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Ms. Yifaat Baron
RoHS exemptions evaluation
Oeko-Institut
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P.O. Box 1771
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Re: Pack 10 Stakeholder Comment Questionnaire Regarding CdQD Exemptions:

Dear Ms. Baron,

This letter is DMSD's response to the Oeko-Institut PACK 10 Stakeholder Comment Questionnaire Regarding CdQD Exemptions:

- Ex. Re. No. 2013-2 for "Cd 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)
- Ex. Re. No. 2013-5 for "Cd in light control materials used for display devices"

The conditions for 3M DMSD's RoHS exemption request have not materially changed since the April 22, 2014 date of the Oeko-Institut and Fraunhofer-Institut IZM Pack 4 Report for the European Commission DG Environment.[1] All three criteria for granting the RoHS exemption still hold true for the case of exemption 39 (b). 3M's exemption case 2013-5 meets each of the criteria specified in Article 5(1) (a) of The RoHS Directive 2011/65/EU.

To further substantiate 3M DMSD's request for granting the RoHS exemption, we are enclosing the following 3 reports with this response:

1. Project Pandia- LCA0014, Comparative Life Cycle Assessment of LED-enabled LCD TVs over their entire life cycle, comparing the effect of the integration of cadmium based and non-cadmium based light enhancement films, 3M Sustainability Center of Expertise West Europe (Dec. 31, 2015).
2. Report Life cycle assessment of a 3M QDEF-film, University of Antwerp, Faculty of Applied Engineering Sciences, Faculty of Applied Economics, Matti Buyle, Johan Braet (18-12-2015).
3. Socio-economic assessment for Cd QD displays, Dr. Paul Goodman, Edif ERA (January 2016).

Oeko-Institut Question 1:

The two applicants originally requested exemptions with different wording formulations, however in the course of the first evaluation it was understood that both exemptions are to allow placing Cd QD technologies on the EU market in various products. During the first evaluation the applicants were asked to confirm if the following formulation would cover the applications for which the exemptions had been

[1] Oeko-Institut and Fraunhofer-Institut IZM, 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 – Pack 4 Report for the European Commission DG Environment under Framework Contract No NV.C.2/FRA/2011/0020 April 22, 2014 Pack 4 Report,

requested:

> *Cadmium in components for lighting applications and display lighting applications, containing downshifting cadmium based semiconductor nanocrystal quantum dots, where the cadmium per display screen area is limited to less than 0.2 ug/mm2*

This formulation was later used as a basis to separate between display lighting and solid-state lighting applications in the context of a possible exemption. If the exemption is to be recommended, a split shall most likely be proposed between the use of such cadmium components in solid state lighting applications and in display lighting applications.

a. Do you agree that the formulation above covers the cadmium quantum dot technologies addressed in the two exemption requests? If not, please explain why.
b. If the exemption is to be split according to application field (SSL and display lighting) please specify what wording formulation would best cover each of the application areas.
c. Please suggest an alternative wording and explain your proposal, if you do not agree with the proposed exemption wording or with the proposed split.
d. Please explain why you either support the applicant's request or object to it. To support your views, please provide detailed technical argumentation / evidence in line with the criteria in Art. 5(1)(a) to support your statement.

3M DMSD Response to question 1a:

3M DMSD agrees with the proposed wording:

> *"Cadmium in components for lighting applications and display lighting applications, containing downshifting cadmium based semiconductor nanocrystal quantum dots, where the cadmium per display screen area is limited to less than 0.2 ug/mm2"*

Please refer to our response to question 1b to address the wording for Solid State Illumination (SSL) and display lighting.

3M DMSD Response to question 1b:

3M DMSD agrees with a split according to application field (between SSL and display lighting applications). Although we agree with the proposed wording in the Question 1, the wording that we believes best covers the display lighting application and reflects the split from SSL application is the wording that was proposed to replace exemption 39(b) to replace exemption 39 in Annex III to Directive 2011/65/EU[2], shown in Table 1 below.

Table 1.

39(b)	Cadmium in downshifting cadmium based semiconductor nanocrystal quantum dots for use in display lighting applications (< 0.2 µg Cd per mm2 of display screen area)

However 3M DMSD wants to emphasize that we do not agree with the proposed expiration dates that had accompanied the original proposed wording for exemption 39(b). To date there are no non-Cd QD available for purchase on the open market. Due to repeated delays of QD manufacturers to bring a non-Cd solution to the market, we are requesting a favorable recommendation under this reassessment. The original exemption request was shortened from the standard 5 year period to 4 years based on representations and assertions that substitutes would become available early 2014. It is now more than a year after the date that the non-Cd solutions

[2] https://members.wto.org/crnattachments/2015/TBT/EEC/15_0243_01_e.pdf

were initially promised to be available for purchase on the market, and there continue to be no sources of non-Cd QDs freely available for purchase on the open market. Accordingly, we respectfully request the full 5 years for the exemption. 5 years will be needed for development of film formulations and reliability and performance testing (of the film and in devices such as televisions), once non-Cd QD materials become freely available on the market in sufficient quantities.

3M DMSD Response to question 1c:

3M DMSD agrees with the proposed wording:

> *"Cadmium in components for lighting applications and display lighting applications, containing downshifting cadmium based semiconductor nanocrystal quantum dots, where the cadmium per display screen area is limited to less than 0.2 ug/mm2"*

3M DMSD Response to question 1d:

3M DMSD supports the request for a RoHS Exemption. The following is a lists of justifications for Directive 2011/65/EU Article 5(l) (a) 1, 2, 3

Directive 2011/65/EU Article 5(l) (a)

1. their elimination or substitution via design changes or materials and components which do not require any of the materials or substances referred to in Article 4(1) is scientifically or technically impracticable;

There is no substitute for CdSe QDs that meet the color quality and energy consumption performance metrics required by 3M's customers in the electronics market. 3M, as a world leading manufacturer of display film, has an open invitation to all QD material manufacturers to purchase a non-Cd solution. Unfortunately, to date no substitutes that deliver color and energy performance required by our customers has been made available on the market. Therefore, the substitution of CdSe QDs is technically impracticable. The following assessment from Oeko-Institut/Fraunhofer-Institut's report is still valid.

> "*... However, most of these alternatives are said not to provide comparable colour gamut performance as is possible with Cd QD products, or otherwise to result in significantly higher energy consumption. Though the colour aspect could be seen as an aesthetic aspect, the applicants have provided quantifications of this quality that allow it to be addressed on a comparative and thus technical basis. In this sense, if the colour gamut aspect is to be understood to suffice, alternatives could be understood to provide performance inferior to that of the Cd QD applications, thus meaning that elimination is not possible on the grounds that substitutes are not practical as the colour gamut provided would be significantly inferior to that of the discussed applications."*[3]

2. the reliability of substitutes is not ensured;

[3] 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 – Pack 4, Öko Institut and Fraunhofer IZM, 22 April, 2014. https://circabc.europa.eu/sd/a/0cbd617f-79a0-4b44-813d-d3bb71a82d79/20140422_RoHS2_Evaluation_Ex_Requests_2013-1-5_final.pdf

There is no freely available substitute non-Cd QD solution on the market that can provide comparable color and energy properties to CdSe QDs (tables 4, 5 & 6 below). 3M's evaluation of leading-edge, experimental non-Cd QDs indicates that they would result in unacceptable in-device lifetimes for electronics industry customers. While Samsung has made a single line of devices (TVs) available on the market using non-Cd based QDs, the QD material itself is not available for purchase by third parties, and the performance of the Cd free material is not equivalent with that of CdSe QDs as shown below. This situation illustrates that the reliability of substitutes is not ensured. It is important to remember once the non-Cd QDs are available, it may still take up to 5 years or more to develop consumer electronic products incorporating those quantum dot materials to meet the new color standards.

3. 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 lower energy consumption of CdSe QDs containing display devices reduces the amount of electrical energy needed, thereby reducing the environmental pollutants created during the electrical energy production process. There is also an economic benefit for consumers. Devices that use less energy cause less pollution from electricity generation and are also cheaper to run.[4] This energy saving is achieved while providing a display device that does not result in any exposure of cadmium to the consumer since the CdSe QDs are bound in a film and further contained in a display device. The following statement from the Oeko-Institut/Fraunhofer-Institut report is still valid.

> *"The consultants conclude that the use of Cd in QD films used for solid state lighting and display lighting applications, would thus not weaken the environmental and health protection afforded by the REACH Regulation"*[5]

3M DMSD had two life cycle assessments (LCA) conducted to further substantiate that the use of 3M QDEF generally has a less negative impact on the environment overall compared to alternative technologies, while providing an energy efficient solution. The following are two excerpts from the LCA conducted by the University of Antwerp

> "This study analyzed the environmental profile of the cadmium containing 3M QDEF film and compared this with a non-Cd film. For the 3M QDEF film, a detailed LCA was carried out, while the non-Cd film is assumed to be burden free. The final conclusion of this study is that in current situation, the benefits of the saved energy surpass the burdens of the film production for the 3M QDEF film, compared to the non-Cd film. A second conclusion is that within the 3M QDEF film, cadmium as such comes with a negligible environmental impact, compared to the non-Cd components in the process, even when conservative scenarios have been applied."[6]

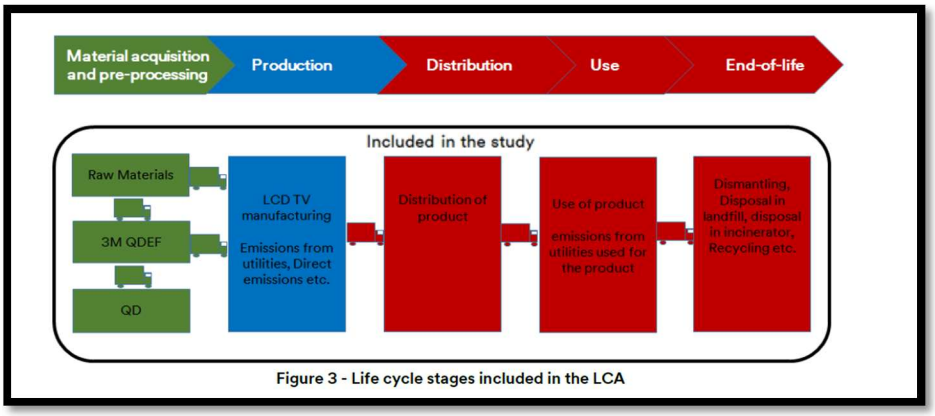
> "Looking at these non Cd-materials more into detail, apparently the main constituent for the film, namely PET, and the electricity consumption during the barrier coating process are the dominant sources. The

[4] Socio-economic assessment for Cd QD displays, Dr. Paul Goodman, Edif ERA, 2015-0001, REG0273001
[5] Pack 4 Report, page 71
[6] UNIVERSITY OF ANTWERP, FACULTY OF APPLIED ENGINEERING SCIENCES, FACULTY OF APPLIED ECONOMICS, Report Life cycle assessment of a 3M QDEF-film, Matti Buyle, Johan Braet, 18-12-2015, page 18

effect of the cadmium content however is barely noticeable.[7]"

3M Sustainability Center of Expertise West Europe conducted a Comparative Life Cycle Assessment of LED-enabled LCD TVs over their entire life cycle, comparing the effect of the integration of cadmium based and non-cadmium based light enhancement films (Project Pandia- LCA0014, version 1 Effective date: 31-Dec-2015) Figure 1 illustrates the in depth analysis conducted by Project Pandia.[8]

Figure 1.



The LCA project Pandia concludes

"The LCA had the following situations compared:
• The environmental impact of a standard LCD TV, not using QDEF (TV1);
• The environmental impact of an LCD TV, incorporating 3M QDEF (TV2);
• The environmental impact of an LCD TV, incorporating an alternative, non-3M light control film (TV3). Note that due to the lack of knowledge related to the alternative technology, the environmental impact of the non-3M light control film is assumed to be negligible.[9]

Given the above conclusions, there is a higher tendency for the environmental impact of TV2 to be lower than TV1 (as compared to TV3 vs. TV1). When taking into account the uncertainty determination, which provides a range in which the environmental impacts are likely to be found (see section 5.4), there are a number of impact categories, including global warming, a topic that is high on the European agenda, for which there is no overlap in environmental impact of TV2 and TV1. This can also be verified by comparing TV1's minimum value in the uncertainty tables, with TV2's maximum value in these tables. Therefore, as a result of the energy benefits in TV2's use phase as compared to TV1, there appears to be a positive effect on the environmental impact for the following categories:
o For CML: ADPf, AP, GWPin, GWPex
o For PEF: Acid, CC_ex, CC_in, IR, OD, RDW[10]

[7] UNIVERSITY OF ANTWERP, Report Life cycle assessment of a 3M QDEF-film, Matti Buyle, Johan Braet, 18-12-2015, page 9

[8] Project Pandia- LCA0014, Version 1 Effective date: 31-Dec-2015, Comparative Life Cycle Assessment of LED-enabled LCD TVs over their entire life cycle, comparing the effect of the integration of cadmium based and non-cadmium based light enhancement films. Non-confidential version, for public consultation, page 17

[9] Project Pandia-LCA0014, Version 1 Effective date: 31-Dec-2015, page 87

[10] Project Pandia-LCA0014, Version 1 Effective date: 31-Dec-2015, page88

…Therefore it can be concluded that the real benefits of the environmental differentiation of TV2 compared to TV1 can be directly related to TV2's energy efficiency benefits."[11]

Table 2 provides a list the terms used in the above quote from the LCA.

Table 2 – Terms used in the LCA Quote

CML	Institute of Environmental Sciences, University of Leiden
ADPf	Abiotic Depletion Potential, fossil
AP	Acidification Potential
GWPin	Global Warming Potential, including biogenic carbon
GWPex	Global Warming Potential, excluding biogenic carbon
PEF	Product Environmental Footprint
Acid	Acidification
CC_ex	Climate Change, excluding biogenic carbon
CC_in	Climate Change, including biogenic carbon
IR	Ionising Radiation, human health
OD	Ozone Depletion
RDW	Resource Depletion, Water

In addition to meeting the RoHS exemption criteria stated in Directive 2011/65/EU Article 5(I) (a) 1, 2, and 3, 3M QDEF is well aligned to support circular economy as proposed by the EU commission in COM (2015) dated 12/02/2015.[12]

- Longer lifetimes
- Energy efficiency
- Reduction in consumption of scarce resources
- Easier recycling
- Reuse of parts and refurbishment

3M's QD technology helps meet these aims in that:

- The lifetime of CdSe QD displays are greater than 30,000 hours per 3M lifetime studies, exceeding even the most stringent of our customers' specifications.
- Energy consumption is lower than alternative display designs. The 3M Pandia LCA indicates that TV2 (3M QDEF) has a significant power savings over TV1(a standard LCD TV) and TV(3) (an LCD TV, incorporating an alternative, indium-based, non-3M light control film). Figure 2 provides the results.
- Cadmium is not classified as critical raw material. Indium is included in the 20 critical raw materials list issued by the European Commission.[13]
- There are established recycling and recovery methods for cadmium.[14] There are no commercial indium recovery processes yet available.[15]

[11] Project Pandia-LCA0014, Version 1 Effective date: 31-Dec-2015, page89

[12] http://www.europarl.europa.eu/RegData/docs_autres_institutions/commission_europeenne/com/2015/0614/COM_COM(2015)0614(ANN)_EN.pdf

13 http://europa.eu/rapid/press-release_IP-14-599_en.htm

14 http://www.preciousmetals.umicore.com/recyclables/eScrap/Process/

[15] http://www.oeko.de/oekodoc/1375/2012-010-en.pdf

- There are no differences in the end of life recycling processes for those electronic devices in which Cd-QD is used from and those devices without these materials. The ability to reuse or refurbish QD-TVs and all other flat screen TV technologies is the same.

Figure 2. - LCD TV Energy Consumption Modeling[16]

Calculation Results				
System	Modelled efficacy	Luminance gain of TV2	Power (W) 48" TV	Power (W) 65" TV
TV1	0.99	2.28	238	386
TV2	2.25	1	140	213,4
TV3	1.44	1.56	183	290
Modelled power savings of TV2 over TV3			24%	26%
Modelled Power savings of TV2 over TV1			41%	45%

The socio-economic assessment for Cd QD displays[17] further supports the circular economy criteria benefits and the socio economic benefits derived from the use of 3M QDEF. Highlights of the socio-economic report, based in part on the LCAs, are listed below:

- *"The use of a Cd QD TV will result in less cadmium in emissions and waste from electricity generation ...,*
- *To be more energy efficient than standard designs of LCDs and also InP QD LCDs used in a television.*
- *Most of the overall impacts from Cd QD displays are less negative than with the alternative standard LED-LCD and InP QD displays*
- *Impact on Innovation - 3M has shown that Cd QD provides the best performance and energy efficiency and this material can be used in all types of display technology as well as in lighting. Removal of exemption 39 would stop further innovation in this area so that future designs of display and lighting would consume more energy and provide inferior performance. This is because there are no suitable substitutes to Cd QD materials commercially available that give equivalent performance."*

Nanoco's October 27, 2015 response to the Oeko Institut[18] stated: "*Note that as energy efficiency is covered by separate EU legislation, it should only be regarded as a secondary factor in conducting a review under RoHS.*" 3M DMSD respectfully points out that while energy efficiency is indeed covered by other legislation (Energy related Products ErP Directive 2009/125/EC) and encourages manufacturers to make products as efficient as possible, it does not specifically address or restrict cadmium. To date cadmium is needed to achieve the desired energy savings. Energy efficiency has

[16] Project Pandia- LCA0014, Version 1 Effective date: 31-Dec-2015, page 28

[17] Socio-economic assessment for Cd QD displays, Dr. Paul Goodman, Edif ERA, 2015-0001, REG0273001

[18] http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_10/Cd_QD_Exs_Nanoco_Response_to_RoHS_Questions_27_Oct_2015.pdf

benefits that are subsumed within one of the primary criteria of the RoHS directive in Article 5.1 for allowing exemptions:

> *A RoHS exemption may be justified if "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".*

3M DMSD notes that the use of 3M QDEF would assist the electronic display manufacturers in meeting Energy related Products ErP Directive 2009/125/EC and other global energy standards, and also is consistent with the primary criteria in RoHS Article 5.1.

Recycling processes in the EU are regulated by the Industrial Emissions Directive (IED) and this directive restricts emissions of all hazardous substances including cadmium. Therefore it is necessary for recyclers to recover cadmium to prevent pollution. The IED is enforced in the European Union (EU) to ensure that cadmium emissions do not exceed safe limits; therefore, there is a mechanism already in place to ensure that safe recovery occurs. The University of Antwerp's LCA[19] however considers as a highly conservative assumption, uncontrolled open air incineration. This in not common practice in the European Union due to current waste treatment regulations, but since the related emissions could potentially have an effect on human health, it is included as a 'worst case' scenario. Despite using this worst case scenario, most life cycle impacts of Cd QD displays are still less negative overall than from the alternative display technologies.

Oeko-Institut Question 2:

At the time of the first review, difficulties regarding the comparison of Cd QDs in display applications and Cd-free QDs in display applications, did not allow making a well-balanced comparison of these technologies. In the meantime, it has become apparent that the market situation of these products has changed, possibly allowing a better comparison and evaluation as to the environmental performance of these technologies and other related aspects. The two applicants and a manufacturer of a substitute candidate have provided information regarding applications that are already on the market using the Cd based and Cd free technologies. Please review this information and comment:

> *a. Regarding the availability of Cd-based and Cd-free products for display applications using these technologies, please specify if you are aware of additional products that have become available since 2014 (display type, dimensions and other characteristic aspects for clarifying the performance class) other than those specified by the applicants and the substitute candidate manufacturer.*
> *b. Please state if you agree with the detailed parameters mentioned by the three actors as relevant for enabling a comprehensive comparison of performance of the technologies (general performance and environmental performance); Please explain your views and if relevant specify other parameters that should be considered.*
> *c. The various actors mention the following standards among others as relevant for comparing the technologies used in display applications: NTSC and Adobe RGB as well as the REC 2020 standard that is understood to be in adoption stages. Please comment as to the suitability of these standards for comparing QD technologies in display applications.*

3M DMSD Response to question 2a:

The following is more detail on the market situation since the first assessment was issued on April 22, 2014.

19 UNIVERSITY OF ANTWERP, LCA, Matti Buyle, Johan Braet, 18-12-2015

Non-Cd QDs are not available on the market to purchase.

a. Samsung, a TV manufacturer, placed an internally sourced non-Cd/indium phosphide-containing television line on the market after entering with a technology licensing agreement with Nanosys. This TV manufacturer is limiting use of its non-Cd QDs to its own devices. The non-Cd QDs are not available to third parties for purchase and use in commercialization of third party products. Samsung's use of non-Cd QDs is limited to one line of TVs, and the non-Cd QDs are not used (or proven to meet customer requirements of color gamut and energy efficiency), in other display applications including tablets, mobile devices, other types of displays.
b. Manufacturers developing non-Cd technology have all repeatedly delayed commercialization and manufacturing scale up of non-Cd QDs. To date, no manufacturer (including the one commercialized non-Cd TV film) has demonstrated an equivalent color gamut and energy performance to cadmium selenide(CdSe) based QDs.
c. Reliability of supply is still a factor in the market today. We are consumers of Quantum Dot (QD) materials; not a manufacturer of QD materials. 3M, as one of the world's leading manufacturers of display film, has an open invitation to all QD manufacturers to purchase a non-Cd solution. To date, no substitutes that deliver color and energy performance required by electronic customers have been made available on the market. At this point, we are utilizing cadmium selenide (CdSe) containing QDs as they provide the most energy efficient solution to achieve current and future color standards.

Table 3. is provided to summarize the type of device on the market, the availability, and the QD chemistry. This information is provided to the best of 3M's knowledge, but is not guaranteed to be complete.

Table 3. Commercial Quantum-Dot Based Displays

Type	Manufacturer	Product Family/Model	Diagonal (")	CdSe Based	Available as of Oct 20, 2015
TV	Samsung	SUHD	48 to 85	No (InP)	Yes
TV	Hisense	ULED	55 to 65	Yes	Yes
TV	Vizio	Reference Series	65	Yes	Yes
TV	TCL	H9700	55 to 65	Yes	Yes
TV	Philips	55PUF6850/T3	65	Yes	Yes
Monitor	Asus	PA329Q	32	Yes	Pending (within 2015)
Monitor	BENQ	SW2700PT	27	Yes	Yes
Monitor	Philips	276E6ADSW	27	Yes	Yes
Notebook	Asus	NX500	15.6	Yes	Yes
Tablet	Amazon	Fire HDX	7	Yes	End of Life
• There are other devices on the market using 3M's QDEF but 3M is not at liberty to disclose this information					

As you can see from the above table, only one product line manufactured by Samsung uses non-Cd based material, but this is not a viable substitute. Please see 3M's answer to question 2b.

The following press releases anticipate additional implementation of Cd based QD technology.

- AUO (large panel supplier to the industry) announced full line up of QD TV's (scaling production, but end TV brands not disclosed yet) http://www.auo.com/?sn=107&lang=en-US&c=9&n=1775
- Changhong QD TV http://www.changhongglobal.com/egdch/1982_10022.htm
- German article: http://www.areadvd.de/tests/ces-2015-die-tv-neuheiten-von-changhong-uhd-curved-und-quantum-dot-technologie/
- 3M and Nanosys demonstrated displays showing over 90% of the Rec. 2020 gamut at SID (June, 2015)
- At IFA (September, 2015) TCL and QD Vision demonstrated a TCL- branded TV that presented over 90% of the Rec. 2020 color gamut
- Vizio announced commercial availability of first REC 2020 TV (R-series) on October 6, 2015

3M DMSD would like to clarify the statement in Nanoco's October 27, 2015 response to the Oeko Institut[20] that "*Nanosys has recently stated that 40% of their sales come from Cd-Free QDs*" Nanosys does indeed get revenue from their Cd-Free QD technology. The revenue is largely from an intellectual property license to Samsung rather than as a result of non-cadmium QD product material sales, as Nanoco's statement might imply.

Oeko-Institut Question 2b:

b. Please state if you agree with the detailed parameters mentioned by the three actors as relevant for enabling a comprehensive comparison of performance of the technologies (general performance and environmental performance); Please explain your views and if relevant specify other parameters that should be considered

3M DMSD Response to question 2b:

The relevant parameters for enabling a comprehensive comparison of performance are:

A. color gamut – the ablility to meet current and future color standards
B. luminance and power -- energy-efficiency
C. net positive environmental impact
D. reliability

It is important to note that devices containing displays (such as televisions, monitors, notebooks, tablets, phones, etc.) are designed and implemented by different manufacturers to meet a variety of different needs. While it is possible to measure the color, luminance, and power consumption of multiple devices, comparing these data is not a meaningful way to compare the relative performance of specific components within the devices. Too many other attributes vary among different devices since a display is an entire system that combines components, and the combination of the performance characteristics impacts the overall system performance. For example it is possible that a device could have an extremely efficient color enhancement film, but

20 http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_10/Cd_QD_Exs_Nanoco_Response_to_RoHS_Questions_27_Oct_2015.pdf

has overall low energy efficiency because of poor electronics design or the choice of cheaper and lower efficiency LEDs.

In 3M's experience, the only meaningful way to compare the relative performance of different, specific components is to evaluate those components in the same device so that you are isolating the performance of the particular component and eliminating the other factors introduced by testing differing systems. This requires modification of the device using the two technologies that are to be compared. 3M has conducted such testing in commercially available SUHD TVs which contain non-Cd QDs from the factory. 3M has replaced the commercial non-Cd QD film with a commercial Cd-based QD film made by 3M. This kind of comparative testing ensures that the only differences in performance are those that result from the QD technologies.

Per the comments with regard to comparative testing in the response to question 2b above, 3M DMSD has evaluated one sample each of two commercial InP-based TV models (UN48JS900F and UN65JS9500FXZA) and modified them with 3M Cd-based film. **At equivalent luminance and color gamut, the two TVs utilizing Cd-based QDs are calculated to consume 22% and 30% less power than the TVs with InP-based QDs (see Table 6)**. The measurement data and steps to determine power at equivalent luminance and color are described below.

First, Table 4 contains luminance, power, and color data for the two TVs with different QD dot chemistries. In this case, the power of the TVs were held constant. The only difference between the as-received and modified TV is the quantum dot film.

Table 4. Measured performance comparison of TVs at constant power (different luminance and color).

SUHD Model	Quantum Dot Film (Chemistry)	Luminance (cd/m^2)	IEC On-Mode Power (W)	Color Gamut (1931 CIE xy)		
				NTSC Area	DCI-P3 Overlap	Rec2020 Overlap
UN48JS9000F	As-Received (InP)	420.2	193.5	88.4%	90.0%	65.9%
UN48JS9000F	3M Modified (CdSe)	537.6	193.5	99.9%	91.6%	74.6%
UN65JS9500FXZA	As-Received (InP)	427.7	339.7	89.3%	90.4%	66.6%
UN65JS9500FXZA	3M Modified (CdSe)	596.6	339.7	99.7%	91.1%	74.5%

As can be seen in Table 4, replacing the InP QD sheet with the CdSe QD sheet results in both an increase in luminance (28% and 39%) and color gamut (13% and 12%) of Rec. 2020 overlap. By decreasing the electrical current to the LEDs (and, hence, reducing energy consumption of the LEDs), the TVs with different QD chemistries can be made to have the same luminance. This is achieved in practice by reducing the backlight setting of the TV. The luminance and power as a function of backlight settings were characterized for both TVs and found to be linear with a

coefficient of determination (R^2) of >0.999. These relationships are used to determine the power consumptions at equivalent luminance which are reported in Table 5.

Table 5. Measured and calculated performance comparison at constant luminance.

SUHD Model	Quantum Dot Film (Chemistry)	Luminance (cd/m^2)	IEC On-Mode Power (W)	Color Gamut (1931 CIE xy)		
				NTSC Area	DCI-P3 Overlap	Rec2020 Overlap
UN48JS9000F	As-Received (InP)	420.2	193.5	88.4%	90.0%	65.9%
UN48JS9000F	3M Modified (CdSe)	420.2	166.8†	99.9%	91.6%	74.6%
UN65JS9500FXZA	As-Received (InP)	427.7	339.7	89.3%	90.4%	66.6%
UN65JS9500FXZA	3M Modified (CdSe)	427.7	264.2†	99.7%	91.1%	74.5%

As can be seen in Table 5, the power of the Cd-based systems is reduced by 14% and 22% at equivalent luminance, but the color of the Cd-based systems is still improved. Due to fundamental properties of human vision, smaller color gamut with less saturated colors is more efficient at producing visible light. Therefore, even further power savings could be realized if the color of the Cd-based system is reduced to match that of the InP-based systems and the two display systems are compared on equal terms.

Unfortunately, there is no television setting control that can reduce the power and color gamut as the backlight setting did for power and luminance. To evaluate the power consumption of the TVs at equivalent luminance and color gamut, we rely on computer modeling. 3M presented a paper at the 22nd International Display Workshops on December 11, 2015 that provides details of the models and how they are used to compare the gamut and efficiency of different technologies.[21] Table 6 shows the results of using this model on the TVs under investigation.

Table 6. Measured and calculated† performance comparison at constant luminance and color gamut.

SUHD Model	Quantum Dot Film (Chemistry)	Luminance (cd/m^2)	IEC On-Mode Power (W)	Color Gamut (1931 CIE xy)		
				NTSC Area	DCI-P3 Overlap	Rec2020 Overlap
UN48JS9000F	As-Received (InP)	420.2	193.5	88.4%	90.0%	65.9%
UN48JS9000F	3M Modified (CdSe)	420.2	150.6†	88.4%†	90.0%†	65.9%†
UN65JS9500FXZA	As-Received (InP)	427.7	339.7	89.3%	90.4%	66.6%
UN65JS9500FXZA	3M Modified (CdSe)	427.7	237.0†	89.3%†	90.4%†	66.6%†

Therefore, at constant luminance and color gamut, 3M predicts the TVs with CdSe QDs to consume 22% and 30% less power than the TVs with InP QDs. These data and models are used as the basis for the LCAs referenced in this response. Additionally, although the above analysis was done specifically for

[21] Thielen, J., et Al., "ITU-R BT.2020 Color in LCDs with Today's Technologies: A Comparative Analysis." The 23rd International Display Workshop. December 8th. Fukuoka Japan. 2015

TVs, it is expected that similar levels of luminance increase and corresponding power reduction would be seen when comparing CdSe QD to InP QDs in other LCD applications such as phones, tablets, laptops and monitors. This power reduction is specifically important to mobile devices (phones, tablets, laptops) where it leads to lower battery requirements and less battery waste.

As previously discussed, this methodology of comparing the efficiency of display components (such as quantum dot films) is fair and meaningful because the QD technology is the only thing that changes in the comparison. It is impossible to infer the energy impact of two different display components by comparing the EU energy rating of two different TVs that use those components. The fact that one type of television that utilizes CdSe QDs consumes more power than a different type of television that utilizes InP QDs says nothing about the efficiency characteristics of different QDs.

Oeko-Institut Question 2c:

The various actors mention the following standards among others as relevant for comparing the technologies used in display applications: NTSC and Adobe RGB as well as the REC 2020 standard that is understood to be in adoption stages. Please comment as to the suitability of these standards for comparing QD technologies in display applications.

3M DMSD Response to question 2 c:

Color Comparison

There are several color specifications for various uses, including televisions, cinema and broadcast standards. Since submission of the original application 2013-5, a new color standard, International Telecommunication Union (ITU-R Rec. 2020), has been published which requires extremely large colour gamut. This is a very suitable standard for comparing technologies since: it is applicable to all devices; it encompasses all of the other smaller gamut standards (e.g., Rec. 709, NTSC and Adobe RGB); and it is envisioned as the future standard that the content development industry will adopt. The Rec. 2020 recommendation covers resolution, frame rate, bit depth and color space, among others. Under this standard, nearly 100 percent of the colors visible to the human eye would be available to consumers. This is a difficult standard to meet; more so when energy efficiency is also the goal. It is intended that upcoming ultra-high definition (UHD) television broadcasting will use the Rec 2020 standard. Additionally, it is anticipated the first UHD BluRay™ players supporting this standard will be introduced to the market in early 2016. This color performance cannot be met by non-Cd technology at this time. International Electrotechnical Commission has established IEC 62087 as the method of choice for evaluating television power consumption in the active use mode. A 10 minute video test clip is run and energy use is integrated to determine the power consumption in a real-world setting. Televisions can be put through this test in a variety of situations (dark room, bright room, different picture settings, etc.). Table 7 describes the color specification, what it covers, where it is used, and characteristics.

Table 7 – Color Specifications*

Color Specification	What It Covers	Where It Is Used	Characteristics
National Television System Committee (NTSC) (Also known as Standard Red Green Blue or S RGB)	Analog television systems, with color specifications, lines and refresh rate, color encoding, transmission modulation. Many countries have shifted to ATSC which contains no defined color standard.	Televisions, mainly. There is a related cinema standard, used rarely.	SMPTE "C" colorimetry, using relatively narrow primary and white point colors based on CIE 1931 standards; covers about **38%** of colors visible to the human eye
International Telecommunications Union recommendation BT.709 (Rec 709 or BT 709)	International standard developed for high definition televisions in 1990; specifies refresh rate, pixel count, chromicity, standards conversion, luma coefficients, transfer characteristics	Televisions	Covers about **36%** of colors visible to the human eye
Adobe RGB	Developed by Adobe Systems Inc in 1998, it was meant to encompass most printed colors covered in CMYK color space.	Generally used by graphic designers and others working with print production to ensure color on a display matches the color in print. Televisions, desktop displays (monitors), notebook computers. Very limited and relatively expensive	Covers about **50%** of colors visible to the human eye
Digital Cinema Initiatives (DCI P3)	This is the common colour space for digital movie projection from the American film industry.	Considered the pre-cursor to the significantly wider color gamut delivered by the BT.2020 or Rec 2020 standard	DCI-P3 is said to have distinct drawbacks in the blue-green range. Covers about **42%** of colors visible to the human eye
International Telecommunications Union recommendation BT.2020 (Rec 2020 or BT 2020)	This ITU recommendation, introduced in 2012, sets standards for broadcast-enabled devices; includes such aspects as resolution, frame rate, chroma subsampling, bit depth, and color space.	Displays on televisions, desktop displays, notebook computers, tablets and smartphones are subject to this recommendation. At this time, no one has achieved 100% of the Rec 2020 color space.	Nearly **100%** of the colors visible to the human eye are included in the Rec 2020 space

* Source*: Noteloop, a group of cinema and broadcast designers who work specifically in color for the industry.*

To further illustrate the importance of color. The UHD Alliance, an industry consortium comprised of film studios, consumer electronics manufacturers, content distributors and technology companies on January 4, 2016 announced a new standard for 4K televisions, which includes color, resolution, and luminance, among other aspects. This group specifies a wide color gamut with signal input of BT.2020 color representation. While this group leaves the issue of energy efficiency to government regulators, consumers expect a certain level of energy efficiency on any device they purchase.

Oeko-Institut Question 3:

Please specify on the basis of what regulations/standards a comparison of these technologies in relation to the performance of the relevant product (TV, display, tablet,

mobile-phone, solid state illumination applications) can be made, in particular in relation to the consumption of energy during various use modes (standby and other operation modes, operation with different brightness/contrast settings; display of images with higher or lower contrast or differing hues; etc.)

3M DMSD Response to question 3:

As stated in the response to question 2 b above. In 3M's experience, the only meaningful way to compare the relative performance of different, specific components is to evaluate those components in the same device so that you are isolating the performance of the particular component and eliminating the other factors introduced by testing differing systems. This requires modification of the device using the two technologies that are to be compared. 3M has conducted such testing in commercially available SUHD TVs which contain non-Cd QDs from the factory. 3M has replaced the commercial non-Cd QD film with a commercial Cd-based QD film made by 3M. This kind of comparative testing ensures that the only differences in performance are those that result exclusively from the QD technologies.

Energy Comparison

IEC has published standards for energy consumption measurement:

- IEC 62087 Ed. 3 and Ed. 2 – Methods of measurement for the power consumption of audio, video and related equipment; and
- IEC 62301 Ed. 2.0 2011 – Household electrical appliances – Measurement of standby power, which addresses standby testing for a broad selection of products, without specific reference to televisions

Oeko-Institut Question 4:

At the time of the first review, it was understood from various stakeholders that the Cd-based and Cd-free quantum dot technologies were also being developed for possible future use in solid-state illumination applications. The two applicants and a manufacturer of a substitute candidate have provided information regarding applications that are already on the market using the Cd based and Cd free technologies. Please review this information and comment:

a. If **additional** lighting products (*solid state illumination)* have become available onthe EU market since 2014.
b. Please clarify for Cd-based and Cd-free products as described in a), what parameters are relevant for enabling a comprehensive comparison of performance to clarify how the technologies compare in relation to performance in general and in particular to environmental performance;
c. Please state if you agree with the detailed parameters mentioned by the threeactors as relevant for enabling a comprehensive comparison of performance of the technologies (general performance and environmental performance); Please explain your views and if relevant specify other parameters that should be considered.

3M DMSD Response to question 4:

3M is not currently developing QD solid state illumination products and cannot speak to these applications and questions posed in 4.

Oeko-Institut Question 5:

The applicants and a manufacturer of a substitute candidate have provided information as to the compounds used in Cd-free and Cd-based technologies relevant to the exemption requests, and as to their potential

hazardousness and toxicity. Please state with which of the views presented you agree or disagree and explain why;

3M DMSD Response to question 5:

When discussing potential toxicity of Cd-free and Cd-based technologies, 3M believes the scope of the RoHS exemption reassessment should be limited to the substances present in the applications being evaluated. The toxicity of elemental and related compounds are only relevant if the hazards of the elemental or related compounds are in fact, applicable and appropriately bridged to the specific compounds present in the quantum dot applications being evaluated. The cadmium in this application is present in the core of the dot in the form of cadmium selenide. This core is surrounded by a ZnS shell and the core-shell structure is further modified by a ligand. As stated previously by 3M, there are no data regarding the toxicity of this specific quantum dot; therefore, 3M believes it is not appropriate for Nanoco to imply that the hazards of elemental Cd are relevant to the Cd-based quantum dots without any evidence to support that conclusion.

The first Nanoco statement[22] 3M respectfully disagrees with is, "Cadmium accumulates in the body, so that even low-level exposure builds up over time to dangerous levels." This statement has no applicability to 3M QDEF. There is no consumer exposure, not even low level exposure, to cadmium from QDEF when the product is used as intended; therefore, QDEF will not contribute to Cd accumulation in the body. Further, 3M believes that this is an oversimplified and potentially misleading statement regarding cadmium toxicokinetics. Alternatively, in the Supplemental Statement of Life Cycle Analysis and Comparison of Cadmium, Cadmium Selenide, vs. Indium Phosphide for Color Conversion in Displays provided by QD Vision[23], the toxicokinetics of cadmium, although not relevant to consumer exposure to Cd from QDEF, are accurately described.

3M also respectfully disagrees with Nanoco's statement[24], "The severe hazards posed by cadmium, in all its forms, are of course recognized in the RoHS Directive itself, in which the allowed level of cadmium is restricted to a level 10 times lower than other toxic heavy metals, such as lead and mercury." The hazards of the RoHS listed heavy metals are well established and 3M finds no purpose in attempting to establish which of the heavy metals is potentially the most harmful based on the RoHS limits. The potential health risks associated with heavy metals are dependent on many factors (e.g. specific compound exposed to, duration and level of exposure, extent of absorption, etc.) and cannot be predicted from regulatory limits. As far as 3M is aware, the difference in the maximum

22 http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_10/Cd_QD_Exs_Nanoco_Response_to_RoHS_Questions_27_Oct_2015.pdf, page 10

23 http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_10/Cd_QD_Exs__QD_Vision_d_QDV_Supplemental_Life-Cycle_Analysis.pdf

24 http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_10/Cd_QD_Exs_Nanoco_Response_to_RoHS_Questions_27_Oct_2015.pdf page 10

concentration limits for cadmium and the other RoHS substances is historical and is not based on their relative toxicity. The cadmium limit pre-dates RoHS, originally in the marketing and use directive, which is now part of REACH. The original reasons for the choice of 0.01% is not known (this was previously used by the Marketing and Use Directive, 76/769/EEC), but is likely to have been chosen as a value that would prevent intentional use.

The RoHS limits for Cd, Pb, Hg, CrVI, PBB, and PBDE were not included in the original directive. The limits were agreed by Member States and the Commission at a meeting in London and the results became a Commission Decision[25]. The 0.1% limit in homogeneous materials (for Pb, Hg, CrVI, PBB, and PBDE) was agreed upon as being sufficiently low to prevent deliberate use, while allowing naturally occurring impurities (e.g. lead in commercial tin metal) and making chemical analysis for market surveillance straightforward to carry out. The limit chosen for cadmium was the previous Marketing and Use Directive limit value to ensure that EU legislation is consistent. This decision was not based on the relative toxicity of the substances.

3M would also like to point out that it is not possible to evaluate the toxicity of the Nanoco CFQDs, as Nanoco has not disclosed the composition of their dots. In addition, the acute oral study, skin and eye irritation studies, and mutagenesis/genotoxicity studies referred to by Nanoco fall well short of the toxicological studies that would be needed to establish a lack of potential hazards for Nanoco's CFQDs. In order to establish that Nanoco's CFQDs lack significant inherent human health hazards, the following endpoints would need to be addressed: acute toxicity via dermal and inhalation exposure, sensitization, target organ toxicity (single and repeat dose), reproductive and developmental toxicity, *in vivo* mutagenicity, and carcinogenesis. Without data demonstrating a lack of hazard associated with either the quantum dots themselves or the components of the dots, it is possible that the Nanoco CFQDs are equally hazardous, and thus a regrettable substitution, when compared to Cd-based quantum dots.

Finally, 3M questions the relevance and accuracy of the Nanoco statement[26], "InP is a compound of the 2 elements indium and phosphorus. When InP based QDs are burned or dissolved the indium and phosphorus are separated and form different compounds that are not classified as carcinogenic, so the hazard is neutralized." Firstly, the anticipated use of QDEF does not include burning or dissolution of the quantum dots; therefore, the burning and dissolution scenarios are not relevant to this reevaluation. That said, 3M would expect that exposure to the smoke and fumes from any burning electronic display to be harmful, regardless of quantum dot used, and that hazards created by the thermal degradation of burning plastics and other components would not be

[25] Commission Decision 2005/618/EC http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32005D0618&from=EN

[26] http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_10/Cd_QD_Exs_Nanoco_Response_to_RoHS_Questions_27_Oct_2015.pdf page 12

significantly increased by the presence of either a Cd-free or a Cd-based quantum dot. Secondly, 3M questions the appropriateness of stating that the hazards of InP are neutralized when the compound is dissolved. Nanoco has provided no information on what conditions are required to dissolve an InP-based quantum dot and how a person could be exposed to this dissolved InP. Further, in the two-year animal bioassays and repeated dose toxicity studies which the cancer, reproductive toxicity, and target organ classifications for InP are based on, the hazards of InP were clearly not neutralized, demonstrating that biological conditions are not sufficient to "dissolve" InP and neutralize the hazards. If a comparison is to be made between Cd-based and Cd-free quantum dots, the comparison should be of InP and CdSe, not elemental forms of the compounds unless as stated previously, these have been demonstrated to be relevant.

3M certainly recognizes and agrees with Nanoco and the general scientific consensus that there are significant human health hazards associated with elemental Cd and some cadmium compounds. However, 3M strongly disagrees with Nanoco's general implication that using Cd-based quantum dots in QDEF film creates a human health risk for consumers using products containing QDEF. As 3M has repeatedly stated, there is no consumer exposure to the CdSe-based quantum dot in QDEF film and without exposure, there is no health risk. Moreover, human health risk is dependent on total exposure from all life cycle phases. 3M LCA shows that the impacts from the Cd QD display option are less negative for most life cycle impacts than with the alternatives.

3M believes that QD Vision has prepared a thorough and generally accurate response to the Oeko-Institut regarding the potential hazards and toxicity of cadmium, cadmium selenide, and indium phosphide in the QD Vision Responses to Oeko-Institut Regarding Exemption 39B and Supplemental Statement on Life Cycle Analysis and Comparison of Cadmium, Cadmium Selenide vs. Indium Phosphide for Color Conversion in Displays documents. [27]

One minor difference between 3M and QD Vision was noted in the "Classification Section" response to question 4c regarding human health hazards. In their response QD Vision states "Based on the CLP classification principles and considering the 28-day rat oral study, CdSe, could be classified as acute inhalation and dermal toxicity Category 4..."

Compared to QD Vision, 3M considers CdSe to be more hazardous than they do. In our first response to Oeko-Institut 3M classified CdSe as Acute Toxicity Inhalation Category 3, Acute Toxicity Oral Category 3, Acute Toxicity Dermal Category 4, and Specific Target Organ Toxicity – Repeat Exposure Category 2. These classifications are based on the most severe of the harmonized generic classifications for cadmium compounds and selenium compounds. However, 3M was not aware of

[27] http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_10/Cd_QD_Exs__QD_Vision_d_QDV_Supplemental_Life-Cycle_Analysis.pdf

the 28-day oral study on CdSe. Now, considering the 28-day oral study, 3M would classify CdSe as Acute Toxicity Oral Category 4 and retain the other classifications of Acute Toxicity Inhalation Category 3, Acute Toxicity Dermal Category 4, and Specific Target Organ Toxicity – Repeat Exposure Category 2.

Most importantly, 3M concurs with the following statement in QD Vision's Supplemental Statement on Life Cycle Assessment, "It is critical to note that the core/shell/ligand CdSe QDs have properties that are distinct from CdSe as well as Cd or other Cd-containing compounds." Given the unique properties of various core/shell/ligand quantum dots, their toxicity or lack thereof will depend on multiple physiochemical factors as well as environmental conditions. Therefore, correctly predicting the *hazards* of either an InP-based or CdSe-based quantum dot in the absence of toxicological data is difficult. While it may seem preferable to replace a compound containing cadmium with an unidentified compound without known human health hazards, it is possible that there is no hazard reduction from replacing the cadmium containing compound, and that the replacement may be a regrettable substitution. Nonetheless, since there is no exposure to quantum dots in 3M QDEF during typical use phase, the film poses no health *risk* to consumers.

The environment and health are also positively impacted indirectly by the quantum dot technologies. As previously presented, the Cd QD display TV has lower energy consumption compared to the standard LCD TVs, which reduces the electrical energy needed. Environmental and health benefits compared to the current situation with standard LCD TVs would be achieved by a reduction in cadmium emissions to air and in solid waste due to lower electricity consumption, as well as from a reduction in the amounts of the other toxic substances present in coal and oil and greenhouse gas emissions.[28]

Oeko-Institut Question 6:

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 in the scope of the requested exemptions (and among others in the scope of Ex. 39);

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.

3M DMSD Response to question 6a:

3M's original exemption dossier[29] section 5 evaluated the following possible alternatives:

[28] Socio-economic assessment for Cd QD displays, Dr. Paul Goodman, Edif ERA, 2015-0001, REG0273001, page 4

[29] 3M(2013) Application for RoHS Exemption: Cadmium in LCD Quantum Dot Light Control Films and Components. Available at http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_IX/Request_2013-5/3M_QDEF_Exemption_Dossier.pdf

5.1 Traditional LED LCDs with More Absorptive Color Filters
5.2 RGB LEDs
5.3 Hybrid LEDs
5.4 Wide Color Gamut White LEDs
5.5 Cadmium Free Quantum Dots
5.6 Other Types of Displays – OLEDs and Plasma

The dossier details the limitations and concludes that these alternative approaches are not feasible as substitutes. For the reasons described in the dossier, QD films used in display technology are the superior technology to provide large color gamut displays for all applications.

Further, for the case of "cadmium free" or InP quantum dots, it has been shown again (confirming the original dossier's assertion) that in the use phase cadmium containing quantum dot systems are significantly more efficient and require less power. The analysis given above for commercially available TVs shows an approximate 35% increase in average luminous efficiency for the cadmium containing technology, which results in these cases to an approximate 26% reduction in average power. A recent presentation given at the 23rd International Display Workshop uses computer modeling and measurement methods and confirms an approximate 35% increase in average luminous efficiency for cadmium containing technology.[30] This decrease in required power during the use phase has been shown by life cycle analysis to result in cadmium containing quantum dot systems having a net positive environmental impact as compare to InP technology.[31]

3M DMSD Response to question 6b:

3M and 3M's technical partners are actively researching/developing a non-Cd based solution(s) that can meet requirements for future UHD broadcast TV and BluRay™ (Rec 2020) standards in conjunction with meeting energy efficiency targets. 3M is not a supplier of QDs and eagerly awaits a viable non-Cd based solution. When a viable non-Cd QD is available that meets our customer's requirements, 3M DMSD would convert to a non-Cd solution. Based on our extensive experience in manufacturing and commercializing display enhancement films, a very aggressive time estimate for the conversion to non-Cd technology would be up to 5 years. Significant scientific and engineering work will be needed to successfully commercialize a film product. This includes new resin designs, coating scale-up, and sufficient time to test industry desired product life times of 30,000 hours. After the Cd free QD film is fully qualified, additional time is needed to design, specify, and qualify non-Cd film into a device and yet more time is need before the devices would appear on store shelves.

3M has demonstrated that each of the criteria of *Article 5(l) (a) have been met even in light of recent market changes; therefore, the original recommendation by the EU Commission to grant the*

[30] Thielen, J., et Al., "ITU-R BT.2020 Color in LCDs with Today's Technologies: A Comparative Analysis." The 23rd International Display Workshop. December 8th. Fukuoka Japan. 2015

[31] Project Pandia- LCA0014, Version 1 Effective date: 31-Dec-2015,

exemption is still valid. With the introduction of new color standards and repeated delay in commercialization of non-Cd based alternatives by QD material manufacturers, the original exemption expiration date of June 30, 2018 is not sufficient to ensure reliable substitution in the market. 3M therefore respectfully requests a positive recommendation from the forthcoming reassessment granting an exemption for 5 years from the time of completion of the reassessment.

Please contact me at (651) 736-2768 if there are any additional questions.

Sincerely,

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