QD VISION RESPONSES TO QUESTION BY OEKO-INSTITUT REGARDING EXEMPTION 39.B

Abbreviations and Definitions

QD	Quantum dot(s)
CdSe	Cadmium selenide
InP	Indium phosphide (formerly referred to as “cadmium-free” in other documents)
CdSe QDs	QDs including a CdSe core typically surrounded by a semiconductor shell
InP QDs	QDs including an InP core typically surrounded by a semiconductor shell

Background

QD Vision welcomes the opportunity to respond to the questions of Oeko-Institut regarding the exemption for cadmium-containing QDs in displays. With the recent market introduction of televisions using InP QDs, it can now be definitively and independently confirmed that significant performance differences exist between CdSe and InP QDs, and that no real non-cadmium containing alternative display material to CdSe QDs exists on the market today - nor in the immediate future.

QD Vision bases this assertion on following key criteria for comparison:

- *Performance* – New wide colour gamut standards are emerging (e.g., AdobeRGB, DCI-P3 and Rec. 2020) that will enable important improvements to the European economy in areas including, but not limited to, medical diagnostics, e-commerce, design and entertainment. Only CdSe QDs provide the capacity to achieve these wider colour gamut standards, thereby allowing Europe to remain competitive with other regions including the U.S. and Asia.
- *Energy efficiency* – InP QDs are not a reasonable alternative to CdSe QDs as they do not and will not, in the foreseeable future, be able to match the energy efficiency gains achieved by CdSe QDs.
- *Safety and environment friendliness* – As a result of these energy-efficiency gains, the use of CdSe QDs actually reduces the amount of elemental cadmium as well as lead (Pb), mercury (Hg) and greenhouse gases released into the environment. In addition, InP is classified as a 1B probable human carcinogen.
- *Cost and economics* – CdSe QD solutions can be delivered at a significantly lower cost, allowing for much greater market penetration and customer access across display applications.

With the recent market introduction of Samsung televisions based on InP QDs, Oeko-Institut will now finally be able to respond to European Parliament’s request for a full and comprehensive comparison of potential alternatives to today’s CdSe QD solutions.

QUESTION 1

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.

QD Vision Response:

QD Vision respectfully disagrees that the original comparison was not balanced. Oeko-Institut and the contributing stakeholders did the best that could then be done with the information that was available at the time. Under the terms of the RoHS directive, the fact that a technology was not available on the market automatically meant that it could not be considered an alternative. In this respect Oeko-Institut was more than generous in taking into account the hypothetical and untested (independently in any case) qualities of Nanoco's technology.

QD Vision also respectfully believes that using the terms "CdQD" and "Cd-free QDs" is not appropriate. The comparison is between CdSe QDs, now on the market through QD Vision and used in displays from Thomson, Hisense, Philips, and others, and InP QDs now used in products on the market from Samsung. As mentioned above and discussed below, the use of CdSe QDs actually reduces emissions of the elemental cadmium in the environment, while the use of InP produces potential negative environmental side effects that have prompted a call to phase out InP and classify it as an improper substitute. The terminology is better expressed as a comparison between "cadmium selenide-based quantum dots and indium phosphide-based quantum dots."

a. Please provide information regarding the availability of Cd-based and Cd-free products for display applications using these technologies that have become available on the market since the review was finalised in 2014, please specify what products have become available (display type, dimensions and other characteristic aspects for clarifying the performance class).

QD Vision Response:

The availability of displays (monitors and televisions) is complex due to the complicated distribution practices of the manufacturers. In the first tab of the annexed file [1] we have provided an overview of all the QD-based displays available globally. In the second tab we have highlighted those available on the market in Europe as of 20/10/2015. At the time of writing this response, two televisions and one monitor have been commercially launched. Their delivery to customers is not expected before November 2015.

CdSe displays available on EU market

1) Current model televisions:
    a. Thomson : 55UA9806
2) Televisions to be launched in October/November 2015:
    a. Hisense : based on K7100
3) Current model monitor:
    a. Philips : 276E6.

InP displays available on the EU market

1) Current model televisions
    a. Samsung UN55JS9000F[2]

In the appended file[3] QD Vision has included all models known to (have been[4]) available in Europe or that will be available very shortly (by end 2015). The testing of all the displays has been done in accordance with European norms[5] and expressed in several different ways.

The models referenced are those known to QD Vision and reportedly available in Europe and/or globally. However, two additional caveats must be noted:

[1] QD Product List 20 October 2015.xlsx

[2] This is the only Samsung TV model tested by QDV to date which has been confirmed to include InP QDs. Samsung advertises several models with Nano crystal range but, based on testing by QDV of some of these (JS7000 series) to date, at least one of such models was not found to actually have QDs in it. There are a further set of Samsung TVs (JS9000, JS9100, JS9500, JS8600, JS8500) which possibly have InP QD films but not all have been tested and no determination has been made either way. All Samsung products of those ranges are marketed as nano-crystals colour technology but this does not imply (apparently) that they have InP QDs.

[3] Display Characterization Summary.xlsx

[4] To our knowledge, Sony models are limited to distribution in Japan at this time.

[5] IEC 62087 referred to in directive 1062/2010 with regard to energy labeling for televisions.

First, QD Vision is not aware of any QD-based monitor on the market in Europe other than the CdSe monitors from Philips referenced in our attachments. As to televisions, the only quantum dot televisions purported to be on the market other than those based on QD Vision's CdSe QDs are televisions based on InP QDs made by Samsung.

Second, for the purposes of this exemption request, QD Vision recommends the reassessment be based on a direct comparison of the CdSe QD and InP QD technologies, not the qualities of the displays in which they are included. While the displays can give some indication of certain colour qualities of the QD technologies, they displays do not permit a fair and complete comparison of the underlying QD technologies themselves. For example, aspects of the display design, e.g., panel choices, optical film choices, and LED selection can all influence the overall system efficiency and colour. Therefore, we strongly urge Oeko-Insitut to look beyond the performance of the display products on the market as their performance is influenced by factors other than the QDs alone which can give rise to misleading conclusions. We will enter further into this matter in our answer to question 1.c.

b. ***For products mentioned in a, please clarify if products are still on the market or please explain why distribution was discontinued.***

QD Vision Response:

To our knowledge all products are still on the market.

c. ***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.***

QD Vision Response:

We refer to the letter we sent dated 01.07.2015 to summarise the primary parameters to evaluate the technologies. Primarily focusing on component level comparisons for the reasons explained in our letter, the parameters required for a comparison are external quantum efficiency and FWHM ("full width at half maximum") of emission. If a system level comparison is also of secondary value, parameters of importance become:

- luminance efficiency (i.e. Nits/Watt) of the electronic device; and
- % coverage of NTSC colour gamut area.

A summary of results is also attached[6], which utilize both methods of comparison (component level and system level). To properly isolate the comparison from any potentially confounding variables, QD Vision strongly encourages OEKO to repeat the studies we have performed whereby:

- an InP-based QD film taken from a Samsung television (model # UN55JS9000F) is placed in a Hisense television (model # LED55XT910X3DUC) originally configured with a CdSe-based QD film from 3M, and

- a CdSe-based QD film from 3M taken from the aforementioned Hisense television is installed in the aforementioned Samsung television originally configured with an InP-based QD film.

[6] QD Television Benchmarking.doc

The results of this test demonstrate the dramatic disparity in performance between the CdSe-based QD film from 3M and the InP-based QD film used by Samsung. Swapping the CdSe-based QD film into the Samsung television originally configured with an InP-based film results in a 32% increase in luminance (resulting from the higher efficiency of the CdSe-based QD film) and an increase in color gamut from 91.7% to 101.3% NTSC area (resulting from the narrower emission spectra from the CdSe-based QD film).

These results are supported by component-level testing, whereby the CdSe-based QD film is found to be significantly more efficient than the InP-based film (EQE of 73% vs. 57%) and to have much narrower emission spectra (FWHM for green and red of 33 and 37nm, respectively, for the CdSe-based QD film, compared to 41 and 55nm for the InP-based QD film).

QD Vision emphasizes that screen quality and the ability to exceed NTSC c.q. meet AdobeRGB or REC 2020 is not an aesthetic aspect, but a crucial criteria for the assessment as it is the linchpin of performance and competitiveness and critical for Europe to remain current and competitive in such fields as medical diagnostics, e-commerce and entertainment.

The future of screen technologies is tied to improved quality displays where today's high-end displays are able to produce only 30% of the colours visible to the human eye. With QD Vision QDs, displays approaching 60% of the human visible colour gamut are possible, allowing for a whole host of new applications that are currently impractical.

We have included a deeper explanation on the importance of the quality of displays.[7] However, in an effort to keep it simple, there are a few key drivers:

- Diagnostics – medical and otherwise – rely in a large part on colour. Higher display quality improves the precision and therefore impact of these technologies;
- Audio-visual productions, whether artistic or of sports and events, have become consistently more popular as screen quality improved; and
- E-commerce is materially affected by the quality of displays as this in part drives their tremendous return rate.

Today's cameras are already capable of capturing still and video images with a much larger range of colours than can be displayed by all but the highest-end displays today. It is this display limitation that is restricting innovation and the introduction of new services to the market. Like HDTV, the availability of the technology will drive the demand in the beginning. However, in a time where most humans spend more time looking at a digital display than another human being, improving screen quality is crucial. To ensure that Europe remains competitive in this increasingly digital society, it needs the higher quality screens for innovation, performance, competitiveness, jobs and, of course, energy savings.

d. ***For the products mentioned in a), please provide detailed information as to the parameters specified in c), including for example performance related to energy consumption, light and colour output parameters, comparison of hazardous material aspects; etc.***

QD Vision Response:

We include, in a separate attachment the comparison made by QD Vision of the different model televisions and their respective QD components. To summarise the main conclusions:

[7] Importance of Quality in Displays.pdf

- *Energy efficiency* -- on a like-for-like (e.g., InP-based QD film vs. CdSe-based QD film) basis, displays configured with CdSe QDs provide a minimum of 30% savings in energy compared to the InP products of Samsung. When factoring in colour quality differences, the energy savings is over 40%.

- *Performance* – As of today, InP QDs have been able to present just over 90% of the NTSC colour space. Televisions in the market today using CdSe QD solutions have been shown to exceed the 100% of the NTSC colour space. As important, today's colour standards are getting wider as the industry embraces broader colour spaces such as AdobeRGB and DCI-P3. No InP QD-based display has fully delivered either of these colour gamuts. Slightly farther out, a growing number of industry leaders are creating new products and technologies to satisfy an even larger colour gamut defined by a standard called Rec. 2020. CdSe QDs are the only known, commercially-accessible path to Rec. 2020;

- *Safety and environmental friendliness* -- To address these aspects, QDV attaches a full LCA we have performed to compare the two substances. In fact, using the very small amounts of Cd in the CdSe in this application, while effecting the energy reduction, produces a net *reduction* of environmental releases of Cd, Hg, Pb, and greenhouse gases to the benefit of all Europeans. CdSe QDs could potentially be made from recovered NiCad batteries or solar panels such that they represent a true example of a "circular economy."

  In contrast, indium is not nearly as recyclable and is classified as a 1B probable human carcinogen. Indium is on the list of the next class of substances meriting bans in Europe. In addition, the Swedish organisation ChemSec has indicated that insofar as InP would be used in substitution for other substances of concern this would be a 'regrettable substitution.' InP has been proposed for inclusion into RoHS. In short, there are no safety or environmental benefits associated with substituting InP for CdSe. In fact, there would be substantial environmental disadvantages from such a substitution.

- *Cost and economics* – As presented above, QD Vision emphasizes, that Oeko-Institut should also consider the economics of integrating these technologies in displays. Today, because of their inability to tolerate high temperature and flux conditions, InP QDs have only been implemented in displays by being sandwiched between two layers of oxygen-barrier film. Because of the cost of this film, an InP QD solution will cost a television manufacturer over $120 for a standard 55" diameter television. Alternatively, CdSe QDs are more stable at higher temperatures and flux levels – and can therefore be mounted closer to the LEDs, and at significantly lower costs. Today, a CdSe QD solution for a 55" television costs about one-third of the cost of an InP QD solution.

  This price differential will prevent ubiquitous acceptance of InP QDs due to two limiting factors:

  1. OEM manufacturers cannot afford to incorporate a component >100$ in a low or medium end product.

     According to data from the European Commission,[8] the average price of a European television hovers around 400-500€. According to the same source the average price for a monitor is 130-180€. A display of average cost cannot integrate a component that costs 100€ per unit. The products with InP on the market today are very high end Samsung Televisions. We have found prices varying from a low of €1,790 to highs of in excess of €15,000. As of the writing of this response the only price available regarding a CdSe TV was the Thomson model that is

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[8] http://ec.europa.eu/eurostat/documents/272892/272992/Consumer+Prices+Research+-+October+2015/badc06ab-bf87-47c9-bc8d-0ef57666dd8c

coincidentally also priced at €1790. Due to the multiplier effect (x3 is the usual estimate) of base material costs in the end price, an InP QD accounts for at least 15% of the final cost for Samsung's TVs. By contrast if we apply that calculation to the Thomson television, we find it's CdSe QD-based solution accounts for around 5% of the final cost. If these percentages were extrapolated to lower priced models the economics of InP become completely unviable. An OEM will therefore only integrate this technology in a top range and top price model.

For monitors, the situation is even more extreme. One of the best quality monitors available in the market today is the Dell U2713H both in terms of display quality. The Dell monitor is available in the market for prices around 700-800€ . The Philips QD Monitor 276E6 which outperforms the Dell model both in terms of screen quality and massively in terms of energy efficiency (2x in efficiency)[9] is on the market for only 309€. Attempting to place an InP QD based monitor on the market would leave the manufacturer a negative margin even compared to current high end priced models. The CdSe monitor by comparison is at the high end of average prices today but the difference is not so material that it cannot eventually come down to the average price. The conclusion is that OEMS will price InP QD displays at several times the average price of a standard product and therefore these products will not gain substantial market share.

2. Price elasticities for displays will yield a similar conclusion to the above. For the purposes of this calculation we need cross-substitution elasticities which are usually calculated internally by OEMs. As business confidential information this is rarely available however there is one study which gives meaningful data for televisions.

Table 6: Demand Estimates

	Sony 32in HD	Vizio 32in HD
Own Elasticity (Lower)	-0.83	-0.94
Own Elasticity (Upper)	-0.61	-0.72

The difference between the elasticities relates to the branding. Sony is a better known brand than Vizio on a global basis. This reflects in the willingness of a consumer to pay. Even if we presume Samsung's brand is as strong as Sony's then even at its current launch price economic models would predict a market share below 1% of the total market for the Samsung TV. If we take the final cost of incorporating the technologies into the display we get the following result:

A CdSe QD-based component will cost an OEM around $40 and therefore account for $120 in the final product price. At current prices this would account for at worst is a 20% increase in the price of a final product based on the average prices referenced above. Applying the above elasticities we can estimate that the CdSe QDs – ceteris paribus – can achieve 81.2%-87.8 %. An InP-based component costs around 120 or $360 in final product which is an increase of ca. 65% in the final product. On the basis of the same calculation a maximum market penetration of 38.9-59.9% could be achieved.

This means that, because of their cost, InP QDs are highly unlikely to achieve significant market penetration in the foreseeable future. Beyond the fact that InP QDs cannot meet CdSe QD colour performance and energy efficiency, their inability to withstand temperature and flux conditions near the LED prevents them from achieving the cost structure needed to deliver on the immediate energy and environmental promise of CdSe QD solutions.

[9] Adobe Monitor Comparison.pdf

Aside from today's significant performance and societal advantages, it is likely that these differences will continue to expand with time, because of the fundamental chemical and physical advantages that CdSe QDs have over InP QDs. CdSe QDs are moving closer and closer to the LED chip as stability improves, allowing for far more efficient optical designs than InP films make possible – and InP stability limits its ability to keep pace with these innovations. CdSe bandgap of ~1.8eV allows for a fundamentally narrower bandwidth and hence superior colour qualities than InP's bandgap of ~1.3eV, which forces InP QDs to be in a more highly confined regime of quantum mechanics. The efficiency and stability benefits ensure that the environmental footprint of CdSe will remain smaller than that of InP over time, as less and less CdSe is required to do the same work as 40-400x more InP. And all of the above contribute to the economic benefits of this technology.

e. ***If possible, please provide a comparison of similar products of the two technologies to support your views as to if the exemption requests mentioned above are justified according to the Article 5(1)(a) criteria.***

QD Vision Response:

'Similar' products are not available, due to the incredible diversity of TV options. As noted in 'c', our report cited in 'd' makes the relevant comparisons, while also making a best-effort at comparing at the TV level.

Simply put Art 5(1) requires that to be considered a substitute technology, any possible alternative must:

– be scientifically and technically practicable;
– reliability must be ensured; and
– the total impact on health/environment should be positive.

As detailed above, InP QDs do not satisfy any of these criteria.

Indeed, rather than compete with CdSe QD-based displays in performance, energy savings, safety and environmental friendliness or cost, InP QD-based televisions do not perform significantly better than today's RGphosphor-based displays. There are inherent limitations in InP that make it extremely unlikely for them to improve far beyond what they currently can do;

Energy efficiency -- The inability of InP QDs to tolerate high temperatures and flux in a display makes it infeasible to use them for on-chip or on-edge QD solutions, severely limiting their capacity to deliver the energy savings of today's CdSe QD-based solutions;

Safety and environmental friendliness -- Absent the energy savings and the corresponding reduction of elemental cadmium, and with its reliance on a regrettable potential substitute that is classified as a 1B probable human carcinogen , InP QD-based products do not come close to the environmental safety and friendliness potential of CdSe QDs;

Performance -- We have also shown that the indium phosphide units cannot come close to delivering the level of colour performance necessary to allow Europe to continue to be competitive, modern and healthy in the 21st century in terms of medical testing, ecommerce, entertainment and modern technology demands.

Price/cost – we have demonstrated that there is no way for indium products to be available to the average European consumer in monitors or televisions in the foreseeable future.

In sum, the total impact of substitution is significantly adverse because InP QDs do not yield quality or energy efficiency benefits that even approach those of CdSe QDs, while the risks associated with the use of a probable human carcinogen can only be considered a huge mistake. Furthermore the cost of the technology is prohibitive for broad introduction and widespread acceptance in displays.

QUESTION 2

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 lighter or darker hues; etc.) or darker.

QD Vision Response:

QD technologies have no impact on standby status of televisions because both are passively illuminated (whether film or on edge) hence there is no difference there. The main impact of the technologies is felt in full filmic modes and where particular parts of the spectrum are more solicited than others. InP for example has difficulty creating the green spectrum whereas CdSe is more comprehensively covering.

We have already answered in 1.c. above what we believe the standards should be. For screen quality the NTSC and Adobe RGB should be used as basis for measurement. QD Vision believes the REC 2020 standard is now so close to adoption that it should be drawn into the comparison.

QUESTION 3

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 use in the future in solid-state illumination applications.

QD Vision Response:

QD Vision is currently serving only the display market. Because our original request for extension of exemption 39 covered a broader set of uses for QDs, and because we have had a product in the lighting market in the past, we previously gave some answers on this matter. At this time, we are aware from our competitors and/or supply chain partners that there are significant efforts on-going efforts in the industry towards several lighting products that would enter the market in 2016. For example, there are Cd-containing QD LEDs for illumination in development and expected to hit the market in late 2016 from a major LED manufacturer. As the specifics of this information are not ours to share, we strongly encourage Oeko-Institut to ask this question in the public commentary period, so that stakeholders engaged in this space can contribute directly.

Given the promise of CdSe based QDs entering the market in 2016, their potential energy savings, and the lack of time for a separate proceeding focused solely on lighting, we strongly encourage consideration of an exemption for CdSe QD-based lighting products, on its own merits separate from displays, but in the same timeline as this continuing assessment of the application that we made in December of 2012.

QUESTION 4

Regarding Cd-based QD materials that have been developed for use in articles relevant to the exemption requests above, please provide the following information:

a. ***Please state what substances are used in Cd-based QD applications of relevance and clarify if such substances are currently in use in products that are available on the market in general and in particular that are expected to remain available on the market in the coming years;***

QD Vision Response:

QDV's CdSe QDs include a CdSe core with a cadmium zinc sulphide shell and organic surface ligands, in its products now, and we expect this technology to remain on the market. We believe that Cd compounds such as CdTe will remain in the economy due to their use in solar panels. Furthermore, there are other uses of Cd that remain permitted such as NiCd batteries, solar panels and in certain types of electrical connectors. Therefore the recycling of Cd will remain part of the circular economy and the approval of our exemption for very small amounts of Cadmium compared to those other sources will have no negative effect.

b. ***If more than one type of Cd-based material is used in QDs in relevant applications, please provide information and data to allow a comparison of the performance of all alternatives (or at least of alternatives understood to be on the market or market ready by the end of 2015);***

QD Vision Response:

They are not different – please see above.

c. ***Please provide information regarding hazardous properties related to substances used, particularly in relation to classifications, Annex XIV and Annex XVII entries relevant to the REACH regulation.***

QD Vision Response:

The following information is summarized from the Supplemental Life Cycle Assessment annexed to this submission by QDV[10]. Please consult that document for further details and references.

Cadmium selenide (CdSe; CASRN 1306-24-7; EC number 215-148-3) is the substance used in the II-VI semiconductor manufactured by QDV. In its commercial application in displays and televisions it is coated with a hydrophobic ligand, homogenized into a lauryl methacrylate (LMA) polymer and sealed in a glass optic.

CdSe is stable and the release of Cd(II) ions is very small in the absence of electron acceptors under reducing conditions. CdSe is subject to photo- and air oxidation and generates free radicals and therefore, gradual dissolution of CdSe can occur in the presence of electron acceptors such as oxygen. CdSe is insoluble in water. Dissolution of CdSe is pH-dependent, but the dissolution rate of CdSe is very low even under the most favorable acidic pH and/or aerobic conditions.

There is not a significant amount of information on the toxicity and health effects of exposure to CdSe in the public literature. It is generally assumed that the systemic toxicity of Cd compounds is attributed to the Cd(II) ion. A few existing studies indicate that the oral bioavailability of CdSe is

[10] QDV Supplemental Life-Cycle Analysis.pdf

very low and its adverse health effects depend primarily on Cd(II) ions released from CdSe and free radicals generated from photo- and air oxidation of CdSe. A 28-day oral (sub-chronic) study in rats showed that CdSe did not cause any toxic effect at doses of 30, 300 and 1,000 mg/kg/day. No chronic studies are available on CdSe.

Classification

CdSe is not specifically identified in Annex VI, Table 3.2 of the Classification, Labeling and Packaging (CLP) regulation, rather its classification is based on the categories of "cadmium compounds" and "selenium compounds."

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, Acute aquatic Category 1 and Chronic aquatic Category 1. CdSe is classified as much less hazardous than the classification for cadmium itself.

More important, the homogenous material is the appropriate level for classification. The homogenous material in QDV's optic tube placed in display units has been determined by multiple RoHS testing laboratories to be the polymer matrix with <0.2% w/w Cd in CdSe QDs, with no residual free cadmium. At this level, none of the thresholds for the various toxicity endpoints are triggered. Considering the hazard classes and assuming that the polymer itself is not classified, the overall classification for the homogenous material is **not classified**.

REACH

CdSe is not yet registered under the European Union's Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) regulation due to its low production and import volume and that its hazard profile does not dictate an earlier registration. To date, it is unclear if CdSe will be registered under REACH. A comprehensive hazard and risk assessment of CdSe is not available under the EU regulatory framework.

CdSe is not listed in REACH Annex XIV (Authorization).

CdSe is not listed in REACH Annex XVII (Restriction).[11]

QUESTION 5

Regarding Cd-free QD materials that have been developed for use in articles relevant to the exemption requests above, please provide the following information:

a. ***Please state what substances are used to substitute Cd in QD applications of relevance and clarify if such substances are currently in use in products that are available on the market in general and in particular that are expected to remain available on the market in the coming years;***

QD Vision Response:

Samsung products have all been stated to use InP/ZnS materials, and this is consistent with QD Vision's own testing of these products. Nanoco purports to use In+mix of main group elements. We presume

[11] Although Cadmium is listed in REACH Annex XVII (Entry no. 23, page 228) when used in mixtures and articles containing certain organic polymers, the LMA polymer that the QDV QDs are homogenized with is not one of the listed polymers.

this to be InP with a mixture of ZnS blended in, but there are NO products on the market that use their materials, world-wide, as of their annual report dated 10/13/15.

We expect InP compounds to become progressively less available on the market due to their likely inclusion in future substance restrictions under RoHS and REACH legislation. Furthermore as they are very difficult to recycle it is likely that emphasis on the circular economy will further reduce the availability of these compounds long term.

b. ***If more than one type of Cd-free material is used in QDs in relevant applications, please provide information and data to allow a comparison of the performance of all alternatives (or at least of alternatives understood to be on the market or market ready by the end of 2015).***

QD Vision Response:

We do not believe there are other QD capable substances on the market in relevant applications. Many have been tried, but the down-converting effect is a function of the specific properties of the element which are unique.

c. ***Please provide information regarding hazardous properties related to substances used, particularly in relation to classifications, Annex XIV and Annex XVII entries relevant to the REACH regulation.***

QD Vision Response:

The following information is summarized from the Supplemental Life Cycle Assessment submitted by QD Vision. Please consult that document for further details and references.

The only “Cd-free” QD known to be on the market in display applications is indium phosphide (InP; CAS# 22398-80-7; EC Number 244-959-5). InP is insoluble in water, soluble in simulated gastric fluid and hardly soluble in simulated lung fluids.

In a well-conducted two-year bioassay by NTP, InP was shown to cause pulmonary inflammation associated with oxidative stress, epithelial cell damage, and lung, adrenal and liver cancers when administrated via inhalation in experimental animals.

InP was determined to be a 1B probable human carcinogen based on well-conducted inhalation toxicity studies in experimental animals. The evidence includes high incidences of malignant neoplasms of the lung, adrenal and liver in rats and mice exposed to InP as low as 0.03 mg/m^3 and for as short as 22 weeks. Analysis of genetic alterations in InP-induced hepatocellular adenomas and carcinomas revealed increases of mutation frequency in β-catenin[26]. Several studies suggested that InP-induced oxidative stress may play an important role in the pulmonary carcinogenesis of InP. There are two cohort studies reporting cancer incidence increased in workers in the semiconductor industry, InP was one of the possible carcinogens workers were exposed to. One study showed increased incidences of skin and rectum cancers in workers at West Midlands, England. The other showed increased incidences of lung and stomach cancers in female workers in Scotland.

As to potential effects on fertility, there are no multi-generation reproductive toxicity studies available. However, repeated dose toxicity studies in hamsters via intra-tracheal instillation showed a decreased sperm count, decreased weights of testes and epididymes, and histopathological lesions in the testes. InP was also shown to accumulate in the rat testis following inhalation exposure. In addition, intravenous administration of ionic In to pregnant rats, mice and hamsters has been reported to produce teratogenic and/or embryolethal effects.

Mild eye irritation may result from exposure to its dust or vapor. Ionic In is concentrated in the kidneys, producing renal failure; colloidal In is taken up by the reticuloendothelial system, causing damage to the liver and spleen. Ionic In has been shown to produce marked ultrastructural damage to the endoplasmic reticulum of both hepatocytes and renal proximal tubule cells, with associated disruption of heme metabolism and hemoprotein function.

Occupational exposure limits for In set by ACGIH, NIOSH and agencies around the world is 0.1 mg/m^3 time-weighted average of threshold limit value (TLV) or recommended exposure limit (REL).

InP is under consideration for inclusion as a restricted substance on Annex II of RoHS.

Classification:

InP was subject to a harmonized classification proposal sponsored by France and reviewed by the Risk Assessment Committee in 2009 in association with EU CLP regulation. The harmonized classification of InP is Carcinogen 1B (H350), Reproductive toxicant Cat 2 (H361f), and specific target organ toxicity (STOT) Repeat (RE) Cat 1 (H372).

REACH:

InP is not yet registered under REACH. A comprehensive hazard and risk assessment of InP is not available under the EU regulatory framework.

InP is not listed in REACH Annex XIV (Authorization).

InP is not listed in REACH Annex XVII (Restriction).

In all fairness the risks of InP and CdSe should not be exaggerated – particularly in the QD form that they have they present no hazard to the user or the environment. Only at the point of recycling can there be an issue of exposure to workers however this is not materially different from far greater risks involved in recycling work. It is arguable that as a suspected carcinogen, the vastly higher quantities required and due to its lower recycling rate InP is the slightly more harmful substance. What further argues in favour of CdSe is that by being on the market further reduction steps are being taken and it is possible that the 0.01% concentration limit will be met in the not too distant future. For these developments to happen the technology must remain on the market at this critical stage.

The correct comparison is therefore to be based on the reduction of harmful uncontrolled Cadmium from fossil fuels burning. That Cadmium is definitely not in a remotely safe form and all of us are routinely exposed to it with all the concomitant risks of osteoporosis and so forth. Although paradoxical in a way, the use of a very tiny amount of contained CdSe can help reduce the exposure of all Europeans to much larger amounts of uncontrolled cadmium.

Summary List of References in This Document

QD Product List 20 October 2015.xlsx

Display Characterization Summary.xlsx

QD Television Benchmarking.doc

Importance of Quality in Displays.pdf

Adobe Monitor Comparison.pdf

QDV Supplemental Life-Cycle Analysis.pdf