SOCIO-ECONOMIC ANALYSIS

Of the impacts of non-renewal of Lead (Pb) exemption for test & measurement industrial type products (Category 9) Exemption 4 – Annex IV

SUBSTANCE: Lead (Pb)

CAS: 7439-92-1

FROM: Test & Measurement Coalition (TMC)

INTENDED USE: in glass frit of X-ray tubes and image intensifiers and in glass frit binder for assembly of gas lasers and for vacuum tubes that convert electromagnetic radiation into electrons.

DATE: 20 January 2023

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Exemption 4 – Annex IV

PROJECT TITLE:
Socio-economic analysis of the impacts of non-renewal of Lead (Pb) exemption for the test & measurement industrial type products category 9, Exemption 4 – Annex IV

VERSION:
20 January 2023

PREPARED FOR:
Test & Measurement Coalition (TMC)

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CITATION:
EPPA, '*Socio-economic analysis of the impacts of non-renewal of Lead (Pb) exemption for the test & measurement industrial type products category 9, Exemption 4 – Annex IV*', Report for TMC, January 2023

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CONTENTS

ABBREVIATIONS

BaO: Barium Oxide
B2B: Business-to-Business
CAR: Competent Authority Report
CAGR: Compound Annual Growth Rate
COTS: Commercial Off-The-Shelf
CTE: Coefficient of Thermal Expansion
EEE: Electrical and Electronic Equipment
EBIT: Earnings Before Interest and Taxes
ECHA: European Chemicals Agency
EU: European Union
EUR: Euro (currency)
NPV: Net Present Value
PCA: Printed Circuit Assembly
PCB: Printed Circuit Board
Pb: Lead
PbO: Lead Oxide
R&D: Research and Development
RoHS: Restriction of Hazardous Substances in Electrical and Electronic Equipment
SEA: Socio-Economic Analysis
SEAC: Committee for Socio-Economic Analysis
SME: Small and Medium Enterprise
T&M: Test & Measurement
TMC: Test & Measurement Coalition
WEEE: Waste from Electrical and Electronic Equipment

1. SUMMARY OF SOCIO-ECONOMIC ANALYSIS

Purpose and methodology

RoHS stands for Restriction of Hazardous Substances and impacts the entire electronics industry and many electrical products. The principal RoHS, also known as Directive 2002/95/EC,[1] originated in the European Union in 2002 and restricted the use of six harmful chemical substances in electric and electronic equipment (EEE), allowed in the EU market. Test & measurement instruments (current Category 9 - industrial) were initially excluded from the scope of RoHS 1. Moreover, **in 2011, the RoHS 1 was revoked and replaced with Directive 2011/65/EU,[2] which is known as RoHS-Recast or RoHS 2. It expanded the scope of products covered in RoHS 1 and imposed new obligations on EEE importers and manufacturers by adding Categories 8 (medical devices) and 9 (monitoring and control instruments).** RoHS 2 included a long transitional period for Category 9 industrial products, extending to mid-2017. On 4 June 2015, the European Commission Delegated Directive (EU) 2015/863[3] amended Annex II of EU RoHS 2 by adding four additional phthalates onto the original list of six restricted substances. Category 9 – Industrial equipment again required an extended transition period before these additional substance restrictions applied in July 2021.

Industrial test and measurement instruments are very different from low mix, high-volume consumer products which are frequently re-designed to follow consumer trends and are placed on the market for a limited duration. Industrial test & measurement (T&M) are high mix, low volume producers, managing portfolios of thousands of highly complex instruments. Each instrument is intentionally designed for high reliability and serviceability to support long useful lifespans and are made available on the market for at least a decade. In comparison with other categories of equipment in scope of RoHS 2, **Category 9 – Industrial equipment contributes a fraction of one percent of the total annual quantities of RoHS substances.**

[1] Directive 2002/95/EC of the European Parliament and of the Council of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32002L0095.

[2] Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (recast) Text with EEA relevance. Available at: https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX:32011L0065.

[3] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015L0863&from=EN.

In line with the **existing official guidance from ECHA on the preparation of the Socio-Economic Analysis,**[4] **this SEA aims to gather technical and economic information to describe ex-ante in both qualitative and (if feasible) quantitative terms the (orders of magnitude of) socio-economic impacts T&M members as well as the relevant EEA supply chain and society are expected to face from the non-renewal of lead (Pb) exemption in glass frit of X-ray tubes and image intensifiers and lead in glass frit binder for assembly of gas lasers and for vacuum tubes that convert electromagnetic radiation into electrons, which would otherwise expire on 21 July 2024.** It has been performed by EPPA[5] at the request of Test & Measurement Coalition (TMC), in view of providing regulators with strong evidence-based findings on the expected social and economic impacts that are expected to occur should the use of lead (Pb) be impacted by the non-renewal of the RoHS exemption.

This SEA is based on information and data gathered from the industrial and professional test and measurement equipment manufacturers. **A survey has been conducted** by providing a detailed questionnaire to gather information and data from actors likely to be affected by a non-renewal of the RoHS exemption in the EU.

TMC manufacturers of industrial and professional test and measurement equipment have participated in the survey. The market share covered by this survey represents approximately **70%** of the EEA market. The assessment is, therefore, highly representative and can serve as a basis for defining the anticipated socio-economic impacts resulting from the non-renewal of the RoHS exemption.

The participating companies indicated that the exemption 4 (Annex IV) information reported in this SEA is relevant for the industrial applications in the following product groupings and corresponding equipment types:

- ***Laser Interferometers and Calibration Systems*** (Monolithic Laser Combiners & Precision Optics).
- ***Application-Specific Test Systems and Components.***
- ***Used Equipment in the above categories.***

TMC members have been carefully instructed to base their statements and estimations as much closer to real data or perception of future changes as possible, so as to have conservative estimates, always putting the protection of the human health and environment upfront.

This SEA covers the safe use of test and measurement equipment, the technical difficulties associated with their substitution via alternatives, the social and economic impacts at different level of the supply chain, and the EU macroeconomic impacts.

Main findings

[4] The ECHA Guideline for the SEA preparation as a part of Application for Authorization is available at: https://echa.europa.eu/documents/10162/23036412/sea_authorisation_en.pdf/aadf96ec-fbfa-4bc7-9740-a3f6ceb68e6e ; The ECHA layout for an SEA to be used in Application for Authorization is available at: https://echa.europa.eu/documents/10162/13637/sea_format_with_instructions_v4_en.docx/0cbc5102-6ba2-2170-480a-0061d2798f55

[5] www.eppa.com

It is shown that there are currently no suitable lead-free alternatives that meet RoHS exemption criteria on the EU market for test & measurement industrial type products and that **re-designing of the test & measurement equipment could take approximately four years if an alternative is found.** Hence, losing the ability to apply Annex IV, exemption 4 when considering RoHS conformity for the associated test and measurement industrial products would entail the development of a radically different design using new alternative compliant materials as well as the increased costs connected to the redesign, retesting, requalification, and replacement of the assembly process, or cessation of sales to the EU.

Overall, the **total impact of a non-renewal is monetized in the range of 15 million EUR and 40 million EUR** (conservative estimates in net losses; potential gains for suppliers of other components have been already taken into account), consisting of:

- **[CONF.]** EUR of economic impacts (EBIT loss) on test and measurement industrial type products' manufacturers;
- **[CONF.]** EUR of substitution costs for test and measurement industrial type products manufacturers.
- **[CONF.]** EUR of social impacts (i.e., unemployment in the EU-27).

2. AIMS AND SCOPE OF THE SEA

2.1 Purpose, scope and methodology of SEA

RoHS stands for Restriction of Hazardous Substances, and impacts the entire electronics industry and many electrical products. The exemptions listed in Annexes III and IV must adapt to scientific and technical progress as defined in article 5 of Directive 2011/65/EU.[6] This application is specifically for the **renewal of Annex IV exemption 4, Lead in glass frit of X-ray tubes and image intensifiers and lead in glass frit binder for assembly of gas lasers and for vacuum tubes that convert electromagnetic radiation into electrons**, which would otherwise expire on 21 July 2024.

A survey has been conducted by providing a detailed questionnaire to gather information and data from industrial and professional test and measurement equipment manufacturers likely to be affected by a non-renewal of the RoHS exemption in the EU.

[6] Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (recast) Text with EEA relevance. Available at: https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX:32011L0065.

The participating companies have provided socio-economic data in view of extrapolating (based on a large total market share) the impacts for the whole market in a conservative approach, as further detailed below. Based on the weight of RoHS substances used in their products, the market share covered by this survey represents approximately 70% of the EEA market. **The estimates reported in this socio-economic analysis should be considered as a minimum (lower bound) of the expected impacts of a non-renewal of Annex IV exemption 4.**

From a geographical perspective, this analysis focuses on the European Economic Area (EEA) territory, comprising the European Union (EU-27), Iceland, Liechtenstein, and Norway. One has followed "SEAC's approach to assessing changes in producer surplus".[7] As there is no alternative available in general (SAGA)[8] to lead (Pb), one has considered a **4-year time horizon for this assessment**, starting from the year 2024, (year of the expiry of the current exemption). In other terms, the SEA accounts for the costs and benefits to the EEA society in the event of RoHS substance is not granted the renewal of the RoHS exemption in test and measurement industrial type products.

Future monetary values have been estimated by using the concept of net present value (NPV), adopting a 4% annual discount rate, which is the standard discount rate, adopted by the European Commission and European agencies (e.g., ECHA) in impacts assessments. All monetized values have been adjusted to a base year, assumed to be 2024. Information and data have been aggregated and anonymized. Statements and estimations from the participating companies are as close to real data or perception of future changes as possible.

2.2 Overview of industrial test and measurement instruments and their value chain

General overview

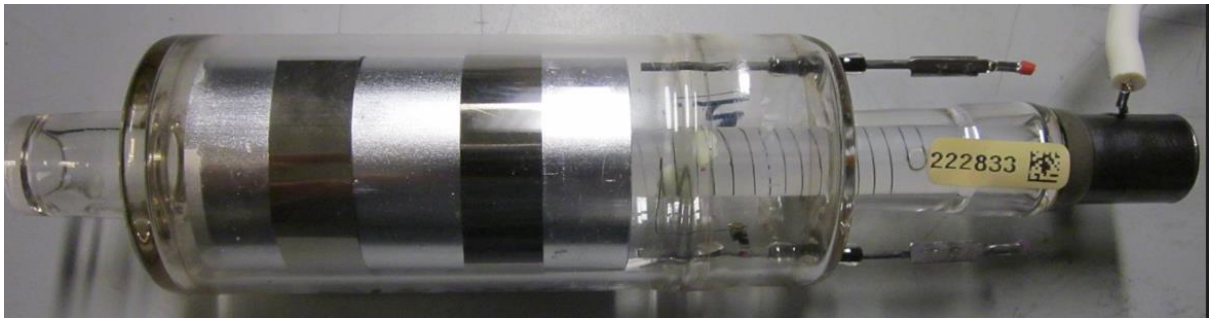
Industrial test and measurement instruments (category 9 – Industrial under the RoHS Directive) are very different from low mix, high-volume consumer products which are frequently re-designed to follow consumer trends and are placed on the market for a limited duration. Industrial test and measurement are high mix, low volume producers, managing portfolios of thousands of highly complex instruments. Each instrument is intentionally designed for high reliability and serviceability to support long useful lifespans, and are made available on the market for at least a decade. These instruments are designed: exclusively for professional and industrial use; to meet high performance requirements in critical applications; and last up to 40 years. Redesign is not frequent and happens every seven years on average (as compared to every 1.5 years or less for consumer products). Once test and measurement instruments are placed onto the market, they are typically accompanied with a long-term customer support arrangement to maintain reliability and calibration.

This renewal request is specifically relevant to gas lasers. These precision lasers have high spectral purity and stability that are 100% custom developed and produced. There is a broad range of

[7] https://echa.europa.eu/documents/10162/0/afa_seac_surplus-loss_seac-52_en.pdf/5e24c796-d6fa-d8cc-882c-df887c6cf6be?t=1633422139138

[8] https://echa.europa.eu/documents/10162/13637/ec_note_suitable_alternative_in_general.pdf/5d0f551b-92b5-3157-8fdf-f2507cf071c1

applications of these Category 9 – Industrial instruments: from Laser Calibration System for machine tools to Laser Interferometer Position Measurement Systems. However, the largest volume of shipments into the EEA relates to lasers designed specifically for use within semiconductor lithography products.



Example of laser tube.

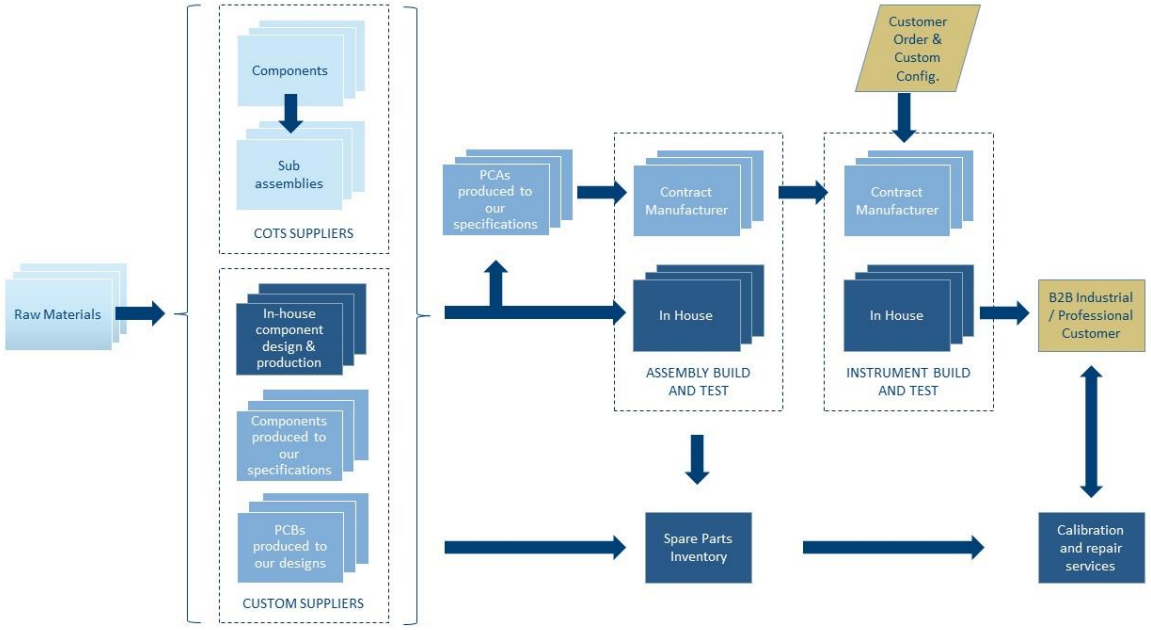
Semiconductor lithography products are fundamental to the production of silicon chips used throughout the electronics sector, creating patterns on silicon for the mass production of integrated circuits.

Considering the EU added-value, test and measurement equipment is manufactured and sold in relatively small volumes (per instrument design) and placed on the global market. There is an added value in community level action, which guarantees more coherent and consistent rules across Europe. But with the expansion of RoHS-like requirements beyond the EU, this creates a risk of discrepancies in RoHS-like national laws adopted in third countries.

These precision lasers have their own development lifecycle and take years to bring into production. When producers are unable to deliver compliant parts that meet current RoHS regulations, the product would be stopped from being sold into the EU.

Typical supply chain

The typical supply chain for test and measurement industrial type products is as follows:



- Raw materials are manufactured globally for component production.
- For laser tubes, glass frit is purchased from a specialty materials company.
- Each batch is tested for its non-documented characteristics, such as processability, brittleness and coefficient of thermal expansion.
- The frit is sent to a subcontractor that produces preforms to custom specifications.
- The preforms and raw frit are used to assemble the laser tube into a housing. This is custom-made in-house according to Test & Measurement designs and specifications.
- Assemblies are built and tested in-house.
- In response to customer orders or for inventory, finished devices are configured, built, and tested at a single site for global distribution.
- End products are supplied into the EU market either directly or through distributors to industrial and professional customers (B2B market).
- Spare parts are made available from the supply chain and utilised in the ongoing support (including servicing, calibration, repair, and refurbishment services) typically provided in-house by Test & Measurement members. Laser assemblies are often refurbished to replace the laser tube, which has a typical lifespan of 5 years.

3. ANALYSIS OF ALTERNATIVES

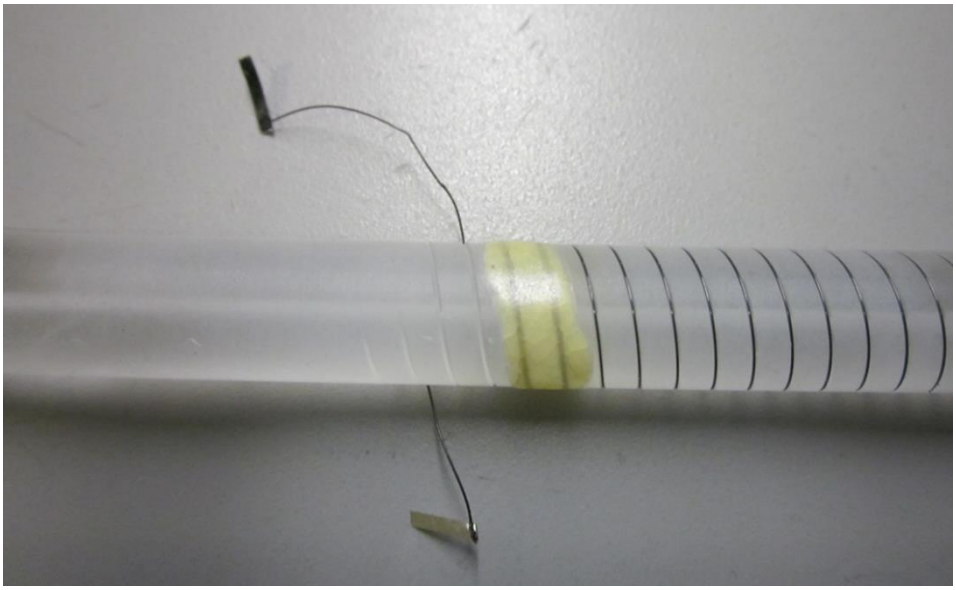
3.1 Function and technical performance of Lead (Pb) and lead-based industrial type 9 products

Exemption 4, Annex IV is used for a few critical applications. Precision lasers with high spectral purity are manufactured with a borosilicate glass rod with glass frit containing lead oxide (PbO) to connect this glass to the metal pieces of the assembly. PbO glass frit has a low melting point and excellent wetting characteristics, which achieves a thermally matched bond of the glass rod to other

components in the manufacture of precision lasers without damaging or distorting the glass. The materials and heat cycle for attaching glass to metal must be precisely controlled to avoid stresses caused by thermal expansion differences.

The coefficient of thermal expansion (CTE) for each material – glass, metal and frit – is slightly different. The higher the temperature, the more these different expansions induce stress either in heating to melt the frit or in cooling after the seal is made. This stress leads to fracture of the seal or the glass. The composition of the glass and the process are therefore carefully controlled to achieve a low stress product.

Example of metal attached to laser tube. The glass frit used for this attachment is not visible.



Heater wire is attached to laser tube with PbO-containing glass frit.

Function of lead (Pb)

The unique characteristics of Pb in glass frit in lasers is vital to successful manufacturing of long-lasting lasers. The specific advantages of lead are:

- Melting point below 490°C, allowing usage with borosilicate glass which has a maximum processing temperature of 500°C, and avoiding damage to the sensitive optics. Alternatives melt at 540°C (for example bismuth Bi-based frit) or higher.
- Good match for coefficient of thermal expansion, which reduces stresses and prevents cracking of the seal or the glass. Heating of the laser rid tunes the cavity length. Thermal expansion and contraction of the heating element / glass frit / glass rod must be closely matched to allow for this tuning and to prevent damage.
- Good wetting, allowing penetration into tighter spaces and effective sealing. Bi-based frit flows poorly below 540°C.

In highly precise, spectrally pure lasers, a heating element is attached to the glass rod to adjust the rod length to allow tuning; this attachment also uses PbO-based glass frit. In the electronics industry, lasers are used in the manufacturing of semiconductors. Lithography using lasers creates patterns down to the nanometer scale. Lasers, such as from Industrial Monitoring and Control companies, are used for precision measurement of the alignment of etched layers, critical to integrated circuit manufacturing. The measurement uses interferometry, a technique that uses the interference of 2 light beams of very stable wavelength to make nanometer scale measurements. The measurement must be more precise than the feature being measured.

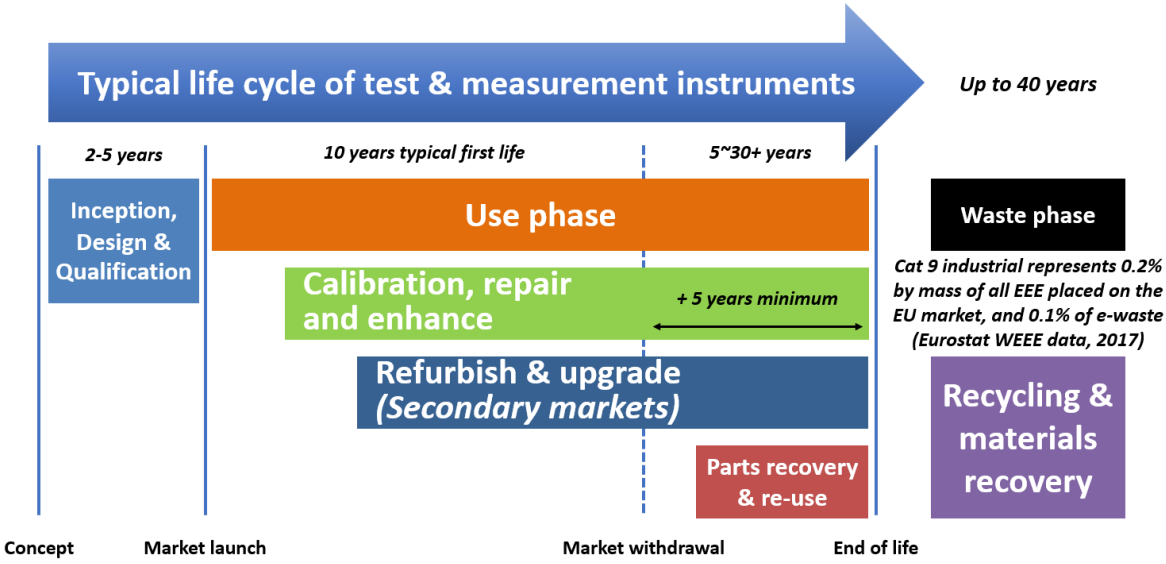
A further description of the lithography process and the use of laser for precise pattern generation in the semiconductor manufacturing process can is provided by ASML technology.[9]

Additionally, lithographic solutions in a semiconductor manufacturing facility may be considered large scale installations, however these customers of T&M companies require compliance to RoHS substance restriction limits within the products or subassemblies incorporated into these solutions.

3.2 Typical Industrial Test and Measurement End-to-End Life Cycle

The market sectors addressed by industrial test and measurement equipment can in some cases require that the instruments can be maintained in use for decades. The end-to-end lifecycle model below helps to illustrate how the members contribute to the circular economy by assuring the materials they consume to produce the equipment are kept in use for as long as possible.

[9] ASLM technology / Supplying the semiconductor industry https://www.asml.com/en/technology?icmp=navigation-homepage-link-technology



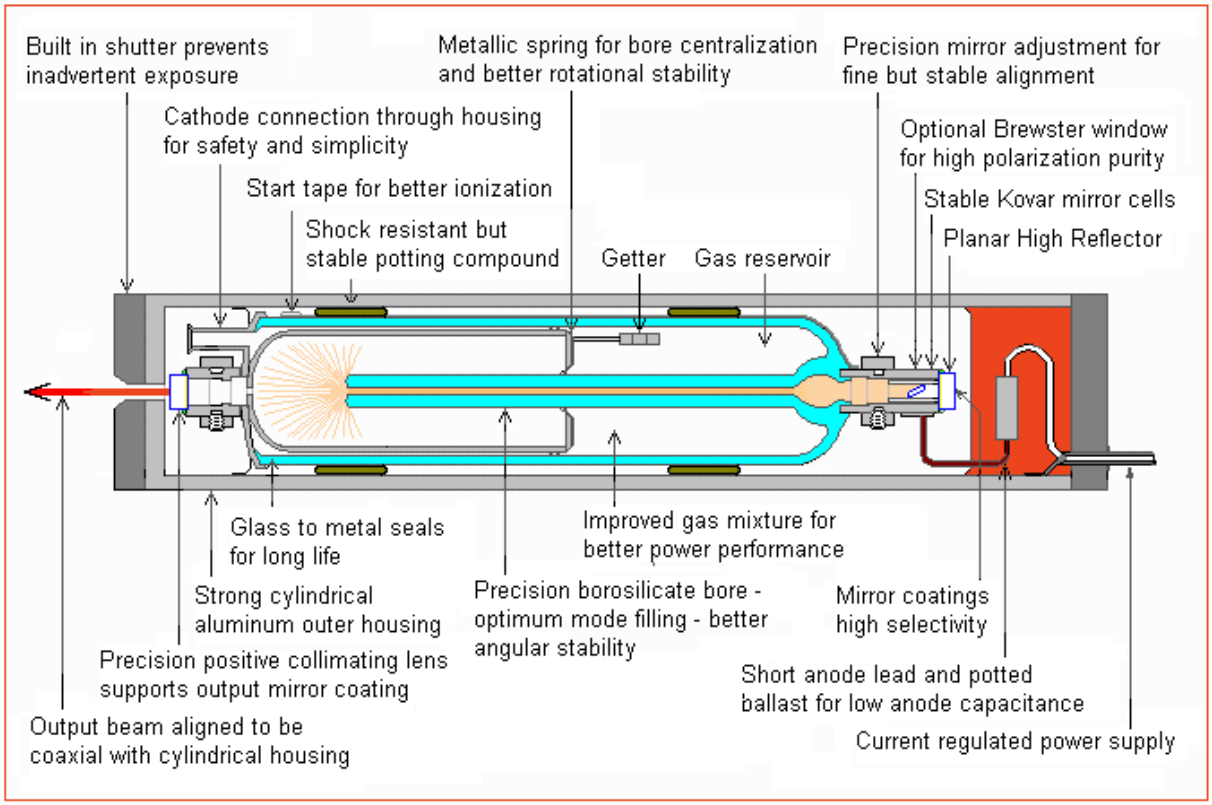
The nature of industrial test and measurement instrument applications demand highly accurate and reproducible results throughout their life. With a typical first use of 10 years and a total life of up to 40 years, great care is taken during the design and qualification phases to ensure that the stringent performance and reliability requirements are met and must incorporate design for serviceability. This provides a continuous supply chain of equipment for refurbishment with extended life through resale providing great economic and environmental benefit. Whilst the instruments are designed for long-term reliability, failures do occur during such an extended period of use requiring ability to service and replace parts. After market withdrawal, equipment is normally supported for a minimum of five years. Moreover, refurbishing and reselling on the secondary market are crucial in this sector and often account for 4–5% of producer turnover for test and measurement manufacturers.

Due to the cost, reliability, and unique applications of T&M equipment, many customers do not dispose of the equipment, but instead keep it for use at a later date or place it on the secondary market. Therefore, Category 9 Industrial equipment's contribution to the Waste Electrical and Electronic Equipment stream is very small (0.2% by weight of EU WEEE) with industrial WEEE being collected through B2B systems. Consequently, the environmental impact of industrial test and measurement products is insignificant. Nevertheless, test and measurement equipment does enter the waste stream, typically many decades after it is placed on the EU market.

3.3 Assessment of potential alternatives to lead (Pb)

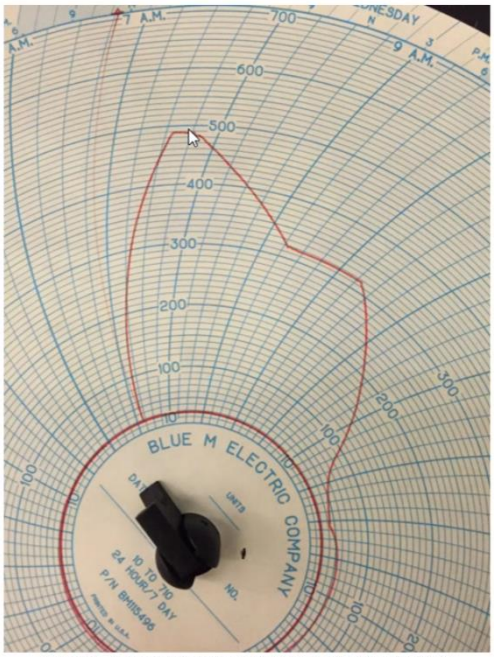
Glass frit bonding uses fine glass particles in a medium that acts as flux and enables adhesion to the mating surfaces. Alternatives that have been suggested or tried are barium oxide (BaO) with a melting point of 1923°C, or strontium oxide, melting point 2531°C.

However, these require processing at conditions well above the maximum workable temperature for borosilicate glass and coefficients of expansion are too different to be usable. PbO, on the other hand, melts at 880°C and when used as a flux in the joining of glass to other materials, it can be processed below 500°C.



Cross Sectional View of a Melles Griot HeNe Laser Head Showing Details of the Plasma Tube

Image from https://www.laserforum.cz/index.php?topic=1215.0. This is an example that shows the glass to metal seals which ensure the gases do not escape and the "borosilicate bore" that is heated to precisely tune.



Example: Program 3 Chart Recording for Primary Blue M Ovens

An example of the thermal profile used to form the glass-metal seal in a helium-neon laser[10] housed in borosilicate glass[11]. Note that the peak is at 490°C.

3.3.1 Challenges with substitution with alternatives

As outlined in the previous section, the companies have indicated that there are currently no suitable alternatives that meet the physical and technical performance criteria.

With the lack of alternatives for attachment of metal to glass for these lasers, some other method or fundamental design would need to be developed to achieve the necessary reliability.

The companies reported that for an alternative product design, the development time would take a minimum of 4 years. In addition, the validation of the alternative design would lead to the organizations incurring additional expenses. These include labour costs and costs arising from potential product resubmission requirements for testing to various notified bodies to ensure that substitution does not create any electrical and functional safety concerns.

3.4 Overall conclusion on suitability and availability of alternatives

As outlined above, the unique characteristics of lead make the substance a necessary part for the proper functioning of glass frit, which cannot be substitute with other substances.

While certain alternatives have been tested, such as barium oxide and strontium oxide, these cannot be considered as viable alternatives as their melting points (1923°C and 2531°C respectively) require processing above the maximum workable temperature for borosilicate glass. Additionally, their coefficients are too different to be usable.

To the best of knowledge of the Test & Measurement Coalition, lead therefore is the only substance which has the necessary physical and technical characteristics when incorporated in the glass frit to reliably assemble T&M precision lasers. A continuation of exemption 4 Annex IV is therefore warranted as the elimination or substitution of lead is scientifically and technically impracticable.

4. ANALYSIS OF IMPACTS

4.1 Human health and environmental impacts

Annex II of the Directive 2011/65/EU (RoHS) specifies the restricted substances referred to in Article 4(1) and maximum concentration values tolerated by weight in homogeneous materials. The maximum concentration value for lead (Pb) tolerated by weight in homogenous materials is 0.1% unless there is an application listed in Annex III or IV available to the product category of EEE.

[10] A technical overview of laser interferometry equipment can be found via this link

[11] Further information on the characteristics of borosilicate glass (tradename Pyrex) can be found via this link

TMC members stressed that approximately 90% of lead by weight is used in their homogenous materials. Overall, through application for which the exemption is requested, approximately 5.8 kg of Pb enters the EEA market every year.

Lead is considered to be a human carcinogen that has an impact on both the neurological and renal systems.

4.1.1 Reduction in the quantity of lead (Pb) placed on the EEA market

The participating companies have reported that no releases to the environment of lead can be anticipated during neither equipment production nor use phases of the concerned products over the next seven years as a consequence of the revocation of the RoHS exemption. During equipment production, the glass frit is carefully handled and waste is controlled. At frit manufacturers and at subcontractors making preforms from this frit, waste is controlled.

Under normal conditions of equipment use, the lead content associated with the application of Annex IV, exemption 4 is encapsulated within the equipment enclosure with finished equipment having lead bound in the glass matrix.[12] As this equipment is sold B2B for professional/industrial use only, equipment that finally reaches end-of-life will be appropriately processed by professional recyclers who are obligated to have suitable controls to avoid any environmental releases and are notified of the presences of the substance under the producers' obligation to provide a SCIP notification.

As a result of the participating companies' relatively low consumption of parts, in comparison to the product Categories 1-7 and 10, renewing this exemption for Category 9 will have a minimal impact on the environment. As previously indicated, Category 9 Industrial producers are only responsible for 0.2% of annual WEEE production. So, the number of components relying on this exemption that are specialized for test and measurement applications combined with their collective use provide a strong rationale to keep the specialist components, that rely on this exemption, in production. The manufacturing of specialist components will represent a minute fraction of the total exemption usage referenced in this report. The majority of the components that utilize this exemption, that constitute Category 9 industrial usage, are common to all product categories. The component manufacturers therefore rely on volume use of the other categories to justify their continued production. Renewing this exemption for Category 9 for the full 7 years will not extend the production life of these higher volume components beyond the exemption renewal period assigned to Categories 1-7 and 10. It will, however, enable the Test & Measurement coalition members to buy sufficient (relatively small) quantities to update the design and continue to use the relevant components for an extended period. As a result, a renewal of this exemption has a minimal environmental impact and has a positive socio-economic impact by enabling the continued production of Category 9 products whilst the multi-year redesign process is executed.

4.1.2 Additional waste in case of a non-compliant stock

[12] All substance is captured in sealed electrical enclosures and chemically or metallurgically bound in alloys, glasses, or ceramics.

The expected additional waste before the end of the regular lifetime (non-compliant stock) reported by the companies is estimated to stand at 30 kg, with consumption likely to continue for sale into non-EU markets. However, as there is no commercial technology alternative today, it is not possible to quantify the pollutants that would result from the shift to RoHS compliant products.

4.2 Economic impacts

The sections below provide a general overview of the social and economic impacts, considering business impacts (i.e., at different stages of the value chain), market impacts (i.e., on the product market), substitution costs, and broader macroeconomic consequences resulting from a potential non-renewal of RoHS exemption 4, Annex IV.

4.2.1 Business impacts on manufacturers

A survey was utilized in preparation of this report. **Data from TMC member companies have been received and aggregated**. These companies are among the biggest producers in the EEA test and measurement equipment market. The market share covered by this survey is more than 70% of the whole EEA test and measurement equipment market. The assessment is, therefore, highly representative. This market share can be used to obtain reliable estimates for the EEA market via extrapolation, as detailed below for the assessment of the economic impacts.

Due to the very specialized nature of the industrial test and measurement equipment, sales volumes are in many orders of magnitude lower than those of consumer products. Industrial test and measurement equipment are not subject to fast-paced changes in market patterns. TMC members have declared that there are **[CONF.]** unique product numbers that apply this exemption. During 2021, > **[CONF.]** units of these products were placed on the EEA market. This was a typical sales year and the volumes are considered representative for annual volumes. TMC members reported an average price of approximately **[CONF.]** EUR per product in the product group of Monolithic Laser Combiners & Precision Optics, therefore the monetized value of the products likely to be affected by a non-renewal of lead (Pb) exemption is expected to be approximately **[CONF.]** EUR.[13]

The average lifetime of products reported by TMC manufacturers is 10 years. A further 5 years of guaranteed support life follows discontinuance to assure availability of spare parts. Nevertheless, the products can remain in use by the customers for up to 40 years, supported by the companies' repair and calibration services. During service life, laser tubes are replaced approximately every 5 years. Service may include replacing an entire unit or refurbishing to replace only the laser tube. The removed units or tubes are appropriately handled.

[13] The calculation is based on the rounded value of the average and maximum price of the products that are going to be likely affected by the non-renewal of the exemption.

TMC members have declared that the non-renewal of lead (Pb) exemption would have significant impacts on their business and customers. The members further reported that due to the specificity of the equipment, there are no known methods to produce compliant lasers meeting the specific performance specifications of production today. Should the exemption not be renewed, this equipment would have to be withdrawn from the EEA market.

The direct cost of a non-renewal of the exemption is represented by the loss of the contribution to the EEA economy of the EBIT generated by manufacturers using lead (Pb). The relevant economic measure to quantify this economic impact is given by EBIT. The monetization (net present value, NPV, with 4% discount rate) of this economic impact (lost EBIT) is reported below.

Therefore, if Annex IV, exemption 4 would not be renewed,[14] it is estimated that **manufacturers of Monolithic Laser Combiners & Precision Optics would face a net EBIT loss of approximately [CONF.] EUR/year. Over four years**, the total impact is expected to be approximately **[CONF.] EUR** (NPV, 4% d.r.)[15] for **Monolithic Laser Combiners & Precision Optics' manufacturers**.

One can use the market share of the test and measurement equipment manufactured by the participating companies to extrapolate **the total economic impact in the EEA across all manufacturers.** The market share covered by this survey is more than 70% of the whole EEA test and measurement equipment market. This market share is used for the extrapolation of the impacts for the whole EEA market in a conservative approach. **The total impact for the EEA market (manufacturers of test and measurement equipment) would therefore be at least: [CONF.]** EUR x 1/0.70 = **[CONF.] EUR (rounded).**

Other companies may benefit from a negative regulatory outcome for lead, especially, competitors based outside the EEA. Because the RoHS restrictions would affect equally the whole EEA T&M industry, the corresponding loss in value added (i.e., loss in EBIT) can be considered an EEA industry-wide impact.

It must be noted that what occurs in Europe also has repercussions on other markets, such as the Asian market. This is because CE mark is used by T&M equipment manufacturers as evidence that their products are suitable for the EU and therefore are considered of acceptable quality in a non-EEA location. Consequently, the economic consequences of a non-renewal for Annex IV, exemption 4 would result in much larger impacts for the industry than those reported above.

[14] Companies were asked to consider how the revenues (and EBIT) for year 2022 were impacted under the assumption that a RoHS restriction on lead in test and measurement industrial products types were to be fully adopted with immediate effect (i.e., in 2023).

[15] Using the Excel function =PV(4%,4, -[CONF.],0,0).

Given the specificity and complexity of industrial test and measurement instruments, it is extremely challenging for the test and measurement sector to adapt to frequent changes of the lead restriction in scope. The main challenge that has been raised by the companies is the fact that deadlines provided by authorities are considered too tight for business adaptability and to develop alternative products. The existing maximum renewal duration of up to 7 years is considerably shorter that product development lifecycles. This renewal request is therefore made to cover the full seven-year maximum duration.

Market impacts

The revocation of Annex IV, exemption 4 from the EU market could lead to certain market distortions. A low number of suppliers could indeed lead to higher prices and supply chain dependences (monopoly or oligopoly), therefore sectors relying on this substance would be particularly affected.

As noted in Section 2.2, the vast majority of sales into the EEA relating to equipment utilizing Annex IV, exemption 4 is sold to EEA producers of semiconductor lithography products for incorporation into their finished equipment. If the exemption is not renewed, such sales would be prevented, having a direct impact on a critical tool in the production of silicon chips from within the EEA. Producers of such equipment located out of the EEA would not be impacted by such a future sales restriction.

Substitution costs for test and measurement equipment manufacturers

It is estimated that 2 years are needed to evaluate the suitability of potential alternatives and that additional 2 years are needed for implementing the substitution or concentration reduction of RoHS restricted substances if a substitution candidate could be identified.

Therefore, **TMC member companies have indicated that the implementation of substitution or concentration reduction of lead would cost approximately [CONF.] EUR**[16] for the companies due to the incremental investment necessary to characterize potential substitutes, and where practicable, tailor production processes to assure existing product's published specifications can be maintained.

In reality, the switching costs are likely to be much larger than this estimate. By making use of the market share of about 70% covered in this SEA, one can extrapolate a total switching cost of **[CONF.] EUR (rounded)** (= **[CONF.]** EUR * 1/70%) for all manufacturers of test and measurement equipment industrial products.

4.3 Wider economic impacts

[16] The replies from the TMC members were given in dollars (500,000 USD), therefore the ECB exchange rate on 16 January 2023 (1 EUR = 0.9249) was used for further calculations (500,000 USD * 0.9249 = 462,450 EUR). Available at: https://www.ecb.europa.eu/stats/policy_and_exchange_rates/euro_reference_exchange_rates/html/eurofxref-graph-usd.en.html.

It is also important to consider the wider macroeconomic impacts and consequences on the EU society at large, by focusing on the expected consequences for the EEA market. In particular, there are concerns on the overall EU trade balance (increase of imported test and measurement industrial product types) and on the competitiveness of EEA market.

Impacts on suppliers

The participating companies maintain a niche and vital supply chain: few actors supply the specialty glass frit for electronics manufacturing, and most assembly processes are completed in-house at the Test and Measurement companies. Qualification of each batch of new frit material requires several months of testing. The quantity used is small, purchases are rare and involve a batch size that will cover usage for a several years.

If **Annex IV, exemption 4** would not be renewed, **there would be little economic impact on frit suppliers**. They would simply lose these small and infrequent sales. Material suppliers currently have no recommendations for replacement and have no economic incentive to develop one.

In case of non-renewal, a substantial impact on chip producers, due to the non-availability of semiconductor lithography products (incorporating test equipment) exclusively needed for this sector, is to be anticipated.

Impacts on the market – Competitiveness

As the RoHS regulation applies to all producers equally when placing equipment on the EEA market and since the majority of the production is based outside of the EEA (mainly in the US), **a non-renewal of the Annex IV, exemption 4 for test and measurement industrial product types in the EEA would disadvantage the EEA markets in their competition with the rest of the world.**

Indeed, as other regions have RoHS-equal regulations which are not market restricting but rather mainly notification based, if the exemption IV-4 is removed, the risk is that customers of test and measurement equipment will be forced to move operations to other areas, such as, for example, the Asia-Pacific region. T&M equipment manufacturers' customer base is global and not limited to businesses located in the EEA. Their portfolio is often highly specialized and so is built at a single location and distributed globally.

Furthermore, non-EEA competitors would not be subject to restriction and would be able to supply and place on the international market a wider range of products, without bearing any redesign costs. Thus, non-EEA competitors are likely to gain market share if the restrictions are applied in the EEA market. In particular, the Asia-Pacific region could greatly benefit in terms of possibility of increasing their market share by taking advantage of the opportunity of additional production. **This gap in availability of products to the EEA will impact the ability of many to perform the necessary functions to compete with non-EEA markets.**

Impacts on the market – Innovation and R&D

The revocation of Annex IV, exemption 4 is expected to have wider impacts on innovation in Europe. A major use of the Category 9 products is for industrial research and development processes, both within private companies and for state sponsored research. The limited access to test and measurement equipment in the EEA will constrict investment in both innovation and commercialization of new technologies in a wide variety of sectors, from life science to chemical and from engineering to material science. The limited access to test and measurement equipment in the EEA will be the main driver for investment in both the development and production of all electronic equipment to other non-EEA regions. This will have a market impact on the innovation and the know-how in the EEA. The removal of products from the market due to the non-renewal of exemption 4, Annex IV will therefore have a **direct negative impact on the research and innovation output within the EEA.**

A possible non-renewal will, as noted before, influence the EEA market's competitiveness and significantly affect the sales of the companies. The significant reduction in sales as a result of a possible non-renewal of **Annex IV, exemption 4** will have an inevitable negative impact on R&D investments. Therefore, based on the assumption that the percentage of revenue spent remains the same, the loss of sales to the EEA market will result in a decrease in R&D spending. Moreover, the manufacturers have further noted that the current geopolitical situation, supply chain disruptions and the inflated cost of materials has already resulted in a cut in R&D investments. The non-renewal of the exemption would solely exacerbate the lack of and decrease in R&D funding.

The current R&D efforts and resource would inevitably be redirected towards redesigning legacy products to accommodate alternate component and will only exacerbate the lack of and decrease in funding R&D for T&M equipment products. This would **adversely affect the resources available for new product design and innovation, as the limited R&D resources available would be spent on responding to a non-renewal instead**.

It is anticipated that chip producers would be particularly impacted due to the non-availability of test equipment exclusively needed for these sectors. the electronics industry has increasingly emphasized the importance of increasing investment and lowering supply chain dependence on manufacturing in other regions (i.e., the recently proposed EU Chips Act). Within this context, **a non-renewal of Annex IV, exemption 4 would be a significant step back for innovation in the semiconductor industry.**

Impacts on the market – Trade

When assessing this aspect, it is important to consider the trade balance of the EU. **A non-renewal of this exemption in the EEA would disadvantage European companies in their trade with the rest of the world.**

A non-renewal of **Annex IV, exemption 4** would effectively prohibit precision laser suppliers from doing business in the EEA. The greatest direct impact would be on the semiconductor producers whose core business is to provide such items to the electronics market. Reduced product volumes from equipment producers would impact profitability (reduced volumes vs. fixed costs) of contract manufacturers.

The non-renewal of **Annex IV, exemption 4** would also have a significant impact on EU-based businesses that also rely on lead-based materials to make precision micro machining technically feasible. A non-renewal would hamper the EU's relative importance as an exporter and trading partner for the goods and industries mentioned above.

The exports from the EEA would be particularly hard hit by a potential restriction (non-renewal of the exemption). As a result, the **overall EU trade balance would be adversely impacted**.

4.4 Social impacts: unemployment

The restriction of lead will not have a direct impact on the headcount of the manufacturer companies. The headcount is dynamically changing based on different factors, including customer relationships, opportunities and market dynamics.

In general, it is difficult to estimate the unemployment because this depends on whether the end user market can be addressed in the future with products that do not rely on **Annex IV, exemption 4** and if that transition is capable of retaining the same precise product specifications and reliability performance.

However, the TMC manufacturers declared that a non-renewal would very likely lead to unemployment within the companies. With the loss of business, action would be deemed necessary to reduce workforce, especially high-skilled (e.g., scientists, engineers, microbiologists, and quality experts. It is estimated that, assuming a RoHS restriction is implemented, approximately **[CONF.]** highly skilled workers in the companies participating in the survey will face layoff in the EEA. Here we report the monetization of the likely social costs of unemployment for these workers.

For the purpose of this SEA, it is assumed that the average annual salary across these European workers (including the employer's social security contributions) is **[CONF.]** EUR.

A well-known guideline in monetizing the social impact of unemployment has been developed by the European Chemicals Agency (ECHA) for evaluating such impact in different regulatory processes.

Estimates have been made in accordance with the ECHA document on the evaluation of unemployment (SEAC/32/2016/04)[17] and the paper of Dubourg (2016)[18] endorsed by ECHA. Therefore:

[17] ECHA (2016). The Social Cost of Unemployment. Available at: https://echa.europa.eu/documents/10162/13555/seac_unemployment_evaluation_en.pdf/af3a487e-65e5-49bb-84a3-2c1bcbc35d25

[18] Richard Dubourg, 2016. Valuing the Social Costs of Job Losses in Applications for Authorization. The Economics Interface Limited.

- Using Table A7 (column G, considering the gross wages including the employer's social security contributions) in Dubourg's paper, the total social cost of unemployment in EU is equal to 2.16 times the annual gross salary.[19]
- Table 1 presents the statistics from Eurostat (data for 2021-Q3) on the average duration of unemployment for both men and women in the age of 15-64 years in EU-27.[20]
- Only 75% of the average duration of employment is considered, to reflect the fact that some affected workers are highly skilled and could find employment sooner.

Table 1:

Duration Grouping	Thousand units	Proportion (A)	Assumed duration (B)	Weighted average (A*B)
Less than 1 month	1328.5	0.096128799	0.5	0.048064399
From 1 to 2 months	2585.5	0.187083936	1.5	0.280625904
From 3 to 5 months	2175.0	0.157380608	4.5	0.708212735
From 6 to 11 months	1953.3	0.14133864	8.5	1.201378437
From 12 to 17 months	1637.8	0.118509407	14.5	1.718386397
From 18 to 23 months	640.3	0.046331404	20.5	0.949793777
From 24 to 47 months	1651.0	0.119464544	35.5	4.240991317
48 months or over	1848.6	0.133762663	48	6.420607815
Total	13820.0	1		**15.56806078**

The social costs of unemployment would therefore be equal to:

[CONF.] EUR x **[CONF.]** people x 2.16 x 15.56806078/12 x 75% = **[CONF.]** EUR.

Although companies along the supply chain would face a reduction in sales over the years, we assume for simplicity that the entire workforce will continue working for other three years. Therefore, we discount the monetized impact derived above by three years due to the assumed delay in the layoff, using discount rate of 4% per year, as follows: **[CONF.]** EUR x $(1 + 0.04)^{-3}$ = **[CONF.]** EUR.

As reported above, the test and measurement industrial type products' manufacturers (participating in the survey) use in total 5.8 kg per year of lead related to the application of Annex IV, exemption 4. One can use the tonnage (proxy for market share) of test and measurement industrial products to extrapolate the total social impact of the unemployment in the EU across all T&M manufacturers: **[CONF.]** EUR x 1/0.70 = **[CONF.] EUR (rounded).**

[19] This value is greater than one (1) because it takes into account the following components: lost wage, costs of job searching, recruitment costs, the impact of unemployment status on future wages (scarring effect) and employment possibilities, and leisure time (which is a benefit and therefore subtracted from the previous components).

[20] Data extracted from http://appsso.eurostat.ec.europa.eu/nui/show.do?wai=true&dataset=lfsq_ugad

We can affirm with a high likelihood that the total social impact of a restriction of lead used in glass frit of X-ray tubes and image intensifiers and in glass frit binder for assembly of gas lasers and for vacuum tubes that convert electromagnetic radiation into electrons *along the whole supply chain* would be much larger than [CONF.] EUR, once one considers all other economic operators having business linked to test and measurement industrial equipment products.

5. CONCLUSION

This SEA identifies the main potential negative consequences that the EU society at large would face in the framework of the potential **non-renewal of Annex IV, exemption 4 - lead in in glass frit of X-ray tubes and image intensifiers and in glass frit binder for assembly of gas lasers and for vacuum tubes that convert electromagnetic radiation into electrons**. It has been performed in line with existing ECHA guidance for the preparation of the Socio-Economic Analysis. The results are based on a survey focused on the EU test and measurement equipment industry, with market share coverage of approximately 70% of the EU market. It therefore provided sufficiently reliable data for a representative extrapolation of the EU market.

Overall, the results of the SEA demonstrate the safe use of lead (Pb) in in glass frit of X-ray tubes and image intensifiers and in glass frit binder for assembly of gas lasers and for vacuum tubes that convert electromagnetic radiation into electrons and can reasonably justify its exemption from the RoHS renewal dossier, on the grounds that a broad restriction would have disproportionate negative impacts on society when compared with the risk to human health, animal health or the environment.

The **total monetized impact** of a non-renewal is estimated in the range of **15 million and 40 million EUR**, including: **[CONF.]** EUR of economic impact for test and measurement industrial product types manufacturers (EBIT losses); **[CONF.]** EUR of substitution costs; **[CONF.]** EUR of social impact deriving from unemployment. This is a conservative estimate (lower bound), on the understanding this is not the sole injury likely to be suffered in the EU.

In terms of **business and market impacts**, a non-renewal would constraint most of the companies currently supplying RoHS-based test and measurement industrial products to cease production and business activities of all products that include lead.

In addition, and pursuant to Article 5 of the RoHS Directive a continuation of exemption 4 Annex IV is warranted as **no suitable alternatives to the RoHS restricted substance are available**.

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