LIGHTINGEUROPE
THE VOICE OF THE LIGHTING INDUSTRY

Request to renew Exemption 4(b)

under the RoHS Directive 2011/65/EU

Mercury in High Pressure Sodium lamps

Date: January 15, 2015

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2 Reason for application

LightingEurope submits this application to:	*request for extension of existing exemption* ***no. 4(b) in Annex III***
LightingEurope proposes to continue using the existing wording which is:	*Mercury in High Pressure Sodium (vapour) lamps for general lighting purposes not exceeding (per burner) in lamps with improved colour rendering index Ra > 60* *4(b)-I P<155W: 30 mg per burner* *4(c)-II 155W<P<405W: 40 mg per burner* *4(c)-III P>405W: 40 mg per burner*
LightingEurope requests a duration of	*Maximum validity period required.*

3 Summary of the exemption request

The validity period of DIRECTIVE 2011/65/EU Article 5(2) Annex III Exemption 4(b) will end automatically per 21/07/2016, unless an application for renewal has been made to the Commission in accordance with Annex V.With reference to the above, this request concerns the extension of the current Annex III exemption 4(b) regarding mercury in High Pressure Sodium (vapour) lamps (HPS) for general lighting purposes.

This exemption request explains the technical characteristics and the applications of High Pressure Sodium lamps with improved colour rendering. The total amount of mercury brought on the European market by lamps of exemption 4(b) is calculated and the result is sent separately for reasons of confidentiality. The unique and specific function of mercury in these lamps is described in detail.

The recycling practises of HPS lamps are discussed. It is estimated that about 46% of the mercury brought onto the European market is recycled.

Existing Life Cycle Analysis reports are discussed. They all clearly show that the environmental impact of the use phase is by far the most important. Hence, the critical factor determining the environmental impact of an HPS lamp is the luminous efficacy.

The exemption request evaluates reduction and substitution initiatives for mercury in High Pressure Sodium lamps in general and High Pressure Sodium lamps with improved colour rendering in particular. It is shown that reduction or omission of mercury inevitably leads to loss of the specific colour rendering properties of these products. It is further established 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.

Hence, it is concluded that the elimination or substitution of mercury via design changes or materials and components which do not require any of the materials or substances listed in Annex II of RoHS is scientifically or technically impracticable.

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

4 Technical description of the exemption request

4.1 Description of the lamps and their applications

4.1.1 Lamps covered by this exemption

This exemption covers High Pressure Sodium (HPS) lamps with increased colour rendering index that are member of High Intensity Discharge Lamps (HID) group. The HPS family contains lamps designed for different purposes in the professional market. These 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.

High Pressure Sodium lamps consist of a cylindrical discharge tube made of poly-crystalline alumina (PCA) in which two electrode assemblies are mounted at each side (Figure 1). The 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 (**Error! Reference source not found.**). 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.

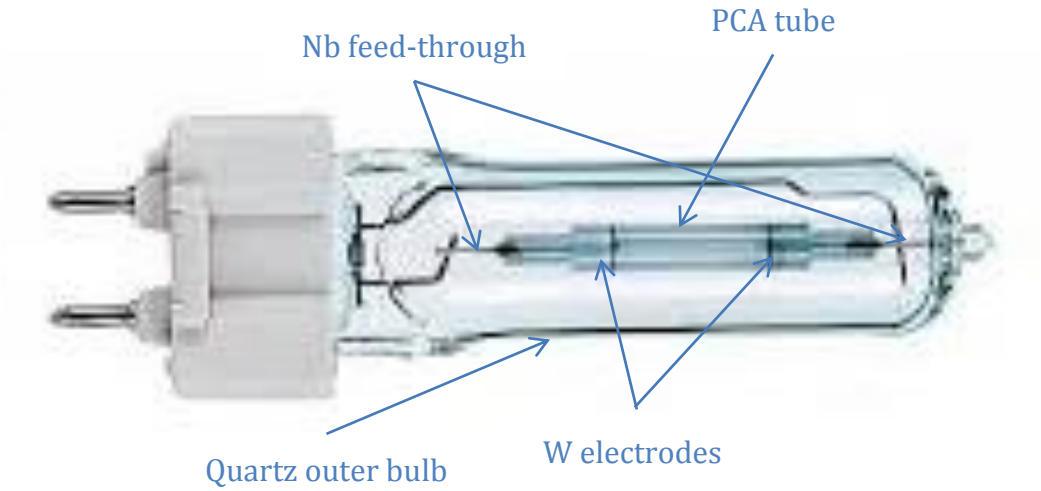

Figure 1: Construction of a High Pressure Sodium lamp with increased colour rendering

Inside the discharge tube there is xenon 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 the Exemptions 4(b) 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.

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 discharge tube is mounted in a vacuum quartz bulb in order to insulate it thermally.

The HPS types with increased Colour Rendering Index 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[1] [2]. Increasing the arc tube diameter also contributes to a higher CRI[3].

[1] 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)

A first class of colour improved commercial high pressure sodium lamps is based on this physical characteristic. A lamp family with colour rendering index of 60, correlated colour temperature of 2200 K and luminous efficacies between 53 and 90 lm/W[4] [5] has successfully been introduced in 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.

A second type of high pressure sodium lamps with increased sodium pressure 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[6] [7] [8] [9] [10] [11] [12], 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 [8] [11].

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[2] Mizuno, H., Akutsu, H. and Watarai, Y., *New high pressure sodium lamp with higher colour rendition*, CIE 17th Session, Barcelona, P. 71.14 (1971)

[3] 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)

[4] Otani, K., Kawahara K., Watanabe, K. and Tsuchihashi M., *A high pressure sodium lamp with improved colour rendition*, J. of IES, july 1982, pp.231-240 (1982)

[5] Bhalla, R.S., Larson D.A. and Unglert, M.C., *HPS lamp with improved colour rendering*, J. Illum. Eng. Soc., 8, 202 (1979)

[6] 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)

[7] Carleton, S.A., Van Kemenade, J.T.C., and Keijser, R.A.J., *White HPS lamps with a color temperature of 2700K*, J. of the IES 20, no.1, p. 134-139 (1992)

[8] Carleton, S.A. and Keijser, R.A.J., *Stabilization of white HPS lamps*, J. Illum. Eng. Soc., winter 1992, p.47-51 (1992)

[9] Van Kemenade, J.T.C, Keijser, R.A.J. and Bolt, B.F, *New possibilities for HPS lamps in indoor lighting,* J. of the IES, vol. 16, no. 1, winter 1987, p.150 (1987)

[10] Ogata, Y.and Saito, N., *A new 50W super high pressure sodium lamp - arc tube design and energy balance*, J. of the IES, vol.17, no. 2, summer 1988, p. 105 (1988)

[11] Keijser, R.A.J., *Color stabilization of white SON lamps*, 5th International Symposium on the Science and technology of Light Sources, York 1989.

[12] Claassens, J.M.M., Peeters, J.I.C. and Van Den Plas, R.J.Q., *Neue Entwicklungen auf dem Gebiet der Natriumdampf-Hochdrucklampen (New developments in the field of high-pressure sodium lamps)*, Tagungsberichte, Licht, Band II, paper 28, (1984)

A review of the operation principles of the HPS lamp with increased colour rendering is given by Geens and Wyner [13].

High Pressure Sodium lamps with increased colour rendering are characterized by long life (15,000 to 24,000 hours), 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 (Figure 2).

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) 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.

Figure 2: Different formats of High Pressure Sodium lamps with increased colour rendering: Edison cap, PG-12 and G12

4.1.2 Applications covered by this exemption

The product characteristics make HPS lamps with increased colour rendering the perfect 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's 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 kind of applications these

[13] R. Geens and E. Wyner,*Progress in High Pressure Sodium Lamp Technology"*, IEE Proceedings-A Vol. 140 No. 6, November 1993, par. 3

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.

The lamps have to be replaced about every 2 to 3 years. The estimated European market for these lamps cannot be disclosed publicly but is given confidentially outside this report.

4.1.3 Annex II category covered by this exemption

List of relevant Annex II categories for this exemption

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☒ 5

☐ 6 ☐ 7 ☐ 8 ☐ 9 ☐ 10 ☐ 11

Application in other categories, which the exemption request does not refer to: not applicable, see comment below.

Equipment of category 8 and 9: not applicable, see comment below.

The requested exemption will be applied in

☐ monitoring and control instruments in industry

☐ in-vitro diagnostics

☐ other medical devices or other monitoring and control instruments than those in industry

LightingEurope is of the opinion that lamps in general are category 5 because 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 HPS lamps with improved colour rendering 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 different kinds of appliances, medical devices or potentially in any RoHS category 1 - 11.

LightingEurope 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 or outside for lighting applications (category 5) but some are used in other types of equipment in all other RoHS categories. The way that lamps are used has no effect on lamp design so will not affect this exemption request.

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

4.2 Description of the substance

4.2.1 Substance covered by this exemption

LightingEurope is asking for exempting

☐ Pb ☐ Cd ☒ Hg ☐ Cr-VI ☐ PBB ☐ PBDE

4.2.2 Function of mercury in High Pressure Sodium lamps with increased colour rendering

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 and sodium and mercury 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[14] [15]. As a 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

[14] Luijks G.M.J.F., *Sodium-PCA interaction in unsaturated HPS lamps*, paper submitted for the LS6 conference in Budapest, Sept. 1992

[15] Itoh, A. and Okamura, K., *Evaluations of the sodium reduction in HPS lamps*, paper submitted for the LS6 conference in Budapest, Sept. 1992

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.

4.2.3 More functions of mercury

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. The mercury however has a number of essential functions to fulfil:

1. 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[16] [17]. It is this red broadening of the sodium spectral resonance line that gives the High CRI HPS lamps its 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 [5] [6]. Too low Hg content gives the lamp a greenish colour, too much Hg shifts the colour point to the pinkish side of the black body locus.

2. The presence of the mercury vapour also greatly reduces the thermal conduction of the sodium-mercury-xenon plasma[18]. 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[19].

3. 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.

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[16] 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)

[17] J.de Groot and J. Van Vliet, The High Pressure sodium lamp, Kluwer Techische Boeken B.V. Deventer, ISBN 9020119028 (1986), p. 141 to 145

[18] J.de Groot and J. Van Vliet, The High Pressure sodium lamp, Kluwer Techische Boeken B.V. Deventer, ISBN 9020119028 (1986), p. 130 to 131

[19] J.de Groot and J. Van Vliet, The High Pressure sodium lamp, Kluwer Techische Boeken B.V. Deventer, ISBN 9020119028 (1986), p. 149 to 153

4.2.4 Location of mercury in lamps

Mercury is present in the so-called discharge tube. In a cold lamp it is present in an amalgam with sodium and the amalgam forms a pill in the solid state. During lamp operation part of the mercury is in the vapour phase, creating a pressure around 1 Bar, and part forms a liquid Na/Hg amalgam located at the coldest spot in the discharge tube.

4.2.5 Amount of mercury

Mercury is dosed in the discharge tube during lamp manufacturing as sodium mercury amalgam with a Hg/Na ratio of about 75%.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(b) the maximum dosed mercury amounts vary between 3 and 40 mg (Figure 3).

For classes 1 and 2 the amalgam dose increases with lamp power (=lamp size). Figure 4 graphs the dose versus the lamp power.

The total amount of mercury brought to the European market by HPS lamps from the 4(b) category is calculated from the total European market volume and the mercury dose per lamp type (supplied confidentially outside this report). The total amount of mercury is also supplied confidentially outside this report.

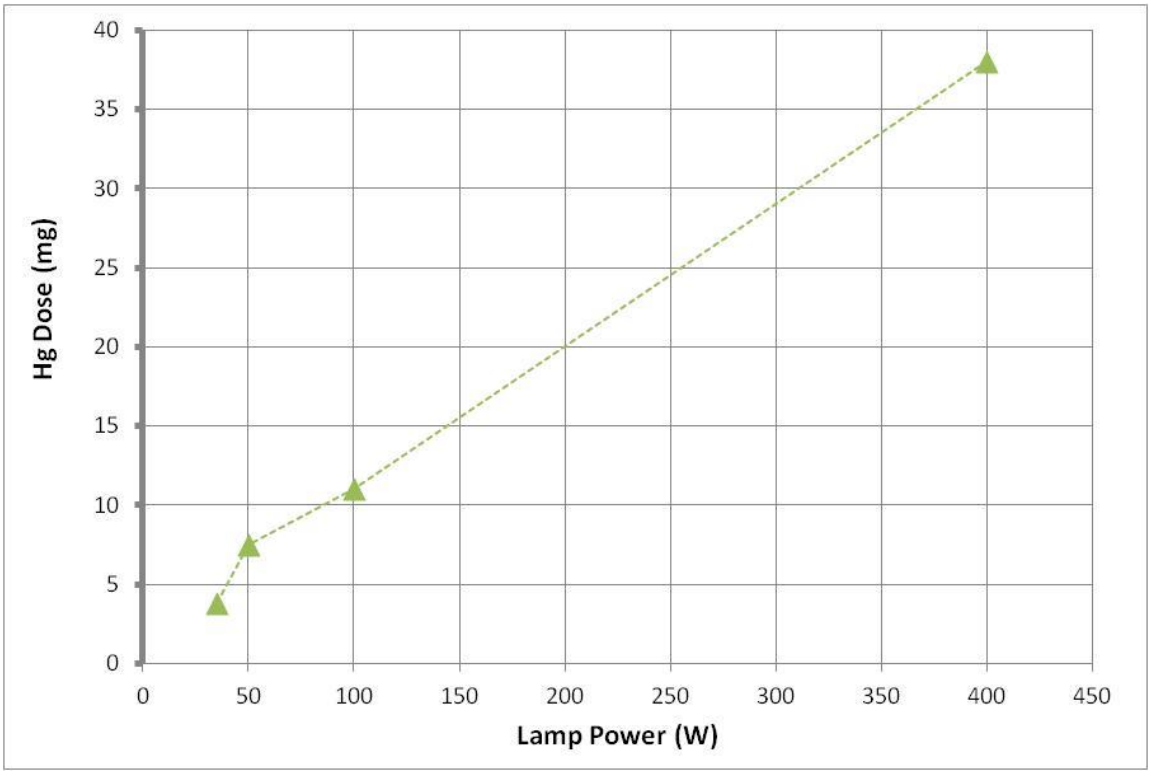

Figure 3: Mercury doses of HPS with increased CRI.

4.2.6 Environmental assessments, LCAs

Specific LCA's of high colour rendering HPS lamps are not publicly available. However, there are several external LCA's performed regarding lighting in general. There is general agreement, that the main environmental impact is created during the use phase, meaning through electricity consumption when burning the lamp[20].

Apart from company internal LCA's three public LCA's have been published for HID lamps[21] [22] [23] in general.

Figure 4 shows the ecological impact of different light sources including LED and Ceramic metal Halide (CMH). Since HPS and CMH have very similar material usage, production methods and efficacy, the results for CMH can also be extrapolated to HPS and -because the efficacy is somewhat lower- to a lesser extent also to colour improved HPS. The graph shows that at the time of publication the environmental impacts of HID were still less than LED replacement lamps ("int LED" in Figure 4) and LED luminaires ("ded. LED" in Figure 4). Meanwhile the performance of LED has improved but it is not clear yet to which extent this influences the LCA. Moreover, as will be shown in section 6.2.1, direct replacement LED lamps are not available for colour improved High Pressure Sodium lamps, nor are there LED luminaire replacements for the colour improved HPS luminaires (section

Since there is no direct replacement lamp for a failed HPS lamp, the LCA should in fact be done by comparing the situation where a failed lamp can be replaced with a new HPS lamp, with the alternative case where a failed lamp leads to replacement of the whole luminaire, including the lamp driver which is then replaced by a LED system + luminaire (with a different colour performance). This replacement system might include an active cooling fan to get rid of the excess heat from the compact luminaire.

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

[21] Department for Environment Food and Rural Affairs (DEFRA). Life Cycle Assessment of Ultra-Efficient Lamps. Navigant Consulting Europe Ltd. 2009

[22] 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).

[23] 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

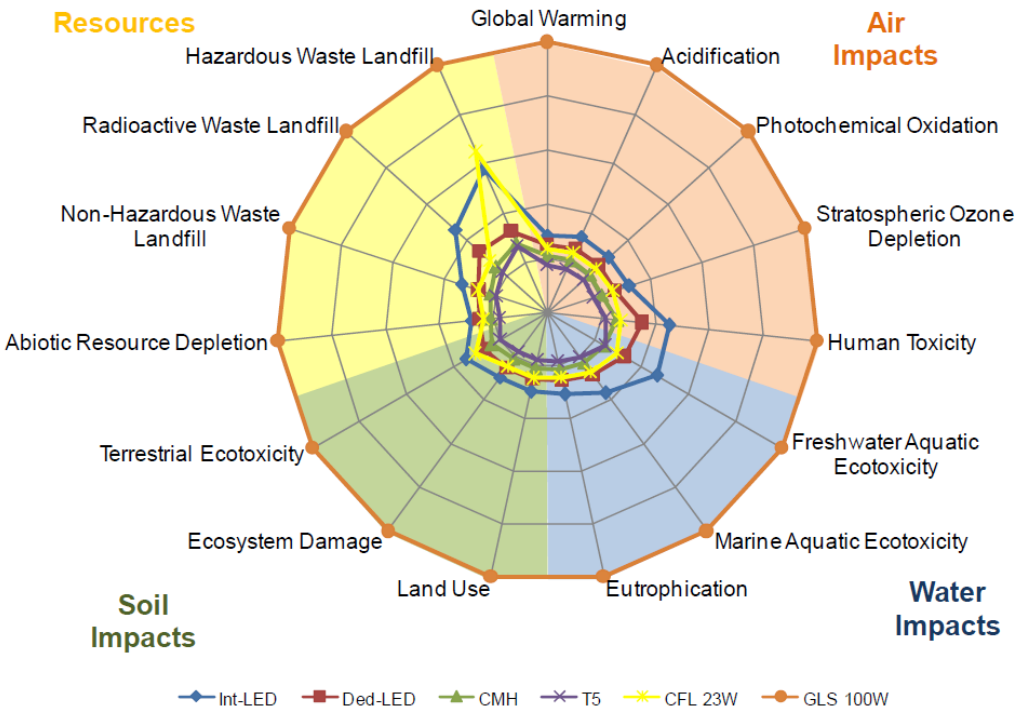

Figure 4: Figure from the Navigant report [5]. LCA of different light sources

5 Waste management

5.1 Waste streams

☒ Article is collected and sent without dismantling for recycling

☐ Article is collected and completely refurbished for reuse

☐ Article is collected and dismantled:

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

☐ Article cannot be recycled and is therefore:

- ☐ Sent for energy return
- ☐ Landfilled

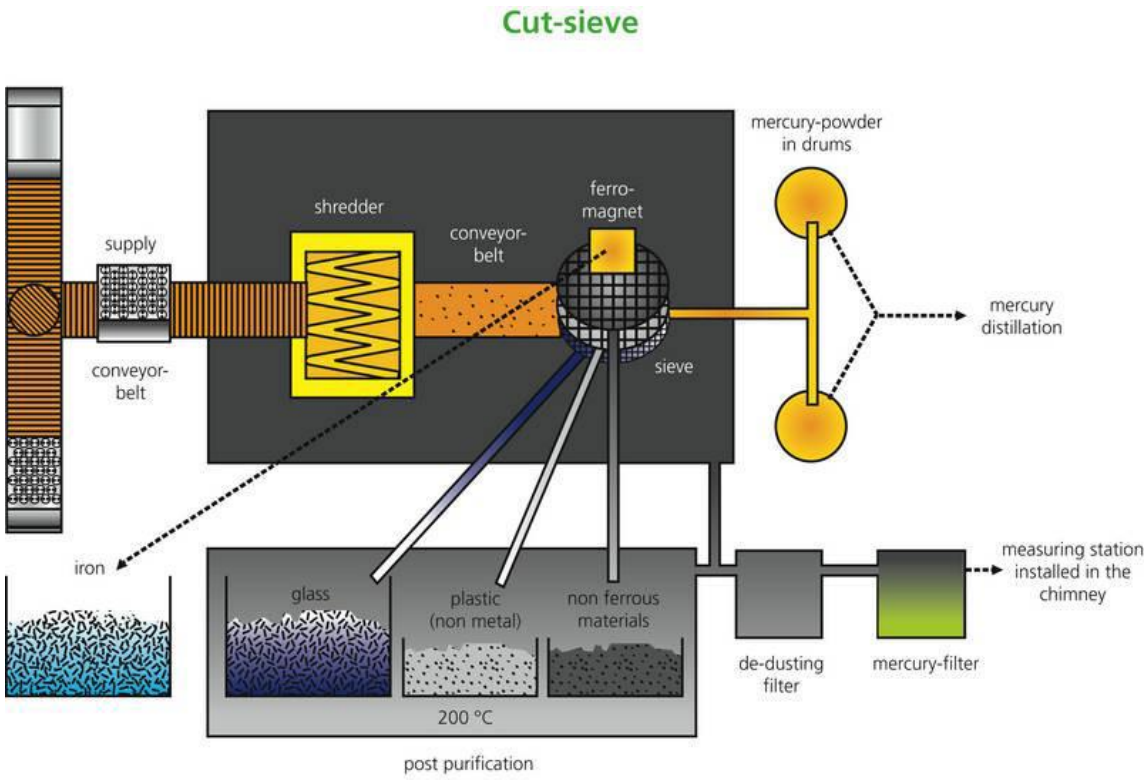

Figure 5. Recycling steps of fluorescent lamps in Indaver (Belgium).

Source:www.indaver.be/waste-treatment/recycling/mercurial-waste.html

High Pressure Sodium lamps are in the scope of EU Directives 2002/96/EC - WEEE and 2012/19/EU– WEEE Recast. Take back systems are installed in all EU Member States: end users and most commercial customers can bring back the lamps free of charge. High Pressure Sodium lamps are collected separately from general household waste and separately from other WEEE waste.

The collection efficiency with these more professional customers is reasonably high. A dedicated recycling process exists for lamps because; according to legislation the mercury shall be removed from the gas discharge lamps. Mercury in treatment facilities is recovered by distillation and captured as Mercury Sulphide (Figure 5). In almost all the installations CFL lamps and HID lamps are processed together (separating is difficult), this makes it impossible to report the recycle percentage for HID High Pressure Sodium lamps separately. The process is running with the machine on under pressure to prevent exposure of the workforce to mercury. The recycling percentage for the combination of house hold and non-household waste combined is 45% and is audited each year.

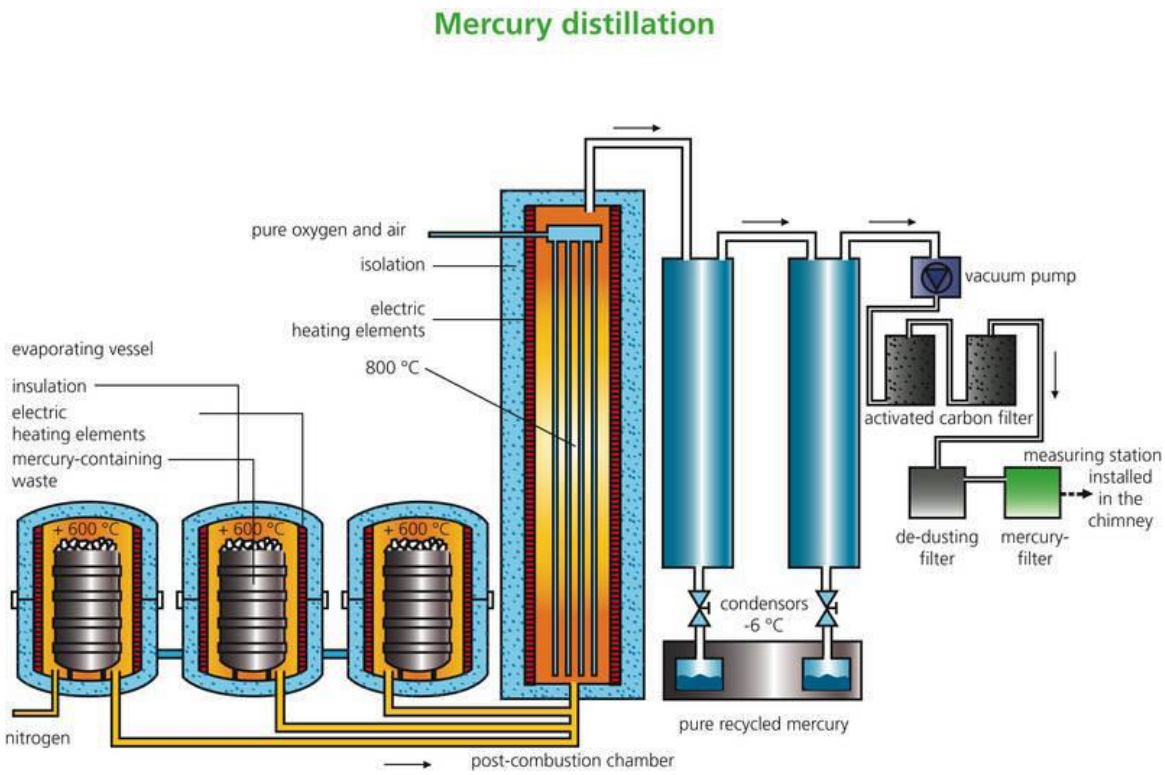

Figure 6. Specific recyclcing steps of mercury in Indaver (Belgium)

Source:www.indaver.be/waste-treatment/recycling/mercurial-waste.html

5.2 Amount of mercury in WEEE

- ☐ In articles which are refurbished
- ☒ In articles which are recycled
- ☐ In articles which are sent for energy return
- ☐ In articles which are landfilled

5.2.1 Amount of mercury recycled from failed HPS lamps

To calculate the amount of mercury that is recovered by the recycling we do the following:

In the installation of the recycler CFL-integrated, CFL-non-integrated, LED lamps and HID are recycled together (household and non-household). The total return percentage is monitored at least for one of the lighting companies and independently reviewed and published publicly (see Figure 7). If we assume that the return percentage is the same for all categories, also for High Pressure Sodium lamps, we estimate that 46% of the installed lamps is recovered. This number is audited and published annually. The total amount of mercury is supplied confidentially outside this report.

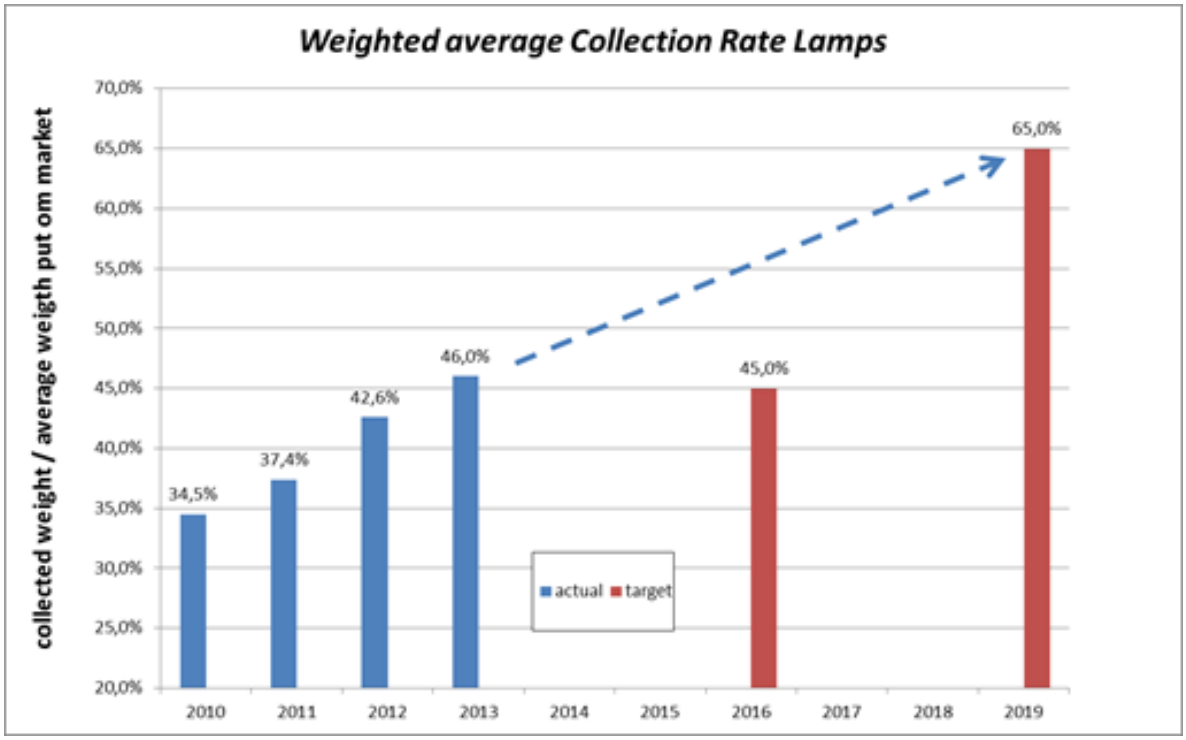

Figure 7. Recovery installed lamps

5.2.2 How does the industry encourage an increase in recycling efficiency?

European legislation on Waste Electrical and Electronic Equipment makes producers responsible for end of life products within this category as from August 13th, 2005. European Lamp Companies have founded Collection & Recycling Organizations in the EU Member-States, with the objective to organize the collection and recycling of gas discharge lamps. Goal is to comply with present and probable future EU legislation and meet or exceed national targets.

In general however we can conclude that the following channels have been established in the respective member-states providing country wide coverage:

1. Direct collection from large end users: containers have been made available, ad hoc or permanently, and will be collected upon notification by the end user that the container is full.

2. Collection through distribution: Wholesale and Retail place collection means at their premises respectively in their shops.

3. Collection upon notification.

4. Collection through municipalities: where infrastructure allows collection means are placed at municipality depots.

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

6 Substitution

Can the substance of this exemption be substituted?

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

☒ No
Justification: see in below chapters

6.1 Substituting mercury in the discharge technology

As explained in section 4.2.3, it is the presence of mercury that broadens the sodium resonance line dramatically into the red part of the spectrum (Figure 8). There are no other elements known that have the same influence on the spectrum of an HPS lamp.

Replacing the mercury pressure by xenon (Figure 9) broadens the spectrum on both sides of the Na resonance line [24] and hence does not have the effect of a warm colour, **h**igh 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[25].

It is concluded that mercury is essential for high CRI HPS lamps and that without mercury they completely lose their properties. Hence, referring to Article 5(a) of the RoHS Directive, the 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.

[24] De Groot, J.J., Schleyer J., Woerdman, J.P. and De Kieviet M.F., *The influence of NaNa, NaHg and NaXe molecules on the spectrum of the high-pressure sodium lamp*, Philips J. Res. 42,pp 87-101 (1987)

[25] Bhattacharya, A.K., *Measurements of breakdown potentials and Townsend ionization coefficients for the Penning mixtures of neon and xenon*. Phys. Rev. A, vol. 13, pp. 1219-1225 (1976)

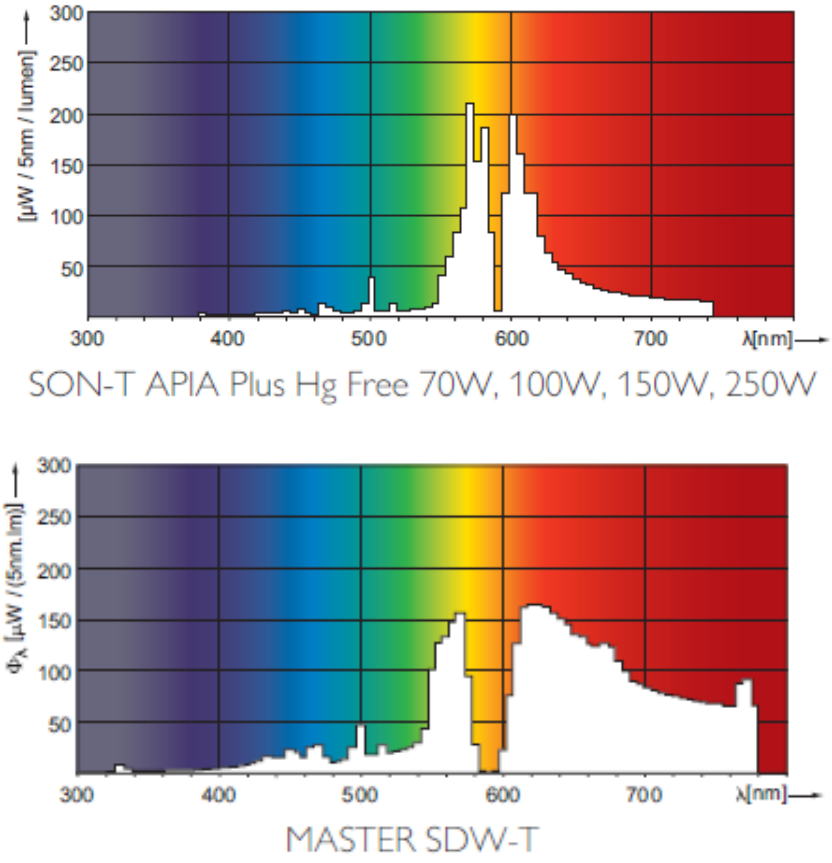

Figure 8. Spectra of a Hg-free and an improved CRI HPS lamp

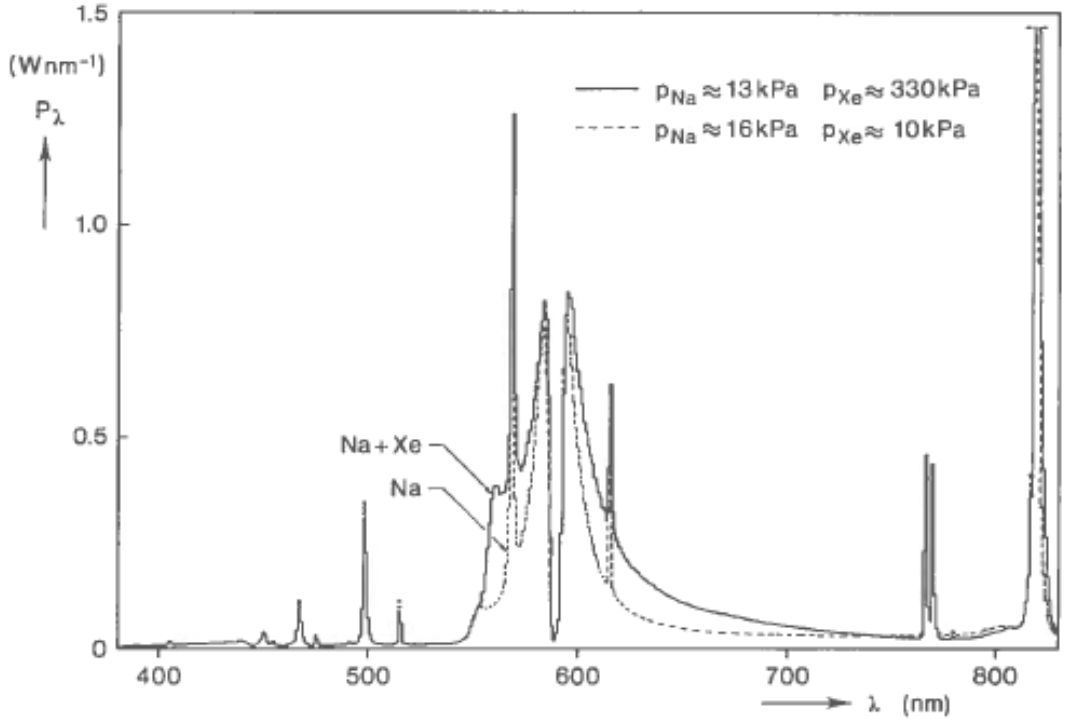

Figure 9. Spectra of a Hg-free HPS lamp with increased Xe pressure (from [16])

6.2 Substituting High Pressure Sodium technology by LED technology

6.2.1 Feasibility of the alternatives

6.2.1.1 LED retrofit lamps

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 not yet available.

6.2.1.2 LED luminaires

LED luminaires that mimic the unique colour properties of colour improved HPS lamps are not available yet.

6.2.2 Availability of substitutes

There are no replacement lamps for the colour improved High Pressure Sodium family available, not at system level and not at LED luminaires level.

6.2.3 Impacts of substitution

6.2.3.1 Environmental impact of substitutes

No substitutes available.

6.2.3.2 Health and safety impact of substitutes

No substitutes available.

6.2.3.3 Socio-economic impact of substitution

Economic effects related to substitution:

- ☐ Increase in direct production costs
- ☒ Increase in fixed costs
- ☐ Increase in overhead
- ☒ Possible social impacts within the EU
- ☒ Possible social impacts external to the EU
- ☒ Other:

Substitution of mercury is not possible.

Social impacts are_loss of jobs due to shut down of manufacturing sites for High Pressure Sodium lamps in Belgium and Hungary.

There is also loss of application: there are no alternatives for the colour characteristics of colour improved HPS.

6.2.3.4 *Impact of substitution on innovation*

Not applicable.

6.2.4 *Future trends of substitution*

LED technology performance is developing rapidly. However, no solution for the deep red rendering typical for 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.

6.3 Links to REACH, according to RoHS Directive Article 5(1)(a)

Do any of the following provisions apply to the application described?

no

☐ Authorisation
- ☐ SVHC
- ☐ Candidate list
- ☐ Proposal inclusion Annex XIV

☐ Restriction
- ☐ Annex XIV
- ☐ Annex XVII
- ☐ Registry of intentions

☐ Registration

Provide REACH-relevant information received through the supply chain.

Not Applicable

7 Removal of mercury from lamps

Can mercury be eliminated?

☐ Yes.
☒ No.

As explained in section 6.1, removal of mercury from a coloured improved HPS lamp completely eliminates its colour characteristics that are crucial for the application it is used in.

8 Reduction of mercury content of lamps

8.1 Lamps with unsaturated vapour dosing

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[26]. In this mode all the Hg/Na amalgam is vaporised

[26] Schmidt, K. , *High pressure sodium vapour lamp*, United States Patent 3,248,590 (1966)

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 (20-100 μg) 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 with the wall cause a rapid depletion of the sodium in the discharge tube[27] [28]. This reduction causes the colour point of the lamp to shift and also raises the lamp voltage (see section 4.2.2) with premature failure following.

Hence, reduction of mercury to unsaturated dosage is not possible.

8.2 R&D efforts to reduce mercury in saturated vapour HPS lamps

With the recent disruptive effect of the introduction of LED lamps and luminaires on the lighting market the volume of all other technologies, including the exempted mercury containing lamps, is rapidly decreasing. The bulk of R&D efforts from lighting companies are directed towards acceleration of the Solid State Lighting (SSL) revolution and R&D aimed at decreases in mercury dose of mercury containing lamps have virtually stopped. Also for the reduction of the total volume of mercury in lamps this is a positive development: faster replacement of mercury containing lamps by LED lamps or luminaires reduces mercury in the environment more than marginal decreases in the dose of mercury containing lamps.

The European Commission has drafted a European Lighting Strategy which predicts the evolution of the lighting market in the next 15 years. This study is based on the current evolution of technology and market trends which are the results of the current allocation and distribution of resources and investment in R&D. From **Error! Reference source not found.**9 it is clear that the gradual decrease in LFL, CFL and HID lamps put in the market will also decrease the amount of mercury. However, the study also implicates that a sudden stop in the sales of mercury containing lamps is not a viable scenario.

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[27] Luijks G.M.J.F., *Sodium-PCA interaction in unsaturated HPS lamps*, paper submitted for the LS6 conference in Budapest, Sept. 1992

[28] Itoh, A. and Okamura, K., *Evaluations of the sodium reduction in HPS lamps*, paper submitted for the LS6 conference in Budapest, Sept. 1992

Hence, the EC study clearly shows that the renewal of the mercury exemptions 1-4 of the RoHS Annexes III is absolutely necessary in order to realize the switch to non-mercury SSL lighting.

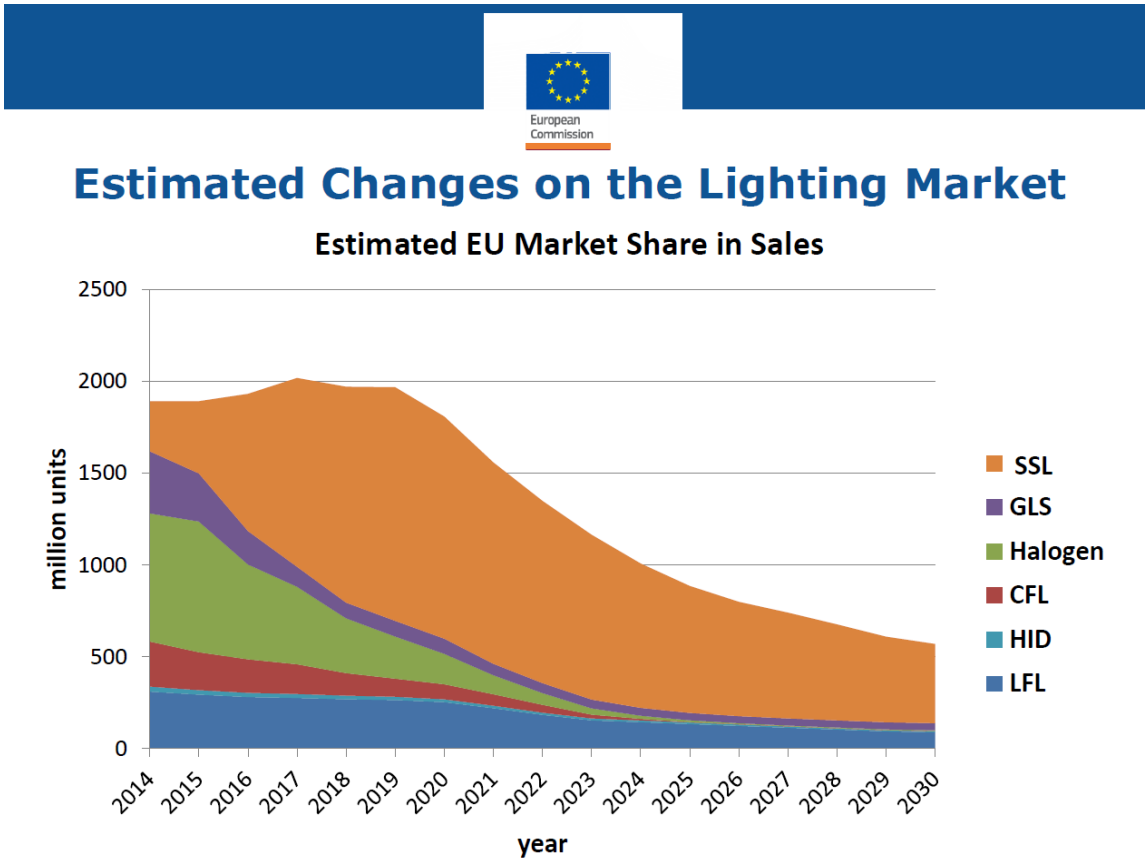

Figure 10. Road Map for lighting (source: Consultation Meeting on "A European Lighting Strategy", in preparation of a draft Commission Communication thereof, DG ENER.C.3 and DG CNECT.A.1, 12 March 2014

9 Other relevant information

During the UNEP Minamata Convention on Mercury end 2013 in Japan agreements have been made on limitation of mercury in various products, including linear fluorescent. This treaty has been agreed upon and signed by 94 countries around the globe. For High Pressure Sodium lamps no limits have been agreed.

10 Information that should be regarded as proprietary

Information on lamp sales volumes are provided separately from this document and are for use by the consultant and EC only.

Mercury-added products	Date after which the manufacture, import or export of the product shall not be allowed (phase-out date)
Compact fluorescent lamps (CFLs) for general lighting purposes that are ≤ 30 watts with a mercury content exceeding 5 mg per lamp burner	2020
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
High pressure mercury vapour lamps (HPMV) for general lighting purposes	2020
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 ≤ 1500 mm) with mercury content exceeding 5 mg per lamp (c) long length (> 1500 mm) with mercury content exceeding 13 mg per lamp	2020

Tabel 1. UNEP Minamata Convention agreements.

List of abbreviations

ADCO	Administrative Cooperation Group
BASI	Bioanalytical Systems, Inc
BSP	Barium Synthetic (Pb^{2+}) phosphor
CCG	Conventional Control Gear
CDM	Ceramic Discharge Metal Halide
CDV	Committee Draft for Voting
CFL	Compact fluorescent lamp
CRI	Color rendering index
CRSO	Collection & Recycling Service Organization
DEFRA	Department for Environment Food and Rural Affairs
DOE	Department of Energy
ECG	Electronic Control Gear
EEE	Electrical and Electronic Equipment
ELC	European Lamp Companies Federation
EM	Electromagnetic: lamp control gear based on a magnetic coil (= CCG)
EMC	Electro Magnetic Compatibility
ERP	Energy related Products; Directive 2009/125/EC establishing a framework for the setting of eco design requirements for energy-related products
FTE	Full Time Equivalent, indicates the workload of an employed person
HF	High frequency: lamp control gear based on high frequency (= ECG)
HID	High intensity discharge lamps
HPS	High Pressure Sodium (vapor) lamps
Hz	Hertz
K	Kelvin: Unit of color temperature (2700 K warm color, 5600K cool daylight)
Lm	Lumen
LFL	Linear Fluorescent Lamps
LCA	Life cycle assessment
LED	Light Emitting Diode
LPD	Low Pressure Discharge lamp
LVD	Low Voltage Directive

mg	Milligram
MH	Metal halide lamps
OEM	Original equipment manufacturer
OLED	Organic Light-Emitting Diode
PCA	Poly-crystalline alumina
PLL	Pi shaped Long Length, compact fluorescent lamp
R&D	Research and Development department(s)
REACH	Regulation on Registration, Evaluation, Authorization and Restriction of Chemicals, 1907/2006/EC
RoHS	EU Directive 2011/65/EU on the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment
SSL	Solid State Lighting
SVHC	Substances of Very High Concern
TF	Task Force
UMICORE	global materials technology group which focuses on application areas where its expertise in materials science, chemistry and metallurgy makes a real difference.
UNEP	United Nations Environnent Programme
UV	Ultraviolet
VDE	German Association for Electrical, Electronic and Information Technologies
W	Watt unit of (electrical) power
WEEE	Waste Electrical and Electronic Equipment
ZVEI	German Electrical and Electronic Manufacturers´ Association