assumed that where new installations are concerned, that LED alternatives shall gradually dominate the market. For this reason the consultants also do not see a need to restrict the use of mercury in quartz MH lamps to lamps >250 watts. Assuming that ceramic MH lamps would not be one-to-one replacements, this may result in an early end of life of quartz MH luminaires and not in a replacement of one discharge lamp with another with less mercury.

Against this background, it is concluded that renewing the exemption would be justified to allow further use of existing MH installations. LEU claims that such installations have a long service life (15-25 years), arguing the need for a long termed exemption. As detailed in the general chapter in Section 4.5.3.2 the consultants cannot conclude whether the exemption would be justified for the full lifetime of existing MH installations, but would recommend monitoring the development of LED lamps and the uptake of LED luminaires on the market.

15.6 Recommendation

Substitutes are understood to be available on the system level (for use in new LED luminaires), as is apparent by the fact that consumers are shifting to LED in new installations. LED substitutes are explained to have various limitations to allow their application as replacement lamps in existing MH luminaires (e.g. size, optical compatibility, thermal compatibility, etc.). The consultants recommend waiting until the next review to consider elimination of MH lamps in favour of LED alternatives, as a phase-out at this stage is not understood to reduce energy consumption, though expected to accelerate the end-of-life of MH luminaires (or luminaire heads). It is thus recommended to renew the exemption for a further 5 years.

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.

	Exemption	Scope and dates of applicability
4(e)	Mercury in metal halide lamps (MH)	For Cat. 5, 8 & 9: 21 July 2021; For Sub-Cat. 8 in-vitro: 21 July 2023; For Sub-Cat. 9 industrial: 21 July 2024

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

15.7 References Exemption 4(e):

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

LEU Ex. 4(e)(2015a) LightingEurope, Request to renew Exemption 4(e) under the RoHS Directive 2011/65/EU: Mercury in metal halide lamps (MH), submitted 15.1.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_4__e_/4e_LE_RoHS_Exemption_Req_Final.pdf

LEU Ex. 4(e)(2015b) LightingEurope, Response to Oeko-Institut regarding the 1st Questionnaire Exemption Request No. 4(e) “Mercury in metal halide lamps (MH)”, submitted 15.9.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_4__e_/Ex_4e_LightingEurope_1st_Clarification-Questions_final.pdf

LEU Ex. 4(e)(2015c) LightingEurope, RoHS, Summary of Critical Observations to the EEB Submission of 16.10.2015, submitted per email on 30.11.2015

VITO & VHK (2015) VITO & VHK, 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.

16.0 Exemption 4(f): "Mercury in other discharge lamps for special purposes not specifically mentioned in this Annex”

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.

Abbreviations

ANSI	American National Standards Institute
BAT	Best available technology
CFL	Compact Fluorescent
CCFL	Cold cathode fluorescent lamps
EEE	Electrical and Electronic Equipment
EEFL	External electrode fluorescent lamps
EEI	Energy Efficiency Index
EoL	End of Life
Hg	Mercury
HID	High Intensity Discharge -
HPMV	High Pressure Mercury (vapour) lamps
HPS	High Pressure Sodium (vapour) lamps
IEC	International Electrotechnical Commission
IR	Infrared
LCD	Liquid crystal displays
LED	Light emitting diode
LEU	LightingEurope
Lm	Lumen (unit)

MH	Metal halide
MPa	Megapascal (unit)
Mpcs	Million pieces
Pa	Pascal (unit)
UV	Ultraviolet (subtypes UVA, UVB, UVC)
VDMA	German Engineering Federation (Verband Deutscher Maschinen- und Anlagenbau)
VskE	German Association for Label and Narrow Web Converters
XeBr	Xenon Bromine
XeI	Xenon iodide
Zn	Zinc

16.1 Background

LightingEurope (LEU)[413], the German engineering federation Verband Deutscher Maschinen- und Anlagenbau (VDMA)[414] and the German Association for Label and Narrow Web Converters (VskE)[415] have submitted requests for the renewal of the above mentioned exemption.

LEU explains that the replacement of mercury in the lamps covered by this exemption is scientifically and technically impracticable. Replacement lamps using a different technology such as Light Emitting Diodes (LED) are available only in very exceptional cases and even then only for a part of the application range. [416]

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[413] LEU Ex. 4f(2015a): LightingEurope (LEU), Request to renew Exemption 4(f) under the RoHS Directive 2011/65/EU Mercury in other discharge lamps for special purposes not specifically mentioned in this Annex, submitted 15.1.2015, available under http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_4_f_/Lighting_Europe/4f_LE_RoHS_Exemption_Req_Final.pdf

[414] VDMA Ex. 4f(2015a), Verband Deutscher Maschinen- und Anlagenbau (VDMA) Exemption Request 4(f) Mercury in other discharge lamps for special purposes not specifically mentioned in this Annex, submitted 15.1.2015, available under http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_4_f_/VDMA/4f_VDMA_excempt_req_4f_RoHS_16Jan14.pdf

[415] VskE Ex. 4f(2015a): VskE - German Association for Label and Narrow Web Converters, Exemption Request 4(f) Mercury in other discharge lamps for special purposes not specifically mentioned in this Annex, submitted 15.1.2015, available under http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_4_f_/Vske/4f_2014-12-09_RoHS_Application_VskE.pdf

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

Applicants do not expect LED alternatives to allow for a full phase-out of Ex. 4(f) lamps within the coming 5 years, and thus request a renewal of the exemption with following wording and for the maximum available duration allowed:

> *"Mercury in other discharge lamps for special purposes not specifically mentioned in this Annex"*

16.2 Description of Requested Exemption

According to LEU[417], the scope of exemption 4(f) covers all the lamps for special lighting purposes, which do not belong to any of the groups identified in the exemptions 1(a)-4(e) by technology and application in Annex III of RoHS Directive 2011/85/EU.

The function of Hg in mercury gas discharge lamps lies within the light generating process to convert electricity into light. Electrons are emitted from a heated electrode colliding with mercury atoms which elevates their electrons to an excited state. When these fall back to their original energy state they emit photons either in the ultraviolet (UVC, UVB, UVA & UVV) or in the visible light wavelength range, depending on the technology. By using a mix of different element atoms in the hot gas plasma, each emitting at specific wavelengths, the spectral distribution of the lamp as a whole as well as the quality of colour rendition properties can be controlled. [418]

According to LEU[419] the use of mercury is essential for all lamps covered by Ex. 4(f) and needs to be kept valid. The mercury vapour is essential: all of the mercury is evaporated and the resulting pressure is chosen in such a way that:

- *"the system can provide the exact power to the lamp,*
- *the discharge radiates as effective as possible,*
- *generates the required wavelengths for the desired application and finally*
- *with a brightness that allows the most effective collection of the light."*

LEU provides a list and detail as to various technologies understood to be covered by Ex. 4(f), as reproduced in Table 16-1.

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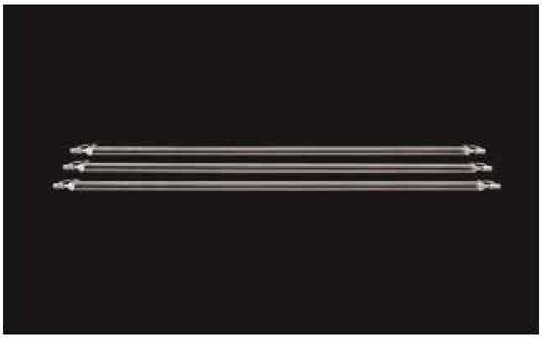
[417] Op. cit. LEU Ex. 4f(2015a)
[418] Op. cit. LEU Ex. 4f(2015a)
[419] Op.cit LEU 4(f) (2015a)

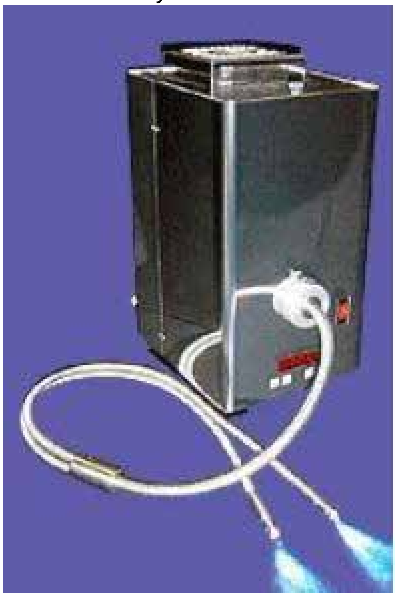
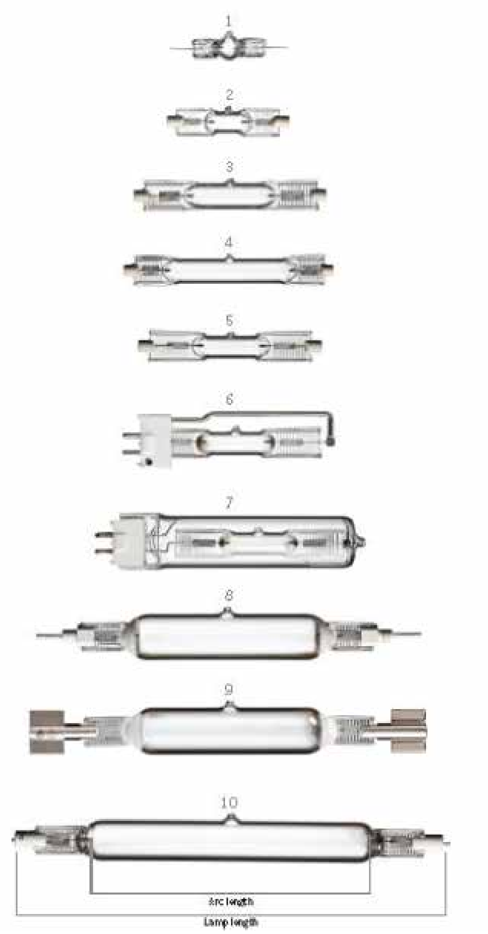
Table 16-1:Non-exhaustive list of examples of lamps and applications falling under Ex. 4(f)

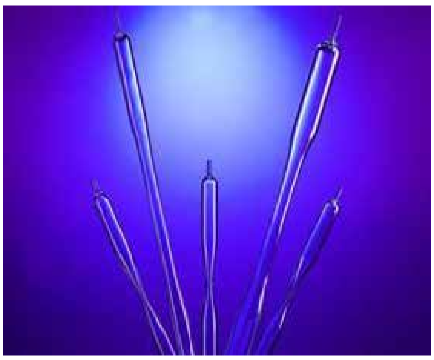
<table>
<tr><th>Examples of application</th><th>Lamp types</th></tr>
<tr><td colspan="2">UV lamp types</td></tr>
<tr><td>Technologies include:
· Curing lamps;
· Photochemistry;
· Development of polymers;
· Cross-linking of resins in varnishes or inks;
· Surface modification processes.

Currently medium pressure lamps containing mercury are used in a wide range of manufacturing applications – including amongst others wood finishing, PCB manufacture, glass bottle decoration, metal container decoration, sewer rehabilitation, contact lens manufacture, plastic bottle decoration, optical fibre coating, ink jet printing, plastic parts coating etc.:

· Vacuum ultraviolet (VUV) irradiation for surface cleaning;
· Hardening and drying of UV-hardened ink, coating and adhesive;
· Hardening of liquid crystal substrates bonded by dripping;
· Bonding of CD and DVD;
· Preliminary tests at chemical reaction plants;
· Resin coating and others;
· Photochemistry, e.g. photolysis of H2O2;
· Skin tanning;
· UV sterilisation with applications in municipal and industrial plants: sewage sterilisation, compact drinking water sterilisation plants;
· UV oxidation e.g. activated wet air oxidation.</td><td>


</td></tr>
</table>

Examples of application	Lamp types
	UV radiation system for ultraviolet curing resin 
UV curing lamps High UV power densities, up to 30 W/cm in the UV-C, can be obtained from mercury arc discharges that are operated at medium pressure of a few bars. They have a broad, pronounced line spectrum in the ultraviolet and visible spectral range.	UV curing lamps 

Examples of application	Lamp types
HID Lamp types	
Projector lamps (visible light range)	
High pressure mercury short arc lamps, which are mainly used in: · Microlithography for producing integrated circuits, liquid crystal displays (LCDs) and printed circuit boards (PCBs); · Visual and fluorescence microscopy, irradiation for photo polymerisation (used in manufacturing processes for, among other things, efficient printing ink, reliable adhesives and effective compound materials); · Boroscopy (used in particular in the aviation industry as part of maintenance work on turbines, engines and other technical equipment); · Semiconductor production.	  
High Pressure Electrodeless Ultra-Violet Light Sources	

Examples of application	Lamp types	
High Pressure Sodium (HPS) lamps for special purposes High Pressure Sodium vapour lamps are used in the following special purpose applications: · Horticultural lighting; · Resin curing; · Plastics polymerisation.		

Source: LEU Ex. 4f(2015a)

As explained by LEU the table above is a non-exhaustive list. LEU states that it is impossible to give a complete overview of all design features and applications. There are numerous lamps with small market shares for very special applications.[420]

According to VskE[421], the request focuses on UV lamps which are defined as "high intensity discharge lamps" (HID) according to Commission Regulation EC No. 245/2009[422] (Ecodesign requirements for fluorescent lamps without integrated ballast, for high intensity discharge lamps, and for ballasts and luminaires able to operate such lamps).

VDMA[423] explains that their application for extension of the existing exemption refers to Hg discharge lamps, which are used for curing / polymerisation (e.g. of layers of ink and coating, adhesives and sealants) and for disinfection (e.g. of water, in the medical field, beverage bottles).

LEU further provides some detail as to the technical function of various sub-groups of the lamps explained to fall under this exemption:

- According to LEU, Hg is used in medium-pressure lamps in a liquid form and generates UV radiation in a range between 200 and 440 nm. During the starting phase of these lamps, the mercury is vaporised and raised to higher energy unstable levels (i.e. exited). The drop from these higher energy levels (return of the electrons from the higher energy level) causes the emission of

[420] Op.cit LEU 4(f) (2015a)
[421] Op. cit. VskE Ex. 4f(2015a)
[422] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:076:0017:0044:en:PDF
[423] Op. cit. VDMA Ex. 4f(2015a)

UV light with the characteristic spectral lines. These spectral lines supply the necessary photons for UV curing and disinfection. [424]

As mentioned above LEU stated that lamps covered by Ex. 4(f) have higher internal pressure compared to fluorescent lamps falling under other exemptions. When asked as to the differences in internal pressure between Ex. 4(f) lamps and lamps of other exemptions, LEU provided the following overview (see Table 16-2)[425]. LEU states[426] further that the mercury pressure is orders of magnitude higher and varies for the different lamp types: roughly from 25 kPa to 35 MPa.

Table 16-2: Overview of Hg pressure in different lamp types

Exemption	Lamp sub-groups	Internal pressure	Application specification
1a-f, 2a, 2b, 3a-c, 4g	Fluorescent lamps (CFL, linear and non-linear FL, Cold cathode FL)	200 Pa ~ 700 Pa by noble gas, 0.1 Pa ~ 5 Pa by Hg	General lighting and special purposes,
4a	Other low pressure discharge lamps	0.1 Pa ~ 5 Pa by Hg	Germicidal and other UV
4f	Lamps for projection	10~35 MPa	White light Point source
	Short arc mercury lamps	1~5 MPa	High intensity light, point source
	High Pressure Sodium	0.1~0.8 MPa	Horticulture and other special purposes
	UV curing lamps	1~5 MPa	Spot area
		0.1~1 MPa	Plane area
	Other high pressure	> 1 MPa	

Source: taken from LEU 4(f) (2015b)

LEU explains[427] that the IEC has defined low pressure lamps as lamps having an internal mercury pressure below 100 Pa[428] (=0,001 bar=1mbar).

[424] Op.cit LEU 4(f) (2015a)
[425] LEU 4(f) (2015b): LightingEurope, Response To Oeko-Institut regarding the 1st Questionnaire Exemption Request No. 4(f) “Mercury in other discharge lamps for special purposes not specifically mentioned in this Annex” submitted September 15, 2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_4_f_/Ex__4f__LightingEurope_et-al_Clarification-Questions_final_20150915.pdf
[426] Op.cit LEU 4(f) (2015b)
[427] Op. cit. LEU Ex. 4f(2015b)
[428] The definition of a low pressure lamp: http://www.electropedia.org/iev/iev.nsf/display?openform&ievref=845-07-22
The definition of a high pressure lamp:

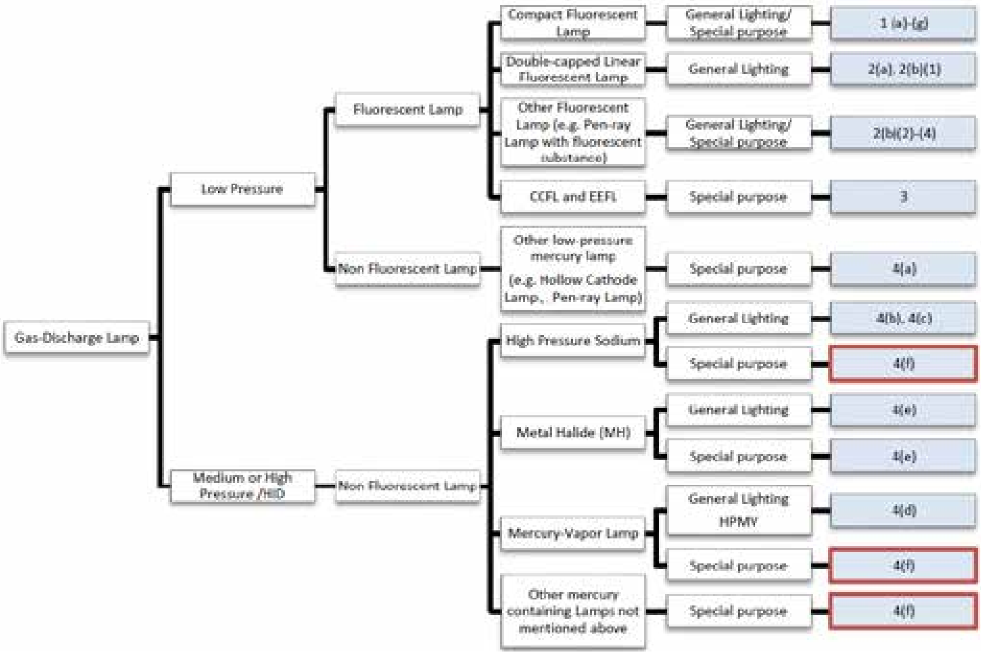
16.2.1 The Scope of the Exemption

LEU explains[429] the scope of Ex. 4(f) to cover all the lamps for special lighting purposes, which do not fall under any of the technology and/or application groups identified in the exemptions 1(a)-4(e) of Annex III of RoHS Directive 2011/85/EU. This is understood to exclude all low pressure discharge lamps and medium and high pressure discharge lamps (high pressure sodium vapour; high pressure sodium mercury; and metal halide lamps) used for general purposes. This also excludes special purpose lamps covered by some of the other exemptions. To summarize the following are understood not to be covered by ex. 4(f):

- Low pressure discharge lamps are understood to include:
  - Fluorescent lamps – compact (CFL), linear (LFL) and cold cathode (CCFL) and external electrode (EEFL); and
  - UV lamps without phosphor coating operating at low pressure.
- Medium and high pressure discharge lamps are understood to include:
  - High pressure sodium vapour (HPS);
  - High pressure mercury vapour (HPVM); and
  - Metal halide lamps (MH).

The figure below illustrates the hierarchy of lamps and currently existing Annex III exemptions for mercury in lamps

Figure 16-1 Chart on the hierarchy of lamps and exemptions



Source: LEU Ex. 4f(2015a)

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http://www.electropedia.org/iev/iev.nsf/display?openform&ievref=845-07-20

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

LEU concludes that the scope of Ex. 4(f) covers lamps, which are not fluorescent, which have a higher internal pressure compared to fluorescent lamps, that are used for special purposes and for which a mercury limit is not specified. Such lamps include for example short-arc mercury lamps for producing LED components, lamps for projection or for UV curing applications. LEU provides multiple examples in its request, providing explanatory information and demonstrative pictures (see Table 16-1).[430]

16.2.2 Specified Lamp Technologies/Applications Falling under Ex. 4(f)

The lamp applications relevant for Ex. 4(f) vary in respect with the designs and the amount of mercury widely. For example very high power lamps, need a certain lamp volume to prevent that the heat generated in the discharge melts the wall of the discharge vessel. At the same time if the same high power lamp is used for projection, the arc must be very compact. This requires a very high mercury pressure. The combination of a very high pressure and a large discharge volume leads to the necessity of a large amount of mercury (up to 100 gram). Other lamps require very efficient UV generation for instance for water purification. Here the generated UV must escape from the discharge without radiation trapping, these lamps have a medium mercury pressure (below 1 bar). [431]

Information is provided in relation to various technologies/applications relevant for this exemption. As alternatives for Ex. 4(f) lamps need to be evaluated in the context of the function of a specific lamp in its application, details are summarised here according to type.

16.2.2.1 Lamps Emitting Light in The Visible Wavelength Range

Projection Lamps: LEU explains that projection applications are very demanding for the light source. In order to reach sufficient brightness, the light of the lamp has to be efficiently collected onto the imaging display. This can only be achieved with a lamp that resembles a point source, i.e. a lamp with a high luminance and a short arc. For UHP [ultra-high pressure lamps – consultants comment] lamps, the high luminance of the plasma is reached by using pure mercury at a very high pressure. [432]

- The fact that only mercury is used, results in the best luminance arc: compared to lamps with spectrum additives (high performance metal halides), the luminance is a factor of 2 higher[433]. Next to that, in a pure mercury gas it is possible to design a halogen cycle which keeps the wall clean. This is necessary to obtain long lifetimes with lamps of small sizes. Mainstream projector lamps currently have lifetimes of 6,000 to 10,000h,

[430] Op.cit LEU 4(f) (2015a)
[431] Op.cit LEU 4(f) (2015a)
[432] Op.cit LEU 4(f) (2015a)
[433] Referenced in LEU Ex. 4f(2015a) as: New UHP Lamp Technologies for Video Projection, Holger Mönch, 2001, SID-ME Meeting on display Materials and Components Fall 2001

whereas typical high performance metal halide lamps (with a lower pressure and less mercury) reach around 1,000h.

- The high pressure reduces the load on the electrodes by reducing the current and serves as a buffer gas to insulate the arc from heat losses. The high pressure limits diffusion of tungsten atoms away from the hot electrode. Next to the halogen cycle, these properties are required to enable long lifetimes compared to other high luminance lamps. The high pressure also improves the spectrum of the lamp so that it matches the required output spectrum for good picture imaging (according REC709 standards). The good colour quality is due to the extreme pressure and the so called Bremsstrahlung (i.e. deceleration radiation) generated by collisions of electrons with mercury atoms[434].

Lamps for Horticulture Applications: High Pressure Sodium (HPS) lamps for use in horticulture are a member of the High Intensity Discharge Lamps (HID) group. The HPS lamps for horticulture are designed to stimulate plant growth (examples are: tomatoes, cucumbers, flowers). The efficiency of the lamps is not expressed in lumens/W since the plant growth responds to the photons almost universally: each photon is of about the same efficiency. Research at universities and applied agricultural research stations has demonstrated that the rate of photosynthesis is related to the amount of photons roughly between 400– 700 nm. This is called 'Photo synthetic Photon Flux' (PPF). This is expressed in micro mole of photons per second (µmol / s)[435]. The PPF value ranges from 2.1 (micro mole photons/Watt), for the most efficient 1000W lamp to 1.6 (micro mole photons/Watt) for the 250W lamps. Since plants are used to receive light from above, these lamps are mounted above the plants and should be as compact as possible. The small size is to avoid blocking the useful sunlight. The luminaire might block the light even when the growth light is not used, for instance during summer. A recently discovered, secondary effect is the irradiation with infra-red light. Many crops benefit from infrared radiation from above from the direction of the sun, especially during winter. The flux depends on the plant but for tomatoes it is about 25-30 W/m^2 which is easily provided by the HPS lighting.

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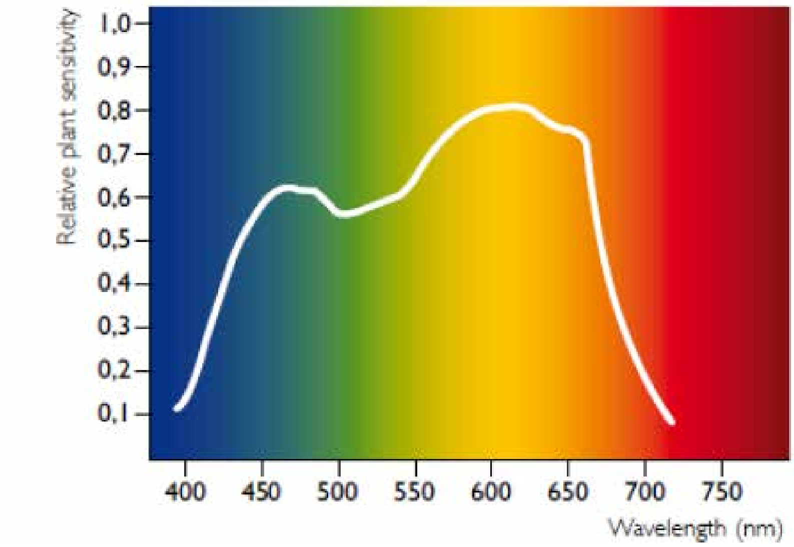
[434] Referenced in LEU Ex. 4f(2015a) as: Bremsstrahlung radiation from electron–atom collisions in high pressure mercury lamps, J E Lawler 2004 J. Phys. D: Appl. Phys. 37 1532; and
Infrared continuum radiation from high and ultra-high pressure mercury lamps, J E Lawler, A Koerber and U Weichmann ,2005 J. Phys. D: Appl. Phys. 38 3071

[435] Referenced in LEU Ex. 4f(2015a) as: Accuracy of quantum sensors measuring yield photon flux and photosynthetic photon flux. Barnes C1, Tibbitts T, Sager J, Deitzer G, Bubenheim D, Koerner G, Bugbee B, HortScience. 1993 Dec 28(12):1197-200.

Figure 16-2: Light sensitivity curve of plants



Source: LEU 4(f) (2015a)

High Pressure Sodium lamps are characterized by very long life (30,000 to 50,000 hours) and very high luminous efficiency (from 80 lm/W to 150 lm/W). HPS lamps can only operate on designated drivers that switch the lamp on and regulate the power. These drivers can be an electro-magnetic ballast (inductive/capacitive load) to stabilize the lamp current in combination with a high voltage pulse generator (ignitor) to ignite the lamp. Nowadays, also electronic drivers are used to stabilize the lamp at the correct power.

16.2.2.2 UV Lamps

LEU provides details for two types of UV lamps in terms of technologies – medium pressure UV lamps and short arc mercury lamps.

Medium pressure UV lamps contain a mixture of mercury and argon gas inside a sealed quartz tube. In operation, this mixture is heated to create a stable mercury plasma which emits radiation at specific wavelengths within the UV range (100-400nm), and which are characteristic of mercury. UV curable inks, coatings and adhesives are formulated to absorb the UV light at specific wavelengths by selecting photo initiators whose absorption profiles match the emission spectrum as closely as possible. [436]

UV energy can be used to disinfect water, surfaces and air. The process reduces the pathogen count in an economical and environmentally friendly way without the need for the addition of chemicals. Furthermore, the UV process can be used to kill-off chlorine resistant pathogens such cryptosporidium. In germicidal applications, the spectra have to be optimized to match the wavelengths required for cell deactivation. UV disinfection

[436] Op.cit LEU 4(f) (2015a)

is effective at wavelengths between 200-300nm: the spectral region for the most effective cell deactivation. The germicidal action curve peaks at 265nm. UV-C radiation has strong bactericidal effect. It is absorbed by the DNA of the microorganism, destroys its structure and inactivates the living cells. Microorganisms such as bacteria, yeasts and fungi are destroyed in a few seconds with UV radiation. [437]

Short Arc mercury UV lamps contain a mixture of mercury and xenon gas inside a sealed quartz tube. They are mainly used in: [438]

- Microlithography for producing integrated circuits, liquid crystal displays (LCDs) and printed circuit boards (PCBs);
- Visual and fluorescence microscopy, irradiation for photo polymerisation (used in manufacturing processes for, among other things, efficient printing ink, reliable adhesives and effective compound materials);
- Boroscopy (used in particular in the aviation industry as part of maintenance work on turbines, engines and other technical equipment);
- Semiconductor production;
- UV curing: Using the 2 atomic lines of mercury to polymerize the inside of the adhesive for UV ray curing at 365nm and to polymerize the surface layer of the adhesive at 248nm. That is why several wavelengths are necessary on one optical axis;
- Photolithography: For the exposure of the 193nm photo resists of semiconductors, UV rays having a specific wavelength between 193 and 250nm are used. The high energy of intensified light is needed to get the necessary discrimination between exposed and unexposed areas.

LEU[439] thus sees the bright line spectra of the mercury-arc lamp as indispensable.

16.2.3 Amount of Mercury Used under the Exemption

LEU explains that there are four common dosing technologies for lamps explained to fall under Ex. 4(f). After the first enquiry LEU details for each dosing technology, in which lamp types (UV lamps, protector, HPS etc.) it is used[440].

- Manual pipetting or needle injection of liquid mercury (100% Hg) in UV lamps (e.g. Short Arc Mercury lamps);
- Semi- or fully automatic dosing, disc needle injection of liquid mercury[441] (100% Hg) in projection lamps, UV lamps;

[437] Op.cit LEU 4(f) (2015a)
[438] Op.cit LEU 4(f) (2015a)
[439] Op.cit LEU 4(f) (2015a)
[440] Op.cit LEU 4(f) (2015b)
[441] Liquid dosing is applied to lamps either manually or in automated injection technologies. The choice is more related to production technologies and number of produced products. Op.cit LEU 4(f) (2015b)

- Mercury-Sodium amalgams Na-Hg (ca 20% Hg) in High Pressure Sodium lamps (Horticulture lamps);
- Amalgam sticks (ca. 20-50% Hg) also in High Pressure Sodium lamps (Horticulture lamps).

The amount of substance entering the EU market annually through Ex. 4(f) lamps is estimated based on different market studies and input of single manufacturing companies submitted to LEU. According to LEU, there is no single database or reliable evaluation that would give accurate data. The following amount of mercury is the best estimation of LEU[442].

Table 16-3 Estimation of the amount of mercury put on the market per year in lamps covered by exemption 4(f)

Lamp type	Mercury range per lamp	Estimated volume of lamps	Mercury put on EU market
Lamps for projection	10-40 mg depending on Wattage, average 15mg	Around 10 Mio projector lamps are marketed worldwide per annum. Calculating a market share of 30% for Europe will lead to 3 Mio lamps.	45 kg (maximum)
Short arc mercury lamps	Up to 100g per lamp, average ca. 1g	Not detailed	20 kg
UV Curing lamps	Typical range 10-3000 mg	According to a market report 2012[1], the worldwide market for UV curing mercury lamps is 440.000 pieces. Calculating a market share of 30% for Europe will lead to 132.000 lamps. These lamps (long and short lamps) will contain roughly 66 kg of mercury.	With a yearly market increase by 6 %, 75 kg in total can be estimated for 2014.
Other high pressure	No information available	Not detailed	No information available

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

Source: LEU 4(f) (2015a) – Information in the column "Estimated volume of lamps" was not originally part of the table and has been copied from the explanatory text for this table.

VDMA[443] further details that according to Yole (see note to Table 16-3 for reference), disinfection will use 535,000 lamps. These lamps are responsible for a worldwide mercury usage of 268 kg and therefore 81 kg within Europe for disinfection.

LEU stresses that Exemption 4(f), and the belonging lamp types represent a small market share and are responsible for a small part of mercury use compared to the other lighting exemptions. [444]

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[442] Op. cit. LEU Ex. 4f(2015a)
[443] Op. cit. VDMA Ex. 4f(2015a)
[444] Op. cit. LEU Ex. 4f(2015a)

16.3 Applicant's Justification for Exemption

The applicants argue that the exemption is still needed as eliminating mercury is not possible and reducing mercury dose per lamp would not allow producing lamps of comparable performance. LED alternatives are becoming more common, but are explained not to be suitable as lamp (component level) replacements in existing installations.

16.3.1 Possible Alternatives for Substituting RoHS Substances

Alternative elements for mercury either lack the required vapour pressure at a low temperature, or do not radiate efficiently upon collisions with electrons or react violently with the transparent quartz wall and block the light when the lamp becomes older. All single elements, stable combinations of elements and stable compounds with suitable vapour pressure have been evaluated as possible alternatives to mercury and none give either the same broad UV spectrum or the required wavelengths with sufficient intensity to perform the required necessary functions. Therefore the only potential future alternatives to use of mercury could be from different technologies. [445]

To substantiate its claims in relation to substance substitutes, LEU provides a few examples of the shortcomings of discharge lamps using other substances, as presented in the following subsections.

16.3.1.1 Mercury-free Discharge Lamps for Projection Purposes:

Hg free discharge technology based on Zn is available[446]. For projection applications this technology is not suited due to a too low metal gas pressure which leads to a low lamp voltage. This results in low energy efficiency. Efforts have been made to develop a high pressure Zn discharge lamp in order to reach reasonable energy efficiency in a projection application. These efforts have been stopped because there was no technical solution to cope with the required extreme high operating temperatures. Further, the zinc atoms violently react with the quartz, damaging the transparency. The loss in transparency reduces the brightness of the source and makes the lamp unfit for the application. This prohibits zinc as an alternative for mercury. [447]

Xenon-lamps can offer the required high luminance for projection purposes, but they suffer from very low energy efficiency. Xenon-lamps are by about a factor of 4 less efficient than Ultra High Pressure-lamps, leading to much larger lamps. As a result, they are used in very limited projection applications[448].[449]

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[445] Op.cit LEU 4(f) (2015a)
[446] Referenced in LEU Ex. 4f(2015a) as: Patent WO2006046171
[447] Op.cit LEU 4(f) (2015a)
[448] Referenced in LEU Ex. 4f(2015a) as: Proc. SPIE 5740, Projection Displays XI, April 10 2005
[449] Op.cit LEU 4(f) (2015a)

The applicants do not provide detailed information about the possible reduction of mercury. VDMA[450] provides a general statement claiming that reduction of the amount of mercury in a certain range or its complete elimination in the lamp is not possible.

16.3.2 Possible Alternatives for Eliminating RoHS Substances

The suitability of alternative technologies is explained to differ per application. For horticulture lighting alternatives are LED's and are discussed under the chapter for horticulture lighting. Alternatives for water purification are chemicals like chlorine[451]. Discussion of other alternatives can be found under the UV lamp chapter. For the projection lamps LED's and lasers are alternatives. Though some of the mentioned alternatives may be applicable to a small part of the application range, LEU explains that they are not *"revers compatible"* with existing installations, i.e., that they cannot be used as replacement lamps in equipment already on the market. [452]

In the following, different Ex. 4(f) lamps and their applications are described in relation to possible alternatives for eliminating RoHS substances (mainly LED technology).

16.3.2.1 Lamps for Projection purposes – Solid State Technology

For projectors the ANSI Lumen (Lm) level on the screen determines the market segments. It is regarded as a basic requirement for a projector to have at least 2000 ANSI Lm brightness level. For lit environments, a brightness minimum level of 3000 ANSI Lm is regarded as the standard. All projectors between 2000 and 5000 Lm are defined as mainstream projectors. Some projector producers have started several years ago to use solid state light sources within a limited area. These can be categorized as: White LED (1), Scanning Laser (2), RGB LEDs (3), LED/Laser (-phosphor) Hybrid (4), Laser-phosphor (5) or RGB Laser (6):

- The luminance level of White LEDs (1) is too small to reach more than 500 Lm. For Scanning Lasers (2), safety requirements limit the scanning beam intensity. Usage of both White LED and Scanning Laser will be limited to the pico projector segment.
- RGB LEDs (3) used for projectors are a surface light source and have a limitation in luminance level. High luminance is required for optical imaging. The range of RGB LED projectors currently available on the market only covers lumen levels up to 1500 ANSI Lm (commercially specified). The measured brightness level is currently still limited to around 800 ANSI Lm[453]. This means that RGB LEDs (3) do not play a role in the mainstream segment.

[450] Op. cit. VDMA Ex. 4f(2015a)
[451] Consultants comment: No further detail was provided in relation to this alternative, assumed to be addition of chlorine to water.
[452] Op.cit LEU 4(f) (2015a)
[453] Referenced in LEU Ex. 4f(2015a) as: See product reviews at e.g. www.projectorcentral.com, e.g. projectors HD91, DG-757, LGPF85U

- The remaining laser-based technologies (LED/Laser (-phosphor) Hybrid (4), Laser-phosphor (5) or RGB Laser (6)) entered the market quite some years ago, but the penetration rate is very low. For several years now, the level of projectors with hybrid or laser solution is stable at approximately 1.5% of the total market[454]. The slow penetration rate is explained through the need to apply various measures for each of the laser types, such as: cooling of semi-conductors, which is bulky, heavy and/or noisy and thus not practical for mobile applications; measures for supressing laser speckle noise, which would otherwise result in a varying intensity of light spots in the projected image; safety measures as the light sources are class 4[455] lasers.

16.3.2.2 Lamps for Horticulture Applications

In LED lighting, irradiation with infra-red light is absent. For the currently available most efficient LED lamps the power that is transformed into light is about 40% and there is no IR or UV. So 60% of the power is transformed into heat that has to be removed by convection/radiation to the surrounding air in the closed luminaire. This makes the design of the luminaire difficult especially since the environment temperature in the greenhouse is high and the size of the luminaire is limited because of the demand to minimise blocking of direct sunlight. LEU further explains that the operating temperature of LED alternatives within an HPS luminaire would be too high and could affect the lifetime of the lamp (see details in Section 14.3.2 of the chapter of HPS lamps of Ex. 4(b)(I-III))

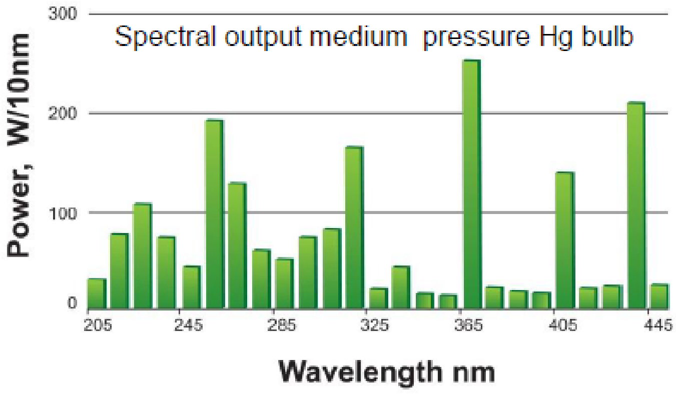
16.3.2.3 Lamps for UV Curing Applications

UV LED lamps are available and may be considered as an alternative technology for medium pressure mercury lamps used in UV curing applications, but their performance characteristics are very different to UV mercury lamps. LEU details various applications of UV curing lamps (See Appendix A.3.0) and explains that inks, coatings and adhesives developed for these processes have been designed to respond very efficiently to the broad emission spectrum from the medium pressure mercury lamps to deliver a finished product that meets a wide range of very demanding product specifications. The broad band emission from the medium pressure lamps is important because it allows the photo initiator, the component in a UV formulation that absorbs the light, to absorb a wide range of wavelengths and thereby enable the ink, coating or adhesive to deliver the required combination of properties. For example, in coatings on interior plastic parts for cars, a hard, scratch resistant surface is required and this can be delivered by utilizing the shorter wavelengths (280-320nm). Other required properties such as resistance to

[454] Referenced in LEU Ex. 4f(2015a) as: Futuresource-consulting
[455] In the revised IEC 60825 standard, lasers are classified by wavelength and maximum output power into four classes and a few subclasses. The classifications categorize lasers according to their ability to produce damage in exposed people, from class 1 (no hazard during normal use) to class 4 (severe hazard for eyes and skin).

aggressive solvents or adhesion to plastic surfaces can be aided by utilising the longer wavelengths (320-365nm).

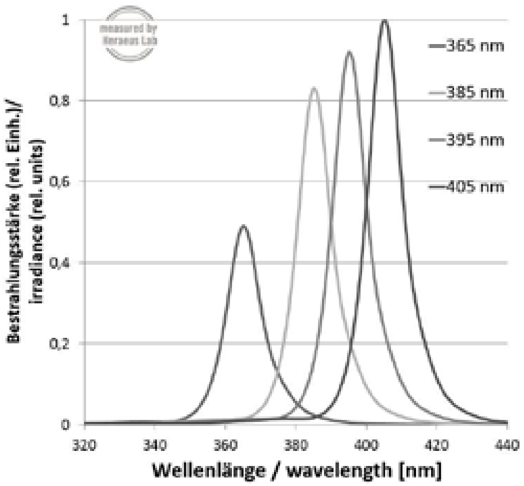
Table 16-4: Spectral output of medium pressure mercury lamps



Source: LEU 4(f) (2015a)

UV LED lamps are a potential alternative technology that has been introduced into UV curing applications. However, to date their commercial success has only been on a relatively small scale in some specific niche applications (see detail in application). One of the drawbacks of the UV LED is that the light is only produced in a very narrow band. UV LED lamps delivering 405nm, 395nm, 385nm and 365nm wavelengths are the most common, commercially available products. The most widely used products deliver 395nm and 385nm; these products have the highest output and the longest lifetimes. Furthermore, the lack of output from the UV LED in the UVB and UVC region means that it can be more difficult and sometimes not possible to produce the hard, scratch resistance coatings required by applications such as coating plastic parts for the automotive industry.

Table 16-5: Spectra of 4 different UV LED lamp types



Source: LEU 4(f) (2015a)

The following table provided by VDMA[456] demonstrates LEDs with a typical peak wavelength in comparison to Hg-UV lamps. The needed power levels (last column in Table 16-6) are calculated as 2/3 of the UV lamp output[457].

Table 16-6: LEDs with a typical peak wavelength

Wavelength [nm]	LED output [mW]	UV lamp output [mW]	To be seen as needed
205	Not available	> 12000	8000
215	Not available	> 15000	10000
225	Not available	> 22000	14500
235	Not available	> 24000	16000
245	0,1	> 9000	6000
255	1	> 30000	20000
265	10	> 24000	16000
285	25	> 4500	3000
300	25	> 6000	4000

Source: VDMA 4(f) (2015b)

VskE[458] details that LED chips with reasonable optical outputs at wavelengths down to 365 nm are available. But for most of the applications radiation at lower wavelength is also needed, or more precisely, the broad UV spectrum of a medium pressure mercury vapour lamp is needed. At lower wavelengths there are no LED chips with good optical yields and reasonable prices available.

In addition the output power of the UV LED is relatively low compared to the medium pressure lamps resulting in much slower processing speeds. Output power of UV LEDs is at present very low in comparison to mercury UV lamps.

- UV lamps maximum power rating for example, 0.370 to 1.26 watts;
- HID UV lamp 250 – 400 W lamps are widely used and more than 25kW are available.

VDMA[459] also explains that the development of printing inks, which are suitable for the radiation spectra of the UV-LEDs is impeded by the limited availability of suitable photo-initiators for UV printing inks (see further detail in application). The printing ink industry resorts to selecting the photo initiators that are most suitable for LED-UV inks from the photo-initiators available on the market and in this respect makes compromises with regard to the range of applications. The absorption curves of the photo-initiators show that most of those that can be used have their main absorption bands in the UVB and UVC range. At present, the radiation energy of LED-UV lamps in this spectral range is too

[456] Op. cit VDMA Ex. 4f(2015b)
[457] VDMA does not explain the basis for calculating 2/3 of the discharge lamp output as the minimum requirement for LED alternatives.
[458] Op. cit. VskE Ex. 4f(2015a)
[459] Op. cit. VDMA Ex. 4f(2015a)

low for the through-curing of ink and coating layers and the operation of UV dryers in an economical and energy-efficient way. Reliable curing is, however, needed for compliance with the European requirements for low migration of substances from food packaging materials (Regulation (EC) No 1935/2004 on materials and articles intended to come into contact with food). The synthesis, approval and registration (REACH) of new suitable photo-initiators requires substantial research efforts and tests. Furthermore, the ink manufacturers state that the development of new LED-UV printing inks, their CMR (CMR=Carcinogenic, Mutagenic and toxic to Reproduction) testing and approval takes 5 to 7 years and, therefore, is not economically reasonable considering the present market volume.

16.3.2.4 UV Lamps for Disinfection Applications

VDMA comments[460] that UV-LEDs cannot be used for disinfection since wavelengths of 265 nm or lower are required for the destruction of DNA. In this application area there are mercury free solutions, such as excimer lamps, however it is explained that these have only been successful in a few applications in niche markets.

LEU states that mercury lamps for disinfection have a wall plug efficiency of up to 50% for generating UV-C photons at 254nm. The stronger version, also mercury based, uses an amalgam to enhance the photon flux, but with a lower wall-plug efficiency of ~35%. The current efficiency of UV LED emitting in the UVA region is 20-30% with typical lifetimes of 10,000 hours but UV LEDs emitting in the UV-C or UV-B region have only a 1-2% efficiency with lifetimes less than 1,000 hours. This makes UV-C and UV-B LEDs unsuitable for many applications. For an explanation and further details as to wall plug efficiency please see Section 28.3.2 of the Ex. 18b chapter).

A possible mercury free solution could be a xenon bromide excimer lamp emitting at 282nm or a xenon iodide excimer lamp emitting 253nm photons. In both alternative cases, the wall-plug efficiency is below 10%. So this is not a realistic alternative given the power consumption comparison with Hg lamps and the poor efficiency. Furthermore the power supply technology is by far more complex and significantly more expensive compared to conventional ones used to drive Hg-based lamps.

Another alternative might be a Xe2- excimer lamp emitting 172nm photons with an efficiency of up to 40%. A phosphor might convert the radiation into the germicidal range around 265nm. Assuming a quantum efficiency for the phosphor of 90% and the Stokes shift being ~65% the total electrical lamp efficiency will come down to ~23%. This low value might only be partly compensated by a larger germicidal action due to the wavelength. Lifetime values for the Hg-based conventional low pressure lamps easily exceed 10,000h, but this would be very hard to achieve with a 172nm based Hg-free version. Currently, mercury free solutions, such as excimer lamps have only been successful in a few applications in niche markets.

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[460] Op. cit VDMA Ex. 4f(2015a)

Other Hg free alternatives include Xe flash lamps but these have a very low germicidal efficiency.

LEU summarises that UV LED lamps are not a suitable alternative technology because UV-C LEDs are not commercially available; the current R&D prototypes have a very low power output, low efficiency, low lifetimes and high costs.

16.3.3 Environmental Arguments

Most environmental arguments provided by LEU are of general nature, inter alia: LCA comparisons; the use of materials and hazardous substances; the health and safety impact of substitutes; aspects related to the waste stream and recycling. Please see Section 4.3.3 of the general chapter in these respects.

According to the applicant[461] the lamps concerned in this exemption request are mainly for professional/commercial use and are used in a wide variety of applications which have different waste routes. This equipment is usually not disposed of in household waste (municipal waste), due to its large size, but is collected mainly by business-to-business collection schemes set up according to the WEEE legislation. Only a small portion could end in private households in projectors.

16.3.4 Socio-economic Impact of Substitution

LEU provides no descriptions of socio-economic impact of substitution as substitution is not possible. VDMA[462] provides an example in relation to products printed with UV inks. *"The prices of UV-LED inks are currently approx. 2/3 higher than those of conventional printing inks. One reason is the higher proportion of photo-initiators in order to achieve adequate curing even with the lower radiation dose of the UV-LEDs. The investment costs of the LED-UV modules for the curing process are substantially higher compared to conventional UV lamps (variety of chips required, integration of optical components and the related construction and connection technology). High expenses are needed for the development of materials and the implementation of reliable processes along the total value chain. The production of certain printed products could be transferred to other regions of the world, which would have direct effects on the employment situation in the European printing industry. Social effects are seen with regard to food safety (migration of low-molecular substances in the event of inadequate curing by means of UV-LED) and/or water treatment (lack of safe and environmentally friendly substitute technology)."*

[461] Op. cit LEU Ex. 4f(2015a)
[462] Op. cit. VDMA Ex. 4f(2015a)

16.3.5 Roadmap to Substitution

LEU claims[463] that Ex. 4(f), and the belonging lamp types represent a small market share and are responsible for a small part of mercury use compared to the other lighting exemptions. Therefore the lamps must remain available on the market for:

- New equipment as there are nearly no (or for certain applications no) alternatives available on the EU market;
- Equipment in the field to replace end of life lamps (EoL) in order to avoid that existing equipment from turning into electronic waste before due time.

16.4 Stakeholder Contributions

A number of contributions have been made by stakeholders. Comments of general nature have been summarised in Section 4.4 in the Chapter regarding lamps in general.

Two further contributions were submitted during the stakeholder consultation and are listed below:

- Contribution by RadTech, submitted 9 October 2015[464]: a non-profit trade association (with around 700 members worldwide) dedicated to the advancement of ultraviolet (UV) and curing processes;
- Contribution by European Printing Ink Association (EuPIA), submitted 13 October 2015[465].

RadTech:

UV curing processes are commonly used in a number of industries including wood and building products, printing and packaging, electronics, automotive, aerospace, food packaging, and 3D printing/additive manufacturing, as well as numerous other applications[466]. RadTech recognize that UV LED is already on the market but they are currently not considered as a suitable replacement technology. Nevertheless, RadTech appreciates an evaluation of the potential for substitution by UV LED in the future.

EuPIA:

EuPIA explains that equivalent UV-LED mercury-free products are not widely available for the printing ink industry due to the limited range of output wavelengths and low

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463 Op. cit LEU Ex. 4f(2015a)

464 RadTech 4f (2015): RadTech Officers; Stakeholder Consultation RoHS II – Exemption 4(f), submitted 9.10.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_4_f_/Support_of_Application_to_renew_Exemption_4_f__in_Annexe_III_as_proposed_by_Lighting_Europe.pdf

465 EuPIA 4f (2015a), European Printing Ink Association – EuPIA, Stakeholder Consultation RoSH II - Exemption 4(f) - EuPIA contribution; submitted 12.10.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_4_f_/151012_EuPIA_support_of_Medium_Pressure_Mercury_Lamp_RoHS_Exemption_Extension.pdf

466 RadTech 4f (2015)

power output, UV-LED currently does not promote enough surface drying. However, EuPIA points out that UV-LEDs will become a capable technology for replacing mercury lamps in the future.

16.5 Critical Review

16.5.1 Scientific and Technical Practicability of Substitution

From the information that LEU provides it can be followed that eliminating mercury in lamps falling under Ex. 4(f) is not practical. Though available information shows that various investigations have been carried out, it is understood that none of these resulted in alternative lamps coming on the market. Such alternatives are explained to lack a sufficient vapour pressure at low temperatures (i.e. to facilitate ignition), do not radiate in the relevant spectrum or shall decrease lamp lifetimes.

A reduction of Hg in Ex. 4(f) lamps is also understood not to be practical. In contrast to low pressure fluorescent lamps, mercury is understood not to be consumed during the lifetime of these kind of lamps, and the amount dosed can neither be decreased (as this would affect lamp pressure and thus the function of the lamp) nor increased (as additional mercury is not required for the lamps function).

In relation to alternatives that could allow elimination, it is important to first make a distinction between the component level (replacement lamps) and the system level (luminaire/installation replacement). Regardless of the development of alternatives, it can be followed that for applications relevant to this exemption, difficulties can be expected with the compatibility of alternatives with existing equipment (i.e. replacement lamps). Many of the lamp technologies addressed in the examples (e.g. HPS) are compact in size, meaning that lamps with larger dimensions could not be used as replacement lamps. As luminaires are small and often closed, heat created by the lamp during operation remains within the luminaire. In the case of LED alternatives, their lifetime would be affected negatively due to higher temperatures within the luminaire. In short, it can be followed that irrespective of the development of alternatives, replacing lamps within existing installations require the retention of the exemption.

On the system level, various application areas are described and detail is given as to the possibility of elimination through alternatives to discharge technologies.

For **UV applications** (**curing** and **disinfection** are named), it can be understood that though first UV LEDs are coming on the market, their spectral output is currently not suitable to allow substitution in most cases. The wall plug efficiency of such lamps is also currently significantly lower compared to discharge lamps and thus would result in lamps which are less efficient, thus consuming more energy.

In the visible range, two applications are named:

1. For **projection lamps** it can be understood that first LED alternatives are coming on the market, however that these currently only operate below 2000 lumen ANSI and would thus not be suitable for a large part of the application range. Though it can also be understood that some laser alternatives have been developed, these are

understood to show various problems as they shall require the application of cooling measures that limit their mobility, measures for reducing speckle noise of the image which affect the function, and safety measures as all such lasers are class 4 under the IEC 60825 standard (severe hazard for eyes and skin). Though information is available[467] that some projection lamps are available in the UV range, LEU refers to projection lamps under the visible light category and it is thus assumed that lamps of relevance to this exemption are all in the visible range. It is also noted here that projector lamps are understood to be high pressure mercury lamps. Though LEU claims that such lamps fall under Ex. 4(f) as special purpose lamps not addressed in other exemption, Ex. 4(d) covers the use of Hg in high pressure mercury lamps and is not restricted to general purpose applications. Thus the consultants wondered whether projection lamps would have not been covered under Ex. 4(d) which expired in April 2015. In this respect it should be noted that in the 2008/2009 evaluation[468] it was explained that "*the corresponding EU Eco-design activities came to the following conclusion 'The proposed Eco-design requirement is to set minimum efficacy targets for street lighting lamps or for 'all' lighting applications so that HPM lamps are actually banned and HPS retrofits are used instead of them in installed luminaires. Even self-ballasted (mixed light) HPM lamps could be excluded, because these can be replaced by CFL's with integrated ballast'*[469]*"* It was however, concluded that for technical lamps that are used in special applications a substitution of HPMV lamps by retrofit HPS lamps is not possible and it was recommended to limit the exemption to "*Mercury in High Pressure Mercury (Vapour) lamps except for general lighting (HPMV)*". It is not clear why it was decided to grant the exemption for all HPMV lamps, however it can be followed that despite their possible lower efficiency (addressed through Eco-design for general purpose lamps) that for special purpose HPMV that a lack of suitable replacement lamps may still justify an exemption.

2. As for lamps used for **horticulture** purposes, from information regarding HPS lamps covered by Ex. 4(b) and Ex. 4(c), it can be followed that where LED alternatives are discussed as replacement lamps for existing HPS installations, there may be various limitations. Most alternatives have geometric dimensions that would prevent their use as alternatives in existing installations. Therefore such lamps would not be practical as retrofit substitutes. Other lamps, particularly in the higher lumen output range, shall not be compatible with existing HPS luminaires thermally, resulting in excess heat within the luminaire and consequently reducing the LED service life. In

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[467] VITO & VHK (2015), Preparatory Study on Light Sources for Ecodesign and/or Energy Labelling Requirements ('Lot 8/9/19'), Final report, Task 1, Annexes Scope, Standards, Legislation ,Prepared for the European Commission, DG ENER.C.3: VKH & VITO indicates in theirits report claims that the projector lamp group comprises of lamps arc-lamps, ultraviolet lamps and as well infrared lamps.
[468] Gensch et al. (2009), Gensch, C-O., Zangl, S., Groß, R. and Weber A., Oeko-Institut e. V. and Deubzer, O., Fraunhofer IZM, Adaptation to scientific and technical progress under Directive 2002/95/EC: Final Report, available under: http://ec.europa.eu/environment/waste/weee/pdf/final_reportl_rohs1_en.pdf.
[469] Referred to in Gensch et al. (2009) as: Vito 2007: Final Report Lot 9: Public street lighting, January 2007

contrast however, for new installations it appears that alternatives to Hg-HPS luminaires are available. From research of publicly available sources, it can be understood that for example LEDs produced by OSRAM stimulate plant growth, while reducing energy consumption through the use of targeted lighting at 730, 660 and 450 nano-meters, which is understood to provide sufficient lighting for all types of plants and flowers.[470] The consultants thus conclude that LED alternatives for horticulture lighting applications are already available on the market and can be used to replace HPS-based luminaires. Similar to other applications however, here too, possible drawbacks related to the replacement of lamps in existing luminaires and installations have to be taken into consideration.

16.5.2 Environmental Arguments

For UV lamps it can be understood that current alternatives based on LED technology have significantly lower wall plug efficiency in comparison to discharge lamps. As discussed above, this would result in lamps with lower efficiency, subsequently increasing the energy consumption and related environmental impacts of relevant applications.

In the case of curing lamps, the possibility to develop new curing inks that would be compatible with UV LEDs is also raised. Some detail is given clarifying that development of such inks would require their approval under chemical legislation. Though it is possible that some inks would be identified as hazardous, thus being considered problematic in comparison with current inks, detail is not given to evaluate this option. As new curing inks could also have advantages over current inks in terms of hazardousness as well as in terms of other aspects, the consultants would not disregard this development direction.

Aspects raised of general nature are discussed in the general chapter under Section 4.5.3.

16.5.3 Stakeholder Contributions

RadTech[471] and the European Printing Ink Association (EuPIA)[472] submitted comments specifically in relation to Ex. 4(f). They underline that although there is potential for substitution with UV LED, further development is needed to allow equivalent UV-LED mercury-free products to become available on the market.

Other comments were of a general nature. They are discussed in Section 4.5.7 of the general chapter.

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[470] http://ledlight.osram-os.com/applications/horticultural-led-lighting/
[471] Op.cit. RadTech 4f (2015)
[472] Op.cit. EuPIA 4f (2015a)

16.5.4 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.

As explained above, despite various efforts to develop such alternatives, it can be followed that Hg cannot be substituted with another substance used in discharge lamps relevant for Ex. 4(f). It can also be followed that reducing (and also increasing) the amount of mercury would affect the function of the lamp negatively. In this sense alternatives are understood not to be available on this level.

On the component level, various limitations of LED alternatives for lamps relevant for Ex. 4(f) are apparent, particularly regarding replacement lamps for existing equipment. For the various application sub-groups addressed, it can be followed that the exemption would further be needed to allow replacing lamps in existing applications, as alternatives (if available) shall not be compatible with existing equipment.

In relation to the availability of alternatives, it can be understood that on the system level, alternatives are available in some cases for applications in the wavelength of visible light:

- For **projector lamps**, it is understood that alternatives cover the range below 2000 lumen ANSI. The lack of alternatives is raised specifically in relation to the range of 2000-5000 lumen ANSI and thus the consultants conclude that an exemption could be limited to this range.
- As for **horticulture lamps**, it can be understood that LED alternatives are available, providing various types of spectral output.

As for the non-visible range, the applications of curing lamps and disinfection lamps have been discussed in detail, showing that current alternatives do not provide sufficient performance in terms of spectral output and wall plug efficiency. Furthermore an early phase-in of substitutes would also result in an increase of energy consumption due to the lacking wall-plug efficiency.

All three applicants recommend not changing the exemption wording. LEU argues in this respect that the list of applications is not exhaustive "*It is impossible to give a complete overview of all design features and applications. There are numerous lamps with small*

market shares for very special applications." [473] However, the consultants do not agree that the diversity of applications presented justifies the further renewal of an exemption with a relatively open scope, which leaves a large potential for misuse and makes market surveillance difficult. As shortly detailed, it is for example not clear if projection lamps should actually fall under the exemption at hand or whether they would be covered by Ex. 4(d), which has expired, but which was not restricted to lamps for general purposes. As neither further detail of additional applications, nor argumentation to justify the renewal of the exemption for such cases was made available, the consultants would recommend limiting the exemption to the specific applications addressed. Here too, development of alternatives should be monitored carefully in the future especially to determine the point in time at which the cost of early end of life of some luminaires is acceptable in relation to the availability and possible higher efficiency of possible system alternatives.

16.6 Recommendation

Though substitutes are understood to be available on the system level in a few cases (for use in new LED luminaires), such substitutes have various limitations to allow their application as substitutes in existing equipment of Ex. 4(f) lamps (lamp replacement). Furthermore, in most of the applications it can also be followed that first alternatives coming on the market would not cover the full product range. Thus it is also concluded that on the system level time is also still needed to develop sufficient alternatives. It is thus recommended to renew the exemption for a further 5 years. To avoid misuse and to ensure market surveillance effectively, the consultants propose narrowing the scope of the exemption to specific cases as detailed below.

It should be noted that the specification of the proposed formulation for Ex. 4(f)(IV) related to curing and disinfection applications could be removed. In general it can be understood that the limitations of LED alternatives emitting in the non-visible range would most likely apply to other applications, should such be communicated (i.e. non-comparable spectral output and insufficient wall plug efficiency). Nonetheless, as opposed to other exemptions permitting the use of Hg in discharge lamps in the UV range, Ex. 4(f) does not limit the amount of mercury that can be used. It is also observed that some lamps have significant doses of Hg, as can be observed from the information in Section 15.2.1. Against this specific background the consultants would recommend addressing relevant applications in the wording formulation, for which the exemption is available. This should at least facilitate awareness to cases, where relatively large amounts of mercury are dosed in single lamps.

Under 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.

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

Exemption 4(f)	Scope and dates of applicability
(I) Mercury in other discharge lamps for special purposes not specifically mentioned in this Annex	For Cat. 8 & 9: 21 July 2021; For Sub-Cat. 8 in-vitro: 21 July 2023; For Sub-Cat. industrial: 21 July 2024
(II) Mercury in high pressure mercury vapour lamps used in projectors where an output ≥2000 lumen ANSI is required	For Cat. 5: 21 July 2021
(III) Mercury in high pressure sodium vapour lamps used for horticulture lighting	For Cat. 5: 21 July 2021
(IV) Mercury in lamps emitting light in the ultraviolet spectrum for curing and disinfection	For Cat. 5: 21 July 2021

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

See also note within text above on the potential to remove Ex. 4(f)(IV).

16.7 References Exemption 4(f):

EuPIA 4f (2015a) European Printing Ink Association – EuPIA, Stakeholder Consultation RoSH II - Exemption 4(f) - EuPIA contribution; submitted 12.10.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_4_f_/151012_EuPIA_support_of_Medium_Pressure_Mercury_Lamp_RoHS_Exemption_Extension.pdf

LEU Ex. 4f(2015a) LightingEurope (LEU), Request to renew Exemption 4(f) under the RoHS Directive 2011/65/EU Mercury in other discharge lamps for special purposes not specifically mentioned in this Annex, submitted 15.1.2015, available under http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_4_f_/Lighting_Europe/4f_LE_RoHS_Exemption_Req_Final.pdf

LEU 4(f) (2015b) LightingEurope, Response To Oeko-Institut regarding the 1st Questionnaire Exemption Request No. 4(f) “Mercury in other discharge lamps for special purposes not specifically mentioned in this Annex” submitted September 15, 2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_4_f_/Ex__4f__LightingEurope_et-al_Clarification-Questions_final_20150915.pdf

RadTech 4f (2015) RadTech Officers; Stakeholder Consultation RoHS II – Exemption 4(f), submitted 9.10.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_4_f_/Support_of_Application_to_renew_Exemption_4_f__in_Annexe_III_as_proposed_by_Lighting_Europe.pdf

VDMA Ex. 4f(2015a) Verband Deutscher Maschinen- und Anlagenbau (VDMA) Exemption Request 4(f) Mercury in other discharge lamps for special purposes not specifically mentioned in this Annex, submitted 15.1.2015, available under

http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_4_f_/VDMA/4f_VDMA_excempt_req_4f_RoHS_16Jan14.pdf

VskE Ex. 4f(2015a) VskE - German Association for Label and Narrow Web Converters, Exemption Request 4(f) Mercury in other discharge lamps for special purposes not specifically mentioned in this Annex, submitted 15.1.2015, available under http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/ Exemption_4_f_/Vske/4f_2014-12-09_RoHS_Application_VskE.pdf

VITO & VHK (2015) Preparatory Study on Light Sources for Ecodesign and/or Energy Labelling Requirements ('Lot 8/9/19'), Final report, Task 1, Annexes Scope, Standards, Legislation, Prepared for the European Commission, DG ENER.C.3

28.0 Exemption 18b: "Lead as activator in the fluorescent powder (1 % lead by weight or less) of discharge lamps when used as sun tanning lamps containing phosphors such as BSP ($BaSi_2O_5$:Pb)”

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

BSP	Barium silicate phosphor doped with lead, also known as $BaSi_2O_5$:Pb
CFL	Compact fluorescent lamp
EEE	Electrical and Electronic Equipment
Hg	Mercury
HID	High intensity discharge lamps
InGaN	Indium gallium nitride
LED	Light emitting diode
OLED	Organic LED
LEU	LightingEurope
NARVA	NARVA Lichtquellen GmbH + Co. KG
NMSC	Non-melanoma skin cancer
Pb	Lead
PUVA	Psoralen (P) and ultraviolet A (UVA) therapy

UV	Ultra violet
UVB	Ultra violet radiation in the range of 280-315 nm
UVC	Ultra violet radiation in the range of 100-280 nm
WEEE	Waste Electrical and Electronic Equipment
WPE	Wall plug efficiency
YPO	Yttrium phosphate phosphor

Declaration

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.

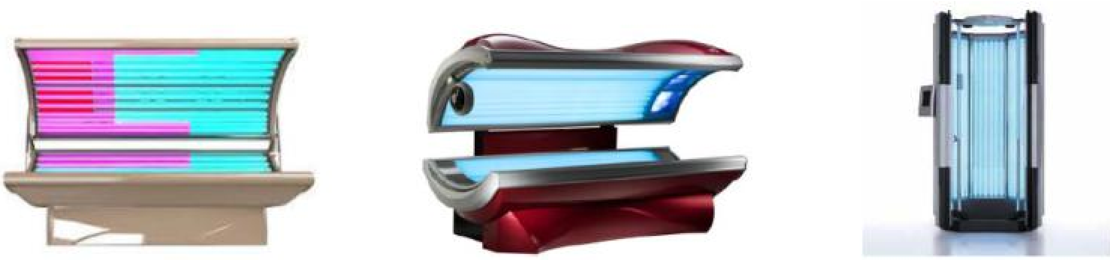
28.1 Background

NARVA Lichtquellen GmbH + Co. KG (NARVA) and LightingEurope (LEU) have applied for a renewal of exemption 18b of Annex III of the RoHS Directive.

According to LEU[1610], indoor tanning lamps are light sources that produce ultraviolet light in the regions of the UVA and UVB spectrums. Their intent is to produce artificial sunlight to replicate sunlight exposure (e.g., similar to that as emitted by the sun) for the human body, yet applied in calculated doses in line with European regulations. The lamps are installed in various commercial- and residential indoor tanning equipment. This can be in the form of a sun tanning bed or booth or a table top appliance for facial tanning. It is estimated that over 90% of indoor tanning lamps produced and used throughout Europe are manufactured with BSP ($BaSi_2O_5$:Pb) phosphors containing 1% or less lead as an activator).

[1610] LEU (2015a), LightingEurope, Request to renew Exemption 18b under the RoHS Directive 2011/65/EU Lead as activator in the fluorescent powder (1 % lead by weight or less) of discharge lamps when used as sun tanning lamps containing phosphors such as BSP ($BaSi_2O_5$:Pb), submitted 15.1.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_18_b_/Lighting_EUrope/18b_LE_RoHS_Exemption__Req_Final_draft.pdf

Figure 28-1: Examples of indoor tanning equipment



Source: LEU (2015a)

NARVA[1611] explain that fluorescent lamps using barium silicate phosphor doped with lead (BSP lamps) are used in tanning equipment. Since the lamps contain lead, an exemption from the RoHS Directive is needed to allow further use in tanning equipment.

Both applicants request the renewal of the exemption for applications of category 5, with the current wording and for the maximum duration:

> "*Lead as activator in the fluorescent powder (1 % lead by weight or less) of discharge lamps when used as sun tanning lamps containing phosphors such as BSP (BaSi2O5 :Pb)*"

28.1.1 Amount of Lead Used under the Exemption

LEU[1612] explains that the phosphor coating represents the homogenous material used in the fluorescent lamps with respect to this exemption. The lead content of the phosphor is less than 1% of the total phosphor weight. There is no published data available for the quantity of tanning lamps entering the EU. However, based on market estimations of LightingEurope the lead content of tanning lamps is limited to 250 kg of lead in total entering the EU per annum[1613].

28.2 Description of Requested Exemption

According to LEU[1614] the exemption covers indoor sun tanning discharge lamps containing lead as activator in the fluorescent powder. The lamps produce UVA and UVB in predetermined dosages and ratios for the purpose of producing artificial sunlight. The lamps are installed in tanning equipment which is calibrated for the use of specific lamp

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[1611] NARVA (2014), NARVA Lichtquellen GmbH + Co. KG, exemption Request for Using Lead in fluorescent Lamps for Tanning, submitted 19.12.2014, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_18_b_/NARVA/18b.pdf

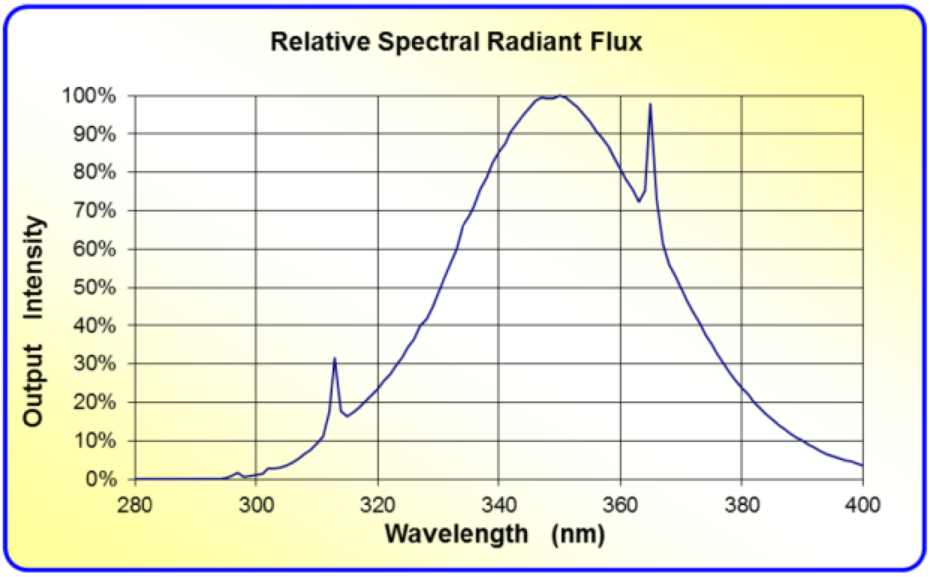
[1612] Op. cit. LEU (2015a)

[1613] According to LEU, lead is also used in similar lamp types for medical and phototherapy applications such as PUVA light therapy for skin conditions such as psoriasis. The mentioned figures are explained not to include estimated usage of lamps used in medical therapy, for which a separate exemption has been requested.

[1614] Op. cit. LEU (2015a)

types, marked in accordance with EU regulations for tanning lamps and equipment[1615]. Lamps are produced in T12, T8 and T5 diameters and compact fluorescent lamp (CFL) configurations. The phosphors contained in these lamps are manufactured from the same components but can vary in spectral discharge across the UVA and UVB spectrum as a result of the specified proportional phosphor mix (see typical example in Figure 28-2).

Figure 28-2: Example of a typical UVA/UVB spectrum



Source: LEU (2015a)

The typical lifetime of these lamps ranges from 600 to 1000 hours with a session or usage time that ranges approximately from 5-30 minutes. These lamps are not used for the production of visible light so general lighting efficacy standards do not apply. UV output efficacy (UVA radiation out vs electrical power in) is typically between 15% and 25%, but the real measure is with what power the desired effect is reached. This is governed by the equipment, lamp type, lamp power, UV output measured by standardized means, user skin type and other such factors.[1616]

The tanning industry is closely monitored and regulated by European authorities under regulations such as EN 60335-2-27 and EN 61228. EN 60335-2-27 is an international standard that deals with the safety of electrical equipment on exposing the skin to

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[1615] LEU (2015a) reference brochures and data about such lamps as follows:

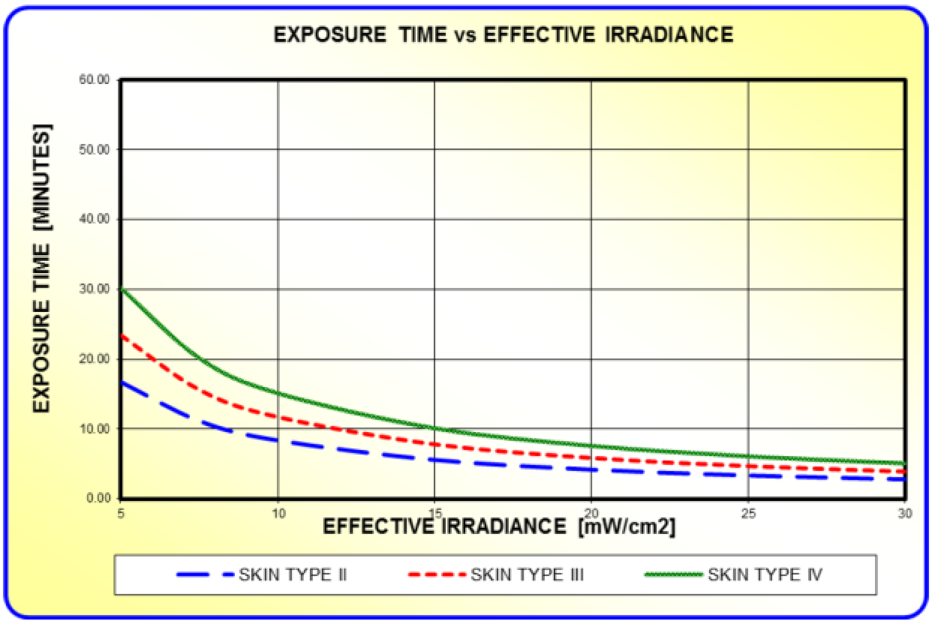
- Lighttech http://www.light-sources.com/tanning/tanning-lamp-products
- Cosmedico http://www.cosmedico.de/en/tubes.html
- Havells-Sylvania: http://www.havells-sylvania.com/media/Downloads/Sylvania%20Lamps%20Brochures/SPG/Suntanning/SY_Bodycare_Broschuere_2011_2012_ENGL_RZ_FINAL_ANSICHT.pdf

[1616] Op. cit. LEU (2015a)

ultraviolet or infrared radiation, for household and similar use in tanning salons, beauty parlours and similar buildings. EN 61228 includes requirements for measurement and details specification methods. Tanning and medical equipment in Europe is subject to unscheduled auditing and measurement of the lamps and equipment, which has been certified for use with lamps that are equivalent or the same as the lamps originally installed by the OEM. This equipment has undergone extensive testing to assure compliance with ultraviolet exposure schedules, and the use of non-equivalent lamps is restricted.

EU regulations govern the allowable output of ultraviolet radiation permitted within a determined exposure time (see Figure 28-3). The EU regulates and enforces tanning equipment and the installed lamps, which are marked on the lamps with a specific "X, Y" code system for the erythemally-weighed UV radiation in accordance with EN standard 61228 Ed.2 (2008-01). This EN standard forms the basis of lamp marking, and needs to be complied with. LEU claims that this limits the possibility of substitution with lead-free phosphors. The regulatory demands come from the LVD Administrative Co-operation working group (ADCO)[1617], which at its 18th meeting on the 14th of November 2006 decided among others that the maximum erythemal-weighted irradiance should not exceed 11 SED/h (0.3 W/m2).[1618]

Figure 28-3: Exposure time vs. effective irradiance



Source: LEU (2015a)

[1617] LEU (2015a) references the declaration of the LVD ADCO Group on the following website: http://ec.europa.eu/enterprise/electr_equipment/lv/guides/index.htm

[1618] Op. cit. LEU (2015a)

28.3 Applicant's Justification for Exemption

LEU[1619] explains that the lead activator is required to allow the barium silicate phosphor to fluoresce. It transforms the 254 nm radiation to the designed UV (290nm-400nm) radiation. A fluorescent lamp uses phosphors which, when activated, will produce light in different wavelengths. The primary wavelengths of "light" produced by indoor tanning lamps are in the UVA and UVB regions or 290-400nm. Lead is the primary activator for the barium silicate phosphors to fluoresce and is used in over 95%[1620] of the indoor low pressure mercury vapour fluorescent lamps used for tanning and certain medical applications, which are not covered by this exemption. The lead is evenly distributed throughout the phosphor coating of the lamps to radiate in the range of 290-400 nm when excited by radiation at 254 nm.

LEU[1621] further explains that UV intensity at the wavelength of 350 nm is crucial in order to get skin pigmentation (tanning result). The UV output of the lamps with narrow band UVA phosphor is negligible at that important wavelength so that they are insufficient for use for a wider range of tanning applications.

Tanning equipment is strictly regulated in the EU, and thus LEU[1622] explains that any possible alternative to lead in BSP type of phosphor would need to fulfil following criteria:

- "*Lamp specification must be the same with regard to:*
  - *UVA and UVB output, and with that Erythema*[1623]*;*
  - *Spectral power distribution*
  - *Compatibility (electrical/mechanical spec) must be OK*
  - *Reliability must be OK*
  - *Safety must be OK*
  - *Lamp operation must be the same in the different equipment in the market*
  - *Lamp start-up and time to peak intensity must be the same.*
  - *Lamp intensity must be the same.*

[1619] Op. cit. LEU (2015a)

[1620] LEU (2015b) explains that these non-BSP lamps emit only a narrow bandwidth of the UVA spectrum and no- UVB and do not produce the required action spectrum required for tanning response. As evidenced by the market size there is limited use of such lamps and when used it is always in conjunction with BSP phosphor lamps to generate the total UVA and UVB spectrums needed to initiate a tanning response.

[1621] LEU (2015b), LightingEurope, Answers to 1st Questionnaire Exemption No. 18b (renewal request), submitted 28.8.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_18_b_/Lighting_Europe/Ex_18b_LightingEurope_1st_round_Clarification_LE_Answers_20150828.pdf

[1622] Op. cit. LEU (2015a)

[1623] In this respect LEU explains that the EU regulates tanning equipment (including lamps) with a specific "X, Y" code system for the erythemally-weighed UV radiation in accordance with EN standard 61228 Ed.2 (2008-01).

- *Lamp maintenance/depreciation must be the same,*
- *Tanning result on patients*
- *Compliance with CE regulations (X/Y coding system for tanning lamps according to EN 60335-2-27)*
- *No (negative) side effects*
- *Economically feasible. Equipment in use today is calibrated and requires lamps to meet output limits using X/Y coding system. Different lamps would need revalidation.*"

28.3.1 Possible Alternatives for Substituting RoHS Substances

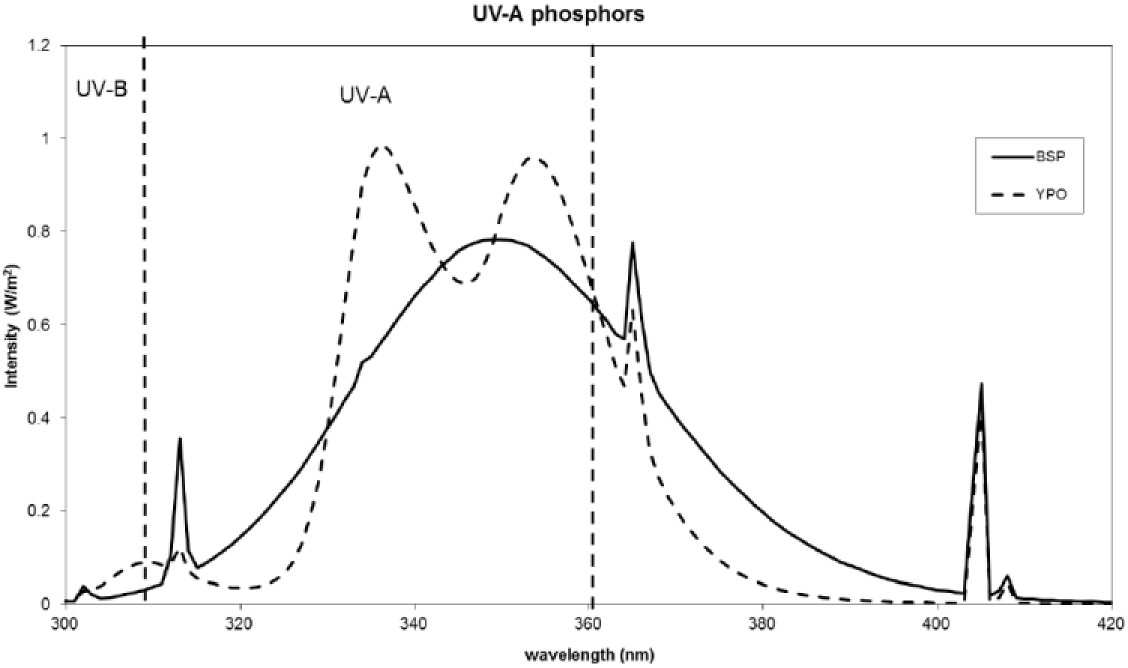
According to LEU[1624], only one alternative substance comes close to the performance of BSP phosphors - cerium (Ce) doped yttrium phosphate phosphor (YPO) phosphor. LEU explains that tanning lamp output is measured on a weighted distribution of UVA and UVB output measured by the output depending on the wavelength (nanometer). The lamps are coded using the X/Y system by lamp type which is then applied for use in each specific piece of equipment. Tests have been done using these phosphors for tanning lamps showing that the spread in UVA and UVB output is too high to be viable as a practically feasible alternative. Such phosphors would not be able to comply with CE regulations for tanning lamps (due to spectral incompatibility) and are thus not allowed for this application.

Figure 28-4 below shows the spectrum of Ce doped YPO phosphor in comparison to BSP. Based on the comparison, LEU concludes that:

- The spectral power distribution shows differences in the UVA and UVB range.
- The ratio for UVA and UVB output is different, which is an important factor for tanning applications and is governed by EU regulations due to the health risks.
- Therefore the cerium-based material has a lower expected treatment effectiveness, with regard to Erythema and NMSC (non-melanoma skin cancer).

[1624] Op. cit. LEU (2015a)

Figure 28-4: Emission spectrum of a cerium-doped phosphor – UV lamp



Source: LEU (2015a)

LEU[1625] raises a second point of relevance, with relation to the variations of the UV output along the lamp length [i.e. its surface area – consultants comment] due to coating thickness. When fluorescent lamps are coated with a phosphor the thickness of the coating varies over the length of the lamp. For current UV-fluorescent coatings used, like BSP, the thickness variations do not cause a severe inhomogeneous output. However, for cerium doped phosphor this thickness difference leads to unacceptable UV output variations, which will affect the skin treatment effectiveness (for further details see Appendix A.5.0).

LEU[1626] also explains why the BSP phosphor cannot be replaced in order to eliminate the need for lead as an activator: besides $BaSi_2O_5$:Pb, below lead doped phosphors are known as UV emitting phosphor.

- $SrBaMgSi_2O_7$:Pb 370nm
- $BaZn_2Si_2O_7$:Pb 303nm
- $BaMg_2Si_2O_7$:Pb 290nm

All above phosphors are doped with lead, but the emission wavelength depends on the chemical composition of the base substance. To get an efficient emission at 350nm, which is effective for sun tanning purpose, only $BaSi_2O_5$ can be used as a base substance. In parallel, though both lead (Pb) and europium can be used as a doper for BSP, barium

[1625] Op. cit. LEU (2015a)
[1626] Op. cit. LEU (2015b)

silicate emits 520nm when it is activated by europium, making $BaSi_2O_5$:Pb the only compound that achieves the 350nm output.

28.3.2 Possible Alternatives for Eliminating RoHS Substances

In relation to different designs of equipment (i.e. alternative technologies that could enable the elimination of lead in this application), LEU[1627] explains that other technologies could be evaluated for replacing fluorescent technology in tanning applications. These could be for example e.g. LED, OLED, HID, and incandescent or halogen technology. However, for any new technology there will be a need to address the replacement market (replacing lamps in existing fixtures) and the market for new equipment using the new technology. The criteria to determine whether a new technology can replace existing fluorescent technology using BSP (and Hg related to the discharge technology of the lamps) in existing equipment are detailed in Section 28.3 above. Since incandescent, halogen and OLED do not emit radiation in the UVA/UVB range, LEU only provides additional information as to the potential of LED technology as an alternative. The following obstacles are detailed in this regard:

- **Wall Plug Efficiency -** In contrast to general lighting lamps, (compact) fluorescent lamps for special purposes emit radiation in UV or blue wavelength bands. LEDs for general lighting purposes are made of indium gallium nitride (InGaN), a material that emits blue light, which with the help of phosphors is converted into the desired visible wavelengths. Theory says you can only convert from shorter wavelengths to longer. It is therefore impossible to create UV light with LED material as used for visible light LEDs. There are other materials available from which LEDs can be made that generate UV light (like AlGaN), however the efficiency (radiated power out / electrical power in) of LEDs with those materials is still very low. In the UVC (100-280 nm) and UVB (280-315 nm), the wall plug efficiency (WPE) of LEDs is below 1%, where the WPE of fluorescent lamps is close to 20% or even higher. There is currently no comparable WPE for LEDs with a spectral output below 380 nm. Therefore, LED lamps are not suitable at present as a practical alternative for tanning applications.
- **Effectiveness (i.e. same tanning effect) -** No tests results, from a comparative study of equipment using fluorescent lamps and equipment using LEDs, are available at present with regard to the effectiveness of alternative lamps to reach the desired effect in terms of tanning results. This is explained to be related to the lacking availability of LED candidates. Thus concluding as to possible effectiveness is not possible at present.
- **Regulation/approbation -** CE conformity and other European directives for special purpose applications (like for instance approbation of medical devices for phototherapy and CE regulations on tanning lamps (CE 60335-2-27)) are

[1627] Op. cit. LEU (2015a)

based on fluorescent discharge lamps (with respect to safety and system responsibility). No CE conformity is available for other lamp technologies.

28.3.3 Environmental Arguments

According to LEU[1628], there are no statistical data available specific to the Life Cycle Analysis of tanning lamps represented in this exemption request, however due to the relatively low market quantities for special lighting, the total environmental impact is expected to be limited.

Sun tanning lamps are further explained to be in the scope of EU Directives 2002/96/EC - WEEE and 2012/19/EU– WEEE Recast. Take back systems are installed in all EU Member States: end users and most commercial customers can bring back the lamps free of charge (see application for additional detail).[1629]

The limited wall-plug efficiency of LEDs currently available that produce light in the non-visible region is also understood to be of environmental relevance. Please see Section 28.3.2 and in 28.5.3 in this respect.

28.3.4 Socio-economic Impact of Substitution

LEU[1630] claims that the use of lead as an activator of the phosphor in these lamps allows the transmission of the specific wavelengths of light to be emitted in such a fashion to be the most effective form for its purpose, which is not achievable with other phosphor types or other technologies. Therefore efficacies of any alternative product types would not be an adequate comparison. The potential substitution or replacement with other wavelengths or ultraviolet dosages would require revalidation of all existing equipment in the EU market or could cause the elimination of such equipment causing great hardship to the small business owners of tanning salons throughout the EU. These current lamp types have been tested, studied and regulated in the EU and changes to these products would require a duplication of the clinical testing which has been compiled over years of study and regulation. LEU further explains that the effect of Ce doped phosphor may have considerable impact on health and safety of customers as the manufacturing tolerance in output and spectrum cannot be controlled to the extent required by EU regulations. For LED as an alternative technology, effects on health and safety will have to be investigated once candidates are developed.

According to LEU[1631], it can be expected that even if UVA LEDs become available with feasible specifications tanning equipment may become much more expensive. It will become therefore an economically unattractive solution and may have significant impact on the application. The possibility for lead-free technology for these lamps is not feasible

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[1628] Op. cit. LEU (2015a)
[1629] Op. cit. LEU (2015a)
[1630] Op. cit. LEU (2015a)
[1631] Op. cit. LEU (2015a)

for replacements lamps in existing equipment due to the scientific and clinical evaluations that would need to be done on every type of fixture or appliance that is in the field. The economic burden this would impose on the small business owners such as tanning salons and dermatologists would cause the closing of many businesses. It can be imagined that new equipment could be changed to non-lead phosphors. However over 90%, and it is estimated that it may be as much as 99%, of the tanning phosphors are lead activated. There are no alternative non-lead activated phosphors available today that provide the same or equivalent spectral radiation.

In a later communication, LEU[1632] however explains that the substitute candidate should have exactly the same spectral distribution curve and power effectiveness like BSP phosphor, because this is the only way to avoid needing to clinically retest all the tanning devices on the EU market.

In terms of social impacts, LEU[1633] explains that as there are no reliable substitutes if the renewal of the exemption is denied it would shut down the indoor tanning industry in Europe. LEU estimates that:

- Almost 100% of the BSP tanning lamps used in Europe are manufactured in Europe by fluorescent lamp companies;
- Almost 100% of the indoor tanning equipment sold in Europe is manufactured in Europe. Almost 100% of the tanning lamps sold as aftermarket lamps are sold by manufacturers or distributors located in Europe;
- Over 90% of the tanning lamps used in the US are manufactured in Europe;
- Over 75% of the tanning equipment sold in the United States is made in Europe.

28.3.5 Road Map to Substitution

LEU[1634] expects that given the market size in combination with strict regulations, efforts to substitute BSP containing lamps are extremely limited (to non-existent). There are no plans to replace Pb with Ce as earlier tests were unsuccessful. With regard to LEDs, other UVA applications are available in LEDs but tanning application development has been limited. At this moment it is impossible to predict if and when UVA LED based equipment will become feasible.

[1632] Op. cit. LEU (2015b)
[1633] Op. cit. LEU (2015a)
[1634] Op. cit. LEU (2015a)

28.4 Stakeholder Contributions

A single contribution was made in relation to Ex. 18b during the stakeholder consultation. The Test and Measurement Coalition (TMC)[1635] 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 and has not provided exemption specific information.

28.5 Critical Review

28.5.1 REACH Compliance - Relation to the REACH Regulation

Appendix A.1.0 of this report lists entry 28 and entry 30 in Annex XVII of the REACH Regulation, stipulating that lead 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. A prerequisite to granting the requested exemption would therefore be to establish whether the intended use of lead in this exemption request might weaken the environmental and health protection afforded by the REACH regulation.

In the consultants' understanding, the restriction for substances under entry 28 and entry 30 of Annex XVII does not apply to the use of lead in this application. Pb used as an activator of BSP phosphors applied in discharge lamps used for tanning, in the consultants' point of view is not a supply of lead and its compounds as a substance, mixture or constituent of other mixtures to the general public. Pb is part of an article and as such, entry 28 and entry 30 of Annex XVII of the REACH Regulation would not apply.

In general, BSP, or silicic acid ($H_2Si_2O_5$), barium salt (1:1), lead-doped (CAS number 68784-75-8) has been addressed in an Annex XV dossier[1636] prepared by the European Chemicals Agency (ECHA), proposing its classification as a substance of very high concern (SVHC). The substance has been proposed to be identified as a substance meeting the criteria of Article 57 (c) of REACH, owing to its classification as toxic for reproduction category 1 A. Furthermore BSP is a registered substance[1637]. Nonetheless, at present,

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[1635] 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

[1636] Available here: http://echa.europa.eu/documents/10162/13638/SVHC_AXVREP_EC_272-271-5_SilicicAcidBariumSaltLead-doped_en.pdf

[1637] Available information from REACH registration dossiers can be found under the following link:

there are no listings of this substance under Annexes XIV and XVII of REACH that restrict its use in products to be placed on the EU market. There are also currently no processes underway to evaluate the need for such listings (restriction / authorisation). Even if further processes should be embarked on, it is currently not possible to assume if this would result in legislation that would restrict the use of BSP in lamps used for tanning (or medical) applications. Though such proceedings should be observed in future evaluations of the RoHS exemption for lead in BSP lamps, the consultants do not think it would be appropriate at present to limit the current exemption or its duration in anticipation of results of such processes.

No other entries, relevant for the use of lead in the requested exemption could be identified in Annex XIV and Annex XVII (status January 2016).

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.

28.5.2 Scientific and Technical Practicability of Substitution

NARVA and LEU explain that lead in BSP lamp types used for tanning applications currently cannot be substituted or eliminated. Though a few candidate alternatives are elaborated on, it can be understood that none of these have reached a stage of maturity in terms of being used in articles to be placed on the market. In this sense, at least at present, it can be understood that substitutes are not available on the market for a number of reasons.

To begin with, an alternative light source providing the same function as BSP lamps using lead is yet to be found. Using an alternative activator to dope BSP instead of lead, such as europium, would not result in a comparable spectral output. Though the option of using YPO phosphors is elaborated on as a substance substitute, it can be understood that such lamps do not provide the same spectral output as BSP lamps either. The change of spectral output is explained to possibly result in larger negative health impacts such as erythema. It can be understood that the spectral output of BSP lamps may also cause such health impacts, however at a lower rate and thus holding lower risks for health effects on patients. From an earlier exemption request evaluation[1638] that led to Ex. 34 of Annex IV, it is also understood that other phosphor compositions that have

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http://apps.echa.europa.eu/registered/data/dossiers/DISS-9fdc6c5f-6d4c-29d1-e044-00144f67d031/AGGR-ec42affe-9178-4b25-911c-415860a9699a_DISS-9fdc6c5f-6d4c-29d1-e044-00144f67d031.html#section_3_5

[1638] Exemption request from Therakos Photopheresis to exempt BSP lamps in extracorporeal photopheresis applications. Application documents can be viewed here: http://rohs.exemptions.oeko.info/index.php?id=146 and final evaluation report here: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_VI/20130412_RoHS2_Evaluation_Proj2_Pack1_Ex_Requests_1-11_Final.pdf

been investigated in the past, would either lead to similar risks or to an ineffective treatment. In parallel, developing alternative light sources with technologies such as LED have also yet to mature. Though first UVA LED lamps may have started to become available, their efficiency (radiated power out ÷ electrical power in) is said to be very low in comparison with BSP lamps, and information predicting when UVA LEDs with acceptable output and efficiency shall become available is not publicly available. Though such lamps are currently not available for use in tanning equipment, it should be noted that differences in efficiency could have relevance to the environmental comparison of alternatives.

To conclude, as an alternative light source is a precondition for developing equipment which would be compatible with such new technologies, further evaluating the performance of such possible equipment is not yet possible, making substitution and elimination not practical at this time.

28.5.3 Environmental Arguments

LEU provides some information regarding environmental aspects of BSP lamps, mainly related to the treatment of waste. As the information does not allow a comparison with possible alternatives (which are in any case understood to not be applicable at present), the information is not further discussed.

As shortly explained above, though first UVA LED lamps may have started to become available, their efficiency is said to be very low in comparison with BSP lamps. This is understood to mean that even if their spectral output would be comparable to that of BSP lamps, their limited efficiency would result in a significantly higher energy consumption than that of BSP lamps.

28.5.4 Socio-Economic Arguments

LEU mentions a number of aspects related to socio-economic aspects.

Among others, information is provided regarding possible differences in health impacts of BSP lamps and of the current candidate alternatives; these have been discussed above in Section 28.5.2.

Furthermore, LEU claims that once an alternative is to be found, the development and implementation of such alternatives in equipment can be expected to result in heavier costs for business (tanning salons). In this respect LEU[1639] mentions that:

- **Even if UVA LEDs become available with feasible specifications, tanning equipment may become much more expensive** – in the consultants' view it is difficult to estimate what costs substitution could lead to. Alternatives may not necessarily be more expensive, especially if they are to be developed after most discharge lamp applications have been replaced with Hg-free

[1639] Op. cit. LEU (2015a)

alternatives. In the transformation of the lighting sector from Hg-based (discharge lamps) to Hg-free applications (other technologies), it can be expected that at some point the burden of manufacturing last Hg-based articles in relatively small quantities shall become an incentive for developing alternatives. In such a case, emerging alternatives could be viewed by businesses more as a blessing than as a burden. As the spectral function of alternative light sources cannot be anticipated at present, it cannot be predicted if in the long run the alternatives may have lower negative impacts on health and thus provide benefits for patients, regardless of the costs of a transformation.

- **Development of replacement lamps for existing equipment shall not to be feasible** as the recertification would need to be performed for every type of fixture or appliance, resulting in an economic burden for small business owners (e.g. tanning salons). The consultants are aware that different technologies may use different fixtures or require rewiring or changes to the interface of the lamp with equipment, however cannot follow that this is always the case. If the spectral out-put of alternatives is the same as well as its directionality and other characteristic properties of the light source, the consultants cannot follow that a change in light source would require extensive recertification of each type of equipment. In this sense, here too, it is difficult to say how costs of development, clinical studies and recertification shall add up. Though it can be expected that such processes for replacement lamps may be time consuming and less practical, it needs to be kept in mind that all equipment has a certain service life and is gradually replaced with new equipment, which has undergone at least some degree of redesign. In this sense, though ensuring replacement lamps for existing equipment with new technologies could justify keeping BSP lamps on the market in some cases, predicting this at present is not straightforward.

28.5.5 Stakeholder Contributions

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 Ex. 18b the wording formulation limits its applicability to tanning applications. As tanning equipment is understood not to fall under Cat. 9, in the consultants’ opinion, sub-category 9 industrial equipment would not benefit from the exemption. Should BSP lamps be in use in Cat. 9 equipment (general and industrial), relevant stakeholders would have been expected to come forward with such information, either in the past evaluations related to medical equipment or in the current one.

28.5.6 The Scope of the Exemption

LEU[1640] explains that technically there is no difference between BSP phosphors used for medical purposes and BSP phosphors used for tanning purposes. Both lamp categories may have the same diameter and same wattage range in principle. Medical lamps may also be used in smaller lengths, diameters and wattages for partial body or spot treatment. The phosphor types may use the same components with a very similar or different blend to produce a specific UV output. In medical applications these would be called PUVA[1641] lamps and produce broad band UVA output. These lamps would be marked accordingly. The differences are in the field of application, in marking of the lamps and in the way to market. The sizes and wattages of certain tanning lamps can be the same as PUVA type of medical lamps for which LightingEurope has submitted a separate application for the use of BSP phosphors in those medical lamps. The manufacturers of tanning lamps do not market tanning lamps for use in medical equipment and therefore do not request an exemption for the use of tanning lamps in medical equipment.

In the consultants view, in relation to the scope of the exemption, the question here is whether a distinction can be made between similar BSP lamps used in different types of equipment. If the same lamp can be used in equipment falling into different categories, there would be a justification to merge all applications to a single exemption with a single validity date, regardless of category. The aim of this would be, on the one side, to ensure that the need to renew exemptions for BSP lamps be evaluated in the future for all applications during the same review, i.e. for a single merged exemption. On the other hand, should all BSP lamps which are interchangeable be addressed by a single exemption, this would simplify the legislation.

LEU was thus asked to clarify the aspect of exclusivity related to the use of BSP lamps in tanning and medical equipment. LEU[1642] explains that differentiation between tanning and medical lamps is done via the following protocol: On each and every sunlamp there is a mandatory warning text which describes clearly that the lamp is made for tanning purposes. This applies for medical lamps as well where the warning text shows that the lamp is intended for use in medical applications. All lamps manufactured for tanning purposes are marked with a so-called ‘equivalency code’ which refers to the UV strength of the lamp. This code ensures that in the application the user applies the correct lamps to avoid over exposure. Such code (i.e. its significance - consultants comment) is well known and widely used by people who replace the lamps in the sunbeds. On each and every sunbed there is a sticker, which specifies what lamp with what ‘equivalency code’ should be used in the device. Such ‘equivalency codes’ are not etched on medical lamps.

1640 Op. cit. LEU (2015b)

1641 The name PUVA comes from a group of medical treatment practices that combine intake of a psoralen drug with exposure to UVA radiation.

1642 LEU (2016a), LightingEurope, Answers to 2nd Questionnaire Exemption No. 18b (renewal request), submitted 19.01.2016 per email.

Each and every tanning lamp is marked accordingly and each and every medical lamp is marked according to legal and safety requirements for its intended use. LEU contends that this sufficiently prevents misuse of the lamps.

Figure 28-5: Warning text, equivalency code and marking examples for lamps

Tanning Lamps	Medical Lamps
Warning text	**Warning text**
Sunlamp - **DANGER**.Ultraviolet radiation. Follow instructions. Use **ONLY** in fixture equipped with a timer.	**WARNING: Medical UV lamp.** **Use only in certified medical devices!** **Use protective eyewear.**
Equivalency code	
180-R-36/2,4	
Marking	**Marking**
R 180W 2m Sunlamp - **DANGER**.Ultraviolet radiation. Follow instructions. Use **ONLY** in fixture equipped with a timer. USA Technology. 180-R-36/2,4	WIDE BAND PUVA 100W **WARNING: Medical UV lamp.** **Use only in certified medical devices!** **Use protective eyewear.**

Source: Op. cit. LEU (2016a)

Nonetheless, when asked whether some BSP lamps were sold on the open market (i.e. accessible to private consumers, LEU[1643] answered positively, explaining that they are sold through professional distribution networks. Regarding the possibility of using medical lamps in tanning applications and vice versa, LEU explained that as some medical lamps and tanning lamps are made to lighting industry standard dimensions and electrical characteristics (e.g. length, diameter, wattage, end fitting) it is mechanically possible that a lamp intended for medical use or tanning use or general lighting use can fit in the same luminaire or equipment. However, these lamps are absolutely not intended to be interchangeable for medical or tanning or general lighting applications and any such misuse could cause harm to the user. All tanning lamps are marked for sun tanning purposes and all medical lamps are marked for medical use in accordance with safety regulations and as demonstrated in our previous responses".

According to the above information, though the consultants can follow that BSP lamps of different types are manufactured for use in specific equipment, it cannot be concluded that tanning lamps and medical lamps would not be interchangeable. It is understood that lamps for other medical applications and lamps for tanning applications are sold as individual lamps. Though they are sold through professional distribution networks, LEU confirms that private consumers could have access to some lamps as is also apparent from searching the internet in this respect[1644]. This can also be followed as it is

[1643] LEU (2016b), LightingEurope, Answers to 3rd Questionnaire Exemption No. 18b (renewal request), submitted 27.01.2016 per email.
[1644] See for example: http://www.uvee.be/puva-uvb-lamps

understood that equipment both for tanning and for medical phototherapy can be purchased by private consumers. In this respect, even if this is not the intended use, lamps manufactured for one application could be implemented by users in the other application type.

The consultants, thus, cannot follow why there should be separate exemptions for sun-tanning lamps and for medical applications as this would mean double regulation of the same product, possibly leading to uncertainties in the future.

In this respect, it is also clear that should substitutes become available, that their applicability would need to be evaluated for all applications, further supporting formulating a single exemption for all BSP applications.

28.5.7 Exemption Wording Formulation

The aspect of lamp exclusivity has been discussed in the evaluation of Ex. 2015-3, evaluated in the course of an earlier project[1645]. In this earlier evaluation, a recommendation was made to merge the exemption for tanning applications and for medical applications (excluding at present applications covered under Ex. 34 of Annex VI, which is due to expire only on 22 July 2021). In this sense the wording recommended in this earlier exemption evaluation is also proposed below, as a means of merging the applications under one exemption.

28.5.8 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, in the case of BSP lamps it can be followed that there are currently no alternatives that would allow either a substance substitution in the existing technology or an elimination of the need for lead through the implementation of new technologies. In this sense, elimination and substitution are considered to be impractical at present.

Furthermore, though it can be understood that none of the named candidate alternatives have matured to the point of being subjected to clinical trials and testing, for some of these candidates negative health risks have been identified due to spectral

[1645] See Report for Pack 8, available under http://rohs.exemptions.oeko.info/index.php?id=164

output differences. Though in theory YPO alternatives could be used in lamps, the first research suggests that their spectrum would raise the risk for Erythema and non-melanoma skin cancer. In this sense such substitutes are understood to also have higher negative impacts on health in comparison with BSP lamps. Though the conclusion that the first criterion is fulfilled would suffice to justify an exemption, this aspect (if true) further strengthens the justification.

As there is currently no information to suggest that alternatives should become market ready in the next few years, setting a short duration for an exemption does not seem practical. As Ex. 34 currently has an expiration date in mid-2021, and addresses BSP lamps used for a different application, and as a positive evaluation of Ex. Request 2015-3 could result in the same expiration date, the consultants would recommend that should an exemption be approved for tanning applications, that its validity be aligned with this date, even if the date of the EU COMs decision would in theory allow extending the duration of the exemption beyond this point in time.

28.6 Recommendation

It is recommended to grant the requested exemption extending its applicability from tanning applications to medical applications. In the consultants' view an amendment of Ex. 34, which also covers a certain type of medical application, should be avoided at present though it should be consider in future reviews. It is thus recommended to amend exemption 18(B) of Annex III as follows:

Exemption 18b	Duration*
Lead as activator in the fluorescent powder (1 % lead by weight or less) of discharge lamps containing phosphors such as BSP (BaSi2O5 :Pb), when used: ***I. in tanning equipment; or*** ***II. in Annex I category 8 medical phototherapy equipment - excluding applications falling under point 34 of Annex IV***	*For Cat. 5: 21 July 2021*

The consultants' do not see a need to grant the exemption to Cat. 9 equipment, or to applications in the scope of Cat. 8 equipment not specifically addressed in the formulation above and in Ex. 34 of annex IV. The current Ex. 18b is restricted to tanning equipment, understood not to fall under Cat. 8 or Cat. 9. Furthermore, in the evaluation of the current request, the recent evaluation of Ex. Re. 2015-3 also applied for by LEU and the evaluation of the Therakos request, information has not become available to suggest that BSP lamps are used in Cat. 9 equipment or in other Cat. 8 equipment.

Nonetheless, as for exemptions listed in Annex III, for which an expiration date is not specified, it is understood that from a legal point of view, they shall be valid for applications of Cat. 8 and Cat. 9 for up to 7 years. This validity period is understood to start from the dates specified in Article 4(3), for when these categories come into the scope of the Directive. Thus if from a formal-legal point of view the original formulation of the exemption needs to remain valid for these categories for the specified duration, the following formulation would be recommended:

Exemption 18b	Duration*
(1) Lead as activator in the fluorescent powder (1 % lead by weight or less) of discharge lamps containing phosphors such as BSP (BaSi2O5 :Pb), when used: ***I. in tanning equipment; or*** ***II. in Annex I category 8 medical phototherapy equipment - excluding applications falling under point 34 of Annex IV***	For Cat. 5: 21 July 2021
(2) Lead as activator in the fluorescent powder (1% lead by weight or less) of discharge lamps when used as sun tanning lamps containing phosphors such as BSP ($BaSi_2O_5$: Pb)	For Cat. 8 and 9: 21 July 2021; For Sub-Cat. 8 in-vitro: 21 July 2023; For Sub-Cat 9 industrial: 21 July 2024

The consultants recommend the next review to be performed along with the review of all other exemptions for BSP applications (e.g. Annex IV Ex. 34), assuming applicants request the renewal of these exemptions.

28.7 References Exemption 18b

LEU (2015a) LightingEurope, Request to renew Exemption 18b under the RoHS Directive 2011/65/EU Lead as activator in the fluorescent powder (1 % lead by weight or less) of discharge lamps when used as sun tanning lamps containing phosphors such as BSP (BaSi2O5 :Pb), submitted 15.1.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_18_b_/Lighting_EUrope/18b_LE_RoHS_Exemption__Req_Final_draft.pdf

LEU (2015b) LightingEurope, Answers to 1st Questionnaire Exemption No. 18b (renewal request), submitted 28.8.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_18_b_/Lighting_EUrope/Ex_18b_LightingEurope_1st_round_Clarification_LE_Answers_20150828.pdf

LEU (2016a) LightingEurope, Answers to 2nd Questionnaire Exemption No. 18b (renewal request), submitted 19.01.2016 per email.

LEU (2016b) LightingEurope, Answers to 3rd Questionnaire Exemption No. 18b (renewal request), submitted 27.01.2016 per email.

NARVA (2014) NARVA Lichtquellen GmbH + Co. KG, exemption Request for Using Lead in fluorescent Lamps for Tanning, submitted 19.12.2014, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_18_b_/NARVA/18b.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

APPENDICES

A.1.0 Appendix 1: Relevant REACH Regulation Entries

Relevant annexes and processes related to the REACH Regulation have been cross-checked to clarify:

- In what cases granting an exemption could “weaken the environmental and health protection afforded by Regulation (EC) No 1907/2006” (Article 5(1)(a), pg.1)
- Where processes related to the REACH regulation should be followed to understand where such cases may become relevant in the future;

The last consolidated version has been consulted in this respect, published on 2 February 2016. Compiled information in this respect has been included, with short clarifications where relevant, in the following tables: Table A. 1 lists those substances appearing in Annex XIV, subject to Authorisation, which are relevant to the RoHS substances dealt with in the requests evaluated in this project. As can be seen, at present, exemptions have not been granted for the use of these substances.

Table A. 1: Relevant Entries from Annex XIV: The List of Substances Subject to Authorization

Designation of the substance, of the group of substances, or of the mixture	Transitional arrangements		Exempted (categories of) uses
	Latest application date (1)	Sunset date (2)	
4. Bis(2-ethylhexyl) phthalate (DEHP) **EC No: 204-211-0** **CAS No: 117-81-7**	21 August 2013	21 February 2015	Uses in the immediate packaging of medicinal products covered under Regulation (EC) No 726/2004, Directive 2001/82/EC, and/or Directive 2001/83/EC.
5. Benzyl butyl phthalate (BBP) **EC No: 201-622-7** **CAS No: 85-68-7**	21 August 2013	21 February 2015	Uses in the immediate packaging of medicinal products covered under Regulation (EC) No 726/2004, Directive 2001/82/EC, and/or Directive 2001/83/EC.
6. Dibutyl phthalate (DBP) **EC No: 201-557-4** **CAS No: 84-74-2**	21 August 2013	21 February 2015	Uses in the immediate packaging of medicinal products covered under Regulation (EC) No 726/2004, Directive 2001/82/EC, and/or Directive 2001/83/EC.
7. Diisobutyl phthalate (DIBP) **EC No: 201-553-2** **CAS No: 84-69-5**	21 August 2013	21 February 2015	
10. Lead chromate **EC No: 231-846-0**	21 Nov 2013	21 May 2015	-

Designation of the substance, of the group of substances, or of the mixture	Transitional arrangements		Exempted (categories of) uses
	Latest application date (1)	Sunset date (2)	
CAS No: 7758-97-6			
11. Lead sulfochromate yellow (C.I. Pigment Yellow 34) EC No: 215-693-7 CAS No: 1344-37-2	21 Nov 2013	21 May 2015	-
12. Lead chromate molybdate sulphate red (C.I. Pigment Red 104) EC No: 235-759-9 CAS No: 12656-85-8	21 Nov 2013	21 May 2015	-
16. Chromium trioxide EC No: 215-607-8 CAS No: 1333-82-0	21 Mar 2016	21 Sep 2017	-
17. Acids generated from chromium trioxide and their oligomers Group containing: Chromic acid EC No: 231-801-5 CAS No: 7738-94-5 Dichromic acid EC No: 236-881-5 CAS No: 13530-68-2 Oligomers of chromic acid and dichromic acid EC No: not yet assigned CAS No: not yet assigned	21 Mar 2016	21 Sep 2017	-
18. Sodium dichromate EC No: 234-190-3 CAS No: 7789-12-0 10588-01-9	21 Mar 2016	21 Sep 2017	-
19. Potassium dichromate EC No: 231-906-6 CAS No: 7778-50-9	21 Mar 2016	21 Sep 2017	-
20. Ammonium dichromate EC No: 232-143-1 CAS No: 7789-09-5	21 Mar 2016	21 Sep 2017	-
21. Potassium chromate EC No: 232-140-5 CAS No: 7789-00-6	21 Mar 2016	21 Sep 2017	
22. Sodium chromate EC No: 231-889-5 CAS No: 7775-11-3	21 Mar 2016	21 Sep 2017	
28. Dichromium tris(-chromate) EC No: 246-356-2 CAS No: 24613-89-6	22. July 2017	22 January 2019	
29. Strontium chromate EC No: 232-142-6 CAS No: 7789-06-2	22 July 2017	22 January 2019	
30. Potassium hydroxyoctaoxodizincatedichromate EC No: 234-329-8 CAS No: 11103-86-9	22 July 2017	22 January 2019	
31. Pentazinc chromate octahydroxide EC No: 256-418-0 CAS No: 49663-84-5	22 July 2017	22 January 2019	

For the substances currently restricted according to RoHS Annex II: cadmium, hexavalent chromium, lead, mercury, polybrominated biphenyls and polybrominated diphenyl ethers and their compounds, we have found that some relevant entries are listed in Annex XVII of the REACH Regulation. The conditions of restriction are presented in Table A. 2 below. Additionally, some amendments have been decided upon, and are still to be included in the concise version. These may be seen in Table A. 3.

Table A. 2: Conditions of Restriction in REACH Annex XVII for RoHS Substances and Compounds

Designation of the substance, of the group of substances or of the mixture	Conditions of restriction
8. Polybromobiphenyls; Polybrominatedbiphenyls (PBB) **CAS No 59536-65-1**	1. Shall not be used in textile articles, such as garments, undergarments and linen, intended to come into contact with the skin. 2. Articles not complying with paragraph 1 shall not be placed on the market.
16. Lead carbonates: **(a) Neutral anhydrous carbonate ($PbCO_3$)** **CAS No 598-63-0** **EC No 209-943-4** **(b) Trilead-bis(carbonate)-dihydroxide $2PbCO_3$-$Pb(OH)_2$** **CAS No 1319-46-6** **EC No 215-290-6**	Shall not be placed on the market, or used, as substances or in mixtures, where the substance or mixture is intended for use as paint. However, Member States may, in accordance with the provisions of International Labour Organization (ILO) Convention 13, permit the use on their territory of the substance or mixture for the restoration and maintenance of works of art and historic buildings and their interiors, as well as the placing on the market for such use. Where a Member State makes use of this derogation, it shall inform the Commission thereof.
17. Lead sulphates: **(a) $PbSO_4$** **CAS No 7446-14-2** **EC No 231-198-9** **(b) Pb_xSO_4** **CAS No 15739-80-7** **EC No 239-831-0**	Shall not be placed on the market, or used, as substances or in mixtures, where the substance or mixture is intended for use as paint. However, Member States may, in accordance with the provisions of International Labour Organization (ILO) Convention 13, permit the use on their territory of the substance or mixture for the restoration and maintenance of works of art and historic buildings and their interiors, as well as the placing on the market for such use. Where a Member State makes use of this derogation, it shall inform the Commission thereof.
18. Mercury compounds	Shall not be placed on the market, or used, as substances or in mixtures where the substance or mixture is intended for use: (a) to prevent the fouling by micro-organisms, plants or animals of: — the hulls of boats, — cages, floats, nets and any other appliances or equipment used for fish or shellfish farming, — any totally or partly submerged appliances or equipment; (b) in the preservation of wood; (c) in the impregnation of heavy-duty industrial textiles and yarn intended for their manufacture; (d) in the treatment of industrial waters, irrespective of their use.
18a. Mercury **CAS No 7439-97-6** **EC No 231-106-7**	1. Shall not be placed on the market: (a) in fever thermometers; (b) in other measuring devices intended for sale to the general public (such as manometers, barometers, sphygmomanometers, thermometers other than fever thermometers). 2. The restriction in paragraph 1 shall not apply to measuring devices that were in use in the Community before 3 April 2009. However Member States may restrict or prohibit the placing on the market of such measuring devices.

Designation of the substance, of the group of substances or of the mixture	Conditions of restriction
	3. The restriction in paragraph 1(b) shall not apply to: (a) measuring devices more than 50 years old on 3 October 2007; (b) barometers (except barometers within point (a)) until 3 October 2009. 5. The following mercury-containing measuring devices intended for industrial and professional uses shall not be placed on the market after 10 April 2014: (a) barometers; (b) hygrometers; (c) manometers; (d) sphygmomanometers; (e) strain gauges to be used with plethysmographs; (f) tensiometers; (g) thermometers and other non-electrical thermometric applications. The restriction shall also apply to measuring devices under points (a) to (g) which are placed on the market empty if intended to be filled with mercury. 6. The restriction in paragraph 5 shall not apply to: (a) sphygmomanometers to be used: (i) in epidemiological studies which are ongoing on 10 October 2012; (ii) as reference standards in clinical validation studies of mercury-free sphygmomanometers; (b) thermometers exclusively intended to perform tests according to standards that require the use of mercury thermometers until 10 October 2017; (c) mercury triple point cells which are used for the calibration of platinum resistance thermometers. 7. The following mercury-using measuring devices intended for professional and industrial uses shall not be placed on the market after 10 April 2014: (a) mercury pycnometers; (b) mercury metering devices for determination of the softening point. 8. The restrictions in paragraphs 5 and 7 shall not apply to: (a) measuring devices more than 50 years old on 3 October 2007; (b) measuring devices which are to be displayed in public exhibitions for cultural and historical purposes.
23. Cadmium and its compounds **CAS No 7440-43-9** **EC No 231-152-8**	For the purpose of this entry, the codes and chapters indicated in square brackets are the codes and chapters of the tariff and statistical nomenclature of Common Customs Tariff as established by Council Regulation (EEC) No 2658/87 (1). 1. Shall not be used in mixtures and articles produced from the following synthetic organic polymers (hereafter referred to as plastic material): — polymers or copolymers of vinyl chloride (PVC) [3904 10] [3904 21] — polyurethane (PUR) [3909 50] — low-density polyethylene (LDPE), with the exception of low-density polyethylene used for the production of coloured masterbatch [3901 10] — cellulose acetate (CA) [3912 11] — cellulose acetate butyrate (CAB) [3912 11] — epoxy resins [3907 30] — melamine-formaldehyde (MF) resins [3909 20] — urea-formaldehyde (UF) resins [3909 10] — unsaturated polyesters (UP) [3907 91] — polyethylene terephthalate (PET) [3907 60] — polybutylene terephthalate (PBT) — transparent/general-purpose polystyrene [3903 11] — acrylonitrile methylmethacrylate (AMMA)

Designation of the substance, of the group of substances or of the mixture	Conditions of restriction
	— cross-linked polyethylene (VPE) — high-impact polystyrene — polypropylene (PP) [3902 10] Mixtures and articles produced from plastic material as listed above shall not be placed on the market if the concentration of cadmium (expressed as Cd metal) is equal to or greater than 0,01 % by weight of the plastic material. By way of derogation, the second subparagraph shall not apply to articles placed on the market before 10 December 2011. The first and second subparagraphs apply without prejudice to Council Directive 94/62/EC (13) and acts adopted on its basis. By 19 November 2012, in accordance with Article 69, the Commission shall ask the European Chemicals Agency to prepare a dossier conforming to the requirements of Annex XV in order to assess whether the use of cadmium and its compounds in plastic material, other than that listed in subparagraph 1, should be restricted. 2. Shall not be used in paints [3208] [3209]. For paints with a zinc content exceeding 10 % by weight of the paint, the concentration of cadmium (expressed as Cd metal) shall not be equal to or greater than 0,1 % by weight. Painted articles shall not be placed on the market if the concentration of cadmium (expressed as Cd metal) is equal to or greater than 0,1 % by weight of the paint on the painted article. 3. By way of derogation, paragraphs 1 and 2 shall not apply to articles coloured with mixtures containing cadmium for safety reasons. 4. By way of derogation, paragraph 1, second subparagraph shall not apply to: — mixtures produced from PVC waste, hereinafter referred to as 'recovered PVC', — mixtures and articles containing recovered PVC if their concentration of cadmium (expressed as Cd metal) does not exceed 0,1 % by weight of the plastic material in the following rigid PVC applications: — (a) profiles and rigid sheets for building applications; (b) doors, windows, shutters, walls, blinds, fences, and roof gutters; (c) decks and terraces; (d) cable ducts; (e) pipes for non-drinking water if the recovered PVC is used in the middle layer of a multilayer pipe and is entirely covered with a layer of newly produced PVC in compliance with paragraph 1 above. Suppliers shall ensure, before the placing on the market of mixtures and articles containing recovered PVC for the first time, that these are visibly, legibly and indelibly marked as follows: '*Contains recovered PVC*' or with the following pictogram:  In accordance with Article 69 of this Regulation, the derogation granted in paragraph 4 will be reviewed, in particular with a view to reducing the limit

Designation of the substance, of the group of substances or of the mixture	Conditions of restriction
	value for cadmium and to reassess the derogation for the applications listed in points (a) to (e), by 31 December 2017. 5. For the purpose of this entry, 'cadmium plating' means any deposit or coating of metallic cadmium on a metallic surface. Shall not be used for cadmium plating metallic articles or components of the articles used in the following sectors/applications: (a) equipment and machinery for: — food production [8210] [8417 20] [8419 81] [8421 11] [8421 22] [8422] [8435] [8437] [8438] [8476 11] — agriculture [8419 31] [8424 81] [8432] [8433] [8434] [8436] — cooling and freezing [8418] — printing and book-binding [8440] [8442] [8443] (b) equipment and machinery for the production of: — household goods [7321] [8421 12] [8450] [8509] [8516] — furniture [8465] [8466] [9401] [9402] [9403] [9404] — sanitary ware [7324] — central heating and air conditioning plant [7322] [8403] [8404] [8415] In any case, whatever their use or intended final purpose, the placing on the market of cadmium-plated articles or components of such articles used in the sectors/applications listed in points (a) and (b) above and of articles manufactured in the sectors listed in point (b) above is prohibited. 6. The provisions referred to in paragraph 5 shall also be applicable to cadmium-plated articles or components of such articles when used in the sectors/applications listed in points (a) and (b) below and to articles manufactured in the sectors listed in (b) below: (a) equipment and machinery for the production of: — paper and board [8419 32] [8439] [8441] textiles and clothing [8444] [8445] [8447] [8448] [8449] [8451] [8452] (b) equipment and machinery for the production of: — industrial handling equipment and machinery [8425] [8426] [8427] [8428] [8429] [8430] [8431] — road and agricultural vehicles [chapter 87] — rolling stock [chapter 86] — vessels [chapter 89] 7. However, the restrictions in paragraphs 5 and 6 shall not apply to: — articles and components of the articles used in the aeronautical, aerospace, mining, offshore and nuclear sectors whose applications require high safety standards and in safety devices in road and agricultural vehicles, rolling stock and vessels, — electrical contacts in any sector of use, where that is necessary to ensure the reliability required of the apparatus on which they are installed. 8. Shall not be used in brazing fillers in concentration equal to or greater than 0,01 % by weight. Brazing fillers shall not be placed on the market if the concentration of cadmium (expressed as Cd metal) is equal to or greater than 0,01 % by weight. For the purpose of this paragraph brazing shall mean a joining technique using alloys and undertaken at temperatures above 450 °C. 9. By way of derogation, paragraph 8 shall not apply to brazing fillers used in defence and aerospace applications and to brazing fillers used for safety reasons. 10. Shall not be used or placed on the market if the concentration is equal to or

Designation of the substance, of the group of substances or of the mixture	Conditions of restriction
	greater than 0,01 % by weight of the metal in: (i) metal beads and other metal components for jewellery making; (ii) metal parts of jewellery and imitation jewellery articles and hair accessories, including: — bracelets, necklaces and rings, — piercing jewellery, — wrist-watches and wrist-wear, — brooches and cufflinks. 11. By way of derogation, paragraph 10 shall not apply to articles placed on the market before 10 December 2011 and jewellery more than 50 years old on 10 December 2011.
28. **Substances which appear in Part 3 of Annex VI to Regulation (EC) No 1272/2008 classified as carcinogen category 1A or 1B (Table 3.1) or carcinogen category 1 or 2 (Table 3.2) and listed as follows:** **— Carcinogen category 1A (Table 3.1)/carcinogen category 1 (Table 3.2) listed in Appendix 1** **— Carcinogen category 1B (Table 3.1)/carcinogen category 2 (Table 3.2) listed in Appendix 2:** **Chromium (VI) trioxide** **Zinc chromates including zinc potassium chromate** **Nickel chromate** **Nickel dichromate** **Potassium dichromate** **Ammonium dichromate** **Sodium dichromate** **Chromyl dichloride; chromic oxychloride** **Potassium chromate** **Calcium chromate** **Strontium chromate** **Chromium (VI) compounds, with the exception of barium chromate and of compounds specified elsewhere in Annex VI to Regulation (EC) No 1272/2008** **Chromium III chromate; chromic chromate** **Sodium chromate** **Cadmium oxide** **Cadmium chloride** **Cadmium fluoride** **Cadmium Sulphate**	Without prejudice to the other parts of this Annex the following shall apply to entries 28 to 30: 1. Shall not be placed on the market, or used, — as substances, — as constituents of other substances, or, — in mixtures, for supply to the general public when the individual concentration in the substance or mixture is equal to or greater than: — either the relevant specific concentration limit specified in Part 3 of Annex VI to Regulation (EC) No 1272/2008, or, — the relevant generic concentration limit specified in Part 3 of Annex I of Regulation (EC) No 1272/2008. Without prejudice to the implementation of other Community provisions relating to the classification, packaging and labelling of substances and mixtures, suppliers shall ensure before the placing on the market that the packaging of such substances and mixtures is marked visibly, legibly and indelibly as follows: 2. By way of derogation, paragraph 1 shall not apply to: (a) medicinal or veterinary products as defined by Directive 2001/82/EC and Directive 2001/83/EC; (b) cosmetic products as defined by Directive 76/768/EEC; (c) the following fuels and oil products: — motor fuels which are covered by Directive 98/70/EC, — mineral oil products intended for use as fuel in mobile or fixed combustion plants, — fuels sold in closed systems (e.g. liquid gas bottles); (d) artists' paints covered by Regulation (EC) No 1272/2008; (e) the substances listed in Appendix 11, column 1, for the applications or uses listed in Appendix 11, column 2. Where a date is specified in column 2 of Appendix 11, the derogation shall apply until the said date.

Designation of the substance, of the group of substances or of the mixture	Conditions of restriction
Cadmium sulphide Cadmium (pyrophoric) Chromium (VI) trioxide Lead Chromate Lead hydrogen arsenate Silicic acid, lead nickel salt Lead sulfochromate yellow; C.I. Pigment Yellow 34; Lead chromate molybdate sulfate red; C.I. Pigment Red 104;	
29. Substances which appear in Part 3 of Annex VI to Regulation (EC) No 1272/2008 classified as germ cell mutagen category 1A or 1B (Table 3.1) or mutagen category 1 or 2 (Table 3.2) and listed as follows: — Mutagen category 1A (Table 3.1)/mutagen category 1 (Table 3.2) listed in Appendix 3 — Mutagen category 1B (Table 3.1)/mutagen category 2 (Table 3.2) listed in Appendix 4 Cadmium chloride Cadmium fluoride Cadmium Sulphate Chromium (VI) trioxide Potassium dichromate Ammonium dichromate Sodium dichromate Chromyl dichloride; chromic oxychloride Potassium chromate Sodium chromate	
30. Substances which appear in Part 3 of Annex VI to Regulation (EC) No 1272/2008 classified as toxic to reproduction category 1A or 1B (Table 3.1) or toxic to reproduction category 1 or 2 (Table 3.2) and listed as follows: — Reproductive toxicant category 1A adverse effects on sexual function and fertility or on development (Table 3.1) or reproductive toxicant category 1 with R60 (May impair fertility) or R61 (May cause harm to the unborn child) (Table 3.2) listed in Appendix 5	

Designation of the substance, of the group of substances or of the mixture	Conditions of restriction
— Reproductive toxicant category 1B adverse effects on sexual function and fertility or on development (Table 3.1) or reproductive toxicant category 2 with R60 (May impair fertility) or R61 (May cause harm to the unborn child) (Table 3.2) listed in Appendix 6: **Bis(2-ethylhexyl) phthalate; di-(2-ethylhexyl) phthalate; DEHP** **Benzyl butyl phthalate; BBP** **Dibutyl phthalate; DBP** **Diisobutyl phthalate** **Cadmium chloride** **Cadmium fluoride** **Cadmium Sulphate** **Potassium dichromate** **Ammonium dichromate** **Sodium dichromate** **Sodium chromate** **Nickel dichromate** **Lead compounds with the exception of those specified elsewhere in this Annex** **Lead hydrogen arsenate** **Lead acetate** **Lead alkyls** **Lead azide** **Lead Chromate** **Lead di(acetate)** **Lead hydrogen arsenate** **Lead 2,4,6-trinitroresorcinoxide, lead styphnate** **Lead(II) methane- sulphonate** **Trilead bis- (orthophosphate)** **Lead hexa-fluorosilicate** **Mercury** **Silicic acid, lead nickel salt**	
47. Chromium VI compounds	1. Cement and cement-containing mixtures shall not be placed on the market, or used, if they contain, when hydrated, more than 2 mg/kg (0,0002 %) soluble chromium VI of the total dry weight of the cement. 2. If reducing agents are used, then without prejudice to the application of other Community provisions on the classification, packaging and labelling of substances and mixtures, suppliers shall ensure before the placing on the market that the packaging of cement or cement-containing mixtures is visibly, legibly and indelibly marked with information on the packing date, as well as on the storage conditions and the storage period appropriate to maintaining the activity of the reducing agent and to keeping the content of soluble chromium VI below the limit indicated in paragraph 1. 3. By way of derogation, paragraphs 1 and 2 shall not apply to the placing on the market for, and use in, controlled closed and totally automated processes in which cement and cement-containing mixtures are handled solely by machines

Designation of the substance, of the group of substances or of the mixture	Conditions of restriction
	and in which there is no possibility of contact with the skin. 4. The standard adopted by the European Committee for Standardization (CEN) for testing the water-soluble chromium (VI) content of cement and cement-containing mixtures shall be used as the test method for demonstrating conformity with paragraph 1. 5. Leather articles coming into contact with the skin shall not be placed on the market where they contain chromium VI in concentrations equal to or greater than 3 mg/kg (0,0003 % by weight) of the total dry weight of the leather. 6. Articles containing leather parts coming into contact with the skin shall not be placed on the market where any of those leather parts contains chromium VI in concentrations equal to or greater than 3 mg/kg (0,0003 % by weight) of the total dry weight of that leather part. 7. Paragraphs 5 and 6 shall not apply to the placing on the market of second-hand articles which were in end-use in the Union before 1 May 2015.
51. The following phthalates (or other CAS and EC numbers covering the substance): **(a) Bis (2-ethylhexyl) phthalate (DEHP)** **CAS No 117-81-7** **EC No 204-211-0** **(b) Dibutyl phthalate (DBP)** **CAS No 84-74-2** **EC No 201-557-4** **(c) Benzyl butyl phthalate (BBP)** **CAS No 85-68-7** **EC No 201-622-7**	1. Shall not be used as substances or in mixtures, in concentrations greater than 0,1 % by weight of the plasticised material, in toys and childcare articles. 2. Toys and childcare articles containing these phthalates in a concentration greater than 0,1 % by weight of the plasticised material shall not be placed on the market. 4. For the purpose of this entry ‘childcare article’ shall mean any product intended to facilitate sleep, relaxation, hygiene, the feeding of children or sucking on the part of children.
63. Lead and its compounds **CAS No 7439-92-1 EC No 231-100-4**	1. Shall not be placed on the market or used in any individual part of jewellery articles if the concentration of lead (expressed as metal) in such a part is equal to or greater than 0,05 % by weight. 2. For the purposes of paragraph 1: (i) ‘jewellery articles’ shall include jewellery and imitation jewellery articles and hair accessories, including: (a) bracelets, necklaces and rings; (b) piercing jewellery; (c) wrist watches and wrist-wear; (d) brooches and cufflinks; (ii) ‘any individual part’ shall include the materials from which the jewellery is made, as well as the individual components of the jewellery articles. 3. Paragraph 1 shall also apply to individual parts when placed on the market or used for jewellery-making. 4. By way of derogation, paragraph 1 shall not apply to: (a) crystal glass as defined in Annex I (categories 1, 2, 3 and 4) to Council Directive 69/493/EEC (*); (b) internal components of watch timepieces inaccessible to consumers; (c) non-synthetic or reconstructed precious and semiprecious stones (CN code 7103, as established by Regulation (EEC) No 2658/87), unless they have been treated with lead or its compounds or mixtures containing these substances; (d) enamels, defined as vitrifiable mixtures resulting from the fusion, vitrification or sintering of minerals melted at a temperature of at least 500 °C. 5. By way of derogation, paragraph 1 shall not apply to jewellery articles placed

Designation of the substance, of the group of substances or of the mixture	Conditions of restriction
	on the market for the first time before 9 October 2013 and jewellery articles articles produced before 10 December 1961. 6. By 9 October 2017, the Commission shall re-evaluate paragraphs 1 to 5 of this entry in the light of new scientific information, including the availability of alternatives and the migration of lead from the articles referred to in paragraph 1 and, if appropriate, modify this entry accordingly. 7. Shall not be placed on the market or used in articles supplied to the general public, if the concentration of lead (expressed as metal) in those articles or accessible parts thereof is equal to or greater than 0,05 % by weight, and those articles or accessible parts thereof may, during normal or reasonably foreseeable conditions of use, be placed in the mouth by children. That limit shall not apply where it can be demonstrated that the rate of lead release from such an article or any such accessible part of an article, whether coated or uncoated, does not exceed 0,05 µg/cm 2 per hour (equivalent to 0,05 µg/g/h), and, for coated articles, that the coating is sufficient to ensure that this release rate is not exceeded for a period of at least two years of normal or reasonably foreseeable conditions of use of the article. For the purposes of this paragraph, it is considered that an article or accessible part of an article may be placed in the mouth by children if it is smaller than 5 cm in one dimension or has a detachable or protruding part of that size. 8. By way of derogation, paragraph 7 shall not apply to: (a) jewellery articles covered by paragraph 1; (b) crystal glass as defined in Annex I (categories 1, 2, 3 and 4) to Directive 69/493/ EEC; (c) non-synthetic or reconstructed precious and semi-precious stones (CN code 7103 as established by Regulation (EEC) No 2658/ 87) unless they have been treated with lead or its compounds or mixtures containing these substances; (d) enamels, defined as vitrifiable mixtures resulting from the fusion, vitrification or sintering of mineral melted at a temperature of at least 500 ° C; (e) keys and locks, including padlocks; (f) musical instruments; (g) articles and parts of articles comprising brass alloys, if the concentration of lead (expressed as metal) in the brass alloy does not exceed 0,5 % by weight; (h) the tips of writing instruments (i) religious articles; (j) portable zinc-carbon batteries and button cell batteries; (k) articles within the scope of: (i) Directive 94/62/EC; (ii) Regulation (EC) No 1935/2004; (iii) Directive 2009/48/EC of the European Parliament and of the Council (**); (iv) Directive 2011/65/EU of the European Parliament and of the Council (***) 9. By 1 July 2019, the Commission shall re-evaluate paragraphs 7 and 8(e), (f), (i) and (j) of this entry in the light of new scientific information, including the availability of alternatives and the migration of lead from the articles referred to in paragraph 7, including the requirement on coating integrity, and, if appropriate, modify this entry accordingly. 10. By way of derogation paragraph 7 shall not apply to articles placed on the market for the first time before 1 June 2016. (*) OJ L 326, 29.12.1969, p. 36. (**) Directive 2009/48/EC of the European Parliament and of the Council of 18 June 2009 on the safety of toys (OJ L 170, 30.6.2009, p. 1). (***) Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and e l e c t r o n i c e q u i p m e n t (O J L 1 7 4 , 1.7.2011, p. 88).

Table A. 3: Summary of Relevant Amendments to Annexes Not Updated in the Last Concise Version of the REACH Regulation

Designation of the substance, of the group of substances, or of the mixture	Conditions of restriction	Amended Annex	Amendment date
Addition of Entry 62 concerning: **(a) Phenylmercury acetate** **EC No: 200-532-5** **CAS No: 62-38-4** **(b) Phenylmercury propionate** **EC No: 203-094-3** **CAS No: 103-27-5** **(c) Phenylmercury 2-ethylhexanoate** **EC No: 236-326-7** **CAS No: 13302-00-6** **(d) Phenylmercury octanoate** **EC No: -** **CAS No: 13864-38-5** **(e) Phenylmercury neodecanoate** **EC No: 247-783-7** **CAS No: 26545-49-3**	1. Shall not be manufactured, placed on the market or used as substances or in mixtures after 10 October 2017 if the concentration of mercury in the mixtures is equal to or greater than 0,01% by weight. 2. Articles or any parts thereof containing one or more of these substances shall not be placed on the market after 10 October 2017 if the concentration of mercury in the articles or any part thereof is equal to or greater than 0,01% by weight.'	Annex XVII, entry 62	20 Sep 2012

As of 28 September 2015, the REACH Regulation Candidate list includes those substances relevant for RoHS listed in Table A. 4 (i.e., proceedings concerning the addition of these substances to the Authorisation list (Annex XIV) have begun and shall be followed by the evaluation team to determine possible discrepancies with future requests of exemption from RoHS (new exemptions, renewals and revocations))[1957]:

Table A. 4: Summary of Relevant Substances Currently on the REACH Candidate List

Substance Name	EC No.	CAS No.	Date of Inclusion	Reason for inclusion
Cadmium fluoride	232-222-0	7790-79-6	17 December 2014	Carcinogenic (Article 57 a); Mutagenic (Article 57 b); Toxic for reproduction (Article 57 c); Equivalent level of concern having probable serious effects to human health (Article 57 f)
Cadmium sulphate	233-331-6	10124-36-4 31119-53-6	17 December 2014	Carcinogenic (Article 57 a); Mutagenic (Article 57 b); Toxic for reproduction (Article 57 c); Equivalent level of concern having probable serious effects to human health (Article 57 f)
Cadmium chloride	233-296-7	10108-64-2	16 June 2014	Carcinogenic (Article 57a);

[1957] Updated according to http://echa.europa.eu/web/guest/candidate-list-table

Substance Name	EC No.	CAS No.	Date of Inclusion	Reason for inclusion
Cadmium sulphide	215-147-8	1306-23-6	16 Dec 2013	Carcinogenic (Article 57a); Equivalent level of concern having probable serious effects to human health (Article 57 f)
Lead di(acetate)	206-104-4	301-04-2	16 Dec 2013	Toxic for reproduction (Article 57 c);
Cadmium	231-152-8	7440-43-9	20 Jun 2013	Carcinogenic (Article 57a); Equivalent level of concern having probable serious effects to human health (Article 57 f)
Cadmium oxide	215-146-2	1306-19-0	20 Jun 2013	Carcinogenic (Article 57a); Equivalent level of concern having probable serious effects to human health (Article 57 f)
Pyrochlore, antimony lead yellow	232-382-1	8012-00-8	19 Dec 2012	Toxic for reproduction (Article 57 c)
Lead bis(tetrafluoroborate)	237-486-0	13814-96-5	19 Dec 2012	Toxic for reproduction (Article 57 c)
Lead dinitrate	233-245-9	10099-74-8	19 Dec 2012	Toxic for reproduction (Article 57 c)
Silicic acid, lead salt	234-363-3	11120-22-2	19 Dec 2012	Toxic for reproduction (Article 57 c)
Lead titanium zirconium oxide	235-727-4	12626-81-2	19 Dec 2012	Toxic for reproduction (Article 57 c)
Lead monoxide (lead oxide)	215-267-0	1317-36-8	19 Dec 2012	Toxic for reproduction (Article 57 c)
Silicic acid ($H_2Si_2O_5$), barium salt (1:1), lead-doped ***[with lead (Pb) content above the applicable generic concentration limit for 'toxicity for reproduction' Repr. 1A (CLP) or category 1 (DSD); the substance is a member of the group entry of lead compounds, with index number 082-001-00-6 in Regulation (EC) No 1272/2008]***	272-271-5	68784-75-8	19 Dec 2012	Toxic for reproduction (Article 57 c)
Trilead bis(carbonate)dihydroxide	215-290-6	1319-46-6	19 Dec 2012	Toxic for reproduction (Article 57 c)
Lead oxide sulfate	234-853-7	12036-76-9	19 Dec 2012	Toxic for reproduction (Article 57 c)
Lead titanium trioxide	235-038-9	12060-00-3	19 Dec 2012	Toxic for reproduction (Article 57 c)
Acetic acid, lead salt, basic	257-175-3	51404-69-4	19 Dec 2012	Toxic for reproduction (Article 57 c)
[Phthalato(2-)]dioxotrilead	273-688-5	69011-06-9	19 Dec 2012	Toxic for reproduction (Article 57 c)
Tetralead trioxide sulphate	235-380-9	12202-17-4	19 Dec 2012	Toxic for reproduction (Article 57 c)
Dioxobis(stearato)trilead	235-702-8	12578-12-0	19 Dec 2012	Toxic for reproduction (Article 57 c)
Tetraethyllead	201-075-4	78-00-2	19 Dec 2012	Toxic for reproduction (Article 57 c)
Pentalead tetraoxide sulphate	235-067-7	12065-90-6	19 Dec 2012	Toxic for reproduction (Article 57 c)
Trilead dioxide phosphonate	235-252-2	12141-20-7	19 Dec 2012	Toxic for reproduction (Article 57 c)
Orange lead (lead tetroxide)	215-235-6	1314-41-6	19 Dec 2012	Toxic for reproduction (Article 57

Substance Name	EC No.	CAS No.	Date of Inclusion	Reason for inclusion
				c)
Sulfurous acid, lead salt, dibasic	263-467-1	62229-08-7	19 Dec 2012	Toxic for reproduction (Article 57 c)
Lead cyanamidate	244-073-9	20837-86-9	19 Dec 2012	Toxic for reproduction (Article 57 c)
Lead(II) bis(methanesulfonate)	401-750-5	17570-76-2	18 Jun 2012	Toxic for reproduction (Article 57 c)
Lead diazide, Lead azide	236-542-1	13424-46-9	19 Dec 2011	Toxic for reproduction (article 57 c),
Lead dipicrate	229-335-2	6477-64-1	19 Dec 2011	Toxic for reproduction (article 57 c)
Dichromium tris(chromate)	246-356-2	24613-89-6	19 Dec 2011	Carcinogenic (article 57 a)
Pentazinc chromate octahydroxide	256-418-0	49663-84-5	19 Dec 2011	Carcinogenic (article 57 a)
Potassium hydroxyoctaoxodizincatedichromate	234-329-8	11103-86-9	19 Dec 2011	Carcinogenic (article 57 a)
Lead styphnate	239-290-0	15245-44-0	19 Dec 2011	Toxic for reproduction (article 57 c)
Trilead diarsenate	222-979-5	3687-31-8	19 Dec 2011	Carcinogenic and toxic for reproduction (articles 57 a and 57 c)
Strontium chromate	232-142-6	7789-06-2	20 Jun 2011	Carcinogenic (article 57a)
Acids generated from chromium trioxide and their oligomers. Names of the acids and their oligomers: Chromic acid, Dichromic acid, Oligomers of chromic acid and dichromic acid.	231-801-5, 236-881-5	7738-94-5, 13530-68-2	15 Dec 2010	Carcinogenic (article 57a)
Chromium trioxide	215-607-8	1333-82-0	15 Dec 2010	Carcinogenic and mutagenic (articles 57 a and 57 b)
Potassium dichromate	231-906-6	7778-50-9	18 Jun 2010	Carcinogenic, mutagenic and toxic for reproduction (articles 57 a, 57 b and 57 c)
Ammonium dichromate	232-143-1	7789-09-5	18 Jun 2010	Carcinogenic, mutagenic and toxic for reproducetion (articles 57 a, 57 b and 57 c)
Sodium chromate	231-889-5	7775-11-3	18 Jun 2010	Carcinogenic, mutagenic and toxic for reproduction (articles 57 a, 57 b and 57 c)
Potassium chromate	232-140-5	7789-00-6	18 Jun 2010	Carcinogenic and mutagenic (articles 57 a and 57 b).
Lead sulfochromate yellow (C.I. Pigment Yellow 34)	215-693-7	1344-37-2	13 Jan 2010	Carcinogenic and toxic for reproduction (articles 57 a and 57 c))
Lead chromate molybdate sulphate red (C.I. Pigment Red 104)	235-759-9	12656-85-8	13 Jan 2010	Carcinogenic and toxic for reproduction (articles 57 a and 57 c)
Lead chromate	231-846-0	7758-97-6	13 Jan 2010	Carcinogenic and toxic for reproduction (articles 57 a and 57 c)
Lead hydrogen arsenate	232-064-2	7784-40-9	28 Oct 2008	Carcinogenic and toxic for reproduction (articles 57 a and 57 c)
Sodium dichromate	234-190-3	7789-12-0, 10588-01-9	28 Oct 2008	Carcinogenic, mutagenic and toxic for reproduction (articles 57a, 57b and 57c)

Additionally, Member States can register intentions to propose restrictions or to classify substances as SVHC. The first step is to announce such an intention. Once the respective dossier is submitted, it is reviewed and it is decided if the restriction or authorisation process should be further pursued or if the intention should be withdrawn.

As at the time of writing (Fall 2015), it cannot yet be foreseen how these procedures will conclude. It is thus not yet possible to determine if the protection afforded by REACH Regulation would in these cases consequently be weakened by approving the exemption requests dealt with in this report. For this reason, the implications of these decisions have not been considered in the review of the exemption requests dealt with in this report. However for the sake of future reviews, the latest authorisation or restriction process results shall be followed and carefully considered where relevant.[1958]

As for registries of intentions to identify substances as SVHC, as of 28 September 2015, Sweden has submitted intentions regarding the classification of cadmium fluoride and cadmium sulphate as CMR, intending to submit dossiers in August 2014.None of the current registries of intentions to propose restrictions apply to RoHs regulated substances.[1959]

As for prior registrations of intention, dossiers have been submitted for the substances listed in Table A. 5.

Table A. 5: Summary of Substances for which a Dossier has been submitted, following the initial registration of intention

Restriction / SVHC Classification	Substance Name	Submission Date	Submitted by	Comments
Restriction	Cadmium and its compounds	17 Jan 2014	Sweden	Artist paints
	Cadmium and its compounds	17 Oct 2013	ECHA	Amendment of the current restriction (entry 23) on use of paints with TARIC codes [3208] & [3209] containing cadmium and cadmium compounds to include placing on the market of such paints and a concentration limit.
	Lead and lead compounds	18 Jan 2013	Sweden	Placing on the market of consumer articles containing Lead and its compounds
	Chromium VI	20 Jan 2012	Denmark	Placing on the market of leather articles containing

[1958] European Chemicals Agency (ECHA), Registry of intentions to propose restrictions: http://echa.europa.eu/registry-of-current-restriction-proposal-intentions/-/substance/1402/search/+/term (28.09.2015)

[1959] ECHA website, accessed 28.09.2015: http://echa.europa.eu/web/guest/addressing-chemicals-of-concern/registry-of-intentions

Restriction / SVHC Classification	Substance Name	Submission Date	Submitted by	Comments
				Chromium VI
	Phenylmercuric octanoate; Phenylmercury propionate; Phenylmercury 2-ethylhexanoate; Phenylmercury acetate; Phenylmercury	15 Jun 2010	Norway	Mercury compounds
	Mercury in measuring devices	15 Jun 2010	ECHA	Mercury compounds
	Lead and its compounds in jewellery	15 Apr 2010	France	Substances containing lead
SVHC Classification	Cadmium chloride	03 Feb 2014	Sweden	CMR; other;
	Cadmium sulphide	05 Aug 2013	Sweden	CMR; other;
	Lead di(acetate)	05 Aug 2013	Netherlands	CMR
	Cadmium	04 Feb 2013	Sweden	CMR; other; Substances containing Cd
	Cadmium oxide	04 Feb 2013	Sweden	CMR; other; Substances Containing Cd
	Trilead dioxide Phosphonate; Lead Monoxide (Lead Oxide); Trilead bis(carbonate)di-hydroxide; Lead Dinitrate; Lead Oxide Sulphate; Acetic acid, lead salt, basic; Dioxobis(stearato)trilead; Lead bis(tetrafluoroborate); Tetraethyllead; Pentalead tetraoxide sulphate; Lead cyanamidate; Lead titanium trioxide; Silicic acid ($H_2Si_2O_5$), barium salt (1:1), lead-doped; Silicic acid, lead salt; Sulfurous acid, lead salt, dibasic; Tetralead trioxide sulphate; [Phthalato(2-)]dioxotrilead; Orange lead (lead tetroxide); Fatty acids, C16-18, lead salts; Lead titanium zirconium oxide	30 Aug 2012	ECHA	CMR; substances Containing Lead
	Lead(II) bis(methanesulfonate)	30 Jan 2012	Netherlands	CMR; Amides
	Lead styphnate; Lead diazide; Lead azide; Lead dipicrate	01 Aug 2011	ECHA	CMR; Substances containing lead
	Trilead diarsenate			CMR; Arsenic compounds
	Strontium Chromate	24 Jan 2011	France	CMR; Substances containing chromate
	Acids generated from chromium trioxide and their oligomers: Chromic acid; Dichromic acid; Oligomers of chromic acid and dichromic acid	27 Aug 2010	Germany	CMR; Substances containing chromate
	Chromium Trioxide	02 Aug 2010	Germany	CMR; Substances containing chromate
	Sodium chromate; Potassium chromate; Potassium Dichromate	10 Feb 2010	France	CMR; Substances containing chromate

Restriction / SVHC Classification	Substance Name	Submission Date	Submitted by	Comments
	Lead chromate molybdate sulfate red (C.I. Pigment Red 104); Lead sulfochromate yellow (C.I. Pigment Yellow 34)	03 Aug 2009	France	CMR; substances Containing Lead
	Lead Chromate	03 Aug 2009	France	CMR; Substances containing chromate
	Lead hydrogen arsenate	27 Jun 2008	Norway	CMR; Arsenic compounds
	Sodium dichromate	26 Jun 2008	France	CMR; Substances containing chromate

Concerning the above mentioned processes, as at present, it cannot be foreseen if, or when, new restrictions or identification as SVHC might be implemented as a result of this proposal; its implications have not been considered in the review of the exemption requests dealt with in this report. In future reviews, however, on-going research into restriction and identification as SVHC processes and the results of on-going proceedings shall be followed and carefully considered where relevant.

A.2.0 Appendix 2: Data as to the Average Number and Type of Light Sources per Household

The information is copied from Annex C of the VHK & VITO 2015 Task 3 Report and is available with additional detail under the following link:

http://ecodesign-lightsources.eu/sites/ecodesign-lightsources.eu/files/attachments/LightSources%20Task3%20Final%2020151031.pdf

Data is presented only for the the three most recent studies. Additional information for each data and additional studies are presented in the original source.

C.1 United Kingdom 2012, lighting measurements in households

The reference [211] presents the results of a survey of 251 households in England that was undertaken to monitor the electrical power demand and energy consumption over the period May 2010 to July 2011. Of the 251 households surveyed, 26 were monitored for a period of one year and the rest were monitored for periods of one month at intervals throughout the year. Different types of houses (terraced, flat, stand-alone) with different types of households (pensioners, workers, with or without children) were involved. Lighting energy consumption was part of the measurements.

A seasonality lighting curve was calculated using the 26 households that were monitored for one year [212]. This curve was used to calculate the annual consumption for the lights monitored for one month.

The average **number of light sources per household**, all types taken together, was **33.6**. As reported in the reference, this value is between the numbers for the ECL100 project in France (28.3) and the SWE400 project in Sweden (42.0). Subdivision over the lamp types:

Lamp type	Number per household	Share of lamps
Incandescent	12.9	38%
halogen MV	5.1	15%
halogen LV	5.4	16%
CFL	7.9	24%
LFL	2.0	6%
LED	0.2	1%
Total	**33.6**	100%

Table 55 Number of lamps per household, United Kingdom, 2012

C.2 Sweden 2009, lighting measurements in households

The reference [213] reports the results of the measurement campaigns that took place in Sweden in cooperation between the Swedish Energy Agency, Enertech (France) and YIT Sverige AB. The campaign went from August 2005 to December 2008. A total of 40 households were measured for one year. Additional 360 households were monitored for one month. The lodgings were approximately 50% apartments and 50% houses. On average, houses had a useful area of 127 m^2 and apartments 76 m^2. The households had a differing number of persons.

The **average total number of light sources [214] per household**, all types taken together, is **42.** For houses this value is 55.2 and for apartments 31.2.

Lamp type	Number per household	Share of lamps
incandescent	25.4	60%
halogen MV	0.7	2%
halogen LV	6.1	15%
CFL	5.5	13%
LFL	4.3	10%
LED	0	0%
Total	42	100%

Table 57 Number of lamps per household, Sweden, 2009 [215].

C.3 REMODECE 2008, lighting survey and measurements in households

REMODECE is an abbreviation for "Residential Monitoring to Decrease Energy Use and Carbon Emissions in Europe". This project of Intelligent Energy Europe was performed in the years 2006-2008. The project also considered energy use for lighting. The information presented below derives from different reports [217].

Data were gathered in the REMODECE project by means of a combination of measurements and of survey's (questionnaires), in the following countries: Belgium, Bulgaria, Czech Republic, Denmark, France, Germany, Greece (Hellas), Hungary, Italy, Norway, Portugal and Romania.

The measurement campaigns were performed in at least 100 households per country, using equipment capable to monitor the energy demand every 1 or 10 minutes. The measurement period has been approximately two weeks per household.

On average, the electric energy consumption for **lighting** was found to be **18% of the total household consumption of electricity** (excluding electric space heating and electric water heating.

The **average number of lamps per household was 26** [218]. As shown in Table 60, this number varied considerably from country to country, from 11 in Romania to 34 in Norway. On average there were 4 compact fluorescent lamps per household. The largest share was incandescent lighting, representing about 50% of the total number of lights installed. Low wattage halogen lamps were the second most used lamps. This is explained in the references by the fact that this type of lighting is used in false ceilings with a high number of light points. Fluorescent and compact fluorescent lamps had small percentages (only in Belgium these two combined were more than 30% of the total lighting lamps). Figure 40 and Figure 41 show the subdivision of lamp types per country and per room-type.

total of lamps by type	Pt	Be	Dk	Gr	Bu	It	No	Ro	Fr	Cz	De	Hu	Average
Incandescent	13	9	14	10	9	15	14	8	14	12	13	8	13
Low wattage Halogen	4	10	9	3	4	7	11	1	4	5	7	2	6
Halogen 230V	1	1	2	1	0	2	0,5	0	1	0	1	0	1
Fluorescent	3	3	3	1	1	3	4,2	1	2	2	2	0	2
Compact Fluorescent (CFL)	4	7	6	4	2	6	4,5	1	4	6	3	3	4
Total	26	31	33	20	16	33	34	11	24	25	25	14	26

Table 60 Number of lamps per household in various European countries (REMODECE project, 2006-200

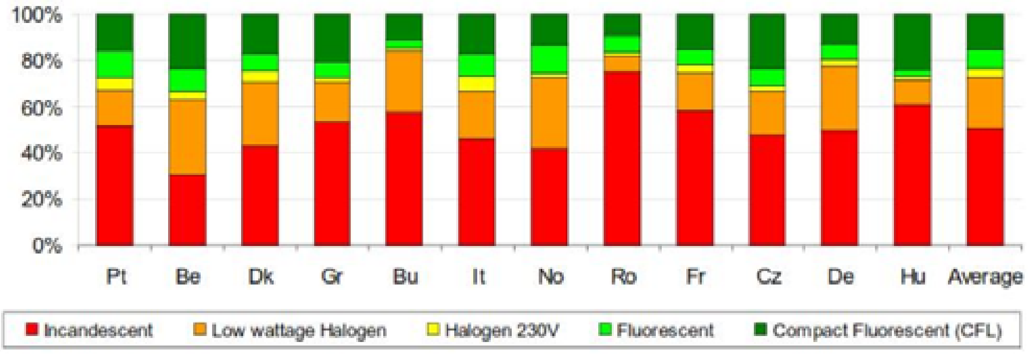

Figure 40 Types of lamps installed in various European countries (REMODECE project, 2006-2008)

A.3.0 Appendix 3: Applications of Ex. 4(f) UV Curing Lamps

According to LEU Ex. 4f(2015a): LightingEurope (LEU), Request to renew Exemption 4(f) under the RoHS Directive 2011/65/EU Mercury in other discharge lamps for special purposes not specifically mentioned in this Annex, submitted 15.1.2015, available under *http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_4_f_/Lighting_Europe/4f_LE_RoHS_Exemption_Req_Final.pdf*

"*Currently medium pressure lamps containing mercury are used a wide range of manufacturing applications – including amongst others; printing, wood finishing, PCB manufacture, glass bottle decoration, metal container decoration, sewer rehabilitation, contact lens manufacture, plastic bottle decoration, optical fiber coating, ink jet printing, coating plastic parts etc. These applications are used in a wide range of well-known markets and industries, e.g.:-*

- *Coating of polycarbonate headlamp lenses for all the major European (and global) automotive manufacturers*
- *Coating of wide range of plastic components for the automotive industry, cosmetic and consumer goods for international companies*
- *Coating of wood and MDF products for furniture companies*
- *Coating of beverage cans for all the European (and global) can manufacturers*
- *Coating optical fibers for telecommunication*
- *Pressure sensitive adhesives manufactured by well-known, international companies*
- *used in tapes and label products*
- *Wide web, high speed printing and coating packaging for many well-known companies*
- *across Europe and beyond.*"

A.6.0 Appendix 6: Ce-doped Phosphor Coating Variations

Copied from LEU (2015b), LightingEurope, Answers to 1st Clarification Questions, submitted 27.3.2015, available under:
http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_7/2015-3/Oko_Ex_Re_2015_3_Answers_2_Clarification_Questions_20150327_final.pdf

"A second problem for the Ce doped phosphors is the variations of the UV output over the lamp length due to coating thickness. When fluorescent lamps are coated with a phosphor the thickness of the coating varies over the length of the lamp. For current UV-fluorescent coatings used, like BSP, the thickness variations do not lead to a severe inhomogeneous output. However, for Cerium doped phosphor this thickness difference leads to unacceptable UV output variations which will affect the skin treatment effectiveness (see table below).

	thin coated side		thick coated side	
	UVB		UVB	
1 P	594		325	
2 P	567		313	
3 P	614		322	
4 P	614		322	
5 P	604		350	
6 P	600		325	
7 P	595		301	
8 P	615		265	
9 P	599		283	
10 P	622		409	
AVG	602,4		321,5	
STDV	14,87	2%	36,96	11%
MAX	622,00		409,00	
MIN	567,00		265,00	
Range	55,00	9%	144,00	45%

Table: Thickness variations of Ce-doped coatings and the impact on UV output