

## Consultation Questionnaire for the Joint Evaluation of Three Requests for Exemption, dealing with Cadmium Quantum Dot Applications:

- “Cadmium selenide in downshifting cadmium-based semiconductor nanocrystal quantum dots for use in display lighting applications (<0.1 µg per mm<sup>2</sup> of display screen area)”;
- “Cadmium in downshifting semiconductor nanocrystal quantum dots directly deposited on LED chips for use in display and projection applications (< 5 µg Cd per mm<sup>2</sup> of light emitting LED chip surface)”;
- “Cadmium (<1000 ppm) in luminescent material for on-chip application on LED semiconductor chips for use in lighting applications of at least CRI 80”.

### Abbreviations and Definitions

Cd	Cadmium
LE	LightingEurope
LED	Light emitting diode
Najing	Najing technology Co.Ltd
OSRAM	OSRAM Opto Semiconductor GmbH
QD	Quantum dots

### Background

The Oeko-Institut and Fraunhofer IZM have been appointed by the European Commission, within a framework contract<sup>1</sup>, for the evaluation of applications for exemption from Directive 2011/65/EU (RoHS 2), to be listed in Annexes III and IV of the Directive.

Three requests for exemption have been included for evaluation in the course of the RoHS Pack 15 project. Initially, the TOR envisioned the review of a single request submitted by LightingEurope (LE) for a new exemption. At a later stage the TOR was amended to include the review of two additional requests for the renewal of Annex III, Ex. 39a, submitted by Najing technology Co.Ltd (Najing) and by OSRAM Opto Semiconductor GmbH (OSRAM) as detailed below. All three requests concern cadmium quantum dot applications and thus these exemptions shall be evaluated jointly to allow an alignment of possible future exemptions (new, renewed or amended) for such applications. The three applicants have requested exemptions as follows:

LE requests a new exemption for:

*“Cadmium (<1000 ppm) in luminescent material for on-chip application on LED semiconductor chips for use in lighting applications of at least CRI 80”.*

<sup>1</sup> The contract is implemented through Framework Contract No. FWC ENV.A.2/FRA/2015/0008 of 27/03/2015, led by Oeko-Institut e.V.

Najing have requested the renewal of Annex III, Ex. 39a with its current formulation for a period of two years, until October 31, 2021:

*“Cadmium selenide in downshifting cadmium-based semiconductor nanocrystal quantum dots for use in display lighting applications (<0.1 µg per mm<sup>2</sup> of display screen area)”.*

OSRAM has requested the renewal of Annex III, Ex. 39a for a period of 5 years, but proposes a change of the existing formulation in light of the expected shift from surface and edge illumination technology to on-chip technology. OSRAM proposes to change the existing wording of the exemption as follows:

*“Cadmium in downshifting semiconductor nanocrystal quantum dots directly deposited on LED chips for use in display and projection applications (< 5 µg Cd per mm<sup>2</sup> of light emitting LED chip surface).”*

The requests and additional information provided have been subject to a first completeness and plausibility check. The applicants have been requested to answer additional questions and to provide additional information, available on the joint evaluation webpage of the stakeholder consultation (<http://rohs.exemptions.oeko.info/index.php?id=316>).

All three applicants address technologies using quantum dot (QD) applications. Exemptions for such applications have been applied for and evaluated in the past and detailed information as to the technical aspects can be viewed in the prior exemption reports, which are available on the joint evaluation webpage of the consultation.

In short, the applicants explain that the use of Cd QD in various application areas allows producing devices (e.g., lighting applications, display applications) that provide improved colour performance (e.g., warmer light output in lighting, higher colour gamut in displays). Additionally, this improved performance can be achieved alongside higher energy efficiency of the product in comparison to alternative technologies (examples are given to show the benefit in terms of energy consumption). In this respect the applicants' main justification for the exemption requests refers to the potential for savings in energy consumption in relation to similar EEE.

For example, Najing explains that cadmium selenide QDs have excellent luminescent properties and energy effectiveness, which still out-performs available substitutes. Najing states that another two years are needed for QD companies to perfect cadmium free QDs, i.e to ensure that alternatives provide a comparable performance. They provide results of life cycle analysis and of cost benefit analysis to support the request.

For lighting applications LE mentions that *“the use of Cd-containing Quantum Dots in on-chip LED applications will enhance the luminous efficacy of LEDs by 10-20 % (based on CCT and CRI) above best-available conventional phosphors. This provides significant energy savings that clearly outweigh the potentially negative effects of a rather limited amount of cadmium entering the market in a safely encapsulated form.”*

As has been explained in past evaluations of Cd QD applications, it can be understood that there are different possibilities for applying the Cd QD converting material. These are referred to in the following as configurations and include on-edge, on-surface and on-chip applications. It can be understood that the amounts of Cd contained in the final product may differ from one configuration to the other.

The applicants argue that alternatives are currently not available, in the sense that similar products would not provide a comparable performance to that of Cd QD versions, i.e., alternatives providing

comparable colour performance show higher energy consumption. In the past the discussion on such alternatives has been limited to comparisons:

- on the substance level (for example Cd QD versus InP QD in display or lighting applications); and
- on the technological level (for example Cd QD displays versus OLED displays or CdQD LED modules versus other LED modules).

In the meantime however it is observed that the market ripeness of on-chip technologies may have also generated an alternative in terms of reducing the amount of Cd within comparable Cd QD products. For example, in this respect LE specifies “*Recently, technology has been developed which allows QDs to be deployed inside the LED package. This allows LED manufacturers to use the least amount of QD material per lumen of light, and is also the lowest cost and most flexible way to utilize quantum dots in either lighting or displays.*” It is thus to be determined, if such alternatives could allow a limitation of the scope of the exemption to certain configuration areas, at present or in the near future.

For further details, please check the applicant’s exemption request at:

<http://rohs.exemptions.oeko.info/index.php?id=316>

The objective of this consultation and the review process is to collect and to evaluate information and evidence according to the criteria listed in Art. 5(1)(a) of Directive 2011/65/EU (RoHS II), which can be found under:

<http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32011L0065:EN:NOT>

If you would like to contribute to the stakeholder consultation, please answer the following questions:

**Questions**

1. Each of the applicants has provided proposals for exemptions covering certain Cd QD applications. LE and OSRAM further provided a proposal for a formulation that could cover all three application areas, assuming they are all justified. The various formulations can be viewed in the table below.

Applicant	Initial requested exemption formulation	Proposed joint exemption formulation
Najing	Cadmium selenide in downshifting cadmium-based semiconductor nanocrystal quantum dots for use in display lighting applications (<0.1 µg per mm <sup>2</sup> of display screen area).	
OSRAM	Cadmium in downshifting semiconductor nanocrystal quantum dots directly deposited on LED chips for use in display and projection applications (< 5 µg Cd per mm <sup>2</sup> of light emitting LED chip surface).	Cadmium in downshifting semiconductor nanocrystal quantum dots - directly deposited on LED semiconductor chips for use in display and projection applications (< 5 µg Cd per mm <sup>2</sup> of light emitting LED chip surface)
LE	Cadmium (<1000 ppm) in luminescent material for on-chip application on LED semiconductor chips for use in lighting applications of at least CRI 80.	- directly deposited on LED semiconductor chips for use in lighting applications of at least CRI 80 (< 1.000 ppm in the luminescent material) - not directly deposited on LED semiconductor chips for use in display and projection applications (< 0.2 µg Cd per mm <sup>2</sup> of display screen area)

Please explain if you support that there is a need for an exemption for Cd QD applications:

- a. If not please explain why?

- b. If yes, please detail which of the proposed formulations you support or provide an alternative proposal, also explaining why you support an exemption and the specific formulation alternative.

In both cases, please provide detailed technical argumentation / evidence in line with the criteria in Art. 5(1)(a) to support your statement.

2. From the information provided by the applicants it can be understood that Cd QDs have various application areas of relevance to the RoHS Directive (displays and lighting) and may be applied in such applications in different configurations (on-edge, on surface, on chip within the LED package and on-chip within a thin layer on top of the chip). As regards the scope of a possible exemption, please provide information to clarify:
  - a. Which of the above application areas should be covered by a future exemption;
  - b. For each application area, which configurations should be included in the scope of a future exemption and with which Cd threshold; and
  - c. For how long would an exemption be needed in your opinion in each of these cases (i.e. proposed duration);

Please consider providing information in a tabular format to clarify your views for each case and provide information to support your views.

3. Please provide information concerning available alternatives or developments that may enable reduction, substitution or elimination<sup>2</sup>, at present or in the future, of Cd Qds in the various application areas and configurations mentioned in question 2.
  - a. In this regard, please provide information as to
    - i. Technological improvements which allow reducing the amount of Cd in a specific EEE;
    - ii. Substance alternatives;
    - iii. Technology alternatives.
  - b. Please provide quantitative data as to application specifications to support your views.
4. Please provide information as to research initiatives which are currently looking into the development of possible alternatives for some or all of the application range of Cd Qds in the various application areas and configurations mentioned in question 2.
  - a. Please explain what part of the application range is of relevance for such initiatives (in what applications substitution may be possible in the future).
  - b. Please provide a roadmap of such on-going research (phases that are to be carried out), detailing the current status as well as the estimated time needed for further stages.

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<sup>2</sup> Reduction refers to the use of less Cd in a certain application for achieving the same function;

Substitution refers to replacement of Cd in the same technology with an alternative substance;

Elimination refers to replacement of the technology in which Cd is used with another technology so that it is no longer necessary to apply Cd in a certain device or product.

5. For the various application areas and configurations mentioned in question 2, please provide data as to actual products currently on the market and how this is to develop within the next five years. Please refer in your answer to:
  - a. Types of products (lighting products for various purposes, displays of various size and type), also specifying the applied Cd QD configuration;
  - b. The amount of Cd contained within the product;
  - c. Alternative products of the same type that are Cd free and that provide similar performance in terms of colour output (CRI, colour gamut, etc. as relevant to the application area) energy efficiency.
  
6. For the various application areas and configurations mentioned in question 2, please provide information to allow a comparison of technologies (within the CdQD portfolio and beyond) in relation to the performance they provide so as to support the views expressed in earlier answers (support of the exemption and its various scope options or objection to an exemption):
  - a. Please refer in your answers to the parameters of relevance for this comparison (including as a minimum colour output parameters, energy consumption and energy efficiency parameters) and provide quantitative data to allow a comparison of relevant products.
  - b. Please specify the relevant standards or methods that are considered as acceptable for measuring and comparing the various parameters mentioned in a.
  
7. As part of the evaluation, socio-economic impacts shall also be compiled and evaluated. The applicants have provided various data and information in this respect. If possible, please provide additional information where more detailed quantification is possible concerning:
  - a. The volume of EEE concerned;
  - b. Amount of Cd to be avoided should the exemption not be granted;
  - c. Estimations as to possible additional waste to be generated through a forced phase-out (if relevant);
  - d. Estimation of impacts on employment in total, in the EU and outside the EU, should the exemption not be granted. Please detail the main sectors in which possible impacts are expected – manufacturers, supply chain, retail, etc.
  - e. Please estimate additional costs associated with a forced substitution should the exemption not be granted, and how this is divided between various sectors (e.g. private, public, industry: manufacturers, suppliers, retailers).

**In case parts of your contribution are confidential, please provide your contribution in two versions (public /confidential). Please also note, however, that requested exemptions cannot be granted based on confidential information!**

**Finally, please do not forget to provide your contact details (Name, Organisation, e-mail and phone number) so that Oeko-Institut/Fraunhofer IZM can contact you in case there are questions concerning your contribution.**