Questionnaire 1 (Clarification) Exemption 4(f) of RoHS Annex III

Current wording of the requested exemption:

Mercury in other discharge lamps for special purpose not specifically mentioned in this annex

Requested validity period: maximum

1. Background

Bio Innovation Service, UNITAR and Fraunhofer IZM have been appointed[1] by the European Commission through for the evaluation of applications for the review of requests for new exemptions and the renewal of exemptions currently listed in Annexes III and IV of the RoHS Directive 2011/65/EU.

LightingEurope AISBL and NEC submitted a request for the renewal of the above-mentioned exemption, which has been subject to a first review. As a result we have identified that there is some information missing. Against this background, the questions below are intended to clarify aspects concerning the request at hand.

We ask you to kindly answer the below questions until 9 February 2021 latest. *(extended deadline to 22 February)*

This initial feedback is submitted on behalf of participants in the Umbrella Project ("UP")´s Exemption # 4f technical Working Group ("WG") (hereafter referred to as "UP Exemption # 4f WG Participants").

2. Questions

1. From your application, it is understood that you recommend a changing of the exemption's wording to make it more actionable.

UP Exemption # 4f WG Participants would like to clarify that the intention of the renewal dossier is to apply for the existing wording. No change was proposed to the wording in the renewal dossier. This has been explicitly stated on pages 4 & 5 of the dossier.

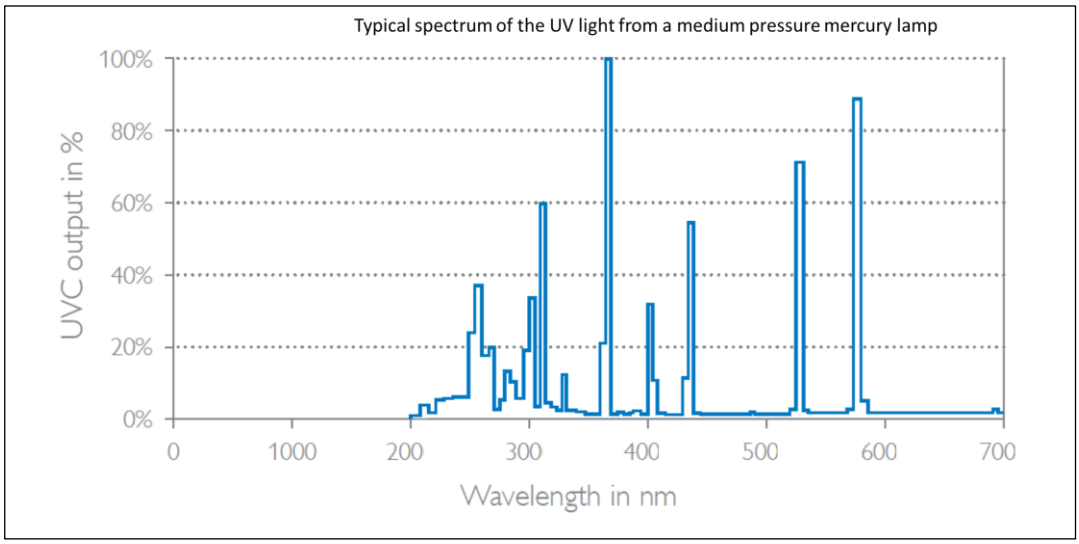
The summary given on pages 7-8 is merely meant to illustrate to the Consultant and European Commission the different lamp types, technologies and applications that fall within the scope of the exemption 4(f) to the knowledge of UP Exemption #4f WG Participants. This description might not be 100% complete. There might be other very specific medical and industrial devices with very low market volume (pcs) using and needing mercury containing medium or high-pressure lamps.

   a. Could you state the wavelengths required for the short arc mercury lamps and the medium and high-pressure mercury lamps?

[1] It is implemented through the specific contract 070201/2020/832829/ENV.B.3 under the Framework contract ENV.B.3/FRA/2019/0017

UP Exemption # 4f WG Participants believe that all wavelengths are required. The short arc mercury lamp is one kind of the medium and high-pressure mercury lamps. Every HID lamp consists of an arc tube which is filled with gas, and the wavelength of the light depends on what type of gas is used. Short arc lamps are available with a UV spectrum but also with a full visible spectrum. All those sources produce a broad polychromatic spectrum from VUV to UV-C/B/A, to visible. The strongest portion is in the UVC & UVA bands. The spectra can be augmented by several metal-halide additives with effects in different spectral regions.

Please see the graphs below for an illustration of the wavelengths required for medium pressure mercury lamps and the short arc, high pressure mercury lamps.



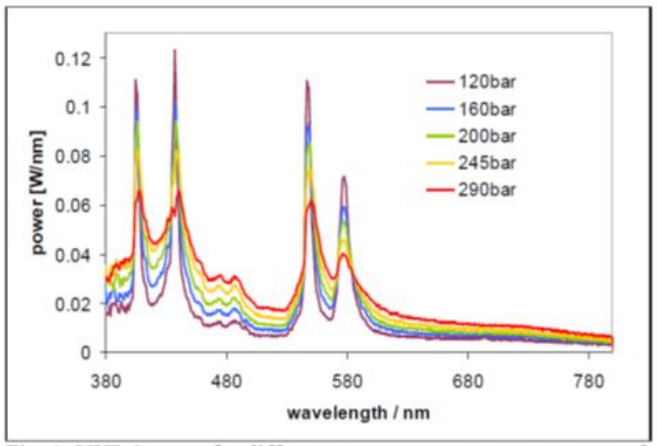


Fig. 1. UHP Spectra for different mercury pressure, an arc gap of 1mm measured at 120W and through an aperture representing an E=10mm²sr collection.

b. Could you please verify if the wording below corresponds to what you suggested:

4(f) Mercury in other discharge lamps for special purposes:

4(f)-I High pressure sodium lamps: “light sources with a photosynthetic efficacy >1.2 µmol/J, and/or emitting 25 % or more of total radiation power of the range 250-800 nm in the range of 700-800 nm, and intended for use in horticulture”

4(f)-II Short arc mercury lamps: “high pressure mercury lamps with a luminous flux > 500 lumen per mm² of projected light-emitting surface area defined as the area of the largest circle that fits between the electrodes of the high pressure lamp”

4(f)-III Medium and high pressure mercury lamps: “light sources with specific effective ultraviolet power >2 mW/klm and intended for use in applications requiring high UV-content”

As stated in question 1, UP Exemption # 4f WG Participants would like to clarify that the intention of the renewal dossier is to apply for the existing wording. No change was proposed to the wording in the renewal dossier. This has been explicitly stated on pages 4 & 5 of the dossier, see extract below:

We submit this application to request an extension of the existing exemption no. 4(f) of Annex III and propose to use the existing wording: 4(f) Mercury in other discharge lamps for special purpose not specifically mentioned in this annex.

The information provided on page 7 of the dossier serves as a reference only and which is essentially in line with the approach taken in the EU Ecodesign Regulation 2019/2020[2]. The descriptions listed above are not valid for category 8 and 9 products, as they are exempted from the EU Ecodesign Regulation 2019/2020. Please take note that the above description cannot cover the scope of Category 8&9 products.[3]

The proposed wording does not address the needs we have identified. UP Exemption # 4f WG Participants recommended in its 2020 renewal dossier and maintains the view that the existing wording should be maintained for the following reasons:

- There is still no decision on the renewal request of January 2015, no draft was shared with UP Exemption # 4f WG Participants so far.
- The changes proposed by the EU Consultant OEKO Institute in their report of June 2016[4] would have a dramatic socioeconomic impact to industrial, medical and entertainment sectors
- A split of the exemption as outlined above would not lead to any reduction of the amount of mercury put on the EU market

[2] COMMISSION REGULATION (EU) 2019/2020 of 1 October 2019 laying down ecodesign requirements for light sources and separate control gears pursuant to Directive 2009/125/EC of the European Parliament and of the Council and repealing Commission Regulations (EC) No 244/2009, (EC) No 245/2009 and (EU) No 1194/2012 https://eur-lex.europa.eu/legal-content/EN/TXT/?toc=OJ:L:2019:315:TOC&uri=uriserv:OJ.L_.2019.315.01.0209.01.ENG

[3] Please see Article 2 (b), and 1(k), 2(d), 3(c) and (j) of Annex III.

[4] RoHS Exemption Evaluation - Part LAMPS (06-June-2016) (oeko.info)

- On the contrary, the complexity of Annex III RoHS would again be increased making market surveillance activities even more difficult.

2. You argue that exemption 4(f) is needed because substitutes and elimination of mercury by LED technology are not possible. It is not always clear whether this is due to a required redesign of equipment so that it can accommodate the needs of LEDs (geometries, electronic environment, etc.) and where LEDs technically cannot provide the required spectra and/or performances, i.e. that LEDs cannot serve the required functions even after a thorough redesign of the respective devices.

UP Exemption # 4f WG Participants believe that in by far most cases where 4(f) applies, the current applications are needed for both reasons:

- For most 4(f) lamp applications LED technology cannot perform in the same way and achieve the same desired effect. In some cases where LED redesign is possible to a certain extent:
  - 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 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. Electronic assemblies always need a certain amount of lead benefiting from exemptions listed in Annexes III and/or IV RoHS.
  - For medical applications often very detailed and justified certification processes are required to allow their use. It can take years to obtain these certificates.
- For all 4(f) applications retrofit solutions are not possible. Such a solution would have to take into account optics, electronic driver, cooling requirements, space and geometry of the electronic device, power, brightness etc.

Below are examples of the challenges for specific products and applications:

- Short arc mercury lamps: These lamps are used in many medical and industrial devices where specific requirements are needed.
  - For example in microscopy low wattage lamps < 100W are replaced by LED technologies in new equipment, and for this specific application mercury-containing lamps are marketed as components mainly.
  - Lamps for medical analysis need 10-12 wavelengths for different analysis targets such as blood, tumor recognition, viruses and markers identification. There are no LED solutions available to cover the variety of applications per device.
  - In general, where lamps with 100W and higher are required, a redesign is not suitable. Contrary to general lighting, there are many very different devices with different functionalities on the market.
- Projection: For lower luminance requirements up to 1500 ANSI lumen, replacements are possible but require significant redesign, as described in the renewal dossier.
- Entertainment/Stage lighting: High luminance is required which can only be realized with Hg-containing lamps in beam fixtures or in Spot-Profile fixtures. They still exceed the performance of LED in terms of brightness. This in turn means that to achieve equivalent or improved performance, an LED based fixture of the same lumen output of a lamp-based fixture (HMI) or the same collimation of a lamp-based fixture (HTI) will be much bigger, heavier (lower resource efficiency, more electronic components, much more difficult to recycle) and still too expensive.
- For lower lumen output or less collimated beams, LED are an advantageous alternative.
- Horticulture: explained in detail in the dossier – see pages 17, 25-27, 41-44, 66-67.
  - 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. Hg containing lamps are very energy efficient. LED based installations can be designed very specific for the plants of interest but need much more resources.

- The redesigns need more electronic assemblies containing lead benefiting from exemptions listed in Annexes III and/or IV RoHS.

Specialty UV bulbs containing mercury are critical to the semiconductor process of photostabilization. Photostabilization ensures optimum resist stability and critical dimension (CD) control through etch and implant sequences, and is a key enabler of improved device quality. The photostabilization process is a balance of UV energy applied to the top of the wafer and thermal heating applied to the backside of the wafer to remove residual solvents from the photoresist and to further crosslink the resist.

The specialty UV bulbs containing mercury irradiator is the source of UV radiation (called UV irradiator) for photostabilizer systems. It generates radiation through a process that first converts high voltage DC power to microwave energy using two magnetrons. The microwave energy, generated by the magnetrons, is used to develop a high temperature-plasma inside a sealed bulb. The plasma then re-radiates this energy in the form of infrared, visible, and ultraviolet radiation. The selected fill and bulb shell materials are tailored to produce high "light" intensities in wavelengths suitable to cure photo masking materials used in the fabrication of semiconductor components, quartz displays, and disk drives. Other uses include curing low-kK dielectrics, SOG, multi-level resist applications and EPROM erasure.

The UV irradiator is capable of producing UV energy at power levels two orders of magnitude greater than that supplied by an excimer laser. Unlike the laser which covers a spot size of approximately 5mm, the irradiator is capable of supplying full power uniformly over the entire wafer surface.

The bulb consists of a hollow quartz sphere filled with materials, including mercury, selected for their specific emission characteristics under high-energy microwave excitation. When microwaves energize the fill materials, plasma is generated. High energy plasma causes the bulb temperature to exceed 1000 degree Celcius. To extend the life of the bulb, it is constantly rotated within air supplied by pre-aligned quartz cooling jets.

Because these bulbs contain no electrodes, there is no possibility of electrode sputtering and decay. As a result, better spectral consistency, longer useful life, improved process control and yields are achieved over other arc bulb assemblies.

3. Without taking the redesign of existing devices into account, could you please let us know which type of lamps have a suitable LED technology replacement available (such as lamps using UVA for curing applications)?

See also response to Question 2 above. For all known 4(f) applications retrofit solutions are not possible. Such a solution would have to take into account:

- Optics of the projector, which are adapted with great precision to the light source ((Liquid Crystal Display or Digital Mirror Device)
- Electronic driver, which is usually integrated in the equipment such as a beamer and which needs totally different capabilities for LED as it has to ignite and run a lamp
- Cooling requirements for very bright LED solutions to protect the electronics and ensure efficiency
- Space and geometry of the electronic device, which is constructed for lamp usage
- Power, brightness requirements cannot be met by replacement units
- Architecture of the device must be met exactly
- Size of the light source
- Product safety of the device (in line with CE obligations) after change of the system cannot be ensured

a. Apart from the redesign of the cooling system, what prevents the use of lasers in the stage lighting market? Moreover, the safety concerns of lasers are due to their power and wavelength, why are they an issue in stage lighting application and not Hg lamps which are meant to deliver the same power and wavelength?

UP Exemption # 4f WG Participants believe that lasers are not useful for illumination. The beam is too narrow using only one or a few wavelengths and this can raise safety concerns which have to be solved e.g. by using low power. The safety concerns of lasers have to do with their coherency and the amount of power they concentrate in a small solid angle (collimation). In contrast, mercury-containing lamps are diffuse sources that don't have the same hazards as lasers, because they are not radiating single wavelengths and are not collimated. Laser beams can irreversibly damage the retina within a very short time, even within the eyelid closing reflex reaction time. In addition, during shows, the iris is often wider compared to daylight. Mercury-containing lamps can also have hazards associated with some specific emitted wavelengths e.g. in the UV area. For both technologies it is required to implement constructive measures as well as correct use instructions to protect human beings.

There are two ways of adopting laser into lighting applications:

- Direct laser emitter sources: like RGB lasers (e.g. ClayPaky XTYLOS)
- Laser Diode-Pumped Phosphor sources: a blue laser exciting phosphors. White light is obtained by combining blue spectrum from laser and yellowish-phosphor spectrum.

The five major limits to the adoption of these configurations are:

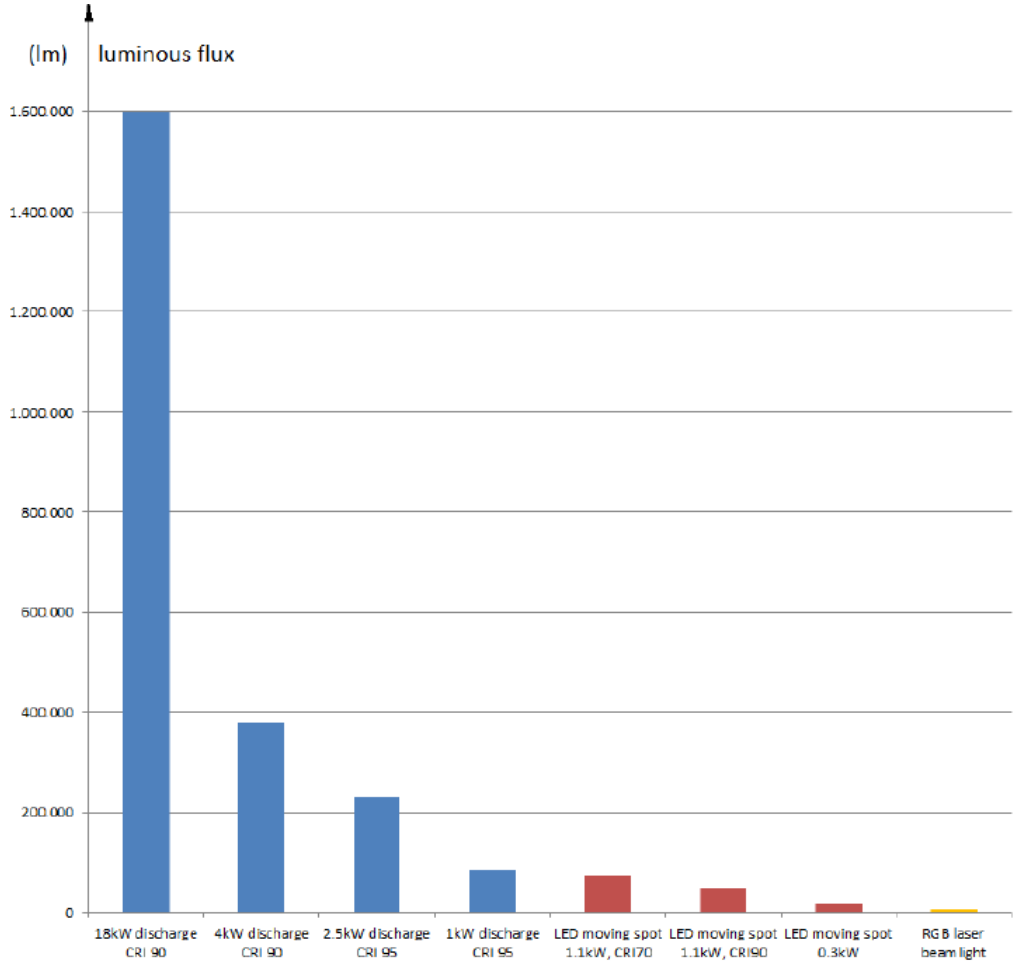
- **Complexity of the design**: Ensuring safe operation of a laser source requires care in design, and operation may be limited by legislation in some global markets.
- **Light quality**: in particular the very poor colour rendering. RGB has a narrow-band spectrum which is not capable of enhancing colours outside the laser diode spectrum. Pumped Phosphor sources are low in CRI, to keep phosphor efficient and reduce thermal load on phosphors. New productions require the highest possible spectrum of light. This is not available from current laser sources. For existing productions, the spectra of the lamps are part of the design of the show – matching the light quality of existing sources with laser technology to maintain the artistic integrity, so that it will not be possible with existing alternative technology such as laser.
- **Density**: >500 lumen/mm² emitting surface is achievable by laser, but not with LED (currently only prox. 200 lumen/mm²).
- **Cooling:** As addressed by the consultants, cooling would require a complete redesign of the fixture, which would result in a much bigger fixture because of thermal limits of laser technology. Contrary to discharge lamps, LED and laser need large and noisy cooling systems which would not be acceptable in noise sensitive environments such as theatres and other live performance venues.
- **Cost**: lumen/$ is still too high. The technology is perfect to develop very narrow-angle beam effects (like the ClayPaky XTYLOS, which performs better than an equivalent fixture using discharge lamps), but it is still too expensive to generate enough flux for a spot or wash applications requiring larger beams (see graph 1 on page 7 of this document).

This makes the laser technology suitable only for a fraction of required applications in entertainment lighting. Due to these listed points, we cannot agree with the assumption made in the above question that laser achieves the same power (luminous flux) as Hg-lamps. Whereas the wavelength is in the

same range, laser only provides for a couple of low power wave lengths instead of covering the full visible spectrum.

To give a specific example with the stage/entertainment industry uses of lamps in the scope of 4(f), Hg-free alternatives to Hg-lamps are “darker” - lower light output - which would not be acceptable for entertainment lighting. To be accepted, replacement light sources must be able to at least match the light output of existing Hg -lamps, in lighting fixtures of a comparable size, with comparable or lower noise levels and at a comparable or lower price. This is not currently possible - even LED sources cannot yet match the performance of Hg-lamps in high-light-output applications, particularly in fixtures with complex optical systems.

Graph 1 below illustrates that new technologies such as lasers are not bright enough to be used in high light output entertainment applications. Additionally, fixtures based on Hg-lamps will continue being used in regions other than the EU even if not allowed in the EU, until such time as new light sources match their performance. Given that many entertainment productions travel the world this would present a challenge in terms of obtaining spare lamps while touring a production in the EU, or of manufacturing fixtures in the EU to also be sold outside the EU. Therefore, we advocate a continued full exemption under RoHS with article 4(f) for entertainment lighting.



Graph 1: Luminous flux of available light sources

Explanation on the graph:

- 18kW discharge – a large film fixture

- 4kW discharge – such as a follow-spot in an arena or concert hall
- 2.5kW discharge – such as a follow-spot in a theatre or opera house
- 1kW discharge – a typical moving spotlight
- 1.1kW LED moving spot - low colour rendering
- 1.1kW LED moving spot - mid quality colour rendering
- 0.3kW LED moving spot - doesn´t require fan due to low power
- RGB laser beamlight – laser technology - low power is a compromise with safety limits and cost targets

On a general note, we urge the European Commission to take into account the current socio-economic context and the crisis which for the wider entertainment and live performance sector, including suppliers of lighting equipment and small manufacturers working in this area, has been devastating with a drop of turnover of 90% for the year 2020 as this recent study shows. The cost of investment for new lighting equipment is supposed to be very high and organisations in the entertainment sector will not be able to face such additional costs in the near and middle-term future.

It is expected that the recovery of the sector from the pandemic will take several years. There is no margin at the moment to invest in new lighting or other technical equipment.

In addition, it is expected that once exemption 4(f) will not be extended anymore, replacement parts will not be put on the market anymore. This means, users of Hg-lamp based fixtures would no longer be able to obtain lamps for their fixtures. The effect would be the creation of a disproportionally high amount of waste, with (still functional) lighting fixtures.

b. You mention the HLD LED new technology for its applications in the projector market, what prevents a retrofit of this technology to existing projectors?

UP Exemption # 4f WG Participants believe that retrofit solutions are not possible. The reason why HLD cannot be used as an accessory or a light source for existing mercury lamp-based projectors is that the projector is equipped with a drive power supply dedicated to mercury lamps, and the design of the system surrounding the mercury lamp, its cooling system, etc. are distinct from that for HLD. Thus, HLD cannot be introduced as a retrofit. Such a solution would have to take into account:

- Optics of the projector, which is exactly adapted to the light source ((Liquid Crystal Display or Digital Mirror Device)
- Electronic driver, which is usually integrated in the equipment such as a beamer and which needs totally different capabilities for LED as it has to ignite and run a lamp
- Cooling requirements for very bright LED solutions to protect the electronics and ensure efficiency
- Space and geometry of the electronic device, which is constructed for lamp usage
- Power, brightness requirements cannot be met by replacement units
- Architecture of the device must be exactly met
- Size of the light source
- Product safety of the device (→ CE) after change of the system cannot be ensured

Therefore, an individual retrofit solution might need to be specifically designed and produced for every projector model/family. For more details, please refer to the separate document submitted with this questionnaire - *Questionnaire_LEU_NEC_OD - ANNEX Q 3B - JBMIAD PG - 20210209*

4. You argue that lamps covered by exemption 4(f) are required to replace lamps in products placed and still made available on the market. RoHS Art. 4(4)(f), however, ensures that spare parts remain available even after the expiry of exemptions.

   Do you agree to this our interpretation of the above-mentioned article, or do you see specific circumstances or conditions where the Art. 4(4)(f) might not guarantee the availability of lamps with mercury in case exemption 4(f) would not be renewed?

In principle, UP Exemption # 4f WG Participants agree with this interpretation of article 4(4)(f) but we do not agree that this provision will sufficiently cover the needs of the EU market for the products covered by exemption 4(f).

In the case of exemption 4(f), there are so many different applications, some of them even not known to lamp producers, and many of the applications, also listed in our renewal request, cannot benefit from an alternative substitute technology. Not renewing the exemption would have a significant negative impact on the users of these lamps, because the equipment they need would no longer be allowed on the EU market.

Our main reasons for requesting the renewal of exemptions for the special purpose mercury lamps is not to save the existing products which were already available on the market but rather to ensure that the EU still has access to the equipment it needs for the applications benefiting from exemption 4(f).

Not renewing exemption 4(f) and relying solely on article 4(4)(f) for legacy spare parts is not a satisfactory solution for the users of these lamps who act mainly in professional markets. The majority of the final products which incorporate the special purpose mercury lamp are delicate and relatively expensive long-life equipment which has been using such lamps in the scope of RoHS exemptions, because the substitute technology is not available to ensure the required performance and reliability. These Hg containing lamps need to continue to be legally used within some specific semiconductor factories lithography manufacturing equipment (also termed tools) that require these special purpose lamps.

The aforementioned semiconductor fabs' lithography equipment are not obsolete, therefore the requirement is not adequately addressed by availability or not of spare parts. But there is a continued and future requirement for the general availability of Hg containing lamps for semiconductor manufacturing in Europe. If 4(f) lamps exemption is not renewed and these were no longer allowed, it would put continued European semiconductor manufacturing at risk, with no direct proportionate benefit to the environment accruing from amending 4f. If these lamps are no longer available, a significant portion of the industry will have to re-invent the process for making these chips (and a lot of them are older designs, where chip producers will not put in development costs for the redesign of the complete chip process, with the risk this business will disappear from Europe to other countries).

Some semiconductor manufacturing equipment) benefit from exemption 4f because of mercury short arc lamps use. The use of such lamps is still critical as there are no alternatives. Machines using such types of manufacturing equipment are specialised to have optical systems for that wavelength and processes are exactly for that wavelength and amount of power, also customer processes cannot be changed. Not extending the exemption will mean that our customer processes cannot operate and all products can no longer be produced.

Photostabilizers such as those discussed above are in use at many locations within the EU. As stated before, the specialty UV bulb is necessary for the functionality of these systems. Without a supply of replacement bulbs, this equipment would become obsolete, harming the productivity and efficiency of the semiconductor manufacturers using this technology.

It would be against not only the principles of RoHS but also against the EU green objectives, as expressed in the EU Circular Economy Action Plan, to prematurely end the service life of such equipment simply because they cannot be supplied with the mercury-containing special purpose lamp that they need as a spare part. In the case of the semiconductor use, not renewing the exemption would also undermine the European Union's clear commitment to reinforce the EU's semiconductor manufacturing capacity, which was again confirmed recently in the Joint Declaration of 19 EU Member States on 7 December 2020.

Please note that answers to these questions will be published as part of the evaluation of this request. If your answers contain confidential information, please provide a version that can be made public along with a confidential version, in which proprietary information is clearly marked.

It would be helpful if you could kindly provide the information in formats that allow copying text, figures and tables to be included into the review report.