Assistance to the Commission on Technological Socio-Economic and Cost-Benefit Assessment Related to Exemptions from the Substance Restrictions in Electrical and Electronic Equipment:

Study to assess renewal requests for 29 RoHS 2 Annex III exemptions [no. l(a to e -lighting purpose), no. l(f - special purpose), no. 2(a), no. 2(b)(3), no. 2(b)(4), no. 3, no. 4(a), no. 4(b), no. 4(c), no. 4(e), no. 4(f), no. 5(b), no. 6(a), no. 6(b), no. 6(c), no. 7(a), no. 7(c) - I, no. 7(c) - II, no. 7(c) - IV, no. 8(b), no. 9, no. 15, no. 18b, no. 21, no. 24, no. 29, no. 32, no. 34, no. 37]

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07 June 2016

Report for The European Commission

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Acknowledgements:

We would like to express our gratitude towards stakeholders who have taken an active role in the contribution of information concerning the requests for exemption handled in the course of this project.

Disclaimer:

Eunomia Research & Consulting, Oeko-Institut and Fraunhofer Institute IZM have taken due care in the preparation of this report to ensure that all facts and analysis presented are as accurate as possible within the scope of the project. However no guarantee is provided in respect of the information presented, and Eunomia Research & Consulting, Oeko-Institut and Fraunhofer Institute IZM are not responsible for decisions or actions taken on the basis of the content of this report.

19.0 Exemption 6b: "Lead as an alloying element in aluminium containing up to 0,4 % lead by weight"

Declaration

In the sections that precede the "Critical Review" the phrasings and wordings of stakeholders' explanations and arguments have been adopted from the documents provided by the stakeholders as far as required and reasonable in the context of the evaluation at hand. Formulations have been altered in cases where it was necessary to maintain the readability and comprehensibility of the text. These sections are based exclusively on information provided by applicants and stakeholders, unless otherwise stated.

Acronyms and Definitions

2011	AA 2011, leaded Al wrought alloy
Al	Aluminium
AA 6023	Lead-free bismuth containing wrought alloy
AlEco62Sn	Lead-free bismuth containing wrought alloy
EAA	European Aluminium Association
ECHA	European Chemicals Agency
EEE	Electrical and Electronic Equipment
ELV	End-of-Life Vehicle
EoL	End-of-Life
JBCE	Japan Business Council in Europe
KEMI	Kemikalieinspektionen, Swedish Chemicals Agency
Pb	Lead
tpa	Tonnes per annum
TMC	Test & Measurement Coalition
WEEE	Waste of Electrical and Electronic Equipment

19.1 Background

The European Aluminium Association (EAA), Sensata Technologies and Dunkermotoren have applied for the renewal of exemption 6b, requesting the current wording formulation of the exemption as appears in Annex III of the RoHS Directive.

Aluminium (Al) alloys can be differentiated into two principal classifications:[606]

- **Wrought alloys:** Al alloys primarily used for wrought products; they have an alloy content up to 10% and therefore strict and very low tolerance limits for the alloying elements. Wrought alloys are designated with a four-digit number according to the alloy designation system.
- **Cast alloys:** Al alloys primarily used for the production of castings; cast alloys have much higher tolerance limits for alloying elements; the alloy concentration is of up to 20%. For cast alloys, a different designation system with five digits is used.

The association of the Al manufacturers, EAA,[607] with support of many EEE manufacturer associations[608] requests the extension of the exemption without specifying an expiration date. Dunkermotoren,[609] a component manufacturer, requests the exemption specifically for the manufacturing of gear parts in engine and transmission parts for a period of two to five years. Sensata Technologies, a manufacturer of sensor and control

[606] EAA (202), European Aluminium Association EAA (2002), The Automotive Manual; http://www.european-aluminium.eu/wp-content/uploads/2012/01/AAM-Materials-3-Designation-system.pdf;
Paraskevas, D. et al. (2013), Closed and Open Loop Recycling of Aluminium: A Life Cycle Assessment perspective; 11th Global Conference on Sustainable Manufacturing, 23rd to 25th September Berlin, Germany.

[607] EAA (2015a), European Aluminium Association (EAA) (2015a), Original Application for Exemption Renewal Request, submitted 16.01.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_6_b_/AISBL/6b_Final_RoHS_Exemption_Renewal_Dossier_2015_01_16.pdf

[608] The EEA's exemption request was supported by the following bodies: American Chamber of Commerce to the EU (AmCham EU); Avago Technologies Limited; DIGITALEUROPE; European Committee of Domestic Equipment Manufacturers (CECED); European Copper Institute (ECI); European Coordination Committee of the Radiological, Electromedical and Healthcare IT Industry (COCIR); European Garden Machinery Industry Federation (EGMF); European Passive Components Industry Association (EPCIA); European Semiconductor Industry Association (ESIA); Gesamtverband der Aluminiumindustrie e.V.; Information Technology Industry Council (ITI); IPC - Association Connecting Electronics Industries; Knowles (UK) Ltd; LightingEurope; SPECTARIS; TechAmerica Europe; WirtschaftsVereinigung Metalle (WVM); ZVEI - Zentralverband Elektrotechnik- und Elektronikindustrie e.V..

[609] Dunkermotoren GmbH (2015), Original Application for Exemption Renewal Request, submitted 15.12.2015, English version available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_6_b_/Dunkermotoren/Ex_6b_Dunkermotoren_150806_Ausnahmeantrag_Aluminium_englisch.pdf

products, stated after an investigation within its supply chain that the company is not making use of this exemption.[610]

EAA thus requests the renewal of Ex. 6b with the following wording:

> "*Lead as an alloying element in aluminium containing up to 0,4 % lead by weight*"

19.1.1 History of the Exemption

As for the history of the exemption, it has to be noted that since the RoHS 1 Directive was published in 2002, Exemption 6 has covered lead as an alloying element in steels, aluminium and copper.[611] After the last revision on 2009[612], exemption 6 was split into three exemptions 6a, 6b and 6c for each alloy respectively.

A corresponding exemption exists under the ELV Directive 2000/53/EC (ELV, listed in Annex II, as Exemption 2(c)). It was reviewed in 2015; the evaluation report has yet to be published. During the ELV revision, the consultants investigated the possibility of introducing a split into the aluminium alloy exemptions making a distinction between cases where Al is not intentionally introduced and cases where a lead content of up to 0,4 % by weight is required in Al alloys to enhance machinability. This split was proposed due to the information of the automotive industry that showed a clear distinction could be made into cast alloys that are used for big parts in vehicles, e.g. engine-blocks or gearbox housings, and between wrought alloys that are mainly used for manufacturing small parts, e.g. valve actuation, axis pins for pivot levers or oil return stop valves. The use of cast alloys in the automotive sector makes up 95% of the total use of leaded Al alloys in this sector.

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[610] Sensata Technologies (2015b), Sensata Technologies Holland B.V. (2015b), Answers to Clarification Questions, submitted 20.08.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_6_c_/Sensata/Ex_6a6b6c_Sensata_Questions_response_20150820.pdf

[611] The wording of exemption 6 was as follows: "Lead as an alloying element in steel containing up to 0,35% lead by weight, aluminium containing up to 0,4% lead by weight and as a copper alloy containing up to 4% lead by weight"; http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32002L0095&from=EN

[612] Gensch, et al. (2009), Carl-Otto Gensch, Oeko-Institut e. V., et al. 20 February (2009), Adaptation to scientific and technical progress under Directive 2002/95/EC: Final Report. With the assistance of Stéphanie Zangl, Rita Groß, Anna Weber, Oeko-Institut e. V. and Otmar Deubzer, Fraunhofer IZM. http://ec.europa.eu/environment/waste/weee/pdf/final_reportl_rohs1_en.pdf

19.1.2 Amount of Lead Used under the Exemption

According to EAA,[613] data availability is limited as to the amount of lead used under this exemption, due to a lack of knowledge on the type of leaded Al alloys used in EEE products and components on the EU market. EAA[614] explains that there are data on the "*amount of wrought products, extruded products and secondary alloys shipped to the EEE and machinery sectors (consumption) from EU producers. However, there is no data available concerning which of these products/alloys contain lead and their quantity. Furthermore, no data available indicates that the amount of final EEE products produced using EU Al alloys is actually placed on the EU market.*"

When asked to indicate at least a range of the amount of leaded aluminium alloys in the EU used for EEE, EEA[615] states that "*the potentially lead-containing Al alloys produced by producers in the EU and EFTA region (not the ones placed on the EU market) used in the high tech engineering sectors (not necessarily only EEE products) is most likely in the range of 100Kt to 1 Mt pa.*"

In this respect it can be noted that the U.S. Geological Survey Minerals Yearbook of 2014[616] estimates that 6.9% of Al product shipments of US and Canada are shipped to electronic end-users. In 2014 this share represented 809 thousand metric tonnes.

19.2 Description of Requested Exemption

According to information provided by EEA[617] in the original renewal request, the use of leaded Al alloys can be differentiated into Al alloys where the lead content is unintentional, due to the use of secondary raw material from aluminium scrap and into aluminium alloys, where lead is intentionally added for machining purposes:

- **Cast alloys** unintentionally contain lead, due to the use of Al scrap for the manufacture of such alloys; relevant applications in which such alloys are used

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[613] EAA (2015b), European Aluminium Association (EAA) (2015b), Answers to Clarification Questions, revised version, submitted 14.08.2015, available under:
http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_6_b_/AISBL/20150814_Ex_6b_EAA_Ex_1st_round_of_Clarification-Questions_final_EAA_answer.pdf
The additional information was supported by the following industry associations and companies: DIGITALEUROPE; European Committee of Domestic Equipment Manufacturers (CECED); European Passive Components Industry Association (EPCIA); European Semiconductor Industry Association (ESIA); Gesamtverband der Aluminiumindustrie e.V.; Information Technology Industry Council (ITI); European Garden Machinery Industry Federation (EGMF); LightingEurope; ZVEI - Zentralverband Elektrotechnik- und Elektronikindustrie e.V.

[614] Op. cit. EAA (2015b)

[615] EEA (2016), European Aluminium Association (EAA) (2016), Answers to 2nd Clarification Questions, submitted 29.01.2016.

[616] USGS (2015), U.S. Geological Survey (USGS) (2015), Minerals Yearbook of 2014 – Aluminium [Advanced Release], table 6, pg. 5-15, available under:
http://minerals.usgs.gov/minerals/pubs/commodity/aluminum/myb1-2014-alumi.pdf

[617] Op. cit. EAA (2015a)

include e.g. frameworks of lamps and lights, heat sinks, electrical and electronic items in housings etc.

- **Wrought alloys**, or Al alloys intentionally containing lead for machining purposes: Relevant applications where such alloys are used are not detailed. The functions of lead are indicated as lubrication, better chip fracturing, surface finish, higher cutting speed and longer tool life. Wrought alloys are often used in screw machine products according to EAA[618], e.g. various machinery components, screws, bolts, fittings, nuts, automatic lathe products.

As this differentiation was in line with information available through the ELV review on leaded Al alloys used in the automotive sector, stakeholders were asked during the RoHS stakeholder consultation[619] whether a possible split of the exemption, differentiating between aluminium alloys where lead is not intentionally introduced and between aluminium alloys where lead is added to obtain certain properties would be practical. Thereupon, EAA[620] submitted a contribution stating the following:

> *"As already stated, lead can be added to the alloys to perform a certain function and lead can be present in the alloys when alloys are produced e.g. from scrap. The former is termed as intentionally leaded alloys and the later, unintentionally leaded alloys. However, there is no straightforward link between intentional/unintentional and wrought/casting, i.e. while casting alloys are mostly produced from scrap, for the production of wrought alloys, scrap can also be used as input. Therefore a distinction of intentional and unintentional cannot be made according to the type of alloys.*
>
> *The exemption 6b has been applied to Al alloys in general which has left the demand and market to determine the most effective utilisation of Al material available to EU producers. An arbitrary distinction of product by the purpose or none-purpose of lead could affect the supply and demand chain. The consequences of these changes are yet to be studied from technical, environmental and economical points of view. The industry will need time to comprehend such studies and changes."*

[618] Op. cit. EAA (2015a)

[619] http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Consultation_Questionnaires/Ex_6b_Consultation_Questionnaire.pdf

[620] EAA (2015c), Contribution by European Aluminium Association (EAA) (2015c), submitted 19.10.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_6_b_/Ex_6b_European_Aluminium_Consultation_Questionnaire_answer_final_20151016.pdf

19.3 Applicant's Justification for Exemption

EAA[621] claims that the exemption of 0,4% lead content in aluminium provides the possibility of the use of recycled aluminium within the EU. EAA[622] explains that the scrap metal arising from products from the past can contain lead and that the presence of lead as impurity in the scrap flow is tolerated to a certain level for the production of many secondary alloys, which is specified in European standards.

EAA[623] states that separation of lead from the scrap is feasible in the remelting stage by for example phase separation, electrochemical refining and vacuum distillation, but that these methods are only approved on a laboratory scale and from an environmental and economical perspective not practicable. According to EAA,[624] the dilution of the scrap with primary aluminium results in higher environmental impacts due to the fact that the production of primary aluminium is very energy intensive.

As for lead in Al alloys used for machining purposes, EAA[625] claims that lead acts as a lubricant during machining processes; through lead, better chip fracturing and surface finish as well as higher cutting speeds and a longer tool life are achieved. EAA was asked to exhaustively specify the functionality of lead in these applications e.g. specific function and properties, performance criteria, etc. EAA[626] provided the following functionalities and performance aspects for lead in Al alloys:

- Corrosion resistance of manufactured articles;
- Surface finish of manufactured articles;
- Longer life of manufacturing tools and less energy consumption during machining of parts;
- Cutting speeds of manufacturing tools;
- Lubrication effect in manufactured articles;
- Better chip fracturing in manufactured articles;
- Temperature resistance;
- Electrochemical potential (of additive);
- Shrinking from liquid to solid phase (of additive);
- Durability of part;
- Eutectic point of alloy.

EAA did not provide performance indicators for these functionalities / performance aspects which would form a basis for testing the performance and comparing between Al alloys with and without lead. EAA[627] stated thereupon that *"the industry will need*

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[621] Op. cit. EAA (2015a)
[622] Op. cit. EAA (2015a)
[623] Op. cit. EAA (2015a)
[624] Op. cit. EAA (2015a)
[625] Op. cit. EAA (2015b)
[626] Op. cit. EAA (2016)
[627] Op. cit. EAA (2016)

sufficient time to organise a team of experts to conduct a comprehensive study, if enough number of manufacturers would be willing to take part in the study. This study shall address the following:

- *listing critical performance indicators for each of the functionalities of lead in Al alloys;*
- *measuring/testing these indicators for lead Al alloys;*
- *measuring/testing these indicators for potential substitutes if available.*

Such study, including an initial information and data collection and analysis and later on carrying out the necessary experiments, usually takes more than one year."

EAA[628] also claims that they cannot clearly distinguish between the use of cast and wrought alloys for specific components:

> *"The applications of Al Alloy (wrought and casting alloys) vary from one component to another. The use of the alloys is not strictly limited to a specific application in a component. Usually components producers design a component and specify the type of alloys they want to use to a supplier. There are hundreds if not thousands of components that may use Al alloys."*

19.3.1 Possible Alternatives for Substituting RoHS Substances

EAA[629] states that *"substitution of lead as alloying element with bismuth is technically feasible."* EAA[630] further states that *"lead-free alloys with bismuth as a substitute, such as AlEco62Sn or AA 6023, have been developed to replace as far as possible some applications of 2011 alloy in the automotive sector. However the current state-of-the-art does not indicate any suitable substitute for lead in aluminium alloys used in the production of EEE products."*

As major constraints, EAA[631] claims that bismuth hampers existing recycling schemes and that secondary aluminium producers observe that bismuth creates an unwanted microstructure effect leading to potential problems in the refining and casting process. According to EAA,[632] bismuth alloys (if in large amount) need to be separated from the others prior to the remelting stage.

EAA[633] further emphasises the possible restricted availability of bismuth as the production of bismuth is connected to the production of lead, in that the source of bismuth that comes to the market is a by-product of the lead production process.

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[628] Op. cit. EAA (2015b)
[629] Op. cit. EAA (2015a)
[630] Op. cit. EAA (2015a)
[631] Op. cit. EAA (2015a) and (2015b)
[632] Op. cit. EAA (2015a)
[633] Op. cit. EAA (2015a) and (2015b)

19.3.2 Environmental Arguments

According to EAA,[634] a closed loop system exists for Al that includes the Al scrap from EEE. EAA[635] further states that Al recycling accounts for about 70% of the Al produced in the EU.

EAA[636] claims that any restriction introduced to the exemption would impact the recycling of Al scrap and thus the EU circular economy.

19.3.3 Socio-Economic Impact of Substitution

As for the substitution of lead by bismuth, EAA[637] expects an increase in direct production costs as bismuth is around 10 to 15 times more expensive than lead. Furthermore EAA states "*if the demand for bismuth increases and the demand for lead decreases, the price of bismuth may become even higher.*" EAA[638] also claims an increase in fixed costs, but without giving further information.

19.3.4 Roadmap to Substitution

EAA[639] did not provide a roadmap arguing that *"given the fact that there is no suitable alternative, it is impossible to draw up any detailed roadmap at this stage."*

19.4 Stakeholder Contributions

Five contributions to exemption 6b have been submitted during the stakeholder consultation. The contributions are presented in order of submission and shortly summarized:

- The **Robert Bosch GmbH**[640] generally supports the applicants without providing further information.
- **JBCE**[641] – Japan Business Council in Europe in a.i.b.l. states that they understand that EEE of category 8 and 9 are out of scope of this review. The JBCE understands that "*the exemption 6(b) in annex III can be applied to category 8&9*

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634 Op. cit. EAA (2015a)
635 Op. cit. EAA (2015a)
636 Op. cit. EAA (2015a)
637 Op. cit. EAA (2015a)
638 Op. cit. EAA (2015a)
639 Op. cit. EAA (2015b)
640 Robert Bosch GmbH (2015), Contribution by Robert Bosch GmbH, submitted 15.10.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_6_b_/Bosch-Stakeholder-contribution-Exemption-request-6b.pdf
641 JBCE (2015), Contribution by JBCE – Japan Business Council in Europe in a.i.b.l, submitted 15.10.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_6_b_/Comment_on_public_cousulation_of_Exemption_request_2015-2_6_b__.pdf

products for seven years from identified date when entry into force for each products, at the earliest July 2021."

EAA[642] adds "*better heat treatment performance of the manufactured material*" as one more function of lead.

EAA further comments on the proposal to split the exemption as detailed in section 19.3.

- **KEMI** Kemikalieinspektionen, the Swedish Chemicals Agency[643], interprets Article 5 in the RoHS Directive in the way that both the material or component and the specific applications need to be defined in the wording formulation of an exemption. Thus, "*it is no longer legally possible to decide on an exemption for lead in aluminium alloys whatever the use is.*"
  KEMI therefore proposes the split into a number of more specific exemptions related to applications where it has been verified that feasible alternatives are currently not available.
- The **Test & Measurement Coalition**[644] submitted a general contribution on Category 9 Industrial monitoring and control instruments, similar in nature to the contribution made by the JBCE.

19.5 Critical Review

19.5.1 REACH Compliance - Relation to the REACH Regulation

Appendix A.1.0 of this report lists Entry 63 in Annex XVII of the REACH Regulation, stipulating that lead and its compounds shall not be placed on the market or used in articles supplied to the general public, if the concentration of lead (expressed as metal) in those articles or accessible parts thereof is equal to or greater than 0,05 % by weight, and those articles or accessible parts thereof may, during normal or reasonably foreseeable conditions of use, be placed in the mouth by children.[645] Entry 63 however further specifies this restriction not to be applicable for articles within the scope of the RoHS Directive 2011/65/EU.

Appendix A.1.0 of this report lists Entry 30 in Annex XVII of the REACH Regulation, stipulating that lead and its compounds shall not be placed on the market, or used, as

[642] EEA (2016), European Aluminium Association (EAA) (2016), Answers to 2nd Clarification Questions, submitted 29.01.2016.
[643] KEMI (2015),Contribution by KEMI Kemikalieinspektionen, Swedish Chemicals Agency, submitted 19.10.2015, available under: http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_6_b_/Ex_6b_KEMI_Answer_to_SC_RoHS_20151016_Lead_in_aluminium.pdf
[644] Test & Measurement Coalition (2015), Contribution by Test & Measurement Coalition, submitted 19 October 2015, available under http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Pack_9/Exemption_1_a-e_/General_Contribution_Test___Measurement_Coalition_package_9_exemptions_20151016.pdf
[645] Other restrictions of entry 63 cover e.g. jewellery and are thus not applicable here.

substances, constituents of other substances, or in mixtures for supply to the general public. A prerequisite to granting the requested exemption would therefore be to establish whether the intended use of lead in this exemption request might weaken the environmental and health protection afforded by the REACH regulation.

In the consultants' understanding, the restriction for substances under Entry 30 of Annex XVII does not apply to the use of lead in this application as lead is used as an alloying element. In the consultants' point of view it is not a supply of a lead as a substance, mixture or constituent of other mixtures to the general public. Pb is part of an article and as such, Entry 30 of Annex XVII of the REACH Regulation would not apply.

No other entries, relevant for the use of lead in the requested exemption could be identified in Annex XIV and Annex XVII (status January 2016).

Based on the current status of Annexes XIV and XVII of the REACH Regulation, the requested exemption would not weaken the environmental and health protection afforded by the REACH Regulation. An exemption could therefore be granted if other criteria of Art. 5(1)(a) apply.

19.5.2 Scientific and Technical Practicability of Substitution

Generally, the assessment of scientific and technical practicability of substitution of lead in Al alloys is hampered by the fact that EAA did not provide data on the use and application of Al alloys in the manufacturing of EEE.

Substitution of lead is relevant in the applications where lead is present to perform a specific function. It is understood from the information provided by EAA that this is the case for Al alloys where lead is needed for machining purposes. Substitution options with tin and bismuth containing Al alloys are discussed in the following Section 19.5.2.1. The arguments provided by EAA generally object to bismuth as an appropriate general substitute for lead and are discussed in Section 19.5.2.2.

The other applicant Dunkermotoren[646] does not specify a substitute, but instead provides an estimate that to requalify each product with alternative materials of equivalent characteristics would require a period of 2 to 5 years.

19.5.2.1 Substitution of Lead in Al alloys

It has to be noted that EAA did not provide information of any new research or other activities that indicate efforts to substitute the applications of these leaded Al alloys. EAA states that there are lead-free bismuth containing Al alloys AlEco62Sn and 6023, but notes that they are used in automotive components. The automotive industry[647] indicated that AlEco62Sn and 6023 are used to substitute some applications of the 2011 Al alloy e.g. in "*housings, disk plates, closing bodies, hexagonal nuts, sealing plugs,*

[646] Op. cit. Dunkermotoren GmbH (2015)
[647] Op. cit. ACEA et al. (2014)

anchors, washers."[648] E.g. nuts are indicated by EAA to be manufactured by leaded Al alloys for EEE. Thus it can be assumed that the mentioned alloys are basically scientifically and technically practicable for substitution.

The Al manufacturer EURAL GNUTTI SpA.,[649] identifying itself as of the largest European extruders of rods and bars in aluminium alloys with lead, contacted the consultants with the following statement:

> *"Since several years all major extrusion companies have studied alloys which can substitute lead, and the results were multiple, and very much satisfactory and already well accepted by the market.*
>
> *We can assure and demonstrate that lead is absolutely unnecessary and can be eliminated, because there are now several alloys already well accepted in the automotive and electric/electronic industries, manufactured by several different extrusion companies, which can provide all the necessary characteristics by lead alloys which are: good machinability and chip forming, high mechanical properties, good surface finishing, good attitude to anodizing. There is no loss in any of the metal properties, no costs increase on the finished parts, on new aluminium lead-free alloys, which can justify the use of lead based alloys any further.*
>
> *I understand that the majority of the industry (aluminium extruders and machining companies) is asking to maintain the actual exemption 6b to remain at Pb max 0,40% on weight, but this is due to an unwillingness to modify the majority of existing industrial drawings. Nevertheless in United States, in Japan, a huge step towards the elimination of lead has been taken since years now, and automotive companies are already choosing lead-free alloys on new drawings and new applications. All worldwide industry, but the European, is expecting the elimination of lead in aluminium alloys."*

A patent and marked research on new Al alloy developments published in 2011 confirms that within wrought Al alloys, the AlMgSi alloys (6xxx series) and AlCu alloys (2xxx series) contain either lead with a maximum of 0.4% or as substitution elements tin or bismuth respectively a combination of both. EURAL[650] stated that lead-free tin containing Al alloys have good machinability and good surface finishing, but suffer temperature limitations > 140°C because tin *"causes weakness and cracking of the machined parts when submitted to stress and high temperature. Due to its brittle nature, tin has the dangerous tendency to sudden brakes without significant previous deformation*

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[648] ACEA et al. (2015), ACEA, JAMA, KAMA, CLEPA and EAA (2015), Answers to Clarification Questionnaire during the review of ELV exemption 2c, provided 27 February 2015.
[649] EURAL (2016a), EURAL GNUTTI SpA. (2016a), Information provided by Email, submitted 26 February 2016
[650] EURAL (2016b), EURAL GNUTTI SpA. (2016b), Information provided by Email, submitted 29 February 2016

(strain)."[651] However, EURAL[652] stresses that as many applications do not have stress and high temperature expositions tin based alloys are largely used on the market. For the tin and tin/bismuth based alloys, EURAL[653] mentions different lead-free alloys of the following Al producers: Alcoa 6020, Eural 6012A, Constellium 6023, Impol 6028 and 2015, Aleris 6262A.

EURAL[654] further states that the bismuth based alloys do not have such temperature limits. EURAL lists as lead-free bismuth containing alloys the above mentioned lead-free alloy AlEco62Sn of Aleris[655] and lead-free developments by Kaiser (e.g. AA 6033)[656] and the EURAL alloy 6026. According to EURAL it took "*quite some time to set up such alloys [...], but now they are absolutely stable and giving excellent results, on each and every aspect related to machinability, chip forming, surface finishing, anodizing, corrosion resistance.*"

The EURAL 6026 alloy specification is presented in Annex A.4.0. The 6026 alloy is offered as being "*particularly suitable for being machined on high speed automatic lathes. It has good resistance to corrosion, medium-high mechanical properties, good suitability for decorative and industrial hard anodizing. It is also used for hot forging purposes.*" EURAL provided a technical laboratory report on the manufacture of brake pistons from alloy 6026, which is provided in Annex A.4.0. EURAL[657] concludes from their tests that there are "*no important differences in any of the mechanical factors, nor in the roughness on surface of the anodized samples, nor in the macro-graphical nor micro-graphical analysis.*"

The performance aspects indicated for leaded Al alloys by EAA such as corrosion resistance, surface finish, temperature resistance and durability of manufactured articles are understood to be covered. Also the machinability aspects such as longer life of manufacturing tools and less energy consumption during machining of parts, cutting speeds of manufacturing tools, lubrication effect and better chip fracturing are understood to be comparable.

As for the application of 6026 in the EEE sector, EURAL[658] explains to have "*customers who are switching to the Bi only in the field of electronic valves, safety components for gas kitchens and burners, pneumatic sector. Quantities are in the range of about 1000 metric tons/year global.*" EURAL[659] estimates that a switch to lead-free Al alloys could be feasible for EEE manufacturers within one year taking into account replacement

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[651] Cited from EURAL 6026 material data sheet provided in Annex A.4.0.
[652] Op. cit EURAL (2016b)
[653] Op. cit EURAL (2016b)
[654] Op. cit EURAL (2016b)
[655] https://www.aleris.com/wp-content/uploads/2014/08/Aluminum-Extrusion-Plant-Overview_engl_DC_2012_11_20_final_web.pdf
[656] http://www.kaiseraluminum.com/customers/products/extrusions/bar/#6033
[657] EURAL (2016c), EURAL GNUTTI SpA. (2016c), Information provided by Email, submitted 01 March 2016.
[658] Op. cit. EURAL (2016c)
[659] Op. cit. EURAL (2016c)

strategy, process of renewing drawings and making all trials and tests, looking for suppliers and the phase out of old remaining stock of old materials.

The consultants understand from this information that there are alternatives on the market for lead based Al alloys that are reliable according to Al producers. It is also understood that in some cases EEE manufacturers already apply lead-free alloys, however the extent of these applications is not conclusive.

19.5.2.2 Arguments provided by EAA

EAA[660] generally excludes bismuth as a substitute for lead in Al alloys for two reasons:

- Bismuth has no own primary production but is a by-product of lead production;
- Difficulties in Al recycling if the share of bismuth Al alloys rises.

A bismuth inventory set up for a life cycle assessment of solders for the US EPA in 2005[661] compiled data according to which bismuth is primarily co-mined with other metals, including lead (35 %), copper (35 %), tungsten (15-20 %, from China), and tin and other miscellaneous metals (10 to 15 %) concluding that lead and copper co-mining consist of the majority (70 percent) of the worldwide bismuth supply. The consultants assume that the co-mining of bismuth with lead is not a sufficient reason to claim that the substitution of bismuth causes higher negative environmental, health and consumer safety impacts compared to lead. It might show however that the availability of bismuth could be limited. Though bismuth is not considered as a critical raw material by the EC[662], there are individual studies[663] that consider bismuth to be critical due to the production in a small number of countries and the production by co-mining. However, those considerations are not foreseen to be part of an exemption evaluation under RoHS. Furthermore, where bismuth would be produced through co-mining of lead, if the lead could not be used for manufacture, it would be concentrated at a single location (the smelting location). This would make the sound handling of lead and the control of possible emissions easier than the case of lead being present at a low concentration in numerous applications, for which proper disposal, collection and treatment are more complex.

As for the argument that bismuth hampers recycling, EAA did not provide any further evidence then the following: "*It has been experienced and discussed within the*

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660 Op. cit. EAA (2015a)

661 Geibig & Leet Socolof (2005), Geibig, J. R., Leet Socolof M. (2005), Solders in Electronics: A Life-Cycle Assessment, EPA 744-R-05-001, August 2005; available under: http://www.epa.gov/sites/production/files/2013-12/documents/lead_free_solder_lca_full.pdf

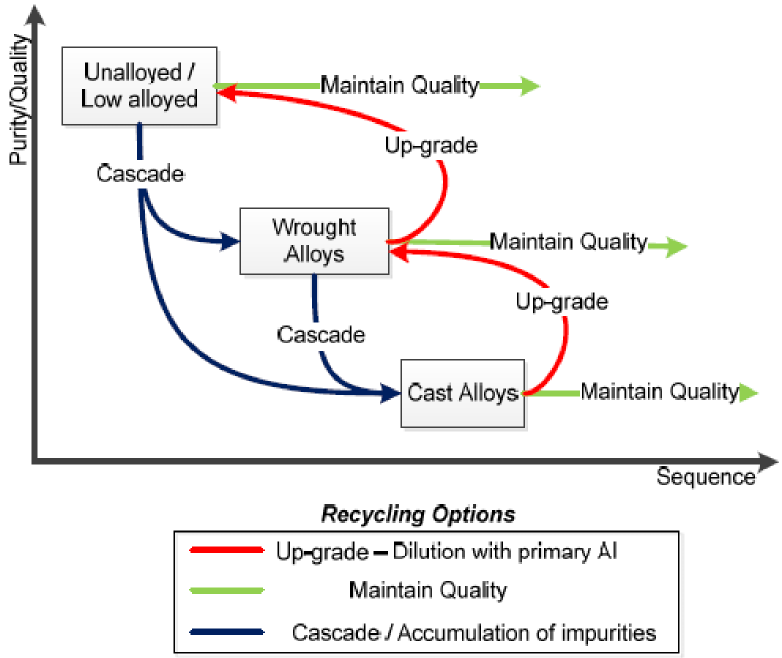
662 http://ec.europa.eu/growth/sectors/raw-materials/specific-interest/critical/index_en.htm

663 E.g. a study available in German on mineral resources: Erdmann, L.; Behrendt, S. Institut für Zukunftsstudien und Technologiebewertung (IZT), Berlin; Feil, M. adelphi, Berlin (2011), Kritische Rohstoffe für Deutschland „Identifikation aus Sicht deutscher Unternehmen wirtschaftlich bedeutsamer mineralischer Rohstoffe, deren Versorgungslage sich mittel- bis langfristig als kritisch erweisen könnte", Berlin, den 30. September 2011; available under: https://www.izt.de/fileadmin/publikationen/54416.pdf

secondary aluminium producers that bismuth creates an unwanted microstructure effect leading to potential problems in the refining and casting process. Thus bismuth alloys (if in large amount) need to be separated from the others for remelting."

On the basis of available documents concerning Al recycling,[664] it is understood that in the recycling of aluminium the accumulation of impurities is a general problem for operators. E.g. the review of Gaustad et al. (2012) [665] but also other publications[666] mention two approaches commonly used today to deal with the presence of undesired impurities in the recycling of aluminium: Dilution and "Down-cycling" where wrought scrap is used in cast products because cast alloys have the lowest purity requirements. Compensation of impurities can take place by dilution with purer aluminium fractions or with primary aluminium in order to reach specified product quality. The following figure illustrates the Al recycling options that depend on the purity of the Al alloys.

Figure 19.1: Al recycling options and Al cascade recycling



Source: Paraskevas, D. et al. (2013)

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[664] Gaustad et al. (2012), Gaustad, G. et al. (2012), Improving aluminum recycling: A survey of sorting and impurity removal technologies; Resources, Conservation and Recycling 58 (2012) 79– 87;
Op. cit. Paraskevas, D. et al. (2013);
EAA/OEA Recycling Division (2006), European Aluminium Association EAA and Organisation of European Aluminium Refiners and Remelters OEA (2006), Aluminium Recycling in Europe, The Road to High Quality Products, 2006; http://www.european-aluminium.eu/wp-content/uploads/2011/08/Aluminium-recycling-in-Europe-2007.pdf

[665] Op. cit. Gaustad et al. (2012)

[666] Paraskevas, D. et al. (2013)

Furthermore, EAA and OEA[667] anticipate a growing volume of wrought alloy scrap as of 2015/2020, due to an increased use of specialized wrought alloys and therefore envisage optimised sorting techniques of different wrought alloys both from cars[668] and from other sources in order to avoid dilution and down-cycling.

To conclude, the consultants cannot follow the arguments provided by EAA as to why bismuth poses a particular impurity problem in Al recycling. The consultants do not assume that if the exemption on leaded Al alloys for machining purposes will expire that Al recycling is endangered.

19.5.3 Environmental Arguments

As for cast alloys, the consultants understand that lead is unintentionally present due to the use of scrap and does not provide a function. In such cases, the consultants agree that the reuse of resources recycled from end-of-life (EoL) products has a positive value from an environmental perspective. According to EAA, the recycling of aluminium requires about 95% less energy than that required to produce primary aluminium.[669] It is thus understood that the use of secondary material results in a significantly lower environmental impact in terms of energy consumption. Furthermore, it has been explained by EAA that the removal of lead from aluminium through a metallurgical process is technically not yet feasible on an industrial scale[670] (see section 19.3). Thus the consultants can follow the estimation of EAA[671] that the elimination of lead from the Al recycling stream by methods such as phase separation, electrochemical refining and vacuum distillation is technically impracticable.

19.5.4 Stakeholder Contributions

Five contributions were submitted to the stakeholder consultation. The contributions of KEMI,[672] Bosch[673] and EAA[674] are discussed in the sections above as well as below.

The contributions submitted by TMC[675] and JBCE[676] raise a legal question as to the availability of the current exemption to category 8 and 9 equipment. TMC and JBCE claim the availability of Annex III exemptions to category 8 and 9 for seven years starting in 22.7.2017.

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667 Op. cit. EAA/OEA Recycling Division (2006)
668 Op. cit. EAA/OEA Recycling Division (2006)
669 http://european-aluminium.eu/data/recycling-data/
670 Op. cit. EAA (2015a)
671 Op. cit. EAA (2015a)
672 Op. cit. KEMI (2015)
673 Op. cit. Bosch (2015)
674 Op. cit. EAA (2015c)
675 Op. cit. TMC (2015)
676 Op. cit. JBCE (2015)

EAA[677] stated in this regard:

> *"We apply for renewal of this exemption for categories 1 to 7, 10 and 11 of Annex I for an additional validity period of 5 years. For these categories, the validity of this exemption may be required beyond this timeframe. Although applications in this exemption renewal request may be relevant to categories 8 & 9 this renewal request does not address these categories. Further, categories 8 & 9 have separate maximum validity periods and time limits for application for renewals...;"*

As leaded Al alloys are understood to be relevant to all categories, it can be concluded that expiration dates should be specified for all categories.

19.5.5 The Scope of the Exemption

The scope of the current exemption is viewed as very wide. As mentioned above, the contribution of the Swedish Chemicals Agency KEMI makes reference to Article 5(1)(a) that stipulates an inclusion of materials and components of EEE for specific applications in the lists in Annexes III and IV. The specifications of applications are so far missing for exemption 6b. KEMI therefore proposes to split into a number of more specific exemptions, related to applications where it has been verified that feasible alternatives are currently not available.

EAA indicated some components manufactured by e.g. cast and wrought alloys but did not provide a comprehensive list because "*there are hundreds if not thousands components may use Al alloys*".[678] It is possible that a comprehensive list of applications may be long and impractical for refining the scope of the exemption, though in lack of substitutes the consultants agree that clarifying this aspect would be of importance for understanding the potential for exemption specification. However, as discussed above there are substitutes for the use of leaded Al alloys for machining purposes. Therefore, it is assumed that such substitutes can be applied, whereas only for applications where performance can be proven as non-comparable could the exemption be renewed again should this be found to be justified in the next review of the exemption. If such applications would be made, it is expected that limiting the exemption to specific components or specific product ranges shall be addressed in applications. This would provide a basis for making such adjustments to future exemptions.

As for cast alloys, the consultants understand that lead is unintentionally present due to the use of scrap and does not provide a function. For the cast alloys produced from Al scrap, the substitution of lead is consequently not an issue. The consultants do not see the added value to specify applications for cast alloys but rather to specify the unintentional presence through an individual exemption. Therefore, the consultants favour the option of splitting the exemption, differentiating between aluminium alloys

[677] Op. cit. EAA (2015a)
[678] Op. cit. EAA (2015b)

where lead is not intentionally introduced and between aluminium alloys where lead is added to obtain certain properties. This is further discussed in the following Section 19.5.6.

19.5.6 Exemption Wording Formulation

The need to narrow down the exemption is evident. However, the consultants cannot conclude a list of exhaustive applications of leaded Al alloys for cast and wrought alloys on the basis of the available information, nor would it be practicable at present to conclude for each component whether lead-free substitutes are applied in some cases or not, i.e. if it is justified to retain the exemption for such components. Instead, a split of the exemption is considered between lead in Al alloys, provided that it is not intentionally introduced and in lead in Al alloys for machining purposes.

The first part covering the cast alloys could be granted for the longest review period, which is possible under RoHS, as to completely eliminate lead in recycled Al would only be possible in the long term. The quicker the shift to lead-free alloys, the quicker such a reduction could be expected, though it must be kept in mind that alloys used for EEE probably consist of less than 10% of the Al alloy market share. The second part of the split would allow setting a short review period for leaded Al used for machining purposes, in order to signalize the short termed validity of the exemption, so that industry can prepare for its expiration.

EAA argues that a differentiation into alloys where lead is unintentionally added is not straightforward because for the production of wrought alloys, scrap can also be used as input. However, in the consultants' opinion the term "not intentionally introduced" is meant to describe the presence of lead where its presence does not provide a function. Where lead is needed for providing a function, regardless if it is added to the alloy or if its presence as an impurity in recycled content is sufficient to ensure the relevant functions, its presence has an intention, i.e. to provide a specific function for the machining and/or in the final component.

The consultants understand from the input of EAA that for wrought alloys, the lead might not always be "newly" added but rather present at a sufficient concentration in Al used for production. However, taking into account the strict chemical composition of wrought alloys, the consultants understand that if wrought alloy scrap is used as input it has to be strictly sorted scrap. According to Paraskevas et al.[679], the production of wrought alloys is heavily dependent on primary Al consumption due to their strict and very low tolerance limits for alloying elements. Thus the consultants understand that even if scrap is used in the production of wrought alloys, the lead level needs to be controlled and not only tolerated as impurity upon a specified level, i.e. the minimum amount needed to provide the relevant performance would need to be monitored and where lacking corrected.

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[679] Op. cit. Paraskevas, D. et al. (2013)

Another aspect for cast alloys, relevant in the long term is that the content of lead in cast alloys produced from scrap is expected to decrease: The automotive industry and European Aluminium Association[680] stated during the recent revision of the corresponding ELV exemption that *"since last stakeholder consultation [on the corresponding ELV exemption in 2009/2010], a slight reduction of the average Lead amount introduced by recycling could have been recognized. This can be explained by larger shares of the cars/industrial goods that will be recycled has been produced under Lead restrictions."* Questioned whether the same is true for WEEE recycling and whether all Al scrap is collected and treated together (or alternatively if applications from different sectors are collected and treated separately), EAA[681] states that *"this decreasing trend observed in the recycling of ELVs is not yet visible in the case of EEEs. Compared to Al scrap from ELVs, the amount of Al scrap from EEE is much smaller. Also, most of the Al scraps from EEE waste, though maybe collected and treated separately, are recycled together with other Al scraps. This could be the main reason that the change of Pb content is not so visible in the case of WEEE."* To conclude however, it can be expected the lead content will decrease, which could be reflected in future reviews by lowering the threshold for the unintentional presence of lead in Al alloys. The automotive industry[682] estimates the maximum lead content in recycled Aluminium from ELVs in 2023 at 0.2% in Western Europe and at 0.24% in South Eastern Europe. As it is understood that Al alloys from EEE are recycled with alloys of other sources, a similar reduction in the amount of lead in lead-based cast alloys can also be expected.

19.5.7 Conclusions

Article 5(1)(a) provides that an exemption can be justified if at least one of the following criteria is fulfilled:

- their **elimination or substitution** via design changes or materials and components which do not require any of the materials or substances listed in Annex II is scientifically or technically impracticable;
- the **reliability** of substitutes is not ensured;
- 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.

In the consultants' opinion, a split of the exemption would allow differentiating in the future between applications of aluminium alloys where lead is unintentionally present and between applications where lead provides necessary properties.

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[680] ACEA et al. (2014), ACEA, JAMA, KAMA, CLEPA and EAA (2014a), Industry contribution of ACEA, JAMA, KAMA, CLEPA and EAA, submitted during the online stakeholder consultation, retrieved from http://elv.exemptions.oeko.info/fileadmin/user_upload/Consultation_2014_1/Ex_2c/20141210_ACEA_AnnexII_2c_amended.pdf
[681] Op. cit. EAA (2015b)
[682] Op. cit. ACEA et al. (2015)

As for the unintentional presence of lead, elimination from the Al recycling stream does not seem to be technically practicable because available methods are not developed beyond a laboratory scale. It is further understood that the use of secondary lead in the production of Al alloys for casting allows a significant reduction in the energy consumed to produce the alloys (i.e. the energy associated with the manufacture of primary Al is significantly reduced). Thus, lead as an impurity is to be accepted though it is understood that the level of impurities in alloys is controlled. Therefore the consultants recommend granting the maximum exemption validity possible under RoHS for various categories. In the long term however, it is expected that that the lead content in the Al recycling stream will decrease and this should be monitored in the future as it can be expected to be the focus of future reviews.

As for lead in Al alloys for machining purposes, it can be followed that substitutes are available on the market for which reliability is claimed by alloy producers. In the consultants opinion EU COM should give a clear sign to industry that this exemption is to expire, that the available substitutes are to be tested and implemented as such. Further exemptions for specific applications shall only be acceptable where there is sufficient evidence that lead cannot be reliably substituted. In this case, the consultants propose a review period of three years.

From available documentation, the consultants cannot conclude to what degree, the majority of EEE manufacturers are aware of these new developments and subsequently if broad range substitution can be assumed to be underway or not. Manufacturers of EEE products and components did not participate in the stakeholder consultation and EEA claims not to have access to such data.

The consultants conclude that the exemption could be renewed for a short period, to allow EEE manufacturers a sufficient transition period for applying lead-free alloys available on the market. From EURAL's information the implementation of substitutes does not require more than a year. Though this could allow a phase-out of lead-based alloys within a short period, EURAL submitted its information shortly before the evaluation concluded. Other stakeholders have not had a chance to become familiar with such information and its possible implications, and shall not have one before the publication of this report, and it is thus anticipated that a longer period could be relevant. E.g. the applicant Dunkermotoren[683] estimates to need a period of 2 to 5 years for requalification of each product (gear parts in engine and transmission parts). Furthermore, as the amount of components to be covered could be significant, a longer transition period would be needed, also allowing manufacturers to apply for new exemptions for the use of specific lead-based alloys in specific components, where third party testing can substantiate that lead-free alloys provide inferior performance.

[683] Op. cit. Dunkermotoren GmbH (2015)

19.6 Recommendation

Based on the above considerations, it is recommended to split the exemption. A review period of five years is proposed for the exemption entry on the unintentionally introduced lead, i.e., alloys used for the production of non-machined parts.

A short review period of three years is proposed for applications where lead is present for machining purposes. This would allow industry a longer transition period towards substitutes, as well as providing time to apply for new exemptions should substitutes not be comparable in performance for specific applications.

Exemption 6b: Lead as an alloying element in aluminium	Duration*
I) with a lead content up to 0.4 % by weight, used for the production of parts not machined with shape cutting chipping technologies	*For Cat. 1-7 and 10 and 11: 21 July 2021*
II) for machining purposes with a lead content up to 0.4 % by weight	*For Cat. 1-11: 21 July 2019*
III) Lead as an alloying element in aluminium containing up to 0,4 % lead by weight	*For Cat. 8 and 9: 21 July 2021* *For Sub-Cat. 8 in-vitro: 21 July 2023* *For Sub-Cat. 9 industrial: 21 July 2024*

Note: As it can be understood that the exemption duration may vary for various categories on the basis of Article 5(2), expiration dates have been specified here for all categories either on the basis of the requested duration in the exemption request which the consultants perceive to be justified, or on the basis of the validity periods specified in Article 5(2) for categories, which are newly in scope.

19.7 References Exemption 6b

ACEA et al. (2014) ACEA, JAMA, KAMA, CLEPA and EAA (2014a), Industry contribution of ACEA, JAMA, KAMA, CLEPA and EAA, submitted during the online stakeholder consultation, available under: http://elv.exemptions.oeko.info/fileadmin/user_upload/Consultation_2014_1/Ex_2c/20141210_ACEA_AnnexII_2c_amended.pdf

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EEA (2016) European Aluminium Association (EAA), Answers to 2nd Clarification Questions, submitted 29.01.2016.

EURAL (2016a) EURAL GNUTTI SpA., Information provided by Email, submitted 26 February 2016.

EURAL (2016b) EURAL GNUTTI SpA., Information provided by Email, submitted 29 February 2016.

EURAL (2016c) EURAL GNUTTI SpA., Information provided by Email, submitted 01 March 2016.

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Gensch, et al. (2009) Carl-Otto Gensch, Oeko-Institut e. V., et al. 20 February 2009, Adaptation to scientific and technical progress under Directive 2002/95/EC: Final Report. With the assistance of Stéphanie Zangl, Rita Groß, Anna Weber, Oeko-Institut e. V. and Otmar Deubzer, Fraunhofer IZM. http://ec.europa.eu/environment/waste/weee/pdf/final_reportl_rohs1_en.pdf

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