Measures to be implemented and additional impact assessment with regard to scope changes, pursuant to the new RoHS Directive

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List of Abbreviations

Abbreviation	Meaning
AAS	Atomic Adsorption Spectroscopy
ABS	Acrylonitrile Butadiene Styrene
AC system	Air conditioning system
AHUs	Air handling units
ANAH	Agence nationale de l'habitat
ASTM	American Society for Testing and Materials
BC	Before Christ
bn	Billion
CEN	European Committee for Standardization
CMR	Riser-rated communication wire
COCIR	European Coordination Committee of the Radiological, Electromedical and Healthcare IT Industry
CT	Computed tomography
CTUe	Comparative Toxicity Unit ecotoxicity
CTUh	Comparative Toxicity Unit human
dB	Decibel
DG ENV	Directorate-General for the Environment
EBWR	Electric Bikes Worldwide Report
EC	European Commission
EDSF	European Door and Shutter Federation
EDX	Energy-Dispersive X-ray Spectroscopy
EE	Electrical and Electronic
EEE	Electrical and Electronic Equipment
EGMF	European Garden Machinery Federation
EHI	European Heating Industry
EMC	Electromagnetic Compatibility
EPA	Environmental Protection Agency
ETRA	European Two-wheel Retailers' Association
EU	European Union

Abbreviation	Meaning
EUSA	European Union of Swimming Pool and Spa Associations
FAQ	Frequently Asked Questions
GDP	Gross Domestic Product
GGE	Greenhouse Gas Emissions
hr	Hour
HVAC	Heating, Ventilating, and Air-conditioning
ICP	Inductively Coupled Plasma
ICT	Information and Communication Technologies
IEC	International Electrotechnical Commission
ISO	International Society of Organbuilders
kJ	Kilojoules
km/h	Kilometres per hour
kW	Kilowatts
L	Litre
LCA	Life Cycle Assessment
LPG	Liquefied Petroleum Gas
LSFI	Large Scale Fixed Installation
MCB	Miniature Circuit Breaker
MDF	Medium Density Fibreboard
MFC	Melamine Faced Chipboard
mg/dl	Milligram per decilitre
Min	minute
MIT	Massachusetts Institute of Technology
MRI	Magnetic Resonance Imaging
MS	Member State
MWh	Megawatt hour
NEMI	National Environmental Methods Index
NFC	Near Field Communication
NIOSH	National Institute for Occupational Safety and Health
ORRChem	Ordinance on Chemical Risk Reduction
OSHA	Occupational Safety and Health Administration
PA	Polyamide

Abbreviation	Meaning
PBB	Polybrominated Biphenyls
PBDE	Polybrominated-Diphenyl-Ether
PBT	Polybutylene Terephtalate
PCB	Printed Circuit Board
PMT	Passenger-miles-travelled
PP	Polypropylene
PPS	Purchasing Power Standards
PVC	Polyvinyl chloride
R&D	Research and development
RCBO	Residual Current Circuit Breaker with Overload protection
RCD	Residual Current Device
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RoHS	Restriction of Hazardous Substances
SCART	Radio and Television Receiver Manufacturers' Association
SEM	Scanning Electron Microscope
SME	Small and Medium Enterprise
TIE	Toy Industries of Europe
UEA	European Federation of Furniture Manufacturers
UK	United Kingdom
USA	United States of America
VDE	Virtual Distributed Ethernet
VOCs	Volatile Organic Compounds
VRFs	Variable Refrigerant Flow systems
WEEE	Waste Electrical and Electronic Equipment
WHO	World Health Organization
XRF	X-ray Fluorescence Spectrometry
Yr	Year

Abstract

Important scope changes between the COM RoHS recast proposal and the final RoHS recast (RoHS II) did not go through an impact assessment prior to this work. It is therefore the objective of this study to assist the European Commission in such an assessment and, based on these findings, to potentially recommend necessary scope amendments. Furthermore, rules for complying with RoHS concentration limits are developed to assist stakeholders in their compliance procedure. Stakeholders were strongly involved during the process through public consultations, meetings and the project website.

The overall results of the assessment show that the impact indicators of waste production/generation/recycling and health are those that would generally be impacted most positively by the scope changes of RoHS II and this would be in line with the overall policy objective of the Directive. The most expected common negative impacts include costs and administrative burdens for industry. Most impacts were limited in their extent as the assessed product groups are not characterised by particularly large market volumes and significant occurrences of RoHS substances. Product groups that were characterised as such were already targeted by RoHS I. Based on the findings of this work, it is recommended to exclude two product groups from the scope of RoHS II: electric bicycles that are not type-approved and pipe organs. The assessment of potential impacts of RoHS II articles 2(2)/4(3) and 4(4) showed that their implications were likely to cause significant environmental, economic and social costs with no or only limited benefits. Amendments to these articles are therefore recommended and options proposed.

The main problems encountered in complying with RoHS concentration limits are related to very thin coatings as well as passivation coatings. The analysis of hexavalent chromium in passivation coatings is the most difficult analytical problem because standard measurement methods do not give results as percent by weight. Guidance developed as part of this work shows that if coating density and thickness (based on colour and type) were assumed, then a reasonable estimate of hexavalent chromium concentration can be made from the result of the hot water extraction test. Regarding the problem of analysing very thin coatings, this work shows that the types of coatings used in EEE that are thinner than 100 nm rarely contain restricted RoHS substances except for some thin passivation coatings. Guidance has therefore been developed that shows that these types of coatings would not necessarily need to be analysed. It is recommended that the two pieces of guidance concerning the analysis of very thin coatings as well as passivation coatings are included in the FAQ document accompanying RoHS II together with a clarification for the assessment of very thin coatings. It is also recommended that three or four new EU RoHS harmonised standards are developed to aid the demonstration of RoHS compliance.

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Executive summary

The RoHS recast Directive (2011/65/EU) came into force on 21 June 2011 and included substantial changes not only compared to RoHS I but also to the COM recast proposal (COM (2008) 809 final), which was published by the European Commission in December 2008. While this original proposal was accompanied by an impact assessment, none of the changes made thereafter had been assessed prior to this work. It was therefore one of the main objectives of this study not only to define which types of electrical and electronic equipment (EEE) were affected by the scope changes between the COM recast proposal and the final Directive but also to assess the impact of the most important of these. Furthermore, according to Article 4(2) of the recast Directive, the Commission shall adopt rules for complying with the RoHS concentration values detailed in Annex II. This work was to support the Commission in this task by proposing such rules. Throughout the entire project, cooperation with stakeholders was ensured through a project website as well as stakeholder meetings and public consultations.

At the outset of this study, an overall list of EEE affected by scope changes between the COM recast proposal and the final text of RoHS II was developed based on desk research and results of the first stakeholder consultation. In cooperation with the Commission, product groups of EEE were chosen from this list for whom the impact of the scope change was estimated as important and which should hence be assessed in further detail. The focus lay on product groups that were newly included in scope of the Directive, as opposed to newly excluded, and on those characterised by high sales volumes as well as a significant occurrence of RoHS substances. Other factors, such as cultural importance, were also taken into account if deemed relevant. During this analysis, it became evident that not only product groups should be assessed but also other scope changes, such as the newly included Article 2(2) of the Directive. Based on this preliminary work, a total of 17 product groups and other issues were to be assessed. The selection was discussed with stakeholders at both stakeholder meetings and it was made available on the project website.

Individual factsheets were developed for each product group and issue to assess the environmental, economic, and social impacts the scope change might have. Relevant indicators were chosen for each of these categories based on the European Commission's Impact Assessment Guidelines (2009). The impact for each indicator was evaluated looking at the difference in situation between the product group being in scope of the recast Directive (Option 2) compared to the situation under the COM recast proposal (Baseline scenario / Option 1). The analyses of product groups and other issues differed significantly based on general data availability as well as contact with stakeholders. While some were characterised by particularly fruitful contact with stakeholders able to provide significant amounts of relevant data, no contact at all could be established for others. The lack of data means that the assessments of the latter were based on many assumptions and so have limited accuracy. Most importantly for industry, no recommendation to exclude a product group from the scope of RoHS II could be based on such an assessment.

What becomes apparent from the results of the individual assessment factsheets is that most impacts are not expected to be substantial. The indicators of waste production/generation/recycling and health are those that would generally be impacted most positively by the scope changes of RoHS II and this would be in line with the overall policy objective of the Directive. The most common negative impacts are expected on costs and administrative burdens for industry while innovation and research may benefit in some cases. Both these impacts would be unintentional. The functioning of the internal market can benefit or suffer from the scope changes, depending on how product groups were treated under RoHS I by the different Member State authorities. The legal certainty achieved by the clarification of grey areas, where a product's RoHS status is unclear as it varies between Member States, would be beneficial to both manufacturers and enforcement authorities.

The reason for most of the impacts being limited is that the assessed product groups are not characterised by particularly large market volumes and significant occurrences of RoHS substances. Product groups that were characterised as such were already targeted by RoHS I. Nevertheless, an impact that is limited should not be misunderstood as insignificant. What becomes evident from the assessment results is that pipe organs are the only product group for which neither environmental nor social benefits are expected from the inclusion in RoHS II. From the inclusion of electric bicycles no environmental benefits are expected either and social benefits are only potentially expected and, if so, to a very limited extent. Overall, it is therefore recommended to exclude both electric bicycles that are not type-approved and pipe organs from the scope of RoHS II.

The implications of article 2(2)/4(3) of the RoHS recast are that all newly included EEE made available after 22 July 2019 must not contain RoHS restricted substances irrespective of when it was first placed on the EU market. The assessment of these articles shows that this is likely to cause significant environmental, economic and social costs with no or only limited benefits. Two options are therefore proposed of how articles 2(2)/4(3) could be amended to avoid these impacts: to delete Article 2(2) and amend Article 4(4); and to exclude categories 8 and 9 from Article 2(2). While Article 4(4) of RoHS II provides an exclusion for cables and spare parts for products in categories 1-7 and 10 in scope since July 2006 and categories 8 and 9 in scope from 2014, 2016 or 2017, this exclusion is legally missing for Category 11 and other products newly in scope. The potential environmental, economic and social costs of the missing exclusion in Article 4(4) could be significant while no particular benefits are envisaged. It is therefore recommended to include other EEE not covered by any of the other categories and placed on the market before 22 July 2019 in Article 4(4).

Results of the second stakeholder consultation as well as in-depth discussions with a number of stakeholders showed that the main problems encountered in complying with the RoHS concentration limits are related to the analysis of very thin coatings as well as passivation coatings. The analysis of CrVI in passivation coatings is the most difficult analytical problem because the standard measurement methods do not give results as percent by weight. Guidance developed as part of this work shows that if coating density and thickness (based on colour and type) were assumed, then a reasonable estimate of CrVI concentration can be made from the result of the hot water extraction test.

The problem regarding very thin coatings is related to the definition of homogeneous material in Article 3(20) of RoHS II, which states that if two materials, such as two layers of a coating, can be separated by physical methods, then these are two different homogeneous materials. In practice it can, however, be impossible to cleanly remove a sufficiently large quantity of one material to carry out some of the more commonly used analysis. As this work shows, the types of coatings used in EEE that are thinner than 100 nm rarely contain restricted RoHS substances except for some thin passivation coatings. Guidance has therefore been developed showing that these types of coatings would not necessarily need to be analysed. This is further explained in a clarification document that could accompany this guidance. It is recommended that the two pieces of guidance concerning the analysis of very thin coatings as well as passivation coatings are included in the FAQ document accompanying RoHS II together with the clarification for the assessment of very thin coatings. It is also recommended that three or four new EU RoHS harmonised standards are developed that would aid the demonstration of RoHS compliance.

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Chapter 1: Objectives

In brief: The objective of this study was to define the scope changes between the COM proposal for the RoHS recast (COM (2008) 809 final) and the final text of RoHS II (2011/65/EU). A maximum of 20 of these scope changes were chosen for an impact assessment, to gather conclusions regarding possible further needs for scope amendments. Furthermore, two options of rules for complying with RoHS concentration limits were proposed to the Commission and stakeholders.

In 2008, the European Commission launched the recast of RoHS I (2002/95/EC) in order to strengthen the existing law. A proposal for the RoHS recast (COM (2008) 809 final) was published in December 2008, accompanied by an impact assessment. Substantial changes were made to the proposal (e.g. the introduction of an open scope) before RoHS II (2011/65/EU) came into force on 21 June 2011. A number of scope changes in the final text of the Directive had therefore not been impact assessed.

Furthermore, the definition of 'homogeneous material' in RoHS II (Art. 3(20)) has a direct impact on the scope of this Directive as maximum concentration values by weight apply to homogeneous materials according to Art 4(2). The Commission will need to adopt rules for complying with these maximum concentration values.

Based on the above, the objectives of the study are threefold:

- To support the impact assessment with regards to scope changes between the RoHS II COM proposal and the final text of the Directive. For reasons of feasibility, the impact assessment was limited to a maximum of 20 product groups and/or issues;
- To assess the needs for further scope amendments based on the results of this impact assessment; and
- To provide data and background information to define two options of rules for complying with RoHS concentration limits.

It should be noted that it was not the objective of this project to re-open scope discussions or for the Commission to re-enter negotiations. These had already been finalised: RoHS II had been published, it came into force on 21 July 2011 and it needs to be transposed by the Member States by 2 January 2013. Neither was the project team in a position to make final decisions on whether specific product groups are in scope of RoHS II. These issues will need to be discussed with Member State authorities in their role of implementing bodies and/or the Commission. Furthermore, even though further clarifications of definitions were of utmost importance for this study, it was not the objective to work on these definitions. A dedicated FAQ working group was in charge of these questions and close cooperation with this working group was ensured.

Chapter 2: Cooperation with stakeholders

In brief: Cooperation with stakeholders was key to the success of this project. It was ensured through a dedicated website, two stakeholder consultations and three stakeholder meetings.

2.1 Project website

The project website (http://rohs.biois.com) was set up within the first two weeks of the project and updated on a regular basis thereafter. As of June 2012, 120 people were registered as stakeholders on the website, including project team members, representatives from Member States, industry associations, manufacturers of EEE, environmental NGOs, consultancy companies and institutes, and other types of organisations (e.g. universities).

All project-relevant documents were made available on this website throughout the duration of the work. Stakeholders were notified by an email of the availability of new documents.

2.2 Stakeholder consultations

The first stakeholder consultation ran for a total of twelve weeks from 18 October 2011 to 6 January 2012. An email introducing the study and asking stakeholders to participate in the consultation was sent to a total of 310 recipients. As of February 2012, the very low number of thirteen responses was received. Respondents were either industry or industry associations.

As scheduled, the second stakeholder consultation was launched on 23 January 2012 and remained open until 13 April 2012. The aim of this consultation was to gather information and data for the discussion on possible rules for complying with RoHS concentration limits. Furthermore, stakeholders were asked for additional data on Category 11 spare parts as well as information on the Category 11 supply chain by July 2019. A total of 20 responses were received and although this number is not high, it should be noted that the quality of answers was very satisfactory and these contributions did feed into the analysis.

2.3 Stakeholder meetings

The first stakeholder meeting took place in Brussels on 29 November 2011 with 35 stakeholders attending. The focus of this meeting was to discuss the product groups affected by scope changes between the COM recast proposal and RoHS II as well as those product groups proposed for the impact assessment.

The focus of the second meeting, which took place in Brussels on 21 February 2012, was to provide stakeholders with an overview of the current state of the project, especially regarding the two stakeholder consultations as well as the impact assessment.

The third and final stakeholder meeting of this project took place in Brussels on 15 May 2012. Following an update on the state of the project, preliminary results of the impact assessment as well as possible rules for complying with RoHS concentration limits were presented to and discussed with stakeholders.

All meeting related documents, such as agendas, presentations and minutes were made available to stakeholders on the project website.

Chapter 3: Product groups affected by scope changes

In brief: Following the coming into force of RoHS II, the full extent of the scope changes introduced after the COM proposal remained unclear. A general list of product groups affected by these scope changes was therefore compiled as part of this study and submitted to stakeholders for their review.

3.1 Objective

Substantial scope changes were introduced to the RoHS recast after the COM proposal and its accompanying impact assessment were published. Most notable is the introduction of an open scope through the newly added Category 11 in Annex I, which includes other EEE not covered by any of the other categories. Another important scope change is the new definition of 'dependent': whereas according to the FAQ related to RoHS I, an equipment was considered as EEE when it needed electricity for its primary function, under RoHS II electricity is only needed for 'at least one intended function' (Art. 3.2) for the equipment to be categorised as EEE. On the other hand, there are product groups that were, at least implicitly, included in the COM proposal but are now explicitly excluded in Art. 2.4 of the Directive, e.g. R&D equipment.

This means that a potentially large number of product groups is either newly included or excluded under RoHS II compared to the COM proposal. As no exhaustive list of these product groups exists at this point, it was the objective of this task to compile one.

It should be noted that Member State authorities might have different viewpoints regarding what constitutes a scope change. This is due to the fact that interpretations and implementation of RoHS I vary depending on the Member State. For this task, however, it is only the changes between the COM proposal and the final text of RoHS II that are addressed, irrespective of how Member States have implemented RoHS I.

3.2 Methodology

A preliminary list of product groups affected by scope changes between the COM proposal and RoHS II was compiled in September and October 2011 and included in the first stakeholder consultation document. Stakeholders were asked for their views on the list of product groups. Following a number of bilateral discussions with stakeholders as well as further internal ones, a revised product group list was sent to stakeholders and made available on the project website in November 2011. The main changes between the preliminary and this revised product group list were the following:

- Products were grouped according to RoHS II category and product category to facilitate reading and understanding
- Product examples were given for each product category
- The following product groups were added to the list:
  - Cables: Finished EEE not in other 10 categories
  - Equipment designed as part of another equipment that is excluded or does not fall within the scope of RoHS II (changed definition)
  - Means of transport

Two more comments were received specific to the revised list of product groups:

- Unicycles are not two-wheeled and should therefore not be included in the electric two-wheeled vehicle category. Segways were proposed instead.
- Ships are means of transport and therefore excluded under Art. 2.4 of the Directive. Ship elevators would therefore also be excluded and should not feature in the large-scale fixed installations category.

Please see Annex I for a list of product groups affected by scope changes between the COM recast proposal and RoHS II, taking into account these comments by stakeholders.

Chapter 4: Impact assessment

In brief: A total of 16 product groups and other issues were assessed to estimate the potential environmental, economic and social impact their inclusion in RoHS II would have. Based on this assessment, it is recommended to exclude pipe organs and electric bicycles that are not type approved from the scope of the Directive. Furthermore, it is recommended to amend articles 2(2)/4(3) and 4(4).

4.1 Objective

A number of product groups affected by scope changes between the COM recast proposal and the final text of the Directive were assessed in greater detail to determine whether a potential scope amendment to RoHS II should be recommended. For reasons of feasibility, the number of product groups was limited to 20. Over the course of this work, it materialised that not only product groups but also other, conceptual, scope changes should be assessed as they would have a potentially significant impact.

4.2 Methodology

As an initial step, the product groups identified as being affected by scope changes between the COM recast proposal and RoHS II were classified as 'limited', 'medium' or 'substantial' in terms of their sales volumes and the occurrence of hazardous substances. This analysis was based on prior studies in the field, further desk research as well the project team's expertise as no information was received from stakeholders on this particular point. All product groups with estimated significant or medium sales volumes were included in the list of proposed product groups for the impact assessment. This was refined based on discussions with stakeholders, the Commission and further research. In particular, it was decided to:

- Take on board additional factors other than sales volumes and the occurrence of hazardous substances, if relevant. E.g. for pipe organs the cultural impact of an inclusion in the scope of RoHS II could be significant even though neither their sales volumes nor the occurrence of hazardous substances within these instruments is substantial compared to other product groups;
- Focus on new RoHS II scope inclusions instead of new exclusions in line with the COM declaration;
- Take into account not only product groups but also more general issues that arose because of scope changes.

A list of 16 product groups and issues was sent to stakeholders on December 6th 2011 for their comments and review. No further comments were received regarding this list but together with the Commission it was decided to add 'combustion-engine powered garden equipment' to the list. This is because the Commission and Member State authorities did not agree with industry that these products were excluded from the scope of RoHS II.

Please see below for the list of product groups and other issues assessed as part of this work:

Table 1: Product groups and other issues for impact assessment

Product category/issue	Example/comment
Automatic doors/gates	Automatic doors, garage doors
Cables: Finished EEE not in other 10 categories	Extension leads, mains distribution sockets
Combustion-engine powered garden equipment for non-professional or dual use	Lawn mowers, chain saws
Complex air conditioning systems	Those excluded in RoHS I but now included in RoHS II
Fuse boxes	Fuse boxes (unless Cat 9 or LSFI)
Gas water heaters with electrical function	Gas water heaters with electrical function
Electric two-wheel vehicles which are not type-approved	Electric bicycles
Furniture with an electrical function	Wardrobes with lights
Lifts and escalators	*Not assessed as draft FAQ defines them as LSFI*
Light switches, power wall sockets	Light switches
Pipe organs	Pipe organs
Power switches	Power switches
Safes	Safes with an electronic function
Swimming pools	Swimming pools for home use with pumps included
Toys with secondary electrical functions	Bears with watch/beep button or speaking function, dolls house with light, shoes with light
Other issues	
Art. 2(2) and 4(3): Compliance date for newly included product groups	Supply chain within the EU must be clear of non-compliant products by 22 July 2019
Art. 4(4): Exclusion for spare parts for Cat. 11 and other newly included products	No spare parts exclusion for Cat.11 and other newly included products in Art. 4(4)

4.3 Product group definitions

For a number of product groups, no commonly agreed definition existed at the time of writing of this report as the FAQ working group had not yet finalised its work. It was therefore agreed with the Commission to work on the strictest possible basis in order to evaluate the strongest impact the inclusion of a product group would have. For combustion-engine powered garden equipment, for example, it was assumed that all of these non-professional products fall within the scope of RoHS II. A similar issue is that of large-scale fixed installations. In line with the aim to assess the strongest potential impact and given the lack of a commonly agreed definition of 'large-scale' at the time of writing, in most cases the impact is assessed disregarding the potential exclusion of equipment as large scale. It should be noted that once the definition has been agreed on it should be straightforward to estimate the percentage of products potentially excluded and to adjust the calculated impact. Based on the above, the following working definitions were developed:

Table 2: Product group working definitions

Product category	Working definition for IA
Automatic doors/gates	All automatic doors/gates
Cables: Finished EEE not in other 10 categories	All cables including unfinished EEE according to Art. 4.1
Combustion powered garden etc. equipment for non-professional or dual use	All combustion powered garden equipment
Complex air conditioning systems	Complex air conditioning systems excluded in RoHS I
Fuse boxes	All fuse boxes
Gas water heaters with electrical function	All gas water heaters with electrical function[1]
Electric two-wheel vehicles which are not type-approved	All electric two-wheel bicycles that are not type-approved
Furniture with an electrical function	All furniture with integrated secondary electrical function
Lifts and escalators	*Not assessed as draft FAQ defines them as LSFI*
Light switches, power wall sockets	All light switches and sockets attached to the wall
Pipe organs	All pipe organs
Power switches	All power switches
Safes	All safes with electric function
Swimming pools	All swimming pools
Toys with minor electrical functions	All toys with secondary electrical function

4.4 Assessment

In order to assess the above-mentioned product groups and other issues, factsheets were developed for each of them. While most factsheets follow the same outline to facilitate comparability, this has not been feasible for cables and swimming pools as well as the discussion

[1] Excluding water heaters that are part of combi-boilers

on articles 2(2)/4(3) and 4(4). Individual factsheets were developed for the latter in order to arrive at meaningful results.

Based on the European Commission's Impact Assessment Guidelines (2009), relevant impact indicators were chosen for each product group. Impact indicators are grouped as environmental, economic and social, although it should be noted that in many cases these are interlinked, for example costs and administrative burdens on companies (economic) and employment (social).

The impact for each indicator is evaluated looking at the difference in situation between the product group being in scope of the recast Directive (Option 2) compared to the situation under the COM recast proposal (Baseline scenario / Option 1). For a detailed discussion on these impacts, please refer to the individual factsheets. Please note that in this assessment the six RoHS substances currently banned by the Directive are taken into account. Other substances that might be of interest for the individual product groups are presented in Annex IV of this report.

As it was highlighted at the second as well as the third stakeholder meeting, very limited data for this assessment was received during the first stakeholder consultation. Bilateral contacts were therefore established with a large number of industry stakeholders as well as industry associations. Many of these contacts were generally willing to participate and very helpful in providing information and data. It should be noted, however, that specific data on RoHS substances quantities in the products in question was not received and had to be estimated in all but a very few cases. Furthermore, particular data needs were identified for the product groups automatic doors and gates; furniture with secondary electrical functions; safes with electrical functions; and swimming pools. For these product groups it was particularly difficult to establish any productive contact with industry or their representatives. The lack of data means that the assessments of these product groups were based on many assumptions and so will have limited accuracy. Most importantly for industry, a recommendation to exclude a product group from the scope of RoHS II cannot be based on such an assessment.

4.4.1 Results for product groups

Table 3 presents the main findings of the product group factsheets in terms of the environmental, economic, and social impacts that would be expected from the inclusion of the product group in the scope of RoHS II, compared to the situation under the COM recast proposal. What becomes apparent from this overview is that most impacts are not expected to be substantial. The more detailed factsheets show that the indicators of waste production/generation/recycling and health are those that would be impacted most positively by the scope changes of RoHS II and this would be in line with the overall policy objective of the Directive. The most common negative impacts are expected to include costs and administrative burdens of firms, while innovation and research may benefit in some cases. Both these impacts would be unintentional. The functioning of the internal market can benefit or suffer from the scope changes, depending on how product groups were treated under RoHS I by the different Member State authorities. The legal certainty achieved by the clarification of grey areas, where a product's RoHS status is unclear as it varies between Member States, would be beneficial to both manufacturers and enforcement authorities.

The reason for most of the impacts being limited is that the assessed product groups are not characterised by particularly large market volumes and significant occurrences of RoHS substances. Product groups that were characterised as such were already targeted by RoHS I. Nevertheless, an impact that is limited is not to be misunderstood as insignificant.

Table 3: Expected impacts from product group inclusion in scope of RoHS II

	Environmental impacts		Economic impacts		Social impacts		Comment
Product category	**Costs**	**Benefits**	**Costs**	**Benefits**	**Costs**	**Benefits**	
Automatic doors/gates	No	Yes, limited	Yes, limited	No	No	Yes, limited	Very limited data
Cables	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	Very limited data, definition issues
Combustion-engine powered garden equipment	No	Yes, limited	Yes, limited	Yes, limited	No	Yes, limited	
Complex air conditioning systems	No	Yes, limited	Yes, limited	No	No	Yes, limited	
Fuse boxes	No	Potentially	Yes, limited	No	No	Potentially	
Gas water heaters with electrical function	No	Yes, limited	Yes, limited	Potentially	Potentially	Yes, limited	
Electric bicycles	No	No	Yes, limited	Yes, limited	No	Potentially	
Furniture with secondary electrical functions	No	No	Yes, limited	Unclear	Unclear	Yes, limited	Very limited data
Light switches, power wall sockets	No	Yes, limited	Yes, limited	No	No	Yes, limited	
Pipe organs	No	No	Yes	Potentially	Yes, substantial	No	
Power switches	No	Yes, limited	Yes, limited	No	No	Yes, limited	
Safes	No	Potentially	Potentially	Potentially	No	Yes, limited	Very limited data
Swimming pools	Unclear	Unclear	Unclear	Unclear	Unclear	Unclear	Very limited data on RoHS substances, definition issues
Toys with secondary electrical functions	No	Yes, limited	Yes, limited	Yes, limited	No	Yes, limited	

What becomes evident from the results presented in Table 3 is that pipe organs are the only product group for which neither environmental nor social benefits are expected from the inclusion in RoHS II. As for the inclusion of electric bicycles, no environmental benefits are expected. Social benefits are only potentially expected and, if so, to a very limited extent.

Exclusions from the scope of RoHS II are therefore recommended for electric bicycles that are not type-approved and pipe organs.

For other product groups whose analysis was characterised by a substantial lack of data, it should be noted that a recommendation for exclusion could not be justifiable based on an assessment of this kind even if it is unclear whether any benefits would result from a scope inclusion.

4.4.2 Results for other issues

RoHS Recast Article 2(2) states that without prejudice to Articles 4(3) and 4(4), all newly included electrical and electronic equipment (EEE) that does not comply with RoHS may be made available until 21 July 2019. Article 4(3) states that category 8 and 9 EEE must comply if they are placed on the EU market after the specified dates and Article 4(4) allows non-compliant spare parts to be used to repair, reuse and update products subject to the specified dates. The implication of Article 2(2) is that all newly included EEE made available after 22 July 2019 must not contain RoHS restricted substances irrespective of when it was first placed on the EU market.

As this is likely to cause significant environmental, economic and social costs with no or only limited benefits, two options are proposed on how articles 2(2)/4(3) could be amended to avoid these impacts:

- *Option 1: Delete Article 2(2) and amend Article 4(3) to include other equipment that was outside of the scope of Directive 2002/95/EC which is placed on the market from 22 July 2019*
- *Option 2: Amend Article 2(2) to exclude categories 8 and 9*

While Article 4(4) of RoHS II provides an exclusion for cables and spare parts for products in categories 1-7 and 10 in scope since July 2006 and categories 8 and 9 in scope from 2014, 2016 or 2017, this exclusion is legally missing for Category 11 and other products newly in scope. The potential environmental, economic and social costs of the missing exclusion in Article 4(4) could be significant while no particular benefits are envisaged.

It is therefore recommended to change Article 4(4) to introduce point (g) to include any other EEE that was outside the scope of Directive 2002/95/EC and placed on the market before 22 July 2019.

Chapter 5: RoHS concentration limit compliance rules

In brief: The second stakeholder consultation as well as further in-depth discussions with stakeholders have shown that the analysis of very thin coatings as well as hexavalent chromium in passivation coatings are the key issues causing concern when it comes to complying with RoHS concentration values. Guidance and a recommendation for RoHS harmonised standards was developed on these issues to assist stakeholders in their compliance process. It is recommended that this guidance is included in the FAQ document.

5.1 Objective

At the outset of this work, one of the objectives was to provide two options of rules for complying with RoHS concentration limits. Through in-depth discussions with stakeholders as well as the stakeholder consultations it became evident that it would not necessarily be legally binding rules that are required but guidance.

5.2 Background

Directive 2002/95/EC restricted six substances in electrical and electronic equipment but did not provide maximum concentration limits. The RoHS Technical Adaptation Committee and the European Commission (EC) subsequently developed a definition for the substance restriction limits which were 0.1% by weight of lead, mercury, hexavalent chromium, PBB and PBDE in homogeneous materials and cadmium had a limit of 0.01% by weight in homogeneous materials. A homogeneous material was defined in the 'FAQ' guidance published by the EC. The recast RoHS directive 2011/65/EU includes these substance concentration limits in Annex II and a homogeneous material is defined in Article2 (20) as:

> "Homogeneous material means one material of uniform composition throughout or a material, consisting of a combination of materials that cannot be disjointed or separated into different materials by mechanical actions such as unscrewing, cutting, crushing, grinding and abrasive processes.

The original intention of EU Member States was that the definition should prevent the intentional use of RoHS substances and the original definition has been effective in achieving this aim. However, several issues have arisen that have caused difficulties for some manufacturers.

It has been fairly common for the definition to be interpreted as instructions for how to analyse components. This is incorrect as it is intended only to define a homogeneous material and it is not necessary to separate material by mechanical methods in order to analyse them. By definition, homogeneous materials can be separated from other materials by for example abrasion, but it is often impossible to cleanly remove a sufficiently large quantity of one material to carry out some of the more commonly used analysis procedures such as by using the wet chemical analysis method atomic adsorption spectroscopy (AAS). This misunderstanding can result in non-compliant components being supplied. If whole components containing several different homogeneous materials were analysed as single materials, any RoHS substances may be diluted to <0.1%.

There is also uncertainty by some manufacturers when analysis is needed. The homogeneous materials definition does not intend to answer this question. The answer depends on the likelihood of a RoHS substance being present and there is no intention by Member State enforcement authorities that EEE manufacturers and importers should analyse all homogeneous materials, this is unnecessary and far too expensive. The approach most often used to demonstrate compliance is by review of documentation and supplier assessment. One approach is to gain reassurance from suppliers that parts and equipment used do not contain RoHS substances and various methods, such as supplier audits, random sample testing, etc., which are used to obtain this reassurance. Only when there is a reasonable likelihood of a RoHS substance being present and a supplier's declarations cannot be trusted is analysis likely to be needed. Decisions on when to analyse are however outside the scope of this study. If there is a significant likelihood that a RoHS substance is present, then analysis may be necessary. For most types of material, reliable chemical analysis methods exist but there are a few where difficulties have been encountered, especially with thin coatings.

Chemical analysis of individual homogeneous materials in complex electrical equipment can be time-consuming and difficult but is often the only option in the EU as most equipment is manufactured outside the EU. The simplest and most accurate analysis option would be to analyse the original raw materials if these are available. This can be accurate and straightforward but most of these raw materials are also manufactured outside the EU and there are often many steps in the supply chain between the original material manufacturer and equipment importer so it is usually impossible for importers or RoHS enforcement authorities to check the composition of the original raw materials. Therefore, the only option is to check that imported components, sub-assemblies and equipment complies with RoHS and this can result in some analysis being necessary.

The aim of this task is to review analysis methods and propose up to two rules to assist with the demonstration of compliance. It is not the aim however, to determine when analysis is necessary and the concentration limits in Annex II cannot be changed.

5.3 Materials in electrical equipment that are difficult to analyse

Analysis methods exist for all six RoHS substances but the analysis of materials can be problematic because of the nature of electrical and electronic equipment. Materials that the electronics industry has experienced difficulties with analysis are as follows:

- Passivation coatings, anodised aluminium coatings, blackened coatings on steel for hexavalent chromium. Treatment solutions that contain hexavalent chromium may be used and can be present in the thin coatings. Hexavalent-chromium-free coatings are also available so it is necessary to analyse these coatings to determine the compliance status.
- Components with electroless and electroplated metal coatings. Single coatings and multiple coatings are used. Analysis of these can be complicated if one RoHS substance is present in two or more different materials. This may be in different layers of a multi-layer coating and it may also be present in the substrate. For example:
  - Lead is not permitted in solderable termination coatings of electronic components
  - Lead present in glass used as a component of thick film coatings of electronic components is exempt due to Annex III 7c(I) of the recast
  - Lead in copper alloys that may be used for component terminals may contain up to 4% lead due to exemption 6c of Annex III of the recast

  Therefore, it is necessary to distinguish between banned lead in a thin coating and exempt lead in other materials. Some components have very thin multiple layers of materials and one of these may contain a RoHS substance. Separation using mechanical methods such as abrasion is possible if a layer is sufficiently thick to be removed from adjacent layers and this will depend on both the layer's thickness and the particle size of the abrasive used. Analysis becomes increasingly difficult as the size of the component decreases. Chip resistors can be as small as 1.0 x 0.5mm and may have an over-glaze layer that contains exempt lead but lead in the plated termination coating is however not exempt. There are many other examples of components that contain lead in an exempt form and in a restricted form.
- An unusual example of a component with a small area of thin coating was reported by a stakeholder who encountered metal parts, which have small areas randomly coated with a thin layer of lead metal as an unintended surface contaminant. This can be detected by SEM/EDX and also XRF, but when the contaminant is present as a very thin layer, it may not be detectable by XRF. The areas covered and thickness are both very variable and cannot easily be removed using physical disjointment techniques such as abrasion. This is an example of the borderline for homogeneous materials where the deposit, although detectable, cannot be disjointed mechanically.
- The quantity of homogeneous materials in very small components and very small features in larger components will be extremely small. Importers of sub-assemblies or finished equipment may have only one of these components for analysis and so accurate chemical analysis can be difficult.

- Several manufacturers have encountered difficulties with analysis of flame retardants in plastic parts. This has occurred even when fairly large samples of plastic have been available. Reliable methods for analysis of flame retardants in plastics are available and the problems encountered are probably due to a lack of skill by the analysts. It is common for flame retardant analysis to be carried out in Asia to reduce the cost but several manufacturers have discovered that the results they received were incorrect. Analysis of flame retardants in small samples of plastic is more difficulty but methods exist which appear to be reliable. As this issue appears to be a lack of skill by some service providers and suitable analysis methods already exist, this issue will not be considered further by this study. Many plastic parts are used in many types of electrical equipment and brominated flame retardants can be used in many of these. Only PBB and PBDE are banned by RoHS, whereas there are many more that are not restricted. Most techniques cannot differentiate the forms of bromine and so mass spectroscopy is usually required, which is a relatively expensive technique. It would be helpful if the suitable analysis methods were available as EU RoHS harmonised standards.

One fact often forgotten when assessing equipment for RoHS compliance is that it is necessary only to determine whether a RoHS substance is at a concentration either above or below the maximum concentration limit; accurate determination of concentration is not usually necessary for showing compliance. When RoHS substances are used intentionally, they are usually present at concentrations that are well above maximum limits although there are circumstances when they are close to the RoHS concentration limits, for example when present as an unintentional impurity, such as cadmium in zinc alloys (at ~0.01 – 0.02%); mercury when used as a polymerisation catalyst (typically at ~0.2%); and lead when used as a brightener in nickel coatings typically at ~0.1%.

5.4 Analysis standards

There are many standard analytical methods for the six RoHS substances although most of these are applicable to materials that are very different to electrical equipment. The most relevant examples of analysis standards are listed below:

Table 4: Analysis standards

Standard	Comments
EN 62321:2009 (in development) - Determination of certain substances in electrotechnical products	Includes analysis methods for Hg, CD and Pb in polymers, metals and electronics as well as XRF screening analysis. Methods for CrVI, PBB and PBDE are guidance only.
EN 15205:2006 - Determination of hexavalent chromium in corrosion protection layers. Qualitative analysis	Method for hot water extraction test applicable to electrical equipment.
EN 12402:1999, "Lead and lead alloys – methods of sampling for analysis"	Detailed procedure for sampling bulk lead and its alloys in the form of ingot. Not suitable for components or solders in other forms. Can be used to analyse high lead content solders
BS 6534:1984, "Method for quantitative determination of lead in tin coatings"	Suitable for analysis of tin coatings on component terminations and on unpopulated PCBs. The procedure will need to be modified for analysis of lead in tin alloy coatings to account for the additional elements
EN 12441-3:2001, "Zinc and zinc alloys – chemical analysis – part 3. Determination of lead, cadmium and copper – Flame atomic adsorption spectrometric method"	Suitable for analysis of bulk zinc and zinc alloys
EN 10318 Determination of thickness and chemical composition of zinc and aluminium based metallic coatings	Method uses glow discharge optical emission spectroscopy so is suitable for fairly thin coatings
BS 6721-9:1989, ISO 4749-1984, "Sampling and analysis of copper and copper alloys. Method for determination of lead in copper alloys by flame atomic absorption spectrophotometry"	Suitable for checking lead content of copper and copper alloys used to make parts for EEE. Analysis by dissolution then AAS. Measures lead from 0.002% to 5%. (lead in copper permitted by RoHS exemption 6c as alloying element up to 4%)
BS 3338-5:1961 Methods for the sampling and analysis of tin and tin alloys. Method for the determination of lead in ingot tin and tin-antimony solders (photometric method)	Suitable for materials (e.g. as ingot). Also, BS 3338-21:1983 is for cadmium in soft solders
EN 1122:2001, "Plastics. Determination of cadmium. Wet decomposition method" (DD ENV 1122:1995, "Determination of cadmium in plastics with the method of the wet decomposition" (withdrawn, revised))	EN 1122:2001 is for analysis of cadmium (from 10mg/kg to 3 g/kg) in non-fluorinated plastics. The plastic is decomposed and the cadmium dissolved. This solution is analysed by AAS. Suitable for plastics used to construct electrical equipment
BS 3900-B9:1986, ISO 3856-4:1984, "Methods of test for paints. Tests involving chemical examination of liquid paints and dried paint films. Determination of 'soluble' cadmium content"	Specific test procedure for cadmium in paints. Cadmium could be used as a pigment

Standard	Comments
BS3900-B10:1986, ISO 3856-5:1984, "Method of test for paints, tests involving chemical examination of liquid paints and dried paint films. Determination of hexavalent chromium content of solid matter"	Procedure for determination of Cr(VI) content of dried paint films in concentrations from 0.05 to 5% Cr. The paint film is first dissolved and this solution is analysed
BS 6068-2.47:1995, ISO 11083:1994, "Water quality. Physical, chemical and biochemical methods. Determination of chromium (VI). Spectrometric method using 1,5-diphenylcarbazide"	One of a series of water analysis standards. Unsuitable for electrical components but could be adapted for use for the analysis of solutions of coatings
BS EN ISO 3613:2001, "Chromate conversion coatings on zinc, cadmium, aluminium-zinc alloys and zinc-aluminium alloys. Test methods"	Colorimetric method based on diphenylcarbazide. Used for detection of CrVI and for determination of mass/unit area of coatings applied more than 24 hour previously and less than 30 days previously. This is a limitation for analysis of coatings on components that might be much older. The method described determines the concentration of only water soluble CrVI.
BS EN ISO 5961:1995, BS 6068-2.21:1995, "Water quality. Determination of cadmium by atomic absorption spectrometry"	Series of standards for analysis of cadmium and other elements in water and other materials using various techniques. New standards could be produced for cadmium in electronic component materials based on these
BS EN ISO 11885:1998, BS 6068-2.60:1998 Water quality. Determination of 33 elements by inductively coupled plasma atomic emission spectroscopy	
EN 13346:2000, "Characterization of sludges. Determination of trace elements and phosphorous. Aqua regia extraction methods"	Could be adapted for analysis of components. Aqua regia will dissolve most metals including gold. The extract solution can be analysed by AAS or ICP
EN 12338:1998, "Water quality. Determination of mercury. Enrichment methods by amalgamation"	Not directly useful for electrical components. Method applicable to water containing very low mercury concentrations
CR 10299:1998, "Guidelines for the preparation of standard routine methods with wavelength dispersive X-ray fluorescence analysis"	This is a different technique to energy dispersive XRF which is used in handheld and desktop XRF that are usually used for identification of non-RoHS compliant materials. Wavelength dispersive XRF gives more accurate analysis than ED XRF but is not easy to use with components or thin coatings
Ford FLTM B1 017-03, Determination of coating weight – chromate / zinc dust. Complex Portaspec X-ray analysis method	

Standard	Comments
National Environmental Methods Index (NEMI), USA	Large number of methods for analysis of trace levels in environmental samples including lead, mercury, cadmium and hexavalent chromium in water
Occupational Safety and Health Administration (OSHA), USA	OSHA has published several analysis methods for hexavalent chromium in air
National Institute for Occupational Safety and Health (NIOSH) – manual of analytical methods	Includes analysis methods for hexavalent chromium in air
EPA Methods such as 3060A (alkaline digestion so not suitable on aluminium) and 7196A (colorimetric method)	Comprehensive list of standards for sampling and analysis of environmental samples such as water, soil and air. Not directly suitable for components
Japanese Standards Association, JIS H 1141 1993, Analysis of tin	Measurement of metals including lead in bulk tin
ISO 3892:2000 Conversion coatings on metallic materials -- Determination of coating mass per unit area - Gravimetric methods	Method to measure CrVI coating weight. May not be very accurate for thin coatings on heavy substrates as relies on weight difference before and after coating removal
JIS H8625 (Japan Industry Standard)	Defines the nominal chromate coating thickness and coating weight (depending on type) using a nominal density of 5 g/cm^3.

Most of the standards listed in the above table are unsuitable for analysis of RoHS substances in homogeneous materials within complex electrical equipment because they require a relatively large amount of a single homogeneous material. Disjointment is needed before most of the methods can be used and this can be difficult. Further, it may be impossible to separate a large enough amount of a pure homogeneous material. A standard has been published which gives useful guidance on disjointment prior to analysis: IEC/PAS 62596 2009 "Electrotechnical products – Determination of restricted substances – Sampling procedure – Guidelines".

EN 62321 is a standard for the analysis of some RoHS substances in certain types of material but not for hexavalent chromium in passivation coatings. This standard includes analysis of CrVI in passivation coatings as an Annex because the method gave inconsistent results in a round-robin trial, although this may have been due to genuine variation in the test samples and not due to the test's inaccuracy. Further work is being carried out to develop an acceptable analysis method that can become a full standard.

- Other relevant standards include:
  - IEC 62476 TR Ed.1: "Guidance for evaluation of product with respect to substance use restrictions in electrical and electronic products" gives guidance on how to design and assess electrical equipment but is not an analysis standard.

- ASTM F 2577 – 06: Standard Guide for Assessment of Materials and Products for Declarable Substances describes procedures for assessment of electrical equipment.

5.4.1 Analysis methods

A number of analytical techniques are available to determine if electrical goods sold within the EU comply with the RoHS directive. The most commonly used by the electronics industry include ICP-MS, AAS, XRF and SEM-EDX and these are described below with particular emphasis on thin coatings. Several mass spectrometric methods are used for the analysis of flame retardants in plastics. The hot water extraction test is the most commonly used for hexavalent chromium in passivation coatings.

5.4.2 Inductively coupled plasma (ICP) spectroscopy and atomic adsorption spectroscopy (AAS)

RoHS analysis standard EN62321 includes ICP and AAS as methods for analysis of lead, mercury and cadmium in metals and in plastics. These techniques require a sufficient quantity of a single material (specified by this standard), which is dissolved into solution and the solution is analysed either by ICP or AAS. Smaller amounts of material can be analysed using ICP-MS, which uses a mass spectrometer to detect and analyse substances and so is more sensitive than standard ICP. With ICP-MS, much smaller quantities of material can be analysed such as might be available on only one component. These techniques rely on having a single pure homogeneous material and this can be difficult to obtain in sufficient quantity from thin coatings. If clean separation is possible then by definition, the material is homogeneous, even though only very small amounts can be separated for analysis. It is not always possible to separate cleanly sufficient material for these analysis methods. The minimum quantity required by EN 62321 is 1 g, which will be impossible if a small component's termination coating needs to be analysed and only one device is available. A smaller amount can be used for analysis by ICP-MS as this is a much more sensitive technique and an allowance is made for the small quantity. However, analysis of thin component termination coatings by AAS or ICP will usually not be possible if only one small component is available.

Although clean separation of sufficient material for AAS or ICP analysis from a single coating layer may be difficult using physical methods, chemical separation methods using selective leaching can be used for RoHS chemical analysis and may be easier. The necessity for mechanical disjointment is only to determine if a material is homogeneous, it is not a requirement for analysis.

5.4.3 X-ray fluorescence spectroscopy (XRF)

XRF is widely used for RoHS screening analysis as the equipment is relatively low cost, is easy to use as long as its limitations are understood and it will give a definitive answer for ~90% of materials that are analysed. A wide variety of X-ray fluorescence analysers are available ranging from relatively low cost hand-held units to more accurate and versatile desktop instruments. All detect Pb, Cd, Hg, Cr and Br but cannot identify the valency state of chromium nor identify which flame retardant is used. The analysis area varies depending on the model and can vary from more than 1 mm diameter to as little as 0.1 mm. Penetration depth depends on the material type, being deeper with light elements such as with plastics than with heavier elements but the depth of material analysed is at least 10µm and so it cannot analyse thin coatings only. For example, the analysis of a thin electroplated tin termination coating in-situ will give results that will include some of the material below the tin. XRF is, however, suitable for screening analysis of termination coatings to check that no lead is present but there can be uncertainty if lead is detected for the reasons explained in section 5.3. A few advanced models include software that estimates the composition of each layer of a multilayer coating but to do this, it is first necessary to input the elements present in each layer. XRF does not usually detect light elements such as carbon and oxygen so that analysis of plastics may not be quantitatively accurate. RoHS analysis of plastics by XRF is, however, possible if the instrument is correctly calibrated with suitable standards and has software that is able to compensate for these types of materials although accuracy may be limited.

Many analysts who test electrical equipment use XRF to screen PCBs and individual parts and so will be using the XRF to analyse several homogeneous materials simultaneously. If no RoHS substance is detected then this indicates RoHS compliance as long as the RoHS substance is not deeper than the analysis depth. In trials carried out by ERA[2], false negatives (i.e. RoHS substance present but not detected) were very uncommon but can occur so care is needed when interpreting results as with any analysis technique. If a RoHS substance is detected at a high concentration then this indicates one of several possible conclusions:

- The part is not RoHS compliant
- There is a RoHS substance but in an exempt form
- There is a RoHS substance in both a restricted form and in an exempt form
- There is no RoHS substance, it is identified due to an artefact of the software

If either Cr or Br are detected, further analysis is needed to determine compliance because XRF cannot determine whether Cr is hexavalent or whether Br is from one of the restricted substances. CrVI is usually identified and the quantity determined using a colorimetric method after hot water or alkali extraction (see section 5.6) and the analysis of PBB and PBDE is best carried out by GC-MS (gas chromatography – mass spectroscopy) although it is sometimes possible to use infrared spectroscopy.

When a RoHS substance is detected by XRF, it is sometimes helpful to dismantle the parts then re-analyse to gain more information on RoHS substances to determine the compliance status but when analysing thin coatings on small components there are limitations to this technique.

[2] Unpublished study carried out for an XRF analyser manufacturer

5.4.4 SEM/EDX - Applicability and limitations of scanning electron microscopy (SEM) with energy dispersive x-ray analysis (EDX)

SEM/EDX is used by some manufacturers and by test houses for RoHS analysis, particularly of very small volumes of material, solder joints and some types of thin coatings often when alternatives such as AAS or ICP are not possible due to the small quantity of material available. This technique can detect Pb, Cd, Hg, Cr and Br at a concentration as low as 0.1% and so can be suitable for RoHS analysis except for cadmium. The related technique SEM/WDX has a lower detection limit of 0.01% and so is suitable also for cadmium. The actual detection limit depends on a number of variables such as the material composition and coating thickness and under worst case conditions, the detection limit that may be achievable could be ~0.5%. SEM/EDX is however often used after XRF has shown that a RoHS substance is present and SEM is used to determine where this is located (i.e. if it is in an exempt form) and so it will usually be used to analyse materials with higher concentrations of RoHS substances. When the detection limit of SEM/EDX is suspected of being more than 0.1% and a RoHS substance is suspected of being present at >0.1% then an option is to use SEM/WDX which will have a lower detection limit. As with XRF however, EDX and WDX do not give information on oxidation state or chemical structure and so cannot determine if the detected chromium is hexavalent or in another state. EDX also cannot identify which flame retardant is present if bromine is detected within a polymer. The main advantage of SEM/EDX over XRF however is that it analyses much smaller areas and thinner layers and so is able to analyse, for example, the electroplated tin alloy coatings used for component terminations which are typically ~2µm thick. A comprehensive assessment of SEM/EDX is given in the appendix to this report and a comparison with XRF is given below.

Table 5: XRF versus SEM/EDX

Characteristic	XRF	SEM/EDX
Instrument price	€25,000 – ~€75,000	€250,000
Detection limit	Variable but usually ~0.01%	EDX = 0.1% WDX = 0.01%)
Minimum analysis area	100µm diameter but most are 1mm or larger	1- 5µm diameter (depends on several variables)
Analysis depth	Several mm for plastics 0.1- 0.01 mm depends on atomic mass	Depends on matrix, element and beam energy Typically 1 - 2µm – see appendix
Multilayer analysis	Possible with some models	Yes, need software

XRF is much cheaper and is usually quicker and more sensitive than SEM/EDX, and so it is widely used for screening analysis of electrical equipment after which other techniques, which may include SEM/EDX, are used for further analysis if necessary. Due to its lower cost, more electrical equipment manufacturers possess an XRF for routine RoHS testing but SEM/EDX are widely available and some larger organisations and test labs that carry out RoHS analysis use SEM/EDX routinely. A limitation of both EDX and WDX is that they can be used to analyse extremely small areas whereas the composition of a homogeneous material may be variable on a microscopic scale; for example, plastics contain filler and pigment particles and SEM/EDX is able to analyse these particles separately without removing them from the polymer matrix. For determination of RoHS compliance, analysis of a sufficiently large area is necessary to determine the composition of what RoHS defines as a homogeneous material.

5.4.5 Methods for hexavalent chromium concentration analysis

There are two methods available for determining the concentration of hexavalent chromium as weight % directly in thin passivation coatings. One is X-ray Near Edge Spectroscopy or "XANES" but this is a very expensive research technique that requires a particle accelerator and so is not a viable option for routine RoHS analysis. X-ray photoelectron spectroscopy (XPS) is reported to be a viable technique and is described in several research publications. One states however that the X-ray beam causes the hexavalent ions to be reduced to the trivalent state and so gives low values[3] although this work showed that chromate passivation coatings on zinc contained between 32 – 42% of Cr and about 8% CrVI. Research using XPS to determine CrVI content of dried passivation coatings showed that CrVI concentrations decreased with drying temperature and so heat causes CrVI to reduce to CrIII. The spectra given in this paper however showed that when the proportion of chromium as CrVI is fairly low, it is very difficult to estimate the percentage of CrVI by weight of the coating as the CrVI appears only as a shoulder on the CrIII peak[4]. Because of the technical difficulties with XPS, it seems unlikely that it can be used as a routine RoHS compliance assessment technique.

5.5 Thin coatings as homogeneous materials

A question that sometimes arises is how thin does a coating need to be before it is no longer regarded as a single homogeneous material? It is by definition a homogeneous material if it can be separated from other materials by mechanical methods such as abrasion. Abrasion is a process where a usually hard material is rubbed over the surface to remove material. The depth of material removal depends on several variables such as:

- Abrasive particle size and shape;
- Hardness of material and of abrasive; and
- Pressure used for abrasion.

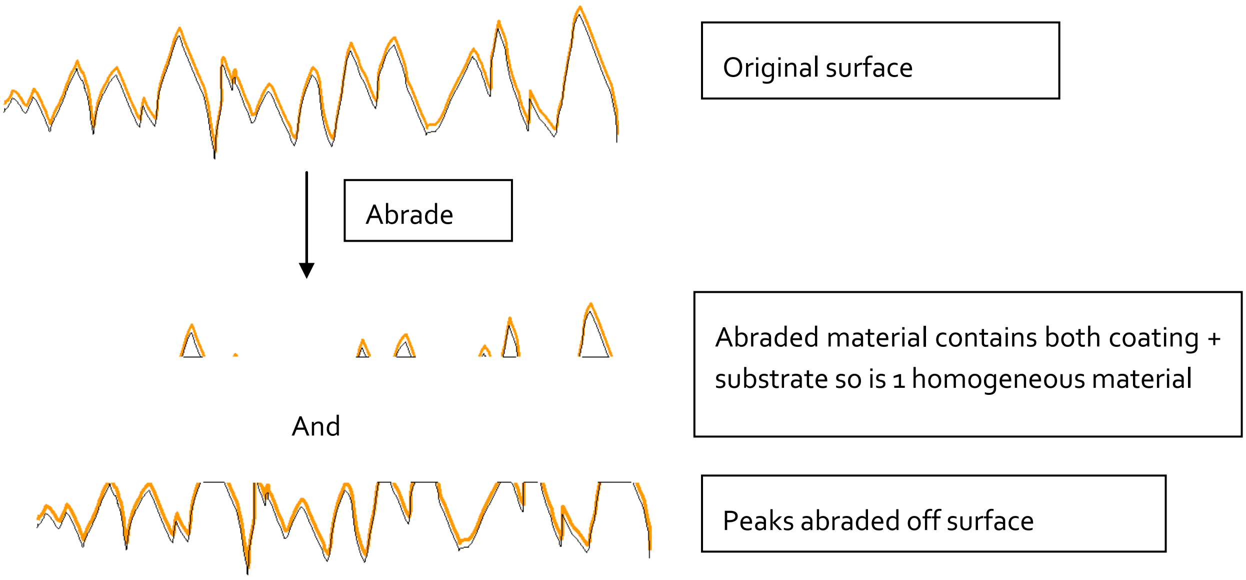
A commonly used hard abrasive material is silicon carbide, which is made with a wide range of different particle sizes for grinding and polishing surfaces. Larger particles remove material more quickly but give rough uneven surfaces, whereas smaller particle sizes remove less material each time the abrasive is wiped across the surface but a smoother surface can be achieved. In practice,

[3] Characterization of chromate conversion coatings on zinc using XPS and SKPFM. X. Zhanga, W.G. Sloofa, A. Hovestadb, E.P.M. van Westingc, H. Terrync, J.H.W. de Wit. Surface and Coatings Technology, Volume 197, Issues 2-3, 22 July 2005, Pages 168-176

[4] X. Zang, et. Al, "Effect of drying temperature on chromate conversion coatings on zinc", Journal Corrosion Science and Engineering, vol 6 (57), 2003.

wiping the abrasive over a surface once removes material to a depth that is less than the diameter of the abrasive particles. Therefore, as abrasives with particle size of <0.25 µm are available, coatings as thin as 0.1 µm can in principal be separated from the layers below. With very thin coatings, the surface roughness may be greater than the coating's thickness so clean separation of the coating from the substrate is not possible. On a microscopic level, all surfaces are rough with peaks and valleys as seen in cross-section. If the thickness of a coating is less than the difference in height between peaks and valleys, it may be impossible to separate the coating from the substrate as shown below:

Figure 1: Example of separation of coating from the substrate not being possible



In this example, the coating cannot be defined as a separate homogeneous material as it cannot be completely separated from the substrate. Where surface roughness is greater than the coating thickness, separation of a thin coating from the rough substrate by mechanical methods would be impossible although the hardness of the coating and substrate also influence whether separation is possible. The minimum thickness that can be removed as a homogeneous material therefore depends on surface roughness which will vary typically from >0.1µm for a matte plated coating to a few nanometres for an optically flat surface. It is therefore not possible to define a coating thickness below which separation is not possible. It may however be possible to define a coating thickness below which analysis is rarely necessary.

RoHS substances are intentionally used in the following examples of thin coatings (typical thickness given):

- Tin/alloy electroplated solderable coatings, e.g. tin/lead >2 µm
- Electroplated nickel, which very occasionally contain cadmium or lead added as a brightening additive >1 µm
- Resistive layers of surface mount chip resistors. These typically contain ruthenium oxide/lead oxide although this lead is currently exempt due to exemption 7cI Typically ~4 µm

- Hexavalent chromium passivation coatings (difficult to analyse as %) Usually >0.1µm (where thinner coatings are used, CrVI is often undetectable so is probably absent)
- Chromate anodised coatings on aluminium vary in thickness from: >0.5 µm (sulphuric acid anodised coatings tend to be thicker)
- Printed ink coatings 2 – 8 µm (thickness variable, occasionally contain lead driers)

All of the above coating types have a thickness of >100 nm and RoHS substances may occur. The following are examples of thinner coatings that are used in EEE but most of these types never contain RoHS substances:

- Silver coatings which act as a light reflector for mirrors 40 nm
- Transparent conduction electrode coatings used for displays consist of tin oxide doped with indium or other elements and are typically ~150 nm thick
- Features on modern state-of-the-art semiconductor circuitry can be as thin as ~30nm or less. Commonly used materials include silica, aluminium, copper and tungsten but RoHS substances are not normally used <30 nm
- The gold coating used on Electroless nickel / immersion gold (ENIG) coated printed circuit boards is typically 0.05µm. This is pure gold and so will not contain RoHS substances ~50 nm
- Embedded thin film resistors[5] built into PCB laminates are made of Ni-Cr or other materials but do not contain RoHS substances (Cr is metal or trivalent). Thickness is typically 10 – 100 nm
- Hexavalent chromium adhesion promotion layers of ~15nm thick are used on the rough side of copper foil to aid bonding to the epoxy resins of circuit board laminates. These layers are much thinner than the depth of surface roughness of the copper foil and so cannot be abraded off as a single material from the copper foil. Once bonded to cured epoxy in finished equipment, separation of this material is physically impossible. It is also very likely that when the epoxy is heat cured, any residual hexavalent chromium will be chemically reduced to the trivalent state as a result of chemical reaction with the epoxy material 15 nm

One of the only types of coating used in EEE of <100nm that sometimes contains an intentionally added RoHS substance is some types of thin chromate passivation coating. Stakeholders have reported that they have found CrVI using the hot water extraction test in coatings as thin as 25 nm. Trivalent chromium passivation coatings are on average ~100 nm and should not contain CrVI.

[5] http://www.ticertechnologies.com/tech_papers/Ticer_TCR.pdf

It is relatively straightforward to measure the thickness of metal coatings, even if these are fairly thin. For coatings of >1 µm, measurement of cross-sections using SEM is possible and optical microscopy can be used for thicker coatings. Methods suitable for thinner metal coatings include XRF with suitable software to calculate coating thickness and this is also suitable for thin multilayer coatings (<100 nm is possible). Other suitable techniques include eddy current thickness measurement.

5.5.1 Thin metal coatings

Thin metal coatings are very common in electrical and electronic equipment. These are used as:

- Tin and tin alloy termination coatings, sometimes electroplated onto a nickel barrier layer
- Thick film coatings which are used as end-terminations of chip components, often coated with a nickel barrier coating and a tin solderable coating. The thick-film coatings are also used as layers on thick-film circuits
- Electroplated zinc coatings on steel used to prevent corrosion.
- Printed circuit boards are made with copper tracks and these are coated with thin layers of materials that maintain solderability. These include electroless silver, electroless nickel and immersion gold, solder alloys, etc.
- The circuitry of integrated circuit is created by complex processes that include depositing thin layers of materials including copper and other metals. These thin layers can be as thin as a few nanometres thick so it is almost impossible to separate one layer from another by abrasion although this depends on the abrasive's particle size. As silicon ICs usually do not use RoHS substances, it is not necessary to analyse these very thin coatings to determine RoHS compliance.
- Thin coatings such as zinc on steel may also be passivated using CrVI and may also have paint or lacquer coatings

Tin alloy termination coatings are typically ~2 – 3 µm, nickel barrier layers are typically ~1µm and electroplated zinc coatings are typically ~4µm thick[6]. Thick-film coatings tend to be thicker at ~10 – 20µm and paint coatings are usually >100µm. Methods are available that are suitable for analysis of coatings of these thicknesses including multi-layer coatings. For example, tin alloys are often electroplated onto nickel barrier coatings. SEM/EDX can be used to selectively analyse the top tin alloy layer. XRF would detect any lead present in the nickel layer although as this is usually at a concentration close to 0.1%, this may not be definitive. SEM/EDX analysis of cross-sections is an option if lead in the barrier layer is suspected. This requires considerable care and skill to obtain accurate results but is a suitable method for determining if lead is suspected of being present.

[6] Results of RoHS analysis using SEM/EDX by ERA.

***Possible guidance for thin coatings**: It appears from the limited data available that the types of coatings that sometimes contain RoHS substances will be at least ~100 nm (0.1µm) thick. Coatings of <100nm thick are very unlikely to contain RoHS substances, except for thin passivation coatings and so an option for a possible guidance is that coatings of <100nm thickness would not normally need to be chemically analysed as RoHS substances are not used in most types of very thin <100 nm coatings used in EEE. Further clarification is provided in section 5.10 and Annex III.*

5.6 Hexavalent chromium in passivation and other thin coatings

Thin coatings that may contain hexavalent chromium (CrVI) are of several main types.

- Passivation coatings – Metals, usually aluminium or zinc coated steel is treated with an aqueous solution that contains CrVI compounds. The CrVI ions in solution react with the metal surface to produce hydroxides or hydrated oxides. These reactions are complex and not fully understood but the main process is:

$$Cr^{6}+ + Al \rightarrow Cr^{3}+ + Al^{3}+ .$$

- The hydroxides or hydrated oxides that form on the metal surface are initially very soft and also readily adsorb ions from solution and so will adsorb CrVI ions. After removal of the metal parts from the treatment solution, any CrVI physically adjacent to the metal surface reacts as above but the rest remains trapped within the coating. The initially soft coating dries and further chemical changes occur to give a much harder and resilient coating. The thickness of these coatings depends on many variables including the treatment solution composition, process temperature and the treatment time.
- Anodised coatings – aluminium and its alloys corrode fairly easily and so can be protected by increasing the thickness of the naturally occurring oxide coating. This is achieved by a process called anodising where the metal parts are immersed in a chemical solution and a current is passed between the aluminium anode and an inert cathode. This causes the aluminium to oxidise. Several types of treatment solutions are used including sulphuric acid and chromic acid. Where chromic acid is used, some CrVI ions from the chromic acid solution are adsorbed into the anodised coating, which improves corrosion resistance. Sometimes, the anodised coating produced with sulphuric acid is "sealed" by dipping it into a solution, which contains CrVI ions, and this also causes some CrVI to be adsorbed into the anodised coating.
- Black passivation – this uses chromic acid to treat steel to obtain a black corrosion resistant coating which may contain adsorbed CrVI ions.

All of these coatings are thin (from ~25 to ~1500 nm) and most can usually be removed from the metal surface with a fine abrasive and so they are by definition homogeneous materials. The amount of chromium present in the hexavalent form varies depending on type of coating and coating thickness. XPS analysis shows about 20 – 30% of the total chromium is present as CrVI which is consistent with several publications and so the CrVI content of the homogeneous material will usually be in the range ~5 – 10% but may be less in the thinnest coatings. Passivation coatings typically contain a mixture of substances including the oxide of the substrate metal (e.g. zinc or aluminium oxide), chromium oxides and additives. Therefore, a typical coating may contain ~40% of chromium oxides of which 20 – 30% is in the hexavalent state and so CrVI would be present in a typical coating at ~25% x 40% =10%, i.e. well above the 0.1% RoHS concentration limit. In one example, the coating contained 28.2% CrIII, (36.9% total Cr) and 8.68% CrVI.

5.6.1 Analysis of thin coatings containing hexavalent chromium

The concentration of hexavalent chromium in thin coatings can be determined directly only by two very uncommon research instruments. The more reliable and accurate is X-ray Near Edge Spectroscopy or "XANES". This can determine the proportion of chromium that is in the hexavalent state but the analysis instrument is very expensive and there are very few available, e.g. in the UK there is only one at Daresbury. The technique uses a synchrotron particle beam for the analysis method so although used for research, it is not appropriate for RoHS testing. The other technique is slightly more common and called X-ray photoelectron spectroscopy or XPS. This can also differentiate between different oxidation states of chromium but this is less accurate than XANES and the sensitivity also depends on the design of XPS. A small number of tests were carried out by ERA using an XPS in the USA and another in the UK. Unfortunately, different results were obtained with CrVI being detected by the US XPS but not by the UK XPS[7]. It has been concluded therefore that XPS was not sufficiently accurate for routine RoHS analysis and is suitable only for research.

*AAS, ICP, XRF and SEM/EDX cannot differentiate oxidation states of chromium and only one method has been found that is sufficiently sensitive and reliable for detecting CrVI in passivation coatings. This is the **hot water test** as defined by EN 15205:2006 or by IEC62321:2008: Part 7-1. This test is rather frequently used for RoHS testing including by at least one Member State RoHS enforcement authority but it does not give results as percentage by weight concentration but as μg/cm^2.*

IEC62321:2008 Annex B included a pass/fail threshold that is equivalent to 0.02 μgCrVI/cm^2, which is a very low value whereas EN 15205:2006 includes a higher threshold of 0.1 μgCrVI/cm^2. The latest version of IEC 62321 will use the higher threshold value of 0.1 μg/cm^2 because IEC believes that this is a more realistic lower detection limit for this test. To convert these values to

[7] Tests carried out to support a study for the European Commission into whether category 8 and 9 could be included in the scope of RoHS, 2006.

%, it is necessary to know both the coating thickness and the coating density but unfortunately, both of these are difficult to measure.

***Thickness and density can however be estimated** and this provides the basis for an analysis method for CrVI in passivation coatings that gives results as percentage.*

This approach is used by NMO in the UK and is being researched by the IEC standards committee TC111 as a possible basis for an analysis standard.

5.6.2 Coating thickness

Several manufacturers of passivation coatings have published their estimates of typical coating thicknesses. These include data from Surtech[8]:

- Yellow 250 – 500 nm
- Olive 1000 – 1500 nm
- Black 250 – 1000 nm
- Pale blue trivalent (no CrVI) 25 – 80 nm

Another publication from MacDermid states that thin electrically conducting CrVI passivation coatings on aluminium are ~40 – 380 nm[9]. Sintef have measured the thickness of trivalent passivation coatings on zinc and published examples of 91, 242 and 402 nm[10]. CrVI passivation coatings that were used by the automotive industry before the End of Life Vehicle Directive banned CrVI were typically 200 nm but coatings used in EEE are much more variable in thickness.

Passivation coating thickness clearly varies depending on the type required. Yellow passivation coatings are used where good corrosion resistance is important and so it is intended that some CrVI is present in the coating and these are typically 250 – 500 nm. Colourless coatings will either be trivalent types or very thin coatings made using CrVI chemicals. There is much less data on the thickness of thin "colourless" coatings made using CrVI chemical but they are likely to be 100 nm or thinner as thicker coatings will be coloured. These thin coatings may contain CrVI although analysis is quite difficult because the total amount of CrVI present is very small although if present it can be detected by the hot water extraction test. This test has shown that these very thin coatings sometimes contain >0.1% CrVI.

5.6.2.1 Coating thickness measurement

An option is to measure the coating thickness. Direct measurement of thickness from a cross-section by SEM can be used for thicker passivation coatings but preparation of cross-sections is difficult requiring a high level of skill that most analysis service providers will not have[11]. ISO 9220

[8] "Chromiting, chromium(VI)-free Passivating Basecoat for Deltacoll on Zinc and Zinc Alloys, P. Hulser, 1999.

[9] "Iridite NCP, A Comparison Of Iridite NCP To Yellow Chromate" Richard Bauer & Justin Girard, MacDermid, 2004.

[10] "Hexavalent chromium-free passivation treatments in the automotive industry", L. Thiery and N. Pommier, 2004

[11] CrIII passivation coating thickess values reported by Sintef in reference 7 are measured from cross-sections.

describes the measurement of thickness of oxide coatings on metals using SEM of cross-sections and states that this can have an accuracy of 10% of the thickness or 100 nm, whichever is greater, indicating that accuracy for thin coatings will be very poor.

Several instrument methods such as Auger combined with an ion beam, Glow discharge spectroscopy and ellipsometry are used to measure thickness of CrVI passivation coatings, anodised coatings, etc. Auger is a relatively expensive surface analysis tool in which the surface coating can be slowly ablated away using an ion beam[12]. The thickness is estimated using Auger to monitor the surface composition while slowly removing the surface with the ion beam until there is a surface composition changes, and then the thickness is calculated from the amount of material removed. Auger does not differentiate between oxidation states of chromium but will detect the difference between the passivation coating, which is a mixture of oxides, and the substrate, which is a metal.

Ellipsometry is an optical measurement method and instruments cost from €20,000 – €50,000 so the cheaper models are similar prices to handheld XRF analysers. It measures the polarisation of reflected light from thin films and the extent of polarisation depends on thickness, refractive index and dielectric constant. Surtech has compared two thickness measurement techniques with SEM of cross-sections and some variability occurs[13]. For example, results with a CrVI passivation coating,

- SEM (from a cross-section)= 300nm,
- Glow discharge spectroscopy = 312nm and
- Ellipsometry = 353nm.

Performing a cross-section to measure passivation coating thickness is extremely difficult, especially if the coating is relatively thin. In Surtech's investigation, thickness measured by glow discharge spectroscopy and by SEM of a cross-section gave similar results although ellipsometry gave a slightly thicker result.

EN ISO 3613 gives a method for measurement of total Cr in passivation coatings using acid dissolution. This is not the same as the total coating weight as the coating contains other substances as well as Cr. Furthermore, as sulphuric acid is used, it is possible that some substrate would also dissolve so this is not suitable for measurement of coating weight. ISO 3892 gives several gravimetric methods for measurement of coating weight. These use chemicals (cyanide for Zn or Cd and nitric acid for Al substrates) that are intended to selectively dissolve the passivation coating so that the coating weight is measured by the difference in sample weight before and after coating removal. This potentially has two problems. Firstly, the difference in weight may be extremely small, especially with thin coatings and so weighing accuracy will not be adequate. The other issue is that the suggested solutions for coating removal may not be completely selective and so this method may over-estimate coating weight.

Any method to measure the thickness of thin coatings such as by ellipsometry, will be more accurate if the instrument / procedure can first be calibrated using standard materials of known

[12] This is described in reference 4

[13] http://www.surtec.com/Presentations/Chromiting.pdf

thickness. Standards of passivation coatings of known thickness are not available and so there will be some uncertainty over any thickness measurement method.

5.6.3 Coating density

Measurement of coating density is difficult, especially if the coating is very thin but this can be estimated by knowledge of their composition. CrVI coatings on aluminium are likely to be a mixture of aluminium and chromium oxides and coatings on zinc are a mixture of zinc and chromium oxides. The densities of these oxides are:

- Cr_2O_3 density = 5.2 g/cm^3. (note that the hydroxide's density is 5.0 g/cm^3.)
- Al_2O_3 density = ~4 g/cm^3.
- ZnO density = 5.6 g/cm^3.

Therefore, to calculate CrVI concentrations, a coating density of 5.0g/cm^3 would be approximately correct except for freshly deposited coatings, which are soft hydrated oxides and will have a lower density. By the time equipment manufacturers receive equipment or components, which they need to analyse, the passivation coatings will have sufficiently aged and dehydrated to be mostly oxides and so assuming a density of 5.0 g/cm^3 is probably reasonable. JIS H8625 also assumes that passivation coatings have a density of 5.0 g/cm^3.

5.6.4 Surface area of parts

The last variable needed for the calculation is the surface area of the part being analysed. Where this is one surface of a piece of flat metal, measurement of the area is straightforward. CrVI passivation films are often used on zinc plated fasteners with screw threads so determination of surface area is more difficult. A method is however provided by EN ISO 3613 for calculation of the surface area of metric screws.

5.6.5 Possible rule for calculation of CrVI concentration in passivation coatings

If the quantity of CrVI as µg/cm^2, the thickness and density are known, then the concentration of CrVI in the homogeneous material as percentage weight can be calculated.

- The quantity of CrVI as µg/cm^2, can be measured with reasonable accuracy using the hot water extraction test according to the method in EN 15206:2006.
- Density will need to be an estimate and a value of 5.0g/cm^3 will usually be approximately correct.
- Thickness could be estimated or measured.

- If thickness is estimated, then choosing a value that is the minimum that is likely would give the highest possible concentration value because by using a higher thickness value, this would give a lower % CrVI result.
- If thickness is estimated, then choosing a value that is the maximum that is likely would give the lowest possible concentration value because by using a lower thickness value, this would give a higher %CrVI result

Some hypothetical example calculations follow:

i) 0.1 µg/cm² measured from a yellow passivation coating so <u>minimum</u> thickness is 250 nm. The coating weight = density x volume = 5.0 g/cm³ x 0.000025 cm x 1 cm x 1 cm (for 1 cm² surface area) = 125 µg. Therefore the concentration is 0.1/125 µgCrVI/µg coating = 0.08% (below concentration limit)

ii) 0.2 µg/cm² measured from a black passivation coating, with a thickness of <u>minimum</u> 250 nm. The coating weight = density x volume = 5.0 g/cm³ x 0.000025 x 1 x 1 (for 1 cm² surface area) = 125 µg. Therefore the concentration is 0.2/125 µgCrVI/µg coating = 0.16% (slightly above concentration limit). Black coatings can be as thick as 1000 nm. If this value is assumed, then the CrVI concentration would be 0.04% and RoHS compliant.

iii) 1.0 µg/cm² measured from a yellow passivation coating so <u>minimum</u> thickness is 250nm. The coating weight = density x volume = 5.0 g/cm³ x 0.000025 x 1 x 1 (for 1 cm2 surface area) = 125µg. Therefore the concentration is 1.0/125 µgCrVI/µg coating = 0.8% (above concentration limit and so not RoHS compliant)

iv) 0.2 µg/cm² measured from a pale blue trivalent passivation coating so <u>maximum</u> thickness is ~100 nm. The coating weight = density x volume = 5.0g/cm³ x 0.00001 x 1 x 1 (for 1cm² surface area) = 50µg. Therefore the concentration is 0.2/50 µgCrVI/µg coating = 0.4% (therefore above concentration limit).

v) 0.02 µg/cm² measured from a thin transparent passivation coating, thickness estimated to be ~50 nm. The coating weight = density x volume = 5.0g/cm³ x 0.000005 x 1 x 1 (for 1cm² surface area) = 25µg. Therefore the concentration is 0.02/25 µgCrVI/µg coating = 0.08% (therefore below concentration limit).

vi) 0.02 µg/cm² measured from a thin transparent passivation coating, thickness estimated to be ~25 nm. The coating weight = density x volume = 5.0g/cm³ x 0.0000025 x 1 x 1 (for 1cm² surface area) = 12.5µg. Therefore the concentration is 0.02/12.5 µg CrVI/µg coating = 0.15% (therefore slightly above the concentration limit).

Comments on these results:

- The estimate for example (i) shows that if 0.1 µg/cm² or less is measured with yellow passivate, these types of coating will be RoHS compliant with <0.1% CrVI. 0.1 µg/cm² is the concentration threshold used in EN15205:2006. For coatings thinner than 200nm, this is equivalent >0.1% and so could give false positive results, i.e. below the 0.1 µg/cm² threshold value but > RoHS concentration limit.

- The thickness of black passivate varies so that the result depends on what thickness value is used. With a measured value of 0.2 µg/cm², only at the thinnest end of the range of typical thickness found with black passivate is not RoHS compliant and so if a generous allowance for thickness were used, e.g. 1000nm, this example would be RoHS compliant.
- Example (iii) has a larger amount of CrVI extracted and so even with fairly thick coatings, this method would always show that CrVI exceeds the RoHS concentration limit.
- Example (iv) is of a thinner coating, which is not intended to contain CrVI. Analysis of these coatings usually finds no CrVI (i.e. no pink colour visible) and so this must be RoHS compliant as CrVI is not detectable. However, sometimes, the coating process is not correctly controlled so that up to 0.2 µg/cm² is measured. As these coatings are much thinner than yellow or olive passivates, this gives an estimate of CrVI concentration in the coating at a level above the RoHS concentration limit and so this method gives a result that indicates that the coating is not RoHS compliant.
- Example (v) was the original threshold value of IEC 62321:2008 Annex B of 0.02 µg/cm², which is lower than the threshold value used by EN15205:2006. The calculated CrVI concentration gives for even this very thin coatings a "pass" result, but higher concentrations with 50µm would show >0.1%CrVI.
- Example (vi) also uses the original IEC 62321:2008 Annex B threshold value with the thinnest likely coating where CrVI has been detected. The calculated CrVI concentration is only slightly above the RoHS 0.1% concentration limit which shows that if the 0.02 µg/cm² were used to show compliance with the 0.1% concentration limit, values of <0.02 µg/cm², would be equivalent to approximately less than 0.1%CrVI. However, if a value of 0.04% were measured for a coating of 100nm, this coating would contain ~0.08%CrVI and so is RoHS compliant but the lower threshold is exceeded, i.e. a false positive result.

Determination of "pass/fail" status: Manufacturers and enforcement authorities could use this method with an assumed coating thickness and density to determine if CrVI is above or below the 0.1% concentration limit. A manufacturer might assume the thinnest coating that is likely in order to ensure that coatings are RoHS compliant. An enforcement authority might however assume the thickest coating that is likely in order to be sure that a non-compliance result were correct and could be used for legal action. However, if there is any doubt over the compliance status, for example if the CrVI concentration is close to 0.1% (a range where the result is uncertain could be from 0.05% – 0.4% and this should be defined by the standard), then measurement of the coating thickness by one of the methods described above could be used to obtain a more accurate CrVI concentration result although this is limited by the accuracy of the thickness measurement method.

The RoHS concentration limit as defined by 2011/65/EU for CrVI is 0.1%. A compliance limit of, for example, 0.1 µg/cm2 cannot be used to demonstrate compliance unless it can be shown that it is directly equivalent. Most passivation coatings, which are intended to contain CrVI will have much more than 0.1% CrVI and also more than 0.1 µg CrVI/cm^2 so this threshold value can be used to determine compliance status. However, a small proportion of coatings, especially thin coatings, will contain <0.1 µg CrVI/cm^2 but contain >0.1% CrVI and so assuming that test results below this threshold value are always RoHS compliant is not correct. Therefore, it is necessary to estimate thickness and use an assumed density of 5.0 g/cm^3.

CrVI variability: Finally, a comment should be made on variability of CrVI concentrations in coatings. Chromate passivation coatings do not have a stable composition and the CrVI content is known to change with time. CrVI is reduced to CrIII when heated and metals and organic impurities can cause a change in its concentration. It is also possible that the concentration on a surface can vary depending on the initial surface cleanliness and other variables. Manufacturers find that CrVI measurements can vary from sample to sample and this does not appear to be due to limitations in the accuracy of the hot water extraction test, but is a genuine effect.

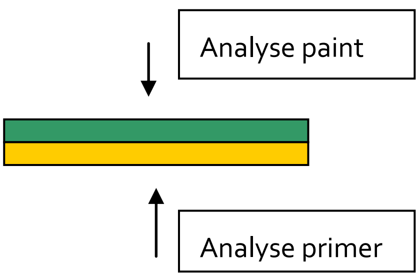
5.7 Paint coatings

Paint and lacquer coatings tend to be significantly thicker than electroplated metal coatings and are typically 100 – 500µm thick. Therefore, the penetration depth of XRF should be no more than the paint or lacquer's thickness. Paint and lacquer coatings are usually applied to metals sometimes to provide corrosion resistance as well as for a decorative effect. When they are used for corrosion resistance, more complex multi-layer coatings are used, for example:

- Passivation treatment – this can be CrVI; then
- Primer coating, some contain chromates (CrVI); and finally
- A paint coating of 100 – 500 µm.

Paint coatings can usually be peeled or scraped off metal surfaces and then analysed by dissolution in alkali and analysis of this solution for CrVI using a colorimetric test. If there is both a primer and paint, these will be two homogeneous materials as they can be separated by abrasion of the paint. Clean separation of sufficient material for analysis may be difficult to achieve but XRF could be used to determine Cr in both materials by analysis of each side of the peeled off layer.

Figure 2: Two-side layer analysis



If a passivation coating is also used on the metal surface, this will be very thin and it may be impossible to mechanically separate this material from either the metal or the paint/primer. It would not be regarded as a separate homogeneous layer but part of either the paint or the substrate materials.

5.8 Small components and small features in complex coatings

Stakeholders were asked whether analysis of very small components can be reliably analysed for RoHS compliance. Some comments were received stating that this is a serious problem whereas others report that very small components can be analysed if suitable methods (such as SEM/EDX) are used. The main concern is with thin coatings. SEM/EDX is a useful technique not only for very small components but also for very small volumes of a material within any component. One stakeholder stated that full quantitative analysis of small components is difficult or impossible. However this is not necessary for RoHS where it is required only to determine whether any RoHS substances exceed the maximum concentration limits and so XRF and SEM/EDX are often suitable.

Stakeholders were also consulted about the China-RoHS approach to defining homogeneous materials. Chinese RoHS legislation assumes that any components of $<4mm^3$ are single homogeneous materials but China RoHS is primarily an information requirement and does not yet include substance restrictions. Although several stakeholders supported this approach for the EU as it simplifies analysis of very small components and would ensure consistency with Chinese legislation, this approach may be inappropriate to use in the EU for the following reasons:

- Assuming that all small components are homogeneous materials would allow manufacturers to intentionally use RoHS substances albeit in small quantities because these would be diluted within the components to <0.1%. For example, a QFP-IC (quad-flat pack integrated circuit) that has an electroplated Sn5%Pb alloy termination coating will contain <0.1% lead overall, typically at ~0.09%Pb.
- RoHS analysis of very small components is nearly always possible using an appropriate technique. Note that it is necessary only to determine if a substance is above or below the maximum concentration value.
- "Components" is a term that is difficult to define. It is quite common for electronic components to consist of several parts, which could themselves be referred to as "components".

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*As **defining small components as single homogeneous materials** could allow an increase in use of RoHS substances whereas RoHS analysis is usually possible, this change of definition will not be proposed as a new rule.*

5.9 Input and comments from stakeholders

Stakeholders were asked to provide their opinions on the issues being studied. Responses were received from several manufacturers and also from Trade Associations whose responses reflect the overall opinions of their members. Comments on homogeneous materials definition are summarised below:

- The current definition of homogeneous materials as defined in Article 3 (20) is satisfactory although some manufacturers have practical difficulties such as with isolating single materials or obtaining data from suppliers. One stakeholder commented that it would be helpful if official RoHS guidance were to state that chromate passivation coatings and polymeric coatings are examples of homogeneous materials. Comments received from stakeholders can be summarised as follows:
  - No change to definition needed 14
  - Current definition not suitable 4
  - Current definition OK but guidance needed 4
- Analyses of thin coatings such as multilayer electroplated coatings are of concern to a few stakeholders. A few also stated that they had difficulty with analysis of very small components, small volumes of material that are not at the outer surface, solder joints on PCBs and brominated flame retardants in plastics. Difficult analysis reported by stakeholders were:
  - No difficulties experienced 3
  - Hexavalent passivation coatings 11
  - Electroplated coatings 3
  - Small components 4
  - Solder joint analysis 4
  - PBDE in plastics – one stakeholder specifically mentioned this although it may be due to a lack of suitable expertise rather than suitable methods.
- Stakeholders were also asked which standards they currently use for RoHS:
  - EN 62321 9
  - DIN 50993-1 (CrVI) 1
  - IEC/PAS 62596 1
  - In-house methods or none 2

Analysis methods such as EN IEC 62321 should preferably be EU harmonised standards for showing compliance with RoHS. One stakeholder suggested that IEC/PAS 62596 is also an EU harmonised standard but this will not be possible until it is converted into a full IEC standard instead of a PAS (publically available specification).

- One stakeholder commented that RoHS analysis of very small components is no more difficult than larger items as difficult analysis issues are not component size dependent.
- Stakeholders were asked which analysis methods they currently use for determining RoHS compliance:
  - XRF 13
  - SEM 7
  - AAS 2
  - ICP (and ICP-MS) 4
  - Mass –spectroscopy 3
- Stakeholders were asked whether they analysed samples themselves or sub-contracted this work:
  - In-house 11
  - Sub-contract 11
  - No RoHS analysis carried out 2
- A pass/fail test method for CrVI passivation coatings defined by an EN harmonised standard is the preferred option for many stakeholders. Stakeholders were asked whether demonstrating RoHS compliance using EU harmonised standards would be preferable and ten stakeholders agreed whereas four did not support this approach. One stakeholder was concerned that they should not be forced to use one method whereas in fact all EU harmonised standards are all voluntary so it is possible that some stakeholders may have misunderstood that this would be optional.
- Stakeholders were asked if the mandatory method for showing RoHS compliance should be in EU legislation. 5 disagreed whereas 4 supported this suggestion.
- Stakeholders were asked if they supported the adoption of the China-RoHS definition of homogeneous materials, i.e. all components of <4mm^3 are one homogeneous material. Nine supported this and four opposed. Three supported this but with reservations. Only one fully supported the Chinese classification of multi-layer coatings as being a single material although several said that they had difficulties analysing these coatings. The Chinese multi-layer coating definition as a single homogeneous material also specifies that the concentration limit is any RoHS substance that can be detected which could be much less than 0.01% and one stakeholder stated that a fixed limit should be specified.
- Some EU legislation such as the End of Life Vehicle Directive has a definition of homogeneous materials that states that they should not be intentionally added. This was not originally used for RoHS as it would be impossible to

determine intent. Stakeholders were consulted on whether this should be used for RoHS; seven stated that it should be used and seven did not support the use of this approach.

Further information on the analysis of CrVI in passivation coatings has been provided by stakeholders:

- The hot water extraction test is probably the best method currently available and tests have shown that it extracts >98% of the CrVI in all coatings except those that are relatively thick and which usually have high concentrations of CrVI.
- Alternative extraction tests have not yet been developed. Alkali extraction with sodium hydroxide is not suitable as any exposed substrate metal rapidly reduces any CrVI to CrIII so the CrVI that was present is not detected. Preliminary research indicates that extraction by weaker alkali may be possible but more work will be needed before a reliable test method can be defined. There is also a risk with alkali extraction tests that some CrIII can be oxidised to CrVI during the test giving an incorrect high CrVI concentration.
- Coating thickness measurement using EN ISO 3613 is not accurate and uses very dangerous chemicals (cyanide).
- There are no industry or EN standards for thickness measurement of passivation coatings using GDOES14 or ellipsometry or for RoHS analysis using SEM/EDX.

5.10 Discussion and possible guidance

The main concern expressed by stakeholders is that analysis of passivation coatings to determine the CrVI concentration is very difficult. Two options are considered for CrVI in passivation coatings. One is to calculate the weight percent concentration of CrVI using estimated thickness and density. This has the advantage that it is directly comparable with the RoHS concentration limit of 0.1%CrVI. The use of a threshold of 0.1 $\mu g/cm^2$ has also been considered but as this can give false negative results, i.e. indicates "pass" when the coasting contains >0.1% CrVI, this is less satisfactory although much easier for industry. Nonetheless, is likely that these false negative results will be relatively uncommon as most coatings will have either ~10% CrVI or <0.1% CrVI but there will be exceptions. Use of the original 0.02 $\mu g/cm^2$ threshold should not give false negative results but IEC believe that the hot water extraction test is not sufficiently accurate at levels below 0.1 $\mu g/cm^2$. Some stakeholders have commented that it is unclear when analysis is expected but this issue is outside the scope of this study, though briefly discussed here.

[14] This is apart from ISO TS 25138 "Surface chemical analysis – analysis of metal oxide film by glow discharge optical emission spectroscopy"

Box 1: Possible guidance I

Passivation coating analysis

Analysis of CrVI as % by weight is difficult whereas a simple, reliable and very sensitive method is available for analysis of CrVI is passivation coatings but which gives results as $\mu g/cm^2$. To convert these values to % requires knowledge of the coating's thickness and density. Coating thickness is not usually known and most electrical equipment manufacturers do not have the equipment or expertise to measure thickness accurately. Density is not known but could be assumed as ~5.0 g/cm^2.

Passivation coatings that are used for electrical equipment are essentially of two types. Either: i) intentionally contain hexavalent chromium at ~10% of the coating (e.g. in yellow or olive coatings) or ii) CrVI is not intended to be present such as in trivalent coatings where CrVI should be present at <0.1%. If the coating density and thickness (based on colour and type) were assumed, then a reasonable estimate of CrVI concentration could be made from the result of the hot water extraction test. This estimated result will usually be much larger than 0.1%CrVI for coatings with intentionally CrVI coatings and will usually be <0.1% if CrVI is not intended to be present, although exceptions do occur.

If borderline results are obtained then coating thickness can be measured so that more accurate CrVI concentrations could be calculated but this would be expected to be necessary only in a small percentage of tests. Thickness measurement can be difficult to carry out and the accuracy is uncertain, as no standard materials are available for calibration of the techniques so it is recommended that thickness is measured only if a borderline result is obtained and non-compliance is suspected. It would be helpful to manufacturers for legal certainty if the hot water extraction test method and the procedure for estimation of CrVI concentration as an acceptable method of showing RoHS compliance were in an EU RoHS harmonised standard which could be referred to in product Declarations of Conformity. The basis of this standard could be EN 15205:2006 or IEC 62321 with a procedure for estimating thickness and a standard density value (e.g. of 5.0g/cm^3). Coating density and thickness could be estimated as described in this report unless this gives a borderline result, in which case thickness measurement is possible and would be needed for greater accuracy and certainty. Standards for coating thickness measurement would in these cases also be useful.

Box 2: Possible guidance II

Very thin coatings

Another issue is the difficulty of analysis of very thin coatings. The RoHS definition of homogeneous materials is that if two materials, such as two layers of a coating can be separated by physical methods, then these are two different homogeneous materials. However this study has found that the types of coatings used in EEE that are thinner than 100 nm rarely contain RoHS restricted substances except for some thin passivation coatings. It is therefore possible to exclude these thin coatings from the necessity to analyse as explained in the guidance in Annex III.

The two pieces of guidance above could be included in the FAQ document accompanying RoHS II together with the clarification for the assessment of very thing coatings (see Annex III).

5.11 Conclusions

The RoHS directive's definition of homogeneous materials has been reviewed with the aim of developing guidance that would simplify compliance and give greater legal certainty to industry and to Member State enforcement authorities. These should however not allow an increase in the use of RoHS substances.

It is clear from this study and from information provided by stakeholders that:

- Analysis of CrVI in passivation coatings is the most difficult analytical problem because the standard methods do not give results as % by weight. Guidance has been proposed that the hot water extraction test is used as the test method in an EU harmonised standard for RoHS. This should also describe how to calculate concentrations from weight of CrVI per unit area using an assumed density of 5.0 g/cm2 and also assuming a coating thickness. Industry would assume the thinnest likely coating so that if a "pass" result is obtained, any likely thickness would be RoHS compliant. Enforcers would assume the thickest likely coating so that a "fail" (i.e. non-compliance) result would be correct for any likely thickness. However, greater accuracy and legal certainty could optionally be achieved by using one of the thickness measurement methods described in this report. Nevertheless, it is not recommended that thickness measurement is a requirement due to the difficulty and uncertainty of these methods. Research into thickness measurement of passivation coatings is needed and standard materials for calibration and an agreed harmonised standard for thickness measurement methods would be helpful.
- Two different "threshold" values have been used in IEC 62321 (Annex B) and EN 15205 of 0.02 and 0.1 µgCrVI/cm^2. 0.02 µgCrVI/cm^2 can be measured but is a very low concentration and IEC believe that values below 0.1 µgCrVI/cm^2 are not accurate. Coatings with >0.02 µgCrVI/cm^2 that are thicker than 100nm

may have <0.1%CrVI. The higher threshold now used in both EN 15205 and IEC 62321 of 0.1 µgCrVI/cm2 can more easily be measured but if values of < 0.1 µgCrVI/cm^2 are measured in very thin coatings, these can contain >0.1%CrVI. Therefore, although thresholds are a useful guide, especially as most passivation coatings have either no CrVI or have much more than 0.1%CrVI, they can potentially give false-positive or false-negative results. Assumption of density and thickness to estimate %CrVI may be a more accurate approach and so would be more suitable for a possible harmonised standard analysis method. There is also the option of measurement of coating thickness when borderline results are obtained to remove any uncertainty. It is suggested that borderline is defined as >0.05% and <0.4% CrVI but more research is needed to determine more suitable values.

- Where manufacturers carry out RoHS analysis and provided comments, XRF is the most commonly used RoHS screening analysis method. It is known that XRF is much more commonly used than SEM/EDX as the equipment costs much less than SEM/EDX and is easier to use. XRF is usually the preferred screening analysis method, which gives a clear pass / fail result in at least 90% of tests. As with all analysis techniques however, the analyst should understand its limitations and be aware of false positive and false negative results. Where there is doubt over the XRF result or a borderline result is obtained then further analysis using an appropriate technique is required and the choice depends on the type of material and the substance to be analysed. The hot water extraction test is the most commonly used method for CrVI in passivation coatings and several mass spectroscopy techniques are most commonly used for PBDE analysis in plastics. Dissolution then analysis by AAS, ICP or ICP-MS is accurate as long as sufficient material is available. Some stakeholders use SEM/EDX but as this equipment is very expensive and requires a high level of skill, it is available only to large-size manufacturers and used by some RoHS analysis test houses. At present there are no EN standards for SEM/EDX analysis of EEE or for flame retardant analysis in the plastics used in EEE.
- Analysis of very small components can be problematic. This is alleviated to a large extent by using SEM/EDX but some stakeholders claim (but not others) that even with SEM/EDX, there can be uncertainty with analysis of the very smallest components, particularly those that may contain both RoHS exempt and RoHS restricted lead.
- Some stakeholders claimed that analysis of multilayer electroplated coatings is difficult but others claim to have no difficulty. Some of those who claim to have no difficulty use SEM/EDX. When multilayer coatings are very thin, of <100nm then SEM/EDX may not be suitable (this depends on composition of each layer) but it is very unusual for RoHS substances to be intentionally used in coatings that are thinner than 100 nm. The approach to assessment of thin coatings could be clarified here using guidance, which is described in this

report. When a coating is very thin and the surface roughness is equal to or greater than the coating thickness, then it may not be possible to separate the coating from the substrate by mechanical disjointment. However very thin coatings on perfectly flat surfaces can be separated if sufficiently fine abrasive is used and thin soft coatings on hard surfaces can also often be mechanically disjointed. It is therefore not possible to define a coating thickness below which mechanical disjointment is not possible. However, as RoHS substances are very unlikely to occur in coatings of <100nm in most types of EEE, it is not usually necessary to analyse for RoHS substances the types of coatings that are <100nm thickness. This would be with the exception of thin passivation coatings for CrVI and possibly also for very unusual types of thin coatings that are not normally used for electrical or electronic equipment but where RoHS substance use is known to be a possibility.

- The majority of stakeholders have stated that the definition of homogeneous materials is satisfactory and should not be changed. However, interpretation can be an issue with some suppliers misunderstanding what a homogeneous material is. Some stakeholders have asked that further guidance be provided. Semiconductor device manufacturers are particularly frustrated that some of their customers insist on full analysis of all homogeneous materials, even though there is no likelihood that RoHS substances are present. Official guidance on circumstances where analysis is not necessary would be as useful as guidance on when it might be needed.

Chapter 6: Recommendations

In brief: Based on the analysis presented above as well as in the factsheets, several recommendations are made. Two product groups, namely electric bicycles that are not type-approved and pipe organs are recommended to be excluded from the scope of RoHS II and articles 2(2)/4(3) and 4(4) are recommended to be amended. Regarding RoHS concentration limit compliance, two pieces of guidance should be included in the FAQ document: One on passivation coatings analysis and the other on very thin coatings. It is also recommended that three or four new EU RoHS harmonised standards are developed that would aid the demonstration of RoHS compliance.

6.1 Potential scope amendments

Based on the analysis presented in the impact assessment factsheets, Table 6 provides an overview of recommendations for the individual product groups as well as other issues that were assessed. A scope amendment in the form of an exclusion from the scope of RoHS II in the future is recommended for two product groups, namely electric bicycles that are not type-approved and pipe organs. Articles 2(2)/4(3) and 4(4) are recommended to be modified in order to avoid potentially significant negative impacts.

Table 6: Recommendations for product groups and other issues

Product category/issue	Recommendation
Product groups	
Automatic doors/gates	No change
Cables: Finished EEE not in other 10 categories	No change
Combustion-engine powered garden equipment for non-professional or dual use	No change, exemption potentially required at substance level for lead and CrVI if research does not provide suitable substitutes
Complex air conditioning systems	No change
Fuse boxes	No change
Gas water heaters with electrical function	No change
Electric two-wheel vehicles which are not type-approved	Exclusion from scope
Furniture with an electrical function	No change
Lifts and escalators	*Not assessed as draft FAQ defines them as LSFI*
Light switches, power wall sockets	No change
Pipe organs	Exclusion from scope
Power switches	No change
Safes	No change
Swimming pools	No change
Toys with minor electrical functions	No change
Other issues	
Art. 2(2) and 4(3): Compliance date for newly included product groups	Option 1: Delete Article 2(2) and amend Article 4(3) to include other equipment that was outside of the scope of RoHS I which was placed on the market from 22 July 2019 Option 2: Amend Article 2(2) to exclude categories 8 and 9
Art. 4(4): Exclusion for spare parts for Cat. 11 and other newly included products	Introduce the following to Art.4(4): "(g) other EEE not covered by (a)-(f) placed on the market before 22 July 2019"

6.2 Guidance for compliance with RoHS concentration limits

Regarding compliance with RoHS concentration limits, it would be recommended to include two pieces of guidance in the FAQ document as outlined in Chapter 5:

- One on passivation coatings analysis;
- One on very thin coatings, accompanied by a clarification on the assessment of very thin coatings, potentially in the annex of the FAQ document.

It is also recommended that three or four new EU RoHS harmonised standards be developed that would aid the demonstration of RoHS compliance. These are:

- The hot water extraction test procedure for estimation of CrVI concentration by weight in passivation coatings and anodised coatings on EEE using estimated coating thickness and density values
- A standard for chemical analysis procedures for thin coatings in EEE using scanning electron microscopy with energy dispersive X-ray analysis and wavelength dispersive X-ray analysis
- Measurement of thickness of passivation and anodised coating in EEE using ellipsometry and glow discharge optical emission spectroscopy (this could be two separate standards)

6.3 Further research

It is stressed that for a number of product groups, it has not been possible to enter into a fruitful discussion with stakeholders and very limited data has been available. These product groups include, in particular, automatic doors and gates; furniture with secondary electrical functions; electronic safes; and swimming pools. Further research might therefore be advisable in order to rule out any significant impact their inclusion in scope of RoHS II might have.

Annex I: List of product groups affected by scope changes

Category	Product category	Product group - examples
Large household appliances (1)	Gas hob, grill with electrical function	Gas hob, grill with electrical function
	Gas oven, wood or oil burning Aga with clock/timer	Gas oven, wood or oil burning Aga
	Gas water heaters with electrical function	Gas water heaters with electrical function
Consumer equipment (4)	Furniture with an electrical function	Reclining beds
		Reclining chairs
Electrical and electronic tools (6)	Petrol engine equipment with electrical function other than the spark, not self-propelled or self-propelled consumer types	Lawnmowers
Toys, leisure and sports equipment (7)	Electric two-wheel vehicles which are not type-approved	Bicycles
		Segways
		Scooters
		Boards
	Jet packs	Jet packs with electrical function
	Toys with minor electrical functions	Bears with watch/beep button or speaking function
		Dolls house with lights
		Shoes with lights
Monitoring and control instruments (9)	Alarm systems	Fire alarms - effect of LSFI exclusion
	Alarm systems	Security alarms - effect of LSFI exclusion
	Weather balloons	Weather balloons (unless used for photography, then Cat. 3)

Category	Product category	Product group - examples
Other EEE (11)	Automatic doors/gates	Automatic doors
		Garage doors
	Automatic doors/gates	Electric gates
	Cables	Extension leads
	Consumer electronics powered by photovoltaics with no batteries or power storage device	Bags with battery chargers
		Calculators
		Laptops
		Mobile phones
		Watches
	Educational equipment not in categories 1-10	Globes
	Fuse boxes	Fuse boxes (unless cat 9 or LSFI)
	Clothing with electrical function (unless used for leisure, then cat 7)	Heated clothing (plug-in)
		Life jackets with lights on contact with water
	Level crossing barriers	Level crossing barriers (independent control so not LSFI)
	Light switches, power wall sockets	Light switches (except those designed only for LSFI)
	Mirrors	Mirrors with decorative LED lights (unless lighting is primary function)
	Pipe organs	Pipe organs (unless large-scale fixed installations)
	Power switches	Power switches
	Safes	Safes with an electronic coded lock
	Suitcases	Electric powered suitcases
	Swimming pools	Swimming pools for home use with pumps included. Might also be Cat 1 or 6. Might also be excluded as large-scale fixed

Category	Product category	Product group - examples
		installations
	Wardrobes	Wardrobes with lights or other electrical feature (e.g. tie rotators)
Newly excluded	Equipment excluded by Article 4.5 - spare parts from old equipment that can be used in new equipment	Components of copiers, printers, games machines that are re-used until 1 July 2016
	Equipment to be sent to space (e.g. satellites, rockets)	Rockets, satellites
	Large-scale fixed installations	Electric doors, lifts, elevators, etc. designed solely for LSFI
		Airport runway lighting installations
		Automatic warehouse transport systems
		Automatic water pump installations
		Cable TV networks (other than separately operable equipment)
		Centralized air conditioning systems (HVAC) designed solely for LSFI
		Electric energy distribution system
		Conveyor belts (except LSIT)
	Large-scale fixed installations	Electrical installations designed only for large buildings classified as LSFI
		Lifts and escalators
		Power transmission networks, sub-stations, etc.
		Radio telescope installations
		Railway infrastructure
		Refrigerated display cabinets connected with centralized cooling station (if LSFI)
		Refrigerated cold stores (cold rooms)
		Ski lifts

Category	Product category	Product group - examples
		Storm surge barrier installations
		Traffic light installations
		Travelators
		Wind turbine stations (Cabin, wings, equipment in tower)
		Cranes
	Mobile electric lifting equipment	Hoists
	Means of transport for persons or goods excl. electric two-typed vehicles which are not type approved (cars and small vans already excluded as covered by ELV)	Airplanes and helicopters
		Boats
		Trains
	Non-road mobile machinery for professionals	Commercial vehicles, coaches, etc. not in scope of ELV
		Electric fork lift trucks
		Professional electric lawnmowers
	R&D equipment for b2b	Development boards, equipment constructed solely for R&D
Changed definition	Equipment designed as part of another type of equipment that is excluded or does not fall within the scope of RoHS II [changed definition might mean more products are excluded]	

Annex II: Scanning Electron Microscopy (SEM)

Because XRF typically measures larger volumes (often several microns in thickness, but dependent on the average density of the sample) SEM-EDX has advantages for smaller electrical components that have thin multilayer coatings or homogeneous phases on the micro scale. It is however important to understand the limitations of this technique to ensure correct measurement of homogeneous phases in the most complex electronic components or analytical conditions.

In SEM, a beam of high energy electrons is scanned across the surface of a sample held in vacuum or partial vacuum. The interaction of the electrons with the near surface layers in the sample produce a range of signals that can be used to characterise the sample on the micro/nano-scale. One of the interactions that occur is inner shell ionisation of the surface atoms. This can lead to the emission of so called characteristic x-rays because their specific energies and wavelengths are characteristic of the specific element, which is excited. It is this process that is used to determine the elemental composition and hence the RoHS compliance of any sample being investigated.

Inner Shell Ionisation

The electrons of an atom occupy specific energy levels, which in x-ray spectroscopy are often defined as major shells (denoted as K, L and M etc.). Beam electrons within the SEM can interact with the tightly bound inner-shell electrons of the surface atoms, ejecting the atoms and leaving a vacancy in that shell. The atom is left as an ion in an excited state and relaxes to its ground state (lowest energy) through a limited set of allowed transitions of outer shell electrons to fill the inner shell vacancies. The energies of the electrons in the shells are sharply defined, with values characteristic of the atomic species. The energy difference of the electron transition is also therefore a characteristic value, which can be released as a photon of electromagnetic radiation, also of sharply defined energy.

The minimum energy necessary to remove an electron from a specific atom shell is known as the critical ionisation energy or critical excitation energy (E_c). The primary ionisation involves removing an electron from a bound state in a shell to an effective infinity outside the atom, whereas the characteristic x-rays are formed by transitions between bound states in shells. The energy of the characteristic x-ray is always less than the critical ionisation energy for the shell from which the original electron was removed.

The electron shell structure around atoms permits multiple ionisation and subsequent relaxation events with the emission of characteristic x-rays as the atomic number (Z) of the element increases. Below atomic number 10 only a single K shell x-ray is normally observed in the x-ray spectrum. Above Z=10 the K shell line in the x-ray spectrum splits to $K\alpha$ and $K\beta$ pairs, indicating the sub-shell structure of the atom. Above Z=21 L shell x-rays become measurable at 0.2kEV by EDX and when Z=50, M-shell x-rays begin to appear above 0.2kV. When the beam energy is sufficient to generate one x-ray line, all other characteristic x-rays of lower energy from the element will also be excited. This occurs because of direct ionisation of those lower energy shells by the beam electrons and x-ray formation resulting from the propagation of a vacancy created in an inner shell to outer shells as a consequence of electron transitions. If K-family x-ray of heavier elements are excited therefore, the L and M family x-rays will also be generated.

Interaction Volume – X-Ray Generation Volume

Modern SEMs are capable of generating electron beams with precisely defined incident energies (typically in the range of 0.5 to 30keV) focused on the sample with a beam diameter of 1nm to 1µm. Whilst there is significant control of the electrons before they reach the sample, once the electrons enter the sample scattering processes they control the volume of sample, often termed the interaction volume, producing different imaging and analysis signals. The interaction volume will increase as the electron beam energy is increased or as the average atomic number of the atoms in the sample decreases.

Inelastic scattering of the beam electrons controls the volume from which the x-ray signal is generated. This "analytical volume" is also a function of the energy of the beam electrons and the atomic number of the atoms within the volume. Higher beam energy electrons and lower atomic number atoms at the surface increase the volume of material that is analysed. Spatial resolutions for chemical analysis by SEM-EDX are therefore ~1 to 5µm depending on the beam energy and sample composition. It is essential to have a good understanding of the factors influencing the analytical volume to ensure either it remains within a homogeneous phase or that X-ray signals generated from more than one homogeneous phase are correctly interpreted.

Depending on the critical excitation energy, characteristic x-rays may be generated over a substantial fraction of the interaction volume of the beam electrons. To predict the depth of x-ray production (or x-ray range) and the lateral x-ray source size (x-ray spatial resolution) first the electron penetration depth should be considered. The Kanaya-Okayama range[15] expression follows the general form:

$$\rho R = K E_0^n \qquad 1$$

Where E_0 is the incident electron beam energy, ρ is the density, K depends on different materials parameters and *n* is a constant in the range of 1.2 to 1.7. This equation considers electrons, which will lose all their energy whilst scattering in a sample. However, characteristic x-rays are only produced within a volume where the electron energy exceeds E_c. The range of direct x-ray generation is always smaller than the electron range. To account for this, the range equation can be modified to the form:

$$\rho R = K(E_0^n - E_c^n) \qquad 2$$

For the Kanaya-Okayama electron range K in this equation has the form:

$$K = \frac{0.0276A}{Z^{0.889}} \qquad 3$$

[15] K Kanaya and S Okayama, 1972, Journal of Physics D: Applied Physics, Volume 5, p43-58

where Z is the atomic number and A is the atomic weight. Other researchers have set K equal to a constant without atomic number/weight dependence. The X-ray range of Andersen and Hasler[16] has the form:

$$\rho R = 0.064(E_0^{1.67} - E_C^{1.67}) \quad 4$$

Where R has the value of micrometres for E in keV and ρ in g/cm^{-3}.

The Anderson-Hasler range (equation 4) is a measure of the region of X-ray generation while the Kanaya-Okayama range (from equation 2) gives the limiting envelope for electron trajectories. For an electron beam normally incident on a surface, the maximum width of the X-ray generation volume projected on the surface is approximately equal to the appropriate range for X-rays. The range of primary x-ray generation is the critical parameter in estimating the sampling volume for x-ray microanalysis. When different analytical lines are available with significantly different energies (e.g. CuLα at 0.93eV and CuKα at 8.04eV) the depth of the sampling volume may differ by a factor of 5 or more.

To demonstrate this, the Kanaya-Okayama range expression can be re-written in the form:

27.6A

$(Z^{0.89}\rho)/E^{1.67}$

$$R = \left[\frac{27.6A}{(\rho Z^{0.89})}\right](E_0^{1.67} - E_C^{1.67}) \quad 5$$

Using this formula the spatial resolution of CuK (E_C=8.98 keV) x-ray production at conventional beam energies of 10 to 30keV is shown in table 1[17]. This considers copper as a trace constituent in various elemental matrices with the requirement that for efficient x-ray production the electron beam overvoltage ($U=E_0/E_C$) must be ≥2 i.e. E_0≥19 keV.

Table 7: Range of x-ray excitation for CuK(EC=8.98 keV) in various elemental matrices

Bulk matrix	25keV	20keV	15keV	10keV
C	6.3 µm	3.9 µm	1.9 µm	270 nm
Si	5.7 µm	3.5 µm	1.7 µm	250 nm
Fe	1.9 µm	1.2 µm	570 nm	83 nm
Au	1.0 µm	630 nm	310 nm	44 nm

Using the same approach but considering only CuL shell excitation and measuring at lower overvoltages, the spatial resolution of x-ray production is significantly reduced (see Table 8).

[16] CA Anderson and MF Hasler, 1966, Proceedings of 4th International Conference on X-ray Optics and Microanalysis, p. 310

[17] DE Newbury, 2006, Journal of Research of the National Institute of Standards and Technology, Vol. 107 (6), p605-619

Table 8: Range of x-ray excitation for CuL(E_C=0.933 keV) in various elemental matrices

Bulk matrix	5keV	2.5keV
C	490 nm	130 nm
Si	440 nm	120 nm
Fe	50 nm	40 nm
Au	80 nm	21 nm

Geometric limitations of common RoHS assessments

It is useful to consider the application of equation 5 to model examples of electronic component construction that may be encountered during RoHS compliance assessments. These examples could include:

1. ***The measurement of lead within a tin rich solder***

   Because the E_C required to excite PbL shell x-rays is so high (PbLα=10.55keV) PbM shell x-rays are used predominantly in SEM-EDX analysis. The X-ray production range is shown in table 3.

   Beam energies below 5keV were not considered as there would be insufficient overvoltage for excitation of the PbM shell x-rays.

Table 9: Range of x-ray excitation for PbM (E_C=2.35 keV) in tin matrix

30 keV	25 keV	20 keV	15 keV	10 keV	5 keV
4.0 µm	2.9 µm	2.0 µm	1.2 µm	590 nm	148 nm

2. ***The measurement of lead or cadmium as pigments within polymers ("carbon matrix")***

   The same factors as for lead in tin solder have been considered for the selection of an appropriate x-ray line to analyse and the minimum applicable beam energy for analysis.

Table 10: Range of x-ray excitation for PbM (E_C=2.35 keV) in carbon matrix

30 keV	25 keV	20 keV	15 keV	10 keV	5 keV
8.6µ m	6.3 µm	4.3 µm	2.6 µm	1.3 µm	320 nm

For cadmium the E_C required to excite CdK shell x-rays is 23.17 keV. The overvoltage required to excite this line (46.34 keV) far exceeds the maximum available accelerating voltage for conventional SEM (30 keV). Therefore the CdL shell x-rays (3.13 keV) are used in SEM-EDX analysis. The minimum beam energy for excitation of this line is 6.26 keV

Table 11: Range of x-ray excitation for CdL (EC=3.13 keV) in carbon matrix

30 keV	25 keV	20 keV	15 keV	10 keV	6.5 keV
8.6 µm	6.3 µm	4.2 µm	2.5 µm	1.2 µm	478 nm

3. *The measurement of cadmium within zinc plating*

The same factors as for cadmium in a polymer matrix have been considered for the selection of an appropriate x-ray line to analyse and the minimum applicable beam energy for analysis.

Table 12: Range of x-ray excitation for CdL (EC=3.13 keV) in carbon matrix

30 keV	25 keV	20 keV	15 keV	10 keV	6.5 keV
3.5 µm	2.6 µm	1.7 µm	1.0 µm	490 nm	196 nm

In these three examples, the values at 30keV represent the maximum thickness of a layer or size of feature that could be analysed for the specific element in a single phase. The values at 5 or 6.5 keV represent the minimum volume/thickness necessary for correct measurement within the individual phase or coating layer.

Thin film/multilayer measurements

Situations may arise where it is not possible to limit the analysis depth or volume to a single phase e.g. analysis of a sample coated with a gold layer that is sub-micron in thickness where the interaction volume will extend into the bulk material beneath. Commercial suppliers of micro-analysis equipment offer software packages to interpret SEM-EDX data obtained from these thin-film layers[18]. The basis of the technique is to measure x-ray line intensities for elements and adjust the unknown parameters in simulation models until the predicted intensities match those measured. The mass thickness or composition for individual layers can then be determined. Models are constructed based on user input information of the elements that may be present in the layers and substrate, in combination with estimates of likely composition and the mass thickness of each layer. The mass thickness (mass or number of atoms per unit area) measured by the technique can then be converted into physical thickness, where the density is known.

[18] http://www.samx.com/ offer the Stratagem software product

Oxford Instruments offer ThinfilmID for integration into their microanalysis software products

Annex III: Clarification for assessment of very thin coatings for RoHS substances in EEE

An issue is the difficulty of analysis of very thin coatings. The RoHS definition of homogeneous materials is that if two materials, such as two layers of a coating can be separated by physical methods, then these are two different homogeneous materials. This definition applies even if it is not possible to remove a sufficiently large quantity of each homogeneous material for chemical analysis using bulk analysis methods such as AAS or ICP, which require in some cases up to 1 gram for accurate analysis. With very thin coatings, physical separation may be difficult or even impossible when the surface roughness is greater than the outer coating's thickness. It is however not possible to define quantitatively a thickness value below which mechanical disjointment is not possible as this will depend on the relative hardness of the materials, the thickness of layers, inter-layer adhesion and surface roughness. The following guidance therefore is intended to provide a procedure to help decide if analysis of coatings is unnecessary.

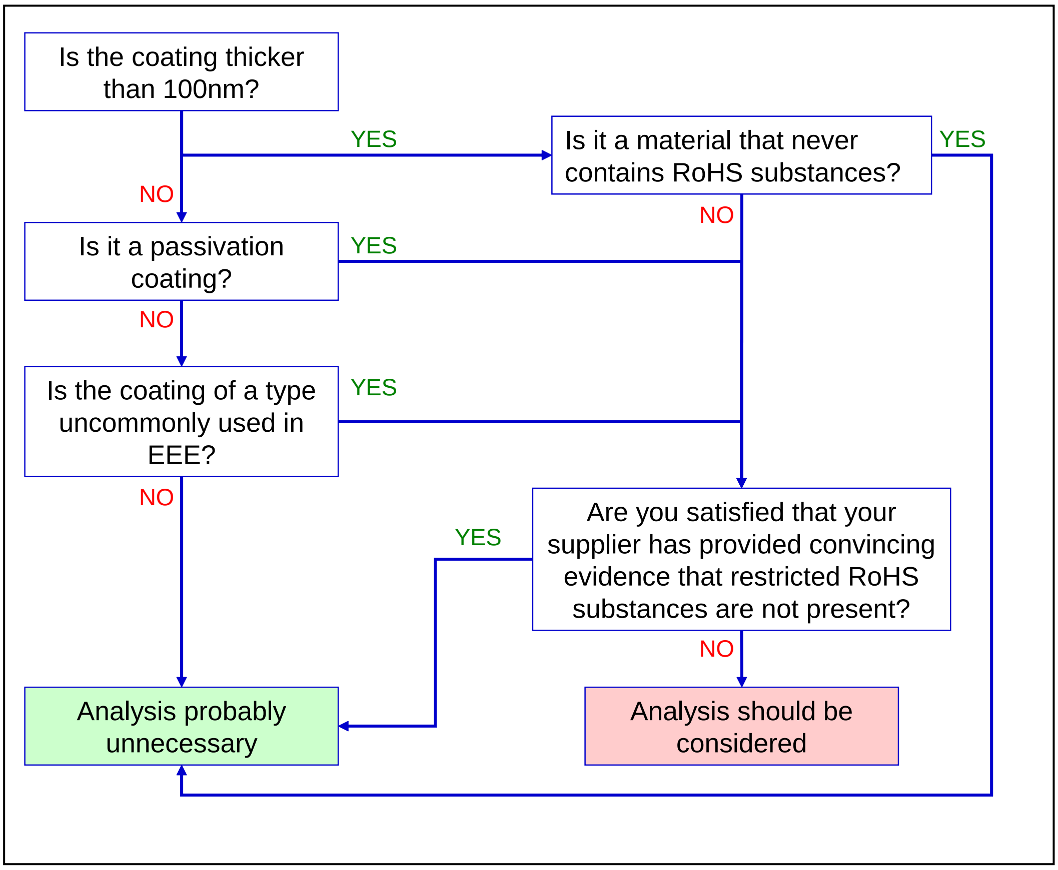
Chemical analysis of very thin coatings can be difficult and accuracy may not be high, however it is usually necessary only to determine whether a RoHS substance is present at below the concentration limit to demonstrate RoHS compliance rather than to obtain a precise concentration value. Although this RoHS Impact Assessment study is not intended to determine when analysis is necessary, an assessment of the likelihood of a RoHS substance being present will help to avoid unnecessary analysis of difficult to analyse thin coatings. The following guidance is therefore provided:

Most electrical and electronic equipment consists of a large number of homogeneous materials and it is impractical to analyse all of these in a complex finished product to ensure compliance. Article 16 of the RoHS recast directive states that compliance can be assessed using harmonised standards or based on tests and measurements. A harmonised standard that can be used to demonstrate conformity is currently being written (EN50581). The basis for achieving conformity is a process based on obtaining and assessing suitable documentation – chemical analysis of every homogeneous material within equipment is not essential to demonstrate compliance. Clearly where there is no likelihood of a RoHS substance being present, such as in an uncoated pure copper wire, RoHS analysis would be pointless. If, however, the manufacturer or importer determines that there is a significant likelihood of a RoHS substance being present, then unless compliance can be demonstrated by other means (e.g. supplier audit, etc.) then analysis would be advisable to ensure compliance. It may however be possible to achieve a high level of confidence that the equipment does not contain RoHS substances as a result of the use of quality control procedures and supplier audits which would be documented in the manufacturer's technical file.

Where thin coatings are being assessed, the likelihood of a RoHS substance being present will depend on the type of coating. Some types never contain RoHS substances and so RoHS analysis is not needed. The types of coating that sometimes contain RoHS substances (such as tin alloy termination coatings which may contain lead) are likely to contain only one or two RoHS substances and so only these substances need to be analysed. For example, passivation coatings may contain CrVI but no other RoHS substances are likely to be present so analysis for Pb, Hg, PBB or PBDE is not necessary. Analysis of cadmium is necessary only if the passivation coating is deposited onto a surface that is suspected to contain cadmium (e.g. cadmium plating).

The RoHS Impact Assessment study has found that coatings used in EEE that are thinner than 100nm rarely contain any RoHS substances. The only commonly used exception is thin chromate passivation coatings which have been found to contain >0.1% CrVI. Therefore it should not generally be necessary to analyse the types of coatings that are normally less than 100nm in thickness, unless they are thin chromate passivation coatings. This also applies to multi-layer coatings where each individual coating is <100nm as RoHS substance use is very unlikely. Analysis of <100nm thick coatings is very difficult as these are too thin to be selectively analysed by most methods including XRF and SEM/EDX/WDX but as RoHS substances are very unlikely, analysis is not usually necessary.

RoHS substances are however known to be used in EEE in some coatings including multi-layer coatings that have individual layers thicker than 100nm. The following sequence of steps could be used to decide if analysis of thin coatings may be necessary or is not required:

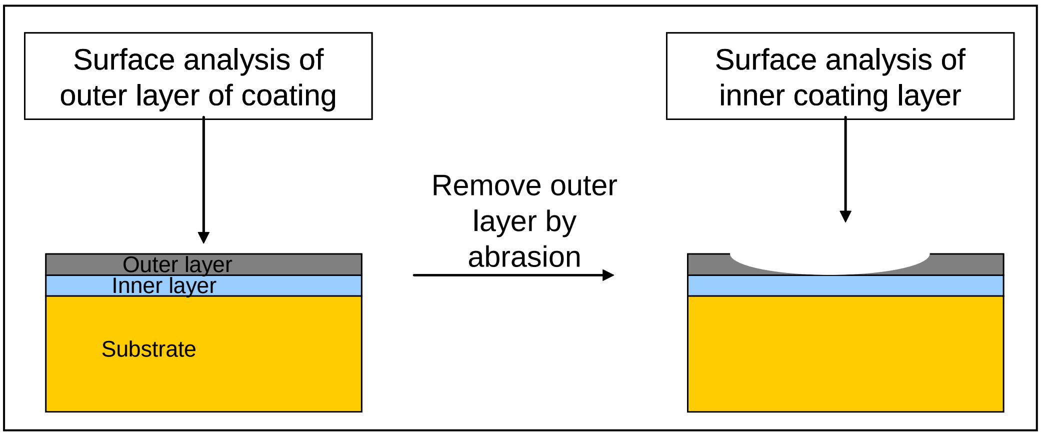


If this assessment shows that there is a significant likelihood that a RoHS substance is present, and its absence cannot be demonstrated by the supplier or by the quality control procedure, then chemical analysis may be required to demonstrate compliance. The method used for analysis should be selected based on the type of coating and the equipment that is available. Most often, XRF will be used first and if no RoHS substances are detected, then no further analysis is normally necessary although care is needed to avoid false-negative results. If a significant amount of a RoHS substance (>0.1%) is found, then further investigations are required.

- If it is possible that the RoHS substance is present in an exempt form in one material, then it needs to be decided if it is possible that this substance could also be present in a non-exempt form in a different material such as another layer of a multi-layer coating. For example, lead is detected when tin plated onto a copper alloy substrate is analysed using XRF (lead is exempt in copper alloy at up to 4% lead). This result indicates; i) lead is present in the electroplated tin coating, ii) it is present in the copper alloy only, or it is present in both.

- If a RoHS substance is detected at >0.1% by XRF and convincing evidence of compliance is not available from suppliers, then analysis of individual homogeneous materials will be needed. There are several analysis options available. If sufficient material is available and the coating can be separated cleanly from other materials, then removal, dissolution and then analysis of the solution by AAS, ICP or ICP-MS can be used and is usually accurate. If there is only a very small amount of material available, then the only option might be SEM/EDX. EN ISO 62321 includes procedures for XRF screening, AAS and ICP analysis but there are no standards for SEM/EDX analysis of EEE.

- If Cr is detected in a thin surface coating, it is necessary to determine if this is CrVI. In passivation coatings and in anodised coatings, the hot water extraction test is the most suitable method but thickness and density will need to be estimated.
- It is possible to analyse thin layers that are not at the outer surface if these are >1 µm in thickness. The outer layer is a homogeneous material as defined by RoHS if it can be mechanically disjointed from the layer below. Therefore, it will be possible to expose an area of the barrier layer using abrasion by removing a small area of the outer coating to expose the barrier layer, which can then be analysed without interference from the outer layer using a suitable surface analysis technique as shown below.



This approach is more difficult with very thin multilayer coatings because the common surface analysis technique XRF analyses to a depth of more than 10 µm and SEM/EDX to a depth of >100 nm. However, as explained above <100 nm thick coatings rarely contain RoHS substances and so analysis should not be necessary.

Annex IV: Additional substances by product group

Product category	Product group / example(s)	**Proposer**	RoHS II					Considered by Oko study & SVHCs						EP RoHS proposal					Other SVHCs		
		Substance	Lead	Cadmium	Hex Cr	Mercury	PBB / PBDE	DEHP	BBP	DBP	Other phthalates	HBCDD	SCCP	Arsenic compounds	Antimony oxide	Beryllium and its compounds	Ni_2O_3	Bisphenol A	tris 2-chloroethyl phosphate (TCEP)	Sodium borate	Boric oxide
		Possible uses	S = solder, A = alloys, St = PVC stabiliser	C = contacts	P = passivation	L = lamps	M = mouldings	plasicisers, PVC wire, lacquers. Potting, adhesives, etc.				FR for PS	FR & plasticiser (PVC)	GaAs	FR	BeCu & BeO	Precursor (so no)	Impurity in PET and will be <0.1%	FR	FR in wood	FR,, ink, adhesives
Automatic doors/gates	Automatic doors		S, A	C	P		M					Y			Y					Y	
	Garage doors		S, A	C	P		M					Y			Y					Y	
Cables			St	As a stabiliser (already banned by REACH). Plating on connectors	P (on connectors)	Very unlikely as a pigment	Connector mouldings	Y	Y	Y	Y		Y		Y	CuBe, BeO in connectors					Y
Petrol-engine powered garden equipment for non-professional or dual use	Lawn mowers, chain saws		S, A, and others		P		Not known but possibly in some mouldings								Y				Y		
Complex air conditioning systems excluded in RoHS I but not large-scale, so included in RoHS II			S, A, St	C	P		M	Y	Y	Y	Y		Y		Y	CuBe			Y		Y
Electric two-wheel vehicles which are not type-approved	Electric bicycles that are not type approved		?		P		?								Y				Y		
Fuse boxes / circuit breakers			S, A	C	P		M					Y			Y	CuBe					

Product category	Product group / example(s)	Proposer	RoHS II					Considered by Oko study & SVHCs						EP RoHS proposal					Other SVHCs		
		Substance	Lead	Cadmium	Hex Cr	Mercury	PBB / PBDE	DEHP	BBP	DBP	Other phthalates	HBCDD	SCCP	Arsenic compounds	Antimony oxide	Beryllium and its compounds	Ni2O3	Bisphenol A	tris 2-chloroethyl phosphate (TCEP)	Sodium borate	Boric oxide
		Possible uses	S = solder, A = alloys, St = PVC stabiliser	C = contacts	P = passivation	L = lamps	M = mouldings	plasiciser, PVC wire, lacquers. Potting, adhesives, etc.				FR for PS	FR & plasticiser (PVC)	GaAs	FR	BeCu & BeO	Precursor (so no)	Impurity in PET and will be <0.1%	FR	FR in wood	FR,, ink, adhesives
Furniture with an electrical function	Reclining beds		S, St	C	P		Deca-BDE used with fabrics	Y	Y	Y	Y	Y	Y		Y	?			Y	Y	Y
	Reclining chairs		S, St	C	P		Deca-BDE used with fabrics	Y	Y	Y	Y	Y	Y		Y	?			Y	Y	Y
	Wardrobes with lights or other electrical feature (e.g. tie rotators)		S, A, St			Y	Deca-BDE	Y	Y	Y	Y	Y	Y		Y					Y	Y
Gas water heaters with electrical function			S, A, St		P		M	Y	Y	Y	Y	Y	Y		Y						
Lifts and escalators			S, A	C	P	Y	M					Y			Y	CuBe					
Light switches, power wall sockets			A	C	P		M								Y	CuBe					
Pipe organs			Lead pipes				?					Y			Y						
Power switches				C			M								Y	CuBe					

Product category	Product group / example(s)	**Proposer**	RoHS II					Considered by Oko study & SVHCs						EP RoHS proposal					Other SVHCs		
		Substance	Lead	Cadmium	Hex Cr	Mercury	PBB / PBDE	DEHP	BBP	DBP	Other phthalates	HBCDD	SCCP	Arsenic compounds	Antimony oxide	Beryllium and its compounds	Ni_2O_3	Bisphenol A	tris 2-chloroethyl phosphate (TCEP)	Sodium borate	Boric oxide
		Possible uses	S = solder, A = alloys, St = PVC stabiliser	C = contacts	P = passivation	L = lamps	M = mouldings	plasicisers, PVC wire, lacquers. Potting, adhesives, etc.				FR for PS	FR & plasticiser (PVC)	GaAs	FR	BeCu & BeO	Precursor (so no)	Impurity in PET and will be <0.1%	FR	FR in wood	FR,, ink, adhesives
Safes	Safes with an electronic coded lock		S, A		P		M					Y			Y						
Swimming pools	Swimming pools for home use with pumps included		S, A	C	P		M					Y			Y				Y		
Toys with minor electrical functions	Bears with watch/beep button or speaking function		S, St				Deca-BDE used with fabrics but not likely in	Y	Y	Y	Y				Y				Y		Y
	Dolls house with light		S, St				Not known but possibly in some mouldings	Y	Y	Y	Y	Y	Y		Y					Y	Y

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Annex V: Impact assessment factsheets

Automatic doors and gates

Important note: In this factsheet, the product group automatic doors and gates will always refer to such products having at least one electric or electromagnetic function that are not part of a large-scale fixed installation.

1.1 Key issues

Automatic doors and gates were not in scope of the COM recast proposal but do fall within the scope of RoHS II. In this factsheet it will be explored what the impact of this change is and whether the benefits of the inclusion of automatic doors and gates in RoHS II outweigh the potential costs.

Only those products will be assessed that are not large-scale fixed installation (see Annex). Equipment of this kind would be excluded from the scope by Art. 2.4(e).

1.2 Background

There are several types of products that are included in the product group automatic doors and gates. The three major product categories are:

- Automatic doors: Table 1 presents different types of automatic doors.

Table 1: Main types of automatic doors

Type of automatic door	Short description
Sliding doors	The most popular automatic doors, available as single-leaf or double-leaf sliding doors: they can be provided with a wide range of functional features (e.g. several operating modes, safety features, sensor equipment, automatic obstruction detection, independent emergency power supply). Curved design is also available to upgrade the architectural appearance of a building, either inside or outside.
Swing doors	Particularly suitable for retro-fitting and for new doors and available in single-leaf and double-leaf versions. In the interior of buildings swing door operators are particularly suitable due to their quiet operation and unobtrusive design.
Revolving doors	Particularly used for building entrances. Available in various standard dimensions, and also in individually requested special dimension. The built-in software and sensors allow individual rotational speeds synchronised to the respective user.
Space-savers	A solution if the site situation does not allow much room. The most popular versions include automatic folding doors (which allow large passage width and small installation dimensions) and telescopic sliding doors (the use of several narrow door leaves allows a large passage width also where space is tight)

Type of automatic door	Short description
Fire doors	Escape or fire doors are subject to the highest requirements. Solutions for sliding, swing or revolving doors alike are possible. According to the particular site requirements, combined solutions can be offered, fulfilling the escape route function as well as the demands on fire and smoke stop doors. An integrated door closer guarantees that after an escape opening the door returns to the safe closed position of a fire door.
Safety doors	Where access control is required and visitors need to be directed, individually identified or registered, automatic safety doors provide solutions. Depending on the application, the doors are locked automatically and can include burglary-resistant options. Safety doors are also available in combination with escape route and fire door features.

Source: European Door and Shutter Federation website[1]

- Garage doors: automated garage doors also exist in several different designs (see Table 2).

Table 2: Main existing types of electrically-operated garage doors

Type of garage door	Short description
Canopy Up and Over	Ideally suited where either economy is a factor or in situations where the garage door cannot intrude fully into the garage due to obstructions. Approximately one third of the door extends forward of the frame to form a canopy. Suitable for automation but using a bow arm converter which makes it expensive to adapt.
Retractable Up and Over	Becoming increasingly popular as it can have automation easily added without expensive conversion. The entire door retracts back into the garage on most makes.
Sectional Overhead	Its principal benefit is that it does not swing out when opening or closing. The whole door is divided horizontally into four or more panels which run on rollers in vertical tracks that then turn 90 degrees at the top into horizontal tracks that follow the roofline. Ideal for automation and low on maintenance. They are made in industrial or domestic sizes.
Insulated sliding folding doors	Horizontally operating equivalent to sectional overhead doors. Usually thermally insulated and weather resistant for external use. Low maintenance requirements and available in powered and manual versions.
Roller Shutter	Individual horizontal slats constructed from either steel or aluminium are linked together to form a tightly coiling curtain which rolls up around a shaft located above the door opening. These doors do not swing out during operation. They are most often supplied ready motorized. Available in industrial or domestic versions, and in fire resisting designs.
Round the Corner	Historically one of the earliest types of gear used to operate a garage door. The door, usually made from timber panels, slides sideways on an overhead track, and bottom guide rail and then turns through 90 degrees to follow the wall back into the garage. An ideal solution to low headroom problems, do not swing out and can be automated.

[1] http://www.edsf.com/aims/products/automatic-doors.html

Type of garage door	Short description
Side Hinged	The original type of garage door fitted before the advent of the up and over door in the 1950s. The doors hinge outwards making them ideal for garages that are used for everything except the car because only one leaf of the pair has to be opened. Side hinged doors are easily automated using a conversion kit.

Source: Door & Hardware Federation website[2]

- Electric gates: can be found in designs already presented for automatic doors, i.e. swinging gates (traditional gate with a wide choice of finishes in wood, steel, PVC, etc.) and sliding gates (saves space in the drive/garden and ideal for installations on a slope but requires side clearance and a runner rail mounted into masonry).

The reason for so many different designs is that electric doors and gates can be used in a variety of different applications, e.g. individual households, commercial buildings such as hospitals, airports, hotels/motels, shopping centre entrances and retail stores. Typically, a sliding door is used on the entrance doors of large retail businesses while smaller retail businesses prefer automatics swing doors. Given the specific considerations due to the location, every automatic door or gate installation is different. The most important design characteristics of automatic doors and gates include, amongst others:

- Size: from domestic standard dimensions to industrial customised ones;
- Safety: many safety features available to reduce the risk of accident;
- Security: a wide range of locking solutions available, including for specific applications;
- Robustness: which depends on the chosen material (glass, wood, steel, etc.);
- Reliability: automatic doors are often operated thousands of times a day and last for several years. Some automatic systems have "self diagnostics".
- Aesthetics: wide range of finishes, from stainless to powder coating;
- Thermal and noise insulation: is also related to cost efficiency with energy savings;
- Speed: in particular, some industrial applications require fast moving devices;
- Noise during operation.

Furthermore, the automation (and thus the power-operated status) is available for some designs as an option, and not a compulsory functionality. In particular, installed manual gates or garage doors can be automated thanks to an upgrade with a door operator. Indeed, automatic doors and gates are generally constituted of two main parts: the actual door/gate (made out of e.g. glass, metal, wood), and the operator, which is responsible for the automatic functionality. For instance, it automatically opens the door, waits, and then closes it. The operator generally includes, amongst others, a motor, a control unit, and a belt. However, there also exist designs where the motor is embedded in the door/gate. The control unit of the operator can be programmed according to

[2] http://www.agds.org.uk/product_selector.html

different operating modes: for instance, for an automatic door, these include "Automatic", "Exit Only", "Enter Only", "Hold Open", "Partial Opening", or "Closed". Several technological options also exist for the activation of the doors and gates: activation sensors (open the door when a user approaches it), presence safety sensor (detects obstructions and stops the door opening or closing if there is a pedestrian in the way), hardwired or wireless push button (activates the door operator to open the door when a user presses the button), and access control features (magnetic locking, keypad, timers) are some of these. Automatic doors can also be linked to fire alarms, depending on the building requirements (the door may be required to close or open in the event of a fire), and can comprise a battery backup in case of mains power interruption.

1.2.1 Legal background

Automatic doors and gates were not previously included within the scope of RoHS I or of the COM proposal. Due to the enlarged scope of RoHS II, all doors and gates that require electricity or electromagnetic fields, even if only for a minor function, will fall within category 11 (Annex I) of the Directive from July 2019. The RoHS II substance restrictions will apply to all components, also non-electrical ones, on the homogeneous material level.

Automatic doors and gates could be excluded from the scope of RoHS II through the 'large-scale fixed installation' exclusion of Article 2.4(e). No officially agreed definition of the term 'large-scale' exists at the time of writing of this report, but based on the most likely criteria, it is estimated that a small percentage of all automatic doors and gates could be excluded as large-scale from the scope. Please see the Annex for more information on these draft criteria. Please note, however, that until the list of criteria has been finalised, no detailed information of the possible impact can be provided.

1.2.2 Quantities and hazardous substances

There is little collection of automatic doors and gates data at European or MS level, despite the existence of the European Door and Shutter Federation (EDSF) and several national associations (e.g. in the UK: the Door and Hardware Federation[3], the Automatic Entrance Systems Installers Federation[4], the Automatic Door Supplier Association[5]).

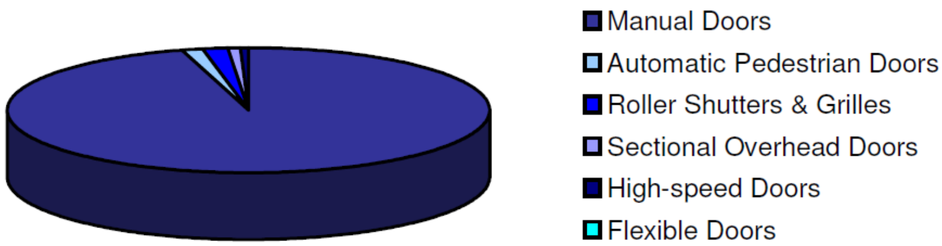
In a newsletter[6], EDSF provided an estimation of the door and gate market in the EU in 2010, based on some national figures and expert knowledge. In this assessment, only commercial-, industrial- and garage- doors, gates and barriers were considered, i.e. automatic/pedestrian doors and driver systems are lacking. 3.29 million units were produced in 2010 according to this source, for a turnover of €2.8 billion. The distinction between manual and powered products is however not made.

[3] http://www.dhfonline.org.uk/
[4] http://www.aesif.org.uk/
[5] http://www.adsa.co.uk/
[6] E.D.S.F. Newsletter 03/2010. Available at: http://www.edsf.com/fileadmin/user_upload/Dokumente/Newsletter_etc/E.D.S.F._newsletter_03.pdf

According to a GfK market study in 2010[7], consumers are increasingly attracted by automated garage and yard gates. In Germany, 30% of the 21 million garage doors and approximately 25% of the 10 million yard gates are motorised, which account for approximately 10 million electric doors and gates installed. Assuming a lifetime of 20 years (see section 1.3.2.2), annual sales in Germany can be estimated to be 500,000 units[8]. An upper EU-27 estimate of 3.1 million units can be made based on population ratios[9]. Consequently, given the EDSF estimate (considering manual products) and this upper EU-27 estimate for electric doors and gates, annual sales of electric garage doors and gates in the EU-27 are probably within the range of 2 to 3 million units.

Regarding automatic pedestrian doors, no absolute market figures could be found. As such products are less likely to be found in individual households, sales are expected to be inferior to the previous estimation, which includes commercial-, industrial- and garage- doors, gates and barriers (2 to 3 million units). Figure 1 shows the market shares of the different types of doors in the UK in 2011. Automatic pedestrian doors represent approximately one third of the total automatic doors sales. They also were the fastest growing segment of the market in value terms (40% increase in volume between 2002 and 2006).

Figure 1: The UK Market for Industrial & Commercial Doors & Shutters, by type of door in 2011



Source: MSI press release, Industrial and Commercial Doors and Shutters: UK[10]

Assuming the market shares in the EU-27 are similar to the market shares in UK and by increasing the previous estimation (2 to 3 million units) by 50% to include automatic pedestrian doors[11], annual sales of electric doors and gates in the EU-27 are estimated between 3 and 4 million units. **The following assessment will therefore assume that the annual sales of automatic doors and gates, not large scale fixed installations[12], represent 3.5 million units per year.** This market has been growing over the period 2002-2006: 15% increase in volume and 25% increase in value[13] . Demand for warehousing for supermarket distribution was strong, as there was a lot of activity within this sector in terms of expansions and takeovers. Garages, warehouses and other industrials end- users

[7] Christian Grabitz, ttz Expert Forum – Automation of Gates – Market Study Results. Available at: http://www.edsf.com/fileadmin/user_upload/Dokumente/Newsletter_etc/TTF_2_11_Grabitz_GB.pdf

[8] Annual sales = Stock / Lifetime

[9] EU-27: approx. 502 million inhabitants in 2011 ; Germany: approx. 81 million inhabitants in 2011

[10] http://www.msi-reports.com/market_research_report_pdfs/CUK3-S.PDF

[11] Since automatic pedestrian doors represent approximately one third of the total automatic doors sales

[12] No market information was found with size considerations. It is assumed that the share of automatic doors and gates being large scale fixed installations is a minor share of the overall market (mainly industrial applications).

[13] Stronger growth in value caused by the increasing costs of steel and aluminium as well as labour. MSI press release, Industrial and Commercial Doors and Shutters: UK

are increasingly upgrading their sectional overhead doors to automatic systems. The MSI report predicted this trend of growth to continue with a 14% increase in volume between 2007 and 2011 market for industrial and commercial doors and shutters. The need for thermal insulation and security are two major drivers of the market stimulation.

No information related to the presence of RoHS substances in automatic doors and gates was found or received from stakeholders. Table 3 lists the estimations of the different hazardous substances, which should be considered with caution given high uncertainty.

Small Printed Circuit Boards (PCBs) in the control units and electric motors are likely to contain lead. Table 5 (in section 1.3.2.2) shows that approximately 0.5% of the weight fraction of automatic doors and gates is EEE components (including lights). Assuming an average door weight of 100 kg, each product contains 500 g of EEE components. Several publications indicate that the lead content of typical PCBs ranges from ~0.2% to 2% in weight, mostly in solder and alloys, which represents in this case between 1 and 10 g. An estimation of 5 g per product will be used for this assessment.

Electric cables may also contain some hazardous substances, e.g. cadmium in contacts, but this is estimated unlikely. No quantitative estimation has been made.

Powder coating is an important part of the door automation industry that is used on operator covers, fitting plates, operator arms, packer bars and safety barriers. It is a type of coating that is applied as a free-flowing, dry powder and it may contain chromium VI. Powder coating is mainly used for coating of metal, such as aluminium extrusions. An estimation of 500 µg per product will be used for this assessment.

Finally, PBBs and PBDEs may be found in plastic mouldings as flame retardants, but this is estimated unlikely. No quantitative estimation has been made.

Table 3: RoHS substances in automatic doors and gates

Substance	Presence in automatic doors and gates
Lead	Possibly in PCBs (solder, alloys) Estimation : 5 g per product
Mercury	No
Cadmium	Possibly in contacts, but unlikely
Hexavalent Chromium	Possibly in passivation coatings (e.g. on galvanized steel) Estimation: 500 µg per product
Polybrominated biphenyls (PBB)	Possibly in mouldings, but unlikely
Polybrominated diphenyl ethers (PBDE)	

Source: Own estimations

1.2.3 Policy objectives and options

The objective of both, the RoHS recast proposal (COM (2008) 809 final) as well as RoHS II (2011/65/EU) is to contribute 'to the protection of human health and the environment, including the environmentally sound recovery and disposal of waste EEE'[14].

The purpose of this work is to look at the impacts of automatic doors and gates falling under the scope of RoHS II compared to automatic doors and gates being excluded from the COM recast proposal. Policy options will then be evaluated according to their effectiveness, efficiency and coherence in reaching the above-mentioned overall objective of the RoHS Directive. The policy options analysed are the following:

OPTION 1 (baseline scenario): The COM recast proposal. Automatic doors and gates are not in scope of the proposed recast Directive.

OPTION 2: RoHS II. Automatic doors and gates are included in the scope of the recast Directive.

1.3 Impacts of policy options

1.3.1 Impact indicators

The following impact indicators have been chosen as relevant for this product group (see Table 4).

Table 4: Impact indicators for the product group automatic doors and gates

Impact indicators		
Environmental	Economic	Social
Energy use	Functioning of the internal market and competition	Employment
Waste production / generation / recycling	Competitiveness	Health
International environmental impacts	Costs and administrative burdens	Social impacts in third countries
	Innovation and research	
	Consumers and households	

[14] 2011/65/EU, Article 1

The following legend will be used in summarising the impacts:

Legend	
+++	Very beneficial effect
++	Substantial beneficial effect
+	Slight beneficial effect
=	No effect
-	Negative effect
--	Substantial negative effect
---	Very negative effect
?	Unknown effect

1.3.2 Environmental impacts

The most important stakes regarding the environmental impacts in the context of RoHS are related to the quantities of hazardous substances used in the equipment. The mere quantity of a substance is however not sufficient to estimate what will be the actual impacts of the substance on the environment and health. These indeed depend upon numerous factors such as the effective treatment of products at the end-of-life, their design for the use phase or their potential emissions during the production phase. The impact of the substances released to the environment is also determined by case-specific and complex dose-response relationships.

It is therefore not straightforward to predict environmental impacts due to hazardous substances found in products. Where possible, the following subsections will make the link between the quantities of hazardous substances and their potential environmental impacts.

1.3.2.1 Energy use

Given the definition of this product group, all products are expected to consume energy during their operation. Still, more than the direct energy consumption of the automatic doors and gates during their use phase, the energy efficiency of the whole buildings and infrastructures in which they are installed represents the actual stake. In particular, the thermal insulation of doors is an important factor that depends on the overall heat transfer coefficient (U value), air leakage and opening time of the door[15]. ESDF developed a tool to calculate the energy losses caused by opening and closing doors, according to different adjustable parameters[16]. As a result, despite limited investment costs, automatic doors effectively reduce wasted energy and often considerably lessen annual heating and cooling costs.

[15] EDSF, Guideline paper, Sustainable impact of doors during the life cycle of buildings. Available at: http://www.edsf.com/fileadmin/user_upload/Dokumente/20120424_E.D.S.F.-GP_Sustainabiliy_doors_final.pdf
[16] http://www.edsf.com/calculator/

The presence of RoHS substances in automatic doors and gates is not expected to have an influence on their direct or indirect energy consumption. It is estimated that equivalent substitutes for lead solder, chromium VI coatings, etc. are currently available for their use in automatic doors and gates without any major consequence on energy consumption.

The European Commission impact assessment accompanying the RoHS recast proposal[17] states that the substitution of lead solder by lead-free solder might lead to an increase in energy consumption during the production phase because of a higher melting point. The additional energy consumption will vary widely depending on the solder type, the equipment specifications and process operating parameters employed by the facility. Nevertheless, it is generally accepted that lead-free soldering requires approximately 15% more energy than tin/lead (SnPb) soldering when comparing equivalent soldering technology for the two types of alloy and the following calculations will be based on this assumption. Based on a typical solder reflow oven to make the PCBs on which the lead is found in automatic doors and gates, the total additional energy required for lead-free solders represents 32.9 MWh per year [18]. Compared to a total EU final energy consumption of 13.6 million PWh[19], this impact of additional energy required is regarded as negligible on this environmental impact indicator. The additional energy consumption will have an extra cost of approximately 3 100 €[20]. Additional CO_2 emissions due to change from tin/lead solder to lead-free solder represent 12.8 tonnes CO_2 eq[21]. In relation to the overall CO_2 emissions of 4 088.8 million tonnes of the EU-27 in 2008[22], this increase would be negligible.

Thus, the inclusion of automatic doors and gates within the scope of RoHS II should have no significant impact on this environmental indicator.

1.3.2.2 Waste production / generation / recycling

The lifetime of automatic doors and gates depends on the type of device considered, its application and its context of use. Being products of the construction industry, automatic doors and gates are usually designed to last a long time. In particular, EDSF mentions a lifetime of 20 to 25 years in the construction sector[23]. **20 years is consequently estimated as an acceptable average for the EU.**

Automatic door systems are normally installed and removed by professionals. In terms of end-of-life management, high recovery and recycling rates can therefore be expected, especially for high value materials, such as metals, which constitute the major weight share of the products. Complex

[17] European Commission (2008), SEC(2008) 2930. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=SEC:2008:2930:FIN:EN:PDF

[18] A typical solder reflow oven operates 16 hours per day, 5 days a week, 49 weeks per year and on average consumes 13.9 kWh for SnPb and 16kWh for lead-free. It is assumed that one oven can produce 300 PCBs per hour or 1 million per year (25 PCBs made in a panel every 5 minutes) as these PCBs are small. The total number of units to be made are approximately 3.5 million units.

[19] 1168.63 Mtoe, European Commission, *EU transport in figures, statistical pocketbook 2011*, accessed at http://ec.europa.eu/transport/publications/statistics/doc/2011/pocketbook2011.pdf

[20] Average EU industrial electricity price = 0.093 €/kWh in 2011 according to Eurostat.

[21] Based on 0.39 kgCO_2 eq/kWh from Eurelectric

[22] 4186.7 million tonnes. European Commission, *EU transport in figures, statistical pocketbook 2011*, accessed at http://ec.europa.eu/transport/publications/statistics/doc/2011/pocketbook2011.pdf

[23] http://www.edsf.com/information/sustainability.html

plastic parts and electronic components are given to existing recycling schemes, but their complexity often reduces the recycling opportunities.

Table 5 shows the typical composition by material for different automatic door types. The quantities of electric components, in which RoHS substances are found, remain limited for all types of doors (1% or less, approx. 0.5% on average). No specific information was found or obtained on the end-of-life management of EEE parts of automatic doors and gates. As a general assumption, the following analysis will be carried out considering that 80% of these parts are recycled, 10% incinerated and 10% landfilled (see Table 6).

Table 5: Typical waste composition by material, for different automatic doors types

	Balanced door	Overhead door	Roller shutter door	Metal curtain	Pedestrian sliding door	(Pedestrian sliding door operator)
Metal	88-94.9%	83.1%	79.1%	91%	30.2%	77%
Plastics and rubber	1.6%	2.6%	10.8%	1%	3.8%	5%
EEE and lamps	1%	0.4%	0.3%	0.5%	0.3%	5%
Packaging (plastics, wood)	2.5%	4.1%	8.7%	8%	2%	13%
Glass	-	-	-	-	63.5%	-
Batteries	-	-	-	-	0.2%	-
Polyurethane foam	-	10.1%	-	-	-	-
Fabric	-	-	1.2%	-	-	-

Source: Syndicat National de la Fermeture, de la Protection Solaire et des Professions Associées - Gestion des déchets pour les entreprises de fabrication, d'installation et de maintenance de fermetures et protections solaires.

Depending on the quality of the end-of-life operations, a certain share of the substances (called the leaching potential) is always lost to the environment. According to BIO (2008)[24], process control of landfills and incinerators, alongside mineralization mechanisms in landfills, are some of the options to reduce this share. But there is limited quantitative data about the fate of hazardous substances going through land filling or incineration processes, in particular their leaching potential.

Policy Option 2 (including this type of equipment in the scope of RoHS II) would progressively (over a 20 year period, between 2019 and 2039[25]) decrease the quantities of hazardous substances from automatic doors and gates found in the waste streams, compared to the baseline scenario. The

[24] BIO (2008), Study to support the impact assessment of the RoHS review – Final Report, for DG ENV.

[25] One estimated product lifetime after this type of equipment falling in scope of RoHS II. Possibly earlier if manufacturers take early measures.

reduction of these substances may have a beneficial effect on their end-of-life treatment. This effect is dependent on the development of the waste management sector as a whole.

Table 6 shows the estimations used to calculate the environmental impacts of RoHS hazardous substances released into the environment at the end-of-life. The assessment is likely to contain high uncertainties, because of the assumptions made to model the end-of-life options.

Table 6: Heavy metal emissions, by end-of-life management options

End-of-life process	Share of total end-of-life products (in %)	Emissions to air during end-of-life process	Emissions to water during end-of-life process	Source of the emissions estimates
Recycling	80%	0.001%	0.059%	COWI (2002)[26]
Incineration	10%	0.5%	2.49%	ERM (2006)[27]
Landfill	10%	-	5%	ERM (2006)

By considering the annual sales and lead quantities presented in section 1.2.2, it is estimated that 17.5 tonnes of lead from solder and 1.75 kg of hexavalent chromium would be sent annually into the end-of-life management circuit from 2039[28] if the product group was not included within the scope of RoHS II. For Option 2, it is assumed that all lead in solder and all Cr VI coatings would be removed from the products from 2019, so that none of these substances would go to the waste streams from 2039.

Based on these assumptions, the ecotoxicity freshwater midpoint indicator was calculated[29] in order to illustrate the avoided impacts for the end-of-life of automatic doors and gates within the scope of RoHS II, in 2039. This indicator was chosen because the release of RoHS hazardous substances in the environment has an influence on its value (this is not the case for Global Warming Potential, for instance).

Table 7: Avoided freshwater ecotoxicity impacts by Option 2, compared to Option 1

Year[30]	Ecotoxicity freshwater midpoint (CTUe[31])
2039	5.53E+04

This result in 2039 represents 0.000000003% of the overall freshwater ecotoxicity annual impact in the EU-27 (USEtox™ normalisation values). Details of the calculations are given in Annex.

In theory, end-of-life impacts also depend on the possible substitutes that would replace the six hazardous substances. A similar quantitative analysis could not be done by considering the impact

[26] COWI (2002), Heavy Metals in Waste – Final Report, for European Commission DG ENV. Applicable to lead, assumed to be the same for other heavy metals

[27] ERM (2006), Battery Waste Management Life Cycle Assessment – Final Report.

[28] 10 years (the lifetime of the product) after the effective implementation of RoHS II.

[29] According to USEtox™ methodology.

[30] RoHS II coming into force for this product group (2019), plus one product lifetime (20 years)

[31] Comparative Toxicity Unit ecotoxicity, equivalent to PAF.m3.day

of the substitution of lead solder by lead-free solder, as the most suitable substitutes are not known yet. Still, some substitutes are likely to leach hazardous substances into the environment too, even if lead is the most toxic alloying element: silver or antimony represent a potential source of toxicity in leachates when used in alloys, while bismuth, indium and copper are regarded as less dangerous[32]. Obviously, the levels of emissions depend on the specific environmental conditions the waste will be exposed to during the end-of-life management. Another source[33] builds a comparative analysis of lead-free solder, by taking into account toxicity, availability and environmental impact of extraction of substitutes to lead in solder alloys. Based on this, only tin and copper appear to have a lower overall impact than lead. These outcomes have to be considered with caution given the subjective assessment grid. Finally, a comparative life cycle assessment[34] also illustrates that depending on the environmental impact considered, either lead solder or one substitute (bismuth-tin-silver or copper-tin) can be best performing.

1.3.2.3 International environmental impacts

Given the waste management options of end-of-life products and the fact that automatic doors and gates are usually dismantled by professionals, there does not seem to be significant treatment (recycling or landfilling) of these products outside the EU-27. Regional and national recycling markets exist with the EU-27. As a consequence, international environmental impacts are expected to be negligible.

However, concerning the production phase, electronics components (e.g. control units) are mainly manufactured outside the EU-27 (e.g. in China) so that the ban of the hazardous substances might have positive effects in extra-EU countries involved in components manufacturing. The overall effect is expected to be relatively low, given the limited amount of electronics in automatic doors and gates, but it nonetheless contributes to an improvement of the supply chain in general.

1.3.2.4 Overview of environmental impacts until 2039

Based on the above, some positive environmental impacts can be expected from automatic doors and gates falling in the scope of RoHS II, in particular during the end-of-life phase, where less hazardous substances would be released to the environment.

32 Edwin B. Smith III, Environmental Impacts and Toxicity of Lead Free Solders: http://leadfree.ipc.org/files/RoHS_16.pdf

33 Anna Kua, Prof. Oladele Ogunseitanb, Prof. Jean-Daniel Saphoresc. Lead-Free Solders: Issues of Toxicity, Availability and Impacts of Extraction: http://trs-new.jpl.nasa.gov/dspace/bitstream/2014/6388/1/03-0222.pdf

34 EPA (2005), Solders in electronics: a life-cycle assessment. Available at: http://www.epa.gov/dfe/pubs/solder/lca/lfs-lca-final.pdf

Table 8: Estimated environmental impacts

Estimated environmental impacts until 2039[35]		
	2012	2039
Energy use	=	=
Waste production / generation / recycling	=	+
International environmental impacts	=	=/+

1.3.3 Economic impacts

According to ESDF[36], the door and gate market in the EU in 2010 represented a turnover of € 2.779 billion for the production of 3.3 million pieces (excluding automatic pedestrian doors), and approximately € 417 million for the service and maintenance activities (15% of the production turnover). This provides an estimation of an average product price at approximately € 850.

According to MSI[37], the increasing labour costs have influenced the overall market value. There seems to be a shortage of skilled labour within this market, which has also been affected by the number of engineers that have become self-employed providing maintenance services on a local or regional basis. It became more difficult for larger companies to recruit and retain qualified staff.

1.3.3.1 Functioning of the internal market and competition

RoHS II should affect all manufacturers of automatic doors and gates in the EU equally, which means that no competitive pressures within the European Union should be expected. Provided there is a common interpretation between Member States on the large scale fixed installation definition and suitable market surveillance, no distortion of the internal market is expected.

1.3.3.2 Competitiveness

No specific figures were found or received from stakeholders regarding international trade (imports and exports) of automatic doors and gates.

For non-RoHS compliant manufacturers, the ban of the RoHS substances in automatic doors and gates may result in some additional costs that, whether passed on to the consumer or not, could reduce their competitiveness. No data regarding possible technical limitations was found or received so that the extent of this effect is unknown. The consequences may represent an advantage to non-EU manufacturers outside the EU, but RoHS compliance might also be regarded

[35] RoHS II coming into force for this product group (2019), plus one product lifetime (20 years)
[36] E.D.S.F. Newsletter 03/2010. Available at: http://www.edsf.com/fileadmin/user_upload/Dokumente/Newsletter_etc/E.D.S.F._newsletter_03.pdf
[37] MSI press release, Industrial and Commercial Doors and Shutters: UK. Available at: http://www.msi-reports.com/market_research_report_pdfs/CUK3-S.PDF

as an advantage by extra-EU consumers if the price difference is reasonable. Within the EU market, all appliances will have to comply with RoHS: the same possible burden would apply to non-EU manufacturers willing to export to the EU market and it could be that these manufacturers would then manufacture and sell RoHS compliant products outside the EU as well.

In brief, the overall effect on the competitiveness of EU manufacturers is unknown but it is expected to be limited in all cases.

1.3.3.3 Costs and administrative burdens

It is very difficult to estimate additional costs due to RoHS II implementation. According to the 2008 Impact Assessment accompanying the Commission's recast proposal[38], there is little experience of actual compliance costs for industry. For products currently included in RoHS, estimates are it would vary from 1-4% of turnover. Other surveys give an average overall cost related to RoHS of 1.9% of turnover (past cost and one-off future costs). Assuming an average price of 850 € for a typical product and 3.5 million annual sales, the annual turnover of the whole sector is approximately € 3 billion. Applying the 1-4% range, compliance costs would represent between € 30 million and € 120 million for all manufacturers.

Technical costs could be due to additional research to come up with new compliant components and to the fact that changed components would have to undergo extensive field testing before being implemented in products. Such costs could be reasonably supported by large manufacturers, but could be more problematic for SMEs of the sector. No information was found on the market composition according to the size of companies, so that the share of SMEs is unknown. Furthermore, the situation may be different between manufacturers: some of them may have already voluntarily changed some RoHS non-compliant components when possible, in order to simplify the production processes and the supply chain.

The replacement of lead-solder by lead-free solder would also result in additional costs due to raw materials prices. With a quantity of lead in solders of 5 g per product, and annual sales representing 3.5 million products, lead solder constitutes 29.8 tonnes of tin and 17.5 tonnes of lead per year. Assuming that 80% of the lead solder is replaced by tin/silver/copper solder, and 20% is replaced by tin/copper solder[39], 16.3 additional tonnes of tin and 1.14 tonnes of silver would be required to replace lead. Additional costs would then represent approximately €1 million[40] annually.

1.3.3.4 Innovation and research

As no specific technical information was found or received on the use and functions of RoHS substances in automatic doors and gates and their possible substitutes, it is difficult to forecast possible needs or costs regarding innovation and research. It seems that no electric function or

[38] European Commission (2008), SEC(2008) 2930. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=SEC:2008:2930:FIN:EN:PDF

[39] Because of the long lifespan, most of the products are likely to have high reliability requirements.

[40] Under the following assumptions: composition of tin/lead solder is 63%/37%; composition of tin/silver/copper solder is 97%/3%/0% (copper is neglected); composition of tin/copper solder is 100%/0% (copper is neglected); prices of metals (LME): 1590€/tonne for lead, 16210 €/tonne for tin; 674000 €/tonne for silver; 1 g of tin/lead solder is assumed to be replaced by 1 g of tin/silver/copper solder or 1 g of tin/copper solder.

component used in automatic doors and gates is specific to this sector, i.e. they can also be found in other products. Therefore, manufacturers would probably not be directly in charge of R&D for these components, but would instead look for alternative RoHS compliant components developed by the electronics industry. These are likely to already exist for other product groups in scope of the Directive. Regarding other components possibly containing RoHS substances (e.g. coatings), manufacturers may have to carry out their own R&D depending on the requirements of their products, but efforts may also be shared with other industries manufacturing products with similar environmental constraints (e.g. garden equipment).

Consequently, the impact on this indicator is considered negligible.

1.3.3.5 Consumers and households

An average retail price for automatic doors and gates (excluding automatic pedestrian doors) has been previously estimated at 850 € (see section 1.3.3.5). However, prices vary from a couple hundred Euros to several thousand Euros so that this average may not be very meaningful. This wide range is due to the variety of products, applications and sizes. In particular, high-speed doors have very high unit prices, which results in a high market value despite a small volume share.

Given the lack of information, it is difficult to predict the possible increase effect that RoHS II implementation would have on final purchase prices. It may be that purchasers would have to partly or fully support the additional costs and administrative burdens (see section 1.3.3.3) due to RoHS II implementation. Even in the event of an increase of purchase prices of automatic doors and gates, the influence on sales is not likely to be significant: as stated by MSI[41], during the period 2002-2006, the market for industrial and commercial doors and shutters experienced strong volume and value growth, despite the continuous increase of purchase prices[42]. However, domestic/household customers would probably be more sensitive to such a price increase than commercial/industrial ones, so that some negative effect may occur.

1.3.3.6 Overview of economic impacts until 2039

Based on the above, economic impacts from automatic doors and gates falling in the scope of RoHS II are expected to be limited. Please note that this is based on a limited amount of data so that these results are to be considered with caution.

[41] MSI press release, Industrial and Commercial Doors and Shutters: UK. Available at: http://www.msi-reports.com/market_research_report_pdfs/CUK3-S.PDF

[42] Due to increasing cost of raw materials (steel, aluminium)

Table 9: Estimated economic impacts

Estimated economic impacts until 2039		
	2012	2039
Functioning of the internal market and competition	=	=
Competitiveness	=	?
Costs and administrative burdens	=/-	-
Innovation and research	=	=
Consumers and households	=	=/-

1.3.4 Social impacts

1.3.4.1 Jobs

Statistics regarding jobs directly and indirectly linked to the door and gate industry are sparse. In a newsletter[43], EDSF provided an estimation of the door and gate market in the EU in 2010. According to this source, taking into account all door and gate manufacturers and assemblers of more than 20 employees (i.e. 416 companies), 26 830 people were employed in the sector in 2010. This figure does not include the service and maintenance activities though. In terms of turnover, service and maintenance represented 15% of the production total. Assuming a similar share in terms of jobs, these activities should represent approximately 4 000 employees, which results in a total number of jobs directly linked to doors and gates of circa 31 000 people. As stated in section 1.3.3, it has become more difficult for larger companies to recruit and retain qualified staff because of the increase in labour costs, and because many engineers have become self-employed providing installation and maintenance services.

The job estimates are not all related to products within the scope of this assessment, given that some products are not automated and some can be considered as large-scale fixed installations. Involved companies are however very likely to be the same, except for some SMEs that manufacture specific types of doors and gates.

The impacts of RoHS II on the jobs in this industrial sector are expected to be weak: on the one hand, a negative impact could come from the possible decrease of sold products (e.g. higher price due to RoHS II, phase-out of some products for lack of substitutes to RoHS substances), but this is believed to be unlikely (see section 1.3.3.5); on the other hand, the development of R&D to find substitutes could stimulate job creation but this effect is not expected to be substantial given that

[43] E.D.S.F. Newsletter 03/2010. Available at: http://www.edsf.com/fileadmin/user_upload/Dokumente/Newsletter_etc/E.D.S.F._newsletter_03.pdf

this research would be at least partially shared, in particular with the electronics industry which supplies the door and gate manufacturers.

1.3.4.2 Health

The overall impacts of hazardous substances on health are difficult to quantify. It needs to be differentiated between possible impacts during the production phase, on users during the actual product's lifetime and at the end-of-life.

First, exposure to these substances during the production phase represents a risk for the facility workers, who are a population group at greatest risk of exposure to lead (especially through air). This risk is very much dependent upon the type of exposure (time, frequency, pathway, etc.). It can be expected that the EU manufacturers already respect the related legislation and implement the necessary precaution to ensure their workers' well-being. The production of the electronics is made outside the EU-27 thanks to automated processes. However, a ban of the six hazardous substances under the scope of RoHS would certainly reduce the health impacts during the production phase, in particular in case of accidental situations. This phenomenon is also dependent on possible developments in other industrial sectors because of the complex structure of supply chains. The importance of these health effects furthermore depends on the potential effects of the substitutes to the six banned substances, if any. Therefore, a quantification of these impacts could not be made.

Impacts on the health of users during the use phase are expected to be low. In normal operation, the product represents a very low risk to the user's health, as this is taken into account in the design phase. Direct contact with hazardous substances is not expected. Beyond the hazardous content, the most important potential hazard with any powered door is the door striking or crushing a person using it with sufficient force to cause injury[44]. Comfort and safety are major criteria for consumers, purchasing a door or gate with an electric drive[45]. There are various types of presence-sensing safety devices which may be fitted in various positions at powered doors. These are used to detect the presence of slow moving or stationary traffic in the path of the door. They include active infra-red, capacitive, ultrasonic or photo-electric types. These devices are arranged to prevent further motion of a door to ensure that the door does not make contact with traffic in its path. Fire protection and means of escape may also be complementary stakes: if powered sliding or folding door s are proposed for installation on an escape route and are intended as means of escape door, then the doors should be capable of manual break-out in the direction of escape. Alternatively and more commonly, the doors should be linked to an automatic fire detection system that opens the doors on activation of the fire detection system or failure of the power supply. The substitution of RoHS substances by alternative compounds is not expected to have any influence on the safety and fire functionality. Consequently, no effects on human health are expected. Please note, however, that no specific data was found or received on this point.

[44] http://www.dhfonline.org.uk/downloads/pub169.pdf

[45] Christian Grabitz, ttz Expert Forum – Automation of Gates – Market Study Results. Available at: http://www.edsf.com/fileadmin/user_upload/Dokumente/Newsletter_etc/TTF_2_11_Grabitz_GB.pdf

Finally, the management during the end-of-life can result in important impacts to the environment and health. These impacts are dependent upon the management options followed by products, which have already been presented (see section 1.3.2.2). Based on the same assumptions regarding the emissions to air and water of the substances during recycling, incineration and disposal (see Table 6), health impacts can be quantified via the human toxicity indicators[46]: assuming the ban of RoHS hazardous substances in automatic doors and gates from 2019 (Option 2), a human toxicity impact of 4.39E-04 CTUh (cancer effects) and 1.01E-01 CTUh (non-cancer effects) would be avoided in 2039 (0.000003% and 0.000025% respectively of overall impacts in the EU-27 annually), compared to Option 1, due to the removal of lead in solder and chromium VI in coatings.

Table 10: Human toxicity indicators

Year[47]	Human toxicity midpoint, cancer effects (CTUh[48])	Human toxicity midpoint, non-cancer effects (CTUh)
2039	4.39E-04	1.01E-01

The monetised benefit of this has been calculated by Defra (UK)[49] which looked at the costs in terms of health impacts of options for management of waste containing hazardous substances including lead. The study estimated health impacts from mathematical models of landfill and incineration and estimates of pollution from these disposal options. Applying these results to the heavy metal emissions per end-of-life treatment options (see Table 6), gives a monetised health benefit from not using lead of between k€ 218 and k€ 5,206[50].

1.3.4.3 *Social impacts in third countries*

No social impacts in third countries are expected based on the EU-27 market description, as automatic doors and gates, which are large appliances dismantled by professionals, are not expected to be massively shipped to developing countries.

1.3.4.4 *Overview of social impacts until 2039*

The social impacts of automatic doors and gates falling in the scope of RoHS II can be expected to be slightly positive given the health benefits, especially during the end-of-life phase of the products.

[46] USEtox™ method.
[47] RoHS II coming into force for this product group (2019), plus one product lifetime (20 years)
[48] Comparative Toxicity Unit human, equivalent to cases
[49] Enviros Consulting Ltd. For Defra, *Valuation of the external costs and benefits to health and environment of waste management options*, December 2004, table 3.2 and page 82)
[50] Based on a monetised impact of lead between €1.46 million/tonne and €35 million/tonne, and assuming a 0.85% leakage rate of lead at the end-of-life.

Table 11: Estimated social impacts

Estimated social impacts until 2039		
	2012	2039
Employment	=	=
Health	=	+
Social impacts in third countries	=	=

1.3.5 Comparison of options

The inclusion of automatic doors and gates in the scope of RoHS II is expected to result in both limited positive and negative impacts. Due to the decrease of the use of the banned substances, environmental and health benefits are expected all along the lifecycle of the products, especially at the end-of-life. On the other hand, increased administrative and technical costs may represent additional burdens for companies (especially SMEs) and consumers.

Please note that the current assessment is based on many assumptions and that detailed information on the RoHS substances specifically used in these products were not found or received from stakeholders. The existence and impacts of possible substitutes are also considerations that could not be taken into account in assessing impacts. Therefore, results should be considered with caution.

Table 12: Comparison of options

Impact indicators	Option 1 : Automatic doors and gates not in scope of COM recast proposal	Option 2: Automatic doors and gates in scope of RoHS II
Environmental impact indicators		
Energy use	=	=
Waste production / generation / recycling	=	+
International environmental impacts	=	=/+
Economic impact indicators		
Functioning of the internal market and competition	=	=
Competitiveness	=	?
Costs and administrative burdens	=	-
Innovation and research	=	=
Consumers and households	=	=/-
Social impact indicators		
Employment	=	=
Health	=	+
Social impacts in third countries	=	=

In relation to the overall policy objective of RoHS II, namely to contribute 'to the protection of human health and the environment, including the environmentally sound recovery and disposal of waste EEE'[51], the discussion above shows that including automatic doors and gates in RoHS II does contribute to this objective, even if slightly:

[51] 2011/65/EU, Article 1

Table 13: Policy objectives and options

Policy options in relation to overall policy objectives			
	Effectiveness	**Efficiency**	**Coherence**
Option 1: Automatic doors and gates not in scope of COM recast proposal	Negative: Hinders the objectives	Efficiency cannot be evaluated as the option does not contribute to the overall objectives	No unintended impacts
Option 2: Automatic doors and gates in scope of RoHS II	Positive: Contributes to reaching the objectives although amounts of RoHS substances are limited	Limited: None of the positive impacts are significant	Limited unintended impacts

Annex

Possible criteria to determine whether an installation is 'large-scale'. Please note that this is only an indicative list.

If the installation exceeds the minimum requirements for **one** of the following criteria, it can be considered large-scale:[52]

- If, when installing or de-installing the installation, it is too large to be moved in an ISO 20 foot container because the total sum of its parts as transported is larger than 5,71m x 2,35m x 2,39m, then it can be considered large-scale.
- The maximum weight of many road trucks is 44 tonnes. Thus if, when installing or de-installing the installation, it is too heavy to be moved by a 44 tonne road truck, because the total sum of its parts as transported weighs more than the truck's load capacity, it can be considered large-scale.
- If heavy-duty cranes are needed for installation or de-installation, the installation can be considered large-scale.
- An installation that does not fit within a normal industrial environment, without the environment needing structural modification, can be considered large-scale. Examples for modifications are modified access areas, strengthened foundations etc.
- If an installation has a rated output greater than 375 kW, it can be considered large-scale.

[52] European Commission, DG ENV, *RoHS 2 FAQ, Final Draft 15 May 2012*

Table 14: Quantities of RoHS substances released to the environment in 2039 without RoHS II implementation, due to end-of-life management options

Substance	Released to	Quantity (in kg)
Cadmium	Air	0
Chromium VI		0.000889
Lead		8.89
Mercury		0
Cadmium	Water	0
Chromium VI		0.0139335
Lead		139.335
Mercury		0

Table 15: Characterisation factor of the RoHS substances (USEtox™ method)

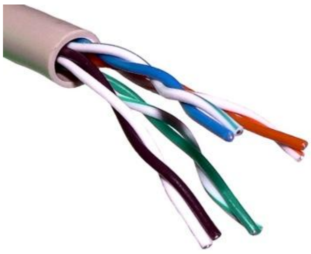
Substance	Type of emissions	Human toxicity midpoint, cancer effects (in CTUh/kg)	Human toxicity midpoint, non-cancer effects (in CTUh/kg)	Ecotoxicity freshwater midpoint (in CTUe/kg)
Lead	Emissions to air, unspecified	2.69E-05	9.44E-03	1.75E+02
	Emissions to water, unspecified	3.42E-07	1.20E-04	3.75E+02
Mercury	Emissions to air, unspecified	7.06E-03	8.35E-01	1.22E+04
	Emissions to water, unspecified	1.20E-04	1.42E-02	2.21E+04
Chromium VI	Emissions to air, unspecified	4.45E-03	4.16E-04	4.20E+04
	Emissions to water, unspecified	1.06E-02	2.40E-05	1.05E+05
Cadmium	Emissions to air, unspecified	2.17E-04	4.55E-02	3.94E+03
	Emissions to water, unspecified	1.59E-06	4.27E-04	9.71E+03

Table 16: Impact assessment results (USEtox™ method)

Impact indicator (unit)	Avoided impacts in 2039 in EU-27, with RoHS II implementation (in impact indicator unit)	Avoided impacts in 2039 in EU-27, with RoHS II implementation (in % of annual EU-27 impacts)	USEtox™ normalisation factors (in impact indicator unit per person per year)
Human toxicity midpoint, cancer effects (in CTUh)	4.39E-04	0.000003%	3.25E-05
Human toxicity midpoint, non-cancer effects (in CTUh)	1.01E-01	0.000025%	8.14E-04
Ecotoxicity freshwater midpoint (in CTUe)	5.53E+04	0.000000003%	3.18E+06

An EU-27 population estimate of 502m inhabitants in 2011 is used for the normalisation (source: Eurostat, in March 2012).

Cables



Important note: In this factsheet, the term 'cable' will be used to refer to all types of cables, both finished and unfinished products. RoHS II gives the following definition of cables: 'all cables with a rated voltage of less than 250 volts that serve as a connection or an extension to connect EEE to the electrical outlet or to connect two or more EEE to each other'.

1.1 Issues to explore

While cables were not included in the scope of the COM recast proposal, Article 4 of RoHS II states that 'Member States shall ensure that EEE placed on the market, including cables and spare parts [...] does not contain the substances listed in Annex II'. In this factsheet, it will be explored what the impact of this change is and whether the benefits of the inclusion of cables in RoHS II outweigh the possible costs.

1.2 Background

A cable usually consists of a wire conductor covered by insulation, and many designs also have a jacket encasing the insulated wire(s). There is a very wide range of different cable types. Two major applications using the electric or electromagnetic properties of cables can be distinguished: telecommunications (including audio/video and ICT equipment) and electricity transmission. Mechanical cables (e.g. wire ropes) are not considered in this assessment as they do not correspond to the definition given by RoHS II.

The following section has been developed based on the work of the FAQ Working Group[1] and presents the different criteria that can be used to differentiate and categorise cables. Depending on these criteria, different considerations regarding RoHS II apply.

- Cables can be:
  - **Internally integrated (intrinsic)** to EEE: internal cables are not 'cables' per se but are internal wirings with specific functions contained within or integral to the EEE. These internal wirings connect individual components within EEE and therefore they do not meet the definition of 'cables' in Article 3(5). Internal wirings of any EEE are subject to the same scope considerations (material restrictions, transition period) as all other parts of the EEE under RoHS II.

[1] At a draft status, at the time of writing.

They are consequently not subject to scope changes between the COM recast proposal and RoHS II.

- **Externally connected (extrinsic)** to EEE: a cable that connects EEE to the electrical outlet or connects two or more EEE to each other, even though parts of the cable are inside the EEE.

- When external, cables can form part of an EEE (placed on the market) or they can be placed on the market either as a standalone piece of EEE or as a spare part:
  - If a cable is **connected to or marketed with an EEE**, it follows the same requirements (substances restrictions, transition period) as the EEE (like an internal cable, see above). In particular, if a cable is marketed with or connected to an EEE that is placed on the market and that this EEE is required to be RoHS II compliant, then the cable itself should also be RoHS II compliant. Where the EEE was in scope of RoHS I or is in categories 8 or9, there is no scope change between the COM recast proposal and RoHS II; but otherwise, there is a change of scope.
  - All finished cables that are **placed on the market individually as separate or standalone EEE** will need to be accompanied by a Document of Compliance and a CE-mark.
- In parallel, external cables can also be:
  - either **'simple' or 'multi-use'**: examples of simple or 'multi-use' cables includes 'ready for use' cables like power extension cords, cable rollers, and multiple socket-outlets with cables. In addition, relative simple cables such as USB-cables are placed in category 2 or 3. Some MS have not included these cables in category 2 in their transposition of the RoHS I Directive. In these MS, these cables will be category 11 when the RoHS II Directive is transposed and therefore subject to a transition period.
  - or **'specialised' and 'dedicated'**: cables that are placed on the market individually and can only be used for a specific EEE follow the same requirements as that specific EEE like as if they were placed on the market together. However the cable will still need its own Document of Compliance and a CE-mark. For instance, specialised cables like SCART-cables, HDMI-cables and network-cables, which are used for example in voice, data and video transfer, are in categories 3 or 4. These cables were already within the scope of RoHS I and are thus within the scope of RoHS II.
- External cables placed on the market individually can be:
  - Cables **with no connectors in either one or two ends**: they are in the scope of the RoHS II and should be placed in category 11; or

- Cables **with connectors in both ends**.

The date on which cables are required to be RoHS II compliant is dependent on which Annex I category the cable is placed in and whether newly included by RoHS II. Table 1 summarises the above.

Table 1: RoHS II scope considerations according to cables categories[2]

1st level categories	2nd level categories	3rd level categories	4th level categories	Category in Annex I	In scope of			In scope of this IA
					RoHS	COM Proposal	RoHS II	
External cables meeting the definitions of EEE in Article 3(1) or cables in Article 3(5): - EEE: "Equipment which is dependent on electric currents or electromagnetic fields in order to work properly and equipment for the generation, transfer and measurement of such currents and fields and designed for use with a voltage rating not exceeding 1 000 volts for alternating current and 1 500 volts for direct current" - Cables: "all cables with a rated voltage of less than 250 volts that serve as a connection or an extension to connect EEE to the electrical outlet or to connect two or more EEE to each other."	**Placed on the market individually as separate products. Note: All cables over 250 volts placed on the market individually are NOT within scope of RoHS II** All cables that are placed on the market individually as separate or standalone EEE will need to be accompanied by a Document of Compliance and a CE-mark.*	With connectors in both ends	Simple or multi-use	Category 2 in some MS	Yes	Yes	Yes	No
				Category 11 in some MS (i.e. not considered as belonging to categories 1-7 and 10 under RoHS I)	No	No	Yes	Yes
			Dedicated or specialised	Cables that can only be used for specific EEE in Categories 1-2-3-4-5-6-7-10 (same category as the EEE)	Yes	Yes	Yes	No
				Cables that can only be used for EEE in Categories 8-9 (same category as the EEE)	No	Yes	Yes	No
				Cables that can only be used for EEE in Category 11 (same category as the EEE)	No	No	Yes	Yes
		With no connectors in either one or two ends		Always category 11	No	No	Yes	Yes
	Marketed together with or connected to EEE			With EEE belonging to Categories 1-2-3-4-5-6-7-10 (same category as the EEE)	Yes	Yes	Yes	No
				With EEE belonging to Categories 8-9 (same category as the EEE)	No	Yes	Yes	No
				With EEE belonging to Category 11 (same category as the EEE)	No	No	Yes	Yes
Internal cables: connect individual components within EEE. They do not meet the definition of 'cables' in Article 3(5) but are intrinsic to the EEE itself. They have the same requirement as the EEE itself: If the EEE is in scope, the internal wiring has to comply. Transition periods are the same as for the EEE itself.				In EEE belonging to Categories 1-2-3-4-5-6-7-10	Yes	Yes	Yes	No
				In EEE belonging to Categories 8-9	No	Yes	Yes	
				In EEE belonging to Category 11	No	No	Yes	No**

* As stated in the draft FAQ document. However, according to the Blue Guide, a finished EEE does not require further manufacturing or processing (http://ec.europa.eu/enterprise/policies/single-market-goods/files/blue-guide/guidepublic_en.pdf, p.60) so that cables without connectors would not be considered as finished EEE and therefore would not require CE marking (Art. 15). This issue might require further clarification.
**With the exception of internal cables in product groups that are part of this impact assessment.

[2] Based on: European Commission, DG ENV, *RoHS 2 FAQ, Final Draft 15 May 2012*

Based on the above table, cables that are considered as part of this assessment are:

- Simple or multi-use cables (placed on the market individually, with connectors in both ends, <250 V) that were not considered as belonging to categories 1-7 and 10 under RoHS I;
- Dedicated or specialised cables (placed on the market individually, with connectors in both ends, <250 V) that can only be used for EEE in category 11;
- Cables with no connectors in either one or both ends (placed on the market individually, <250 V);
- Cables marketed together with or connected to EEE belonging to category 11.

Given the definition of Category 11 (all EEE not elsewhere included) and data availability, it is not feasible to get a bottom-up estimate of cables related to this category (first, second and fourth cable types), even by listing major product groups belonging to Category 11. Therefore, assumptions will have to be made based on the overall cable market.

1.2.1 Legal background

According to the draft RoHS II FAQ[3], cables are within the scope of RoHS II if they meet the definitions of EEE in Article 3(1)[4] or cables in Article 3(5)[5]. Except mechanical and separately sold optical cables, most types of cables will meet these definitions as cables are both dependent on electrical currents and electromagnetic fields to work properly and are primarily used for the transfer of electrical currents and electromagnetic fields. However, all cables with a rated voltage higher than 250 volts that are placed on the market individually are not in scope of RoHS II.

Some simple or multi-use cables (see Table 1) were already included in scope of RoHS I and the COM proposal. This consideration differs on a geographical basis, i.e. some MS interpreted that they belonged to Category 2 when implementing RoHS I while others considered them as not belonging to categories 1-7 and 10 and therefore as out of the scope.

1.2.2 Quantities and hazardous substances

Cables consist of a conducting fraction and an isolation fraction. Copper and aluminium are the two classic conducting materials that are used in cables, while isolation is usually ensured by polymeric materials.

The global cable market followed an average growth rate of 5.3% over the period 2003-2007, before slowing down and eventually contracting in 2009 due to the economic crisis[6]. Except China, this

[3]European Commission, DG ENV, *RoHS 2 FAQ, Final Draft 15 May 2012*
[4] "Equipment which is dependent on electric currents or electromagnetic fields in order to work properly and equipment for the generation, transfer and measurement of such currents and fields and designed for use with a voltage rating not exceeding 1 000 volts for alternating current and 1 500 volts for direct current"
[5] "All cables with a rated voltage of less than 250 volts that serve as a connection or an extension to connect EEE to the electrical outlet or to connect two or more EEE to each other".
[6] Robert Daniels (2010), CRU Group, Presentation to 6th Arabcab Conference (Beirut 3-4 May 2010). Available at: http://arabcab.org/Arabcab_Presentation_CRU.pdf

decrease affected all regions of the world. In 2009, the global market represented $122 billion (versus $160 billion in2007 and 2008) and approximately 14 million tonnes of conductor. Cables considered in this assessment are estimated to be part of the three following families: low voltage energy, data cable and telecom cable.

Table 2: Market share by cable type on the global cable market

Cable type	Short Description	Market share
Low Voltage Energy	Rated below 1kV	37%
Power Cable	Rated 1 kV and above	30%
Winding Wire	All enamelled wire and covered conductors	13%
Data Cable	All types for data transmission	10%
Fibre Optic	All types of fibre optic cables	6%
Telecom Cable	External copper telecom cable	4%

Source: Robert Daniels (2010), CRU Group, Presentation to 6th Arabcab Conference

The cable market is very sensitive to raw material prices and their volatility (e.g. copper). After the economic crisis during which companies face overcapacity and falling demand, the cable market is expected to stabilise and grow again. The table below presents production figures in some countries and regions for 2010.

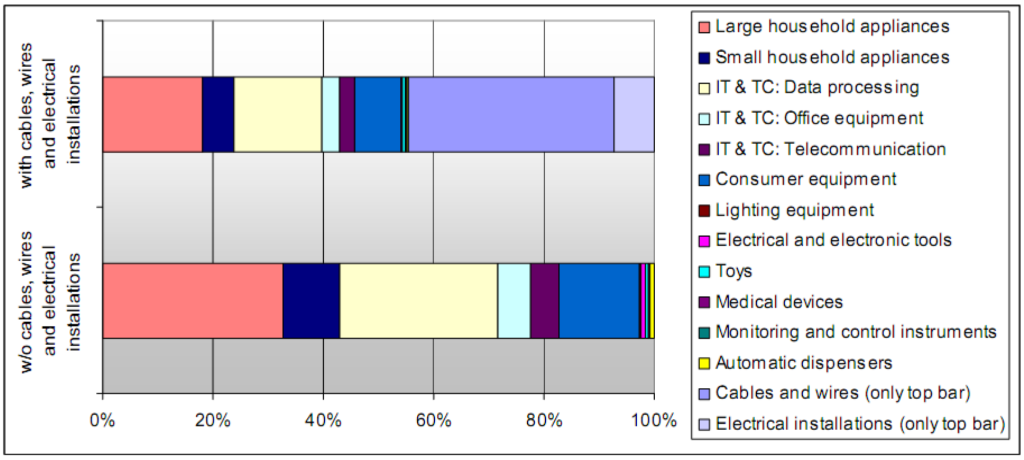
Table 3: Production of metallic wire and cable in 2010

Country/Region	Quantity in k tonnes of conductor	Change compared to 2009 in %
France	227	3.7
Germany	489	6.9
Italy	391	9.1
Spain	180	-5.9
United Kingdom	113	2.0
Nordic Countries	175	8.4
Benelux	107	0.6
Total Europe	2 783	8.2
North East Asia	1 459	5.9
North America	1 672	6.1
China	5 114	9.6
World Total	**14 767**	**9.2**

Source: Adapted from ICF public statistics, http://www.icf.at/en/3646/statistics.html

The three largest cable producing countries are China, the USA and Japan respectively. The market share of China has constantly increased since 2000, to reach almost 35% of global production in 2009, at the expenses of the shares of the USA (19% in 2000, 9% in 2009) and Japan (8% in 2000, 5% in 2009)[7]. Consequently, a large share of cables put on the EU-27 market is expected to be imported, especially from China. There are no global or EU statistics on imports/exports available so that this share could not be determined. According to Europacable figures[8], its member companies totalled €20 billion wire and cable consumption in 2010, representing a share of almost 20% of the global market and some 38 million km of cables produced per year in Europe. Looking at the insulation and jacket fractions, Figure 1 shows that cables and wires represent a very large share (almost 40% in 2000) of the plastics use in EEE production. According to PlasticsEurope (2011)[9], the plastic demand for EEE applications in the EU-27, plus Switzerland and Norway, represented 5.6% of 46.4 million tonnes in 2010, i.e. 2.6 million tonnes. Consequently, it is estimated that approximately 1 million tonnes of plastics was consumed in cables applications in the EU-27 in 2010.

Figure 1: Relative plastics consumption in the EEE domain in Western Europe in 2000



Source: APME (2001). Plastics – A material of innovation for the electrical and electronic industry.[10]

PVC (for its insulation and sheathing qualities) and PE represent the two main polymer types used for cables insulation and jacketing (see Figure 2).The resin (plastics fraction of the cable) has to possess specific characteristics that will make it suitable for the intended application (e.g. earthing, telecommunications, automotive industry, etc.). Consequently, additives such as stabilisers, plasticisers, pigments, UV absorbers and flame retardants are added to the plastics fraction in order to improve the quality and performance of the cables (e.g. heat stability, electrical and mechanical characteristics, and colour[11]).

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[7] Robert Daniels (2010), CRU Group, Presentation to 6th Arabcab Conference (Beirut 3-4 May 2010). Available at: http://arabcab.org/Arabcab_Presentation_CRU.pdf

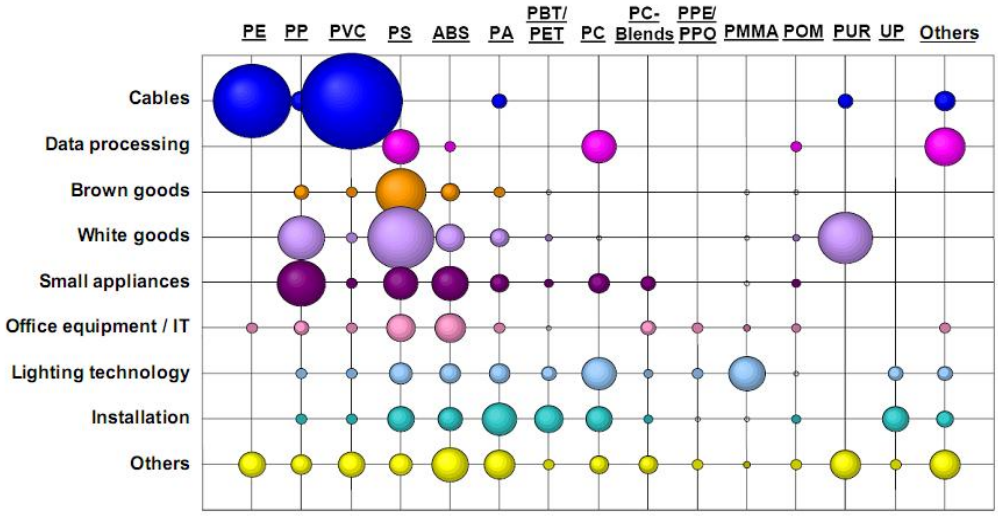
[8] Europacable represents approximately 85% of Europe's industry in this sector: http://www.europacable.com/about-main/key-facts.html, accessed in June 2012

[9] PlasticsEurope (2011). Plastics – the Facts 2011. Available at: http://www.plasticseurope.org/Document/plastics---the-facts-2011.aspx?Page=DOCUMENT&FolID=2

[10] In Wäger, P., M. Schluep and E. Müller (2010), RoHS Substances in Mixed Plastics from Waste Electrical and Electronic Equipment – Final Report. Available at: http://ewasteguide.info/files/Waeger_2010_Empa-WEEEForum.pdf

[11] http://www.stabilisers.org/applications

Figure 2: Plastics use in the Western European EEE industry, by application



Source: Wäger, P., M. Schluep and E. Müller (2010)[12]

Regarding hazardous substances, PVC for cables and wires was known to contain lead based stabilisers: their cost/performance ratio and physical properties ensure a long service life to cables[13]. However, given the health concerns induced by lead, a voluntary initiative called VinylPlus[14] was launched by the European PVC industry, setting, amongst others, the objective of replacing lead in additives by 2015 in the EU-27 but lead is still widely used outside of the EU although much less than previously in cable insulation because of the RoHS directive. In the period 2000-2010, lead stabilisers (in the EU-15) decreased by 75.9%, being substituted by calcium-based stabilisers. Also as part of this initiative, cadmium stabilisers were already phased out in the EU-15 (2001), EU-25 (2006) and EU-27 (2007)[15]. Cadmium stabilisers for PVC are banned in the EU by REACH. The ESPA[16] also plans to actively promote VinylPlus outside the EU-27.

Brominated flame retardants are also used in the plastic fractions of cables which use polymers other than PVC. Table 4 shows the mean concentrations of PBDEs found in copper cable scrap in Switzerland.

[12] RoHS Substances in Mixed Plastics from Waste Electrical and Electronic Equipment – Final Report.
[13]http://www.stabilisers.org/stabilisers-types/lead-stabilisers
[14] Vinyl 2010 – reporting on the activities of the year 2010. Available at: http://www.vinyl2010.org/images/progress_report/2011/vinyl2010_progress_report_2011_final.pdf
[15] http://www.vinyl2010.org/images/progress_report/2011/vinyl2010_progress_report_2011_final.pdf
[16]European Stabiliser Producer Association

Table 4: Mean concentration of brominated flame retardants in copper cable scrap in WEEE in Switzerland

Brominated Flame Retardant	Mean concentration (in mg/kg)
PentaBDE	25 ± 10
OctaBDE	100 ± 150
DecaBDE	170 ± 110
TBBPA	5 ± 2
HBCD	25 ± 10

Source: Morf L. S ., J. Tremp, R.Gloor, Y.Huber, M. Stengele, and M. Zennegg (2005)[17]

The data in table 3 represents cables manufactured well before 2000 before the restrictions on PBDEs were adopted in the EU. The concentrations of these substances found in cable scrap do not provide evidence that PBDE exceeds the RoHS concentration limit (0.1% per unit mass for PBDEs). According to EPA(2008)[18], the percent mass that is insulation ranges from 10 to 21% of the cables, and jacketing ranges from 19 to 34%. Thus, assuming the insulation or jacketing represent 20% of the scrap mass each and they are homogeneous materials, the mean concentration of PBDE in the scrap would have to be above 200 mg/kg to be above the RoHS limit of 0.1% at homogeneous material level (in the insulation or jacketing).

Table 5 summarises the RoHS substances applications in cables. As explained above, lead based stabilisers are currently being phased out in PVC (but not in all non-EU countries) and cadmium stabilisers for PVC is banned by REACH so that none of these substances should be found in PVC cables manufactured in the EU-27 after 2015. However, an important share of the cables on the EU-27 market is also imported from extra EU countries so that these cables may contain such substances after 2015. The use of cadmium in plastics and as electroplated coatings is already banned under REACH Directive so that RoHS will not have any impact on this substance's occurrence.

According to several EU stakeholders, all their cables are already RoHS compliant as none of the regulated substances are used. Reasons for this include the simplification of the supply chain[19] and customers' requests.

[17] Brominated Flame Retardants in Waste Electrical and Electronic Equipment: Substance Flows in a Recycling Plant. Environmental Science and technology, 39, 8691-8699.

[18] EPA (2008), Wire and Cable Insulation and Jacketing: Life-Cycle Assessments For Selected Applications. Available at: http://www.epa.gov/dfe/pubs/wire-cable/lca.htm

[19] A given type of cable can be integrated in a EEE or sold separately.

Table 5: RoHS substances applications in cables and wires

RoHS substance	Possible applications in cables and wires (past or current)	Possible Substitutes
Lead	- Lead-based heat stabilisers in PVC (provide long-term thermal stability and electrical resistance with low water absorption)[20]: tetra-basic lead sulphate, tri-basic lead sulphate, di-basic lead phosphite, di-basic lead phthalate, di-basic lead stearate, neutral lead stearate[21] - In alloys: lead alloys with up to 0.075% cadmium are sometimes used as sheaths for cables subject to cyclic stress[22]	- Calcium organic stabilizers. The European Stabiliser Producer Association (ESPA) and the European Plastic Converters (EuPC) have committed themselves to substitute lead-containing stabilizing agents until the year 2015, under the VinylPlus initiative.
Mercury	None expected	
Cadmium	Uses banned under REACH Directive: - Pigments for insulation plastics (also increases pigments' durability and resistance to heat): usually incorporated in plastics in proportions of 0.01 to 0.75 % by weight[23]. - Stabilisers for PVC (to retard degradation due to ultraviolet light and heat) - Plating of electrical connector shells (for its corrosion resistance, lubricity, electrical conductivity and solderability) - Alloy conductors (for applications requiring high electrical conductivity, flexibility and higher strength than pure copper)[24]	- Colorants based on organic materials and other elements - Zinc and calcium based stabilizers - Cadmium-free alloy conductors are available that are suitable as replacements for CuCd wire
Hexavalent Chromium	Passivation coatings on connectors, possibly as pigments	Trivalent passivation coating and alternative pigments
Polybrominated biphenyls (PBB)	Only used in high voltage power cables so out of scope	
Polybrominated diphenyl ethers (PBDE)	Flame retardants in PE, PP but rarely in PVC	Alumina trihydrate; EBP; EBTPI; TBBP-A[25]bis(2,3-dibromopropylether).

1.2.3 Policy objectives and options

The objective of both, the RoHS recast proposal (COM (2008) 809 final) as well as RoHS II (2011/65/EU) is to contribute 'to the protection of human health and the environment, including the environmentally sound recovery and disposal of waste EEE'[26].

[20]EPA (2008), Wire and Cable Insulation and Jacketing: Life-Cycle Assessments For Selected Applications. Available at: http://www.epa.gov/dfe/pubs/wire-cable/lfs-lca-chap1.pdf
[21]http://www.stabilisers.org/stabilisers-types/lead-stabilisers
[22] International Cadmium Association website: http://www.cadmium.org/pg_n.php?id_menu=10
[23]International Cadmium Association website: http://www.cadmium.org/pg_n.php?id_menu=13
[24] Document by Fisk Alloy Conductors, available at: http://www.fiskalloy.com/pdf-pages/cableandcad.pdf
[25] Respectively 1,2-bis(pentabromophenyl)ethane,Ethylene bistetrabromophtalimide and Tetrabromobisphenol A
[26] 2011/65/EU, Article 1

The purpose of this work is to look at the impacts of cables falling in the scope of RoHS II compared to cables being excluded from the COM recast proposal. Policy options will then be evaluated according to their effectiveness, efficiency and coherence in reaching the above-mentioned overall objective of the RoHS Directive. The policy options analysed are the following:

OPTION 1 (baseline scenario): Cables not in scope of the COM recast proposal.

OPTION 2: RoHS II. Cables included in the scope of the recast Directive.

1.3 Main issues regarding cables

The following subsection presents the main issues that were encountered regarding the assessment of potential impacts of cables falling in scope of RoHS II. Because of these issues, a quantitative assessment could not be carried out in the way it has been done for other product groups. Impacts of the policy options are therefore only qualitatively discussed in section 1.4.

1.3.1 Cable definition

The first issue concerns the two definitions under which cables can be considered within the scope of RoHS II:

- Under the 'EEE' definition, given in Art 3.1: 'equipment which is dependent on electric currents or electromagnetic fields in order to work properly and equipment for the generation, transfer and measurement of such currents and fields and designed for use with a voltage rating not exceeding 1 000 volts for alternating current and 1 500 volts for direct current';
- Under the 'cable' definition, given in Art 3.5: 'all cables with a rated voltage of less than 250 volts that serve as a connection or an extension to connect EEE to the electrical outlet or to connect two or more EEE to each other'.

The draft FAQ document states that 'most types of cables will meet these definitions as cables are both dependent on electrical currents and electromagnetic fields to work properly and are primarily used for the transfer of electrical currents and electromagnetic fields'. However, the 'cable' definition is more specific (and more restrictive) than the 'EEE' definition, for instance regarding the voltage limit, and it remains unclear to, at least some, stakeholders what would happen to a cable fulfilling the 'EEE' definition, but not the 'cable' one.

Regarding this issue, the draft FAQ document states that 'cables that are placed on the market individually with a rated voltage higher than 250 volts are not within scope of RoHS 2', which would mean that the 'cable' definition is predominant but this remains unclear at the point of writing.

1.3.2 Lack of data on RoHS substances

No quantitative data on the current RoHS substances used in cables was found. Furthermore, a number of contacted stakeholders would not contribute to this work as long as they were still discussing fundamental definition issues with the FAQ working group and the Commission. An estimation of additional administrative costs, for example, remains difficult as long as industry does not agree with the FAQ working group on the types of cables that will need CE marking. Finally, the large number of different cable types and RoHS requirements regarding those particular types makes the data gathering process particularly time consuming for contributing stakeholders. Nevertheless, several EU stakeholders have indicated that all their cables are already RoHS compliant, but this information was not documented.

Given the integration of cables in many other EEE already in scope of RoHS I, it is likely that almost all types of cables are already RoHS compliant, because the manufacturing process and supply chain do not necessarily depend on the end-application (e.g. integrated in an EEE or sold separately).For cables manufactured outside the EU-27, no information was found so that it is possible that the situation might be different and that the applications listed in Table 5 are still used. The discussion will therefore consider that EU manufacturers are already RoHS compliant while it is possible that extra-EU manufacturers are not.

1.4 Impacts of policy options

Taking into account the limitations presented above, this section discusses the possible environmental, economic and social impacts of the two policy options.

1.4.1 Environmental impacts

Waste production/generation/recycling is the key impact to investigate regarding RoHS substances in cables (also see the EPA LCA study, briefly presented in the Annex). It is due to emissions and leaching of these substances to the environment during the end-of-life treatment processes, especially if these are unsafe and not properly controlled as widely occurs in some developing countries. The lifetime of cables depends upon their type and application, but it is usually long. According to EPA (2008)[27], communications cables have an expected lifetime of 10 to 15 years, due to obsolescence resulting from technological advancements, while low-voltage power cables have a lifetime of approximately 25 to 40 years. Consequently, the delay between their production and installation, and their management at the end-of-life can be important. In particular, this may result in recycling limitations as end-of-life cables may contain old additives that are not used anymore by the industry and not desired in new products.

Nonetheless, cables are valuable as a large share of their weight consist of copper from the wires (approximately 50% for communications and low power voltage cables). As it is the case for other materials (e.g. plastics recycling depending on oil prices), the recovery and recycling rates of cables

[27] EPA (2008), Wire and Cable Insulation and Jacketing: Life-Cycle Assessments For Selected Applications. Available at: http://www.epa.gov/dfe/pubs/wire-cable/lca.htm

is dependent on raw material availability, and especially copper prices. According to EPA (2008), the historically high price of copper ensures that an estimated 95% of cables and wires are recycled at the end-of-life. This figure may be different in the EU but a high recycling trend is very likely. Overseas competition, especially from China, is often cited as a source for changes that have greatly affected the wire and cable recycling sector in recent years. Cables are often exported from the EU to developing countries for reuse or recycling, where the copper (and aluminium) conductors have a sale value to smelter operators, but the plastics fraction (PVC and PE, in insulation and jacketing) is frequently disposed of, often by open burning.

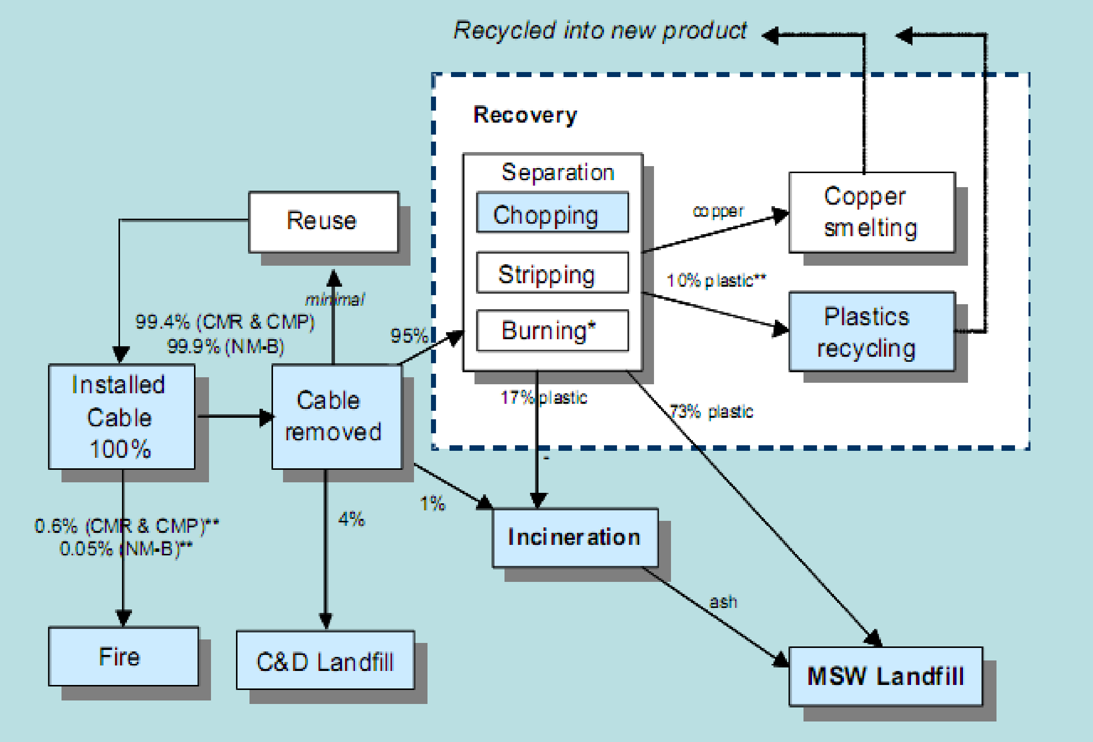
Regarding the recycling process, the conductor has to be separated from the insulation and jacketing, by chopping (mostly used in developed countries) or stripping (typically in developing countries). Depending on the process details, the purity of the polymer stream obtained varies between 95% and 99.5% (EPA (2008)). Another process used to recover the metal fraction (but not the plastics one) is separation by incineration. Specific incinerators are used in order to control the process conditions in order to limit the emissions of hazardous combustion products into the air (e.g. furans and dioxins from PVC combustion and polycyclic aromatic hydrocarbons from all types of polymer) and PVC and PE fractions are typically separated before incineration. For emissions during incineration, EPA (2008) indicates that 98.5% of the lead (stabiliser) content is assumed to be disposed of with the ash to a landfill and 1.5% is released to the air. Finally, the last possible management option is landfill, which according to Scheirs (2003)[28] represents the predominant way of disposing of PVC waste throughout the world. Leachate rates for lead from communication cables are estimated to be between 1 to 2% if the cable has not been chopped/stripped significantly, and approximately 10% for smaller, chopped cable particles[29], for a 100-year lifetime of a landfill although the latter might not be typical.

Consequently, the higher the recycling rates, the lower the potential emissions of RoHS substances to the environment. Figure 3 shows the distribution of the different end-of-life management options for cables and wires used in the LCA performed by EPA (2008). For the copper fraction (and more generally metal fraction), 95% of the content is recycled, 1% is incinerated and 4% is landfilled. For the plastics fraction, 9.5% is recycled, 73.5% is landfilled and 17% is incinerated.

[28] Scheirs, J. (2003). End-of-Life Environmental Issues with PVC in Australia. ExcelPlas Polymer Technology (EPT).

[29] http://www.epa.gov/dfe/pubs/wire-cable/lfs-lca-chap2.pdf

Figure 3: End-of-life management options for communication and low-voltage power cables



* Burning within recovery process to segregate cable could include open burning (under an "unregulated" recycling scenario) or incineration to separate conductor from resin system.
** These estimates are not well documented and are used as defaults based on available data and best professional judgment, which are varied in a multivariate uncertainty analysis.
Shaded boxes illustrate EOL distribution options modeled in this analysis.
Figures may not sum due to rounding.

Source: EPA (2008), Wire and Cable Insulation and Jacketing: Life-Cycle Assessments For Selected Applications.

As a result, depending on the uses of RoHS substances in cables (metal fraction or plastic fraction), the quantities released to the environment will be very different. Negative impacts can occur in the EU and also in third countries, either in manufacturing countries exporting cables to the EU, or in developing countries where scrap cables are exported from the EU. The environmental impacts for Option 2 compared to the baseline scenario could not be quantified. They depend on the quantities of RoHS substances still used in cable manufacturing outside the EU (under the assumption that RoHS are no longer used in EU manufacturing processes).

1.4.2 Economic impacts

In terms of functioning of the internal market and competition, RoHS II implementation should not have any influence on the cable market, assuming that proper market surveillance is implemented and that a common interpretation of the Directive is implemented by Member States. In particular, this is one of the objectives of the current FAQ working group.

Depending on the specific situation of manufacturers, RoHS II implementation may have a different effect on their competitiveness: for the ones that are already RoHS compliant, it would result in a beneficial effect compared to non-EU manufacturers. In case the non-EU manufacturers are still using RoHS substances in their products above the RoHS limits, they will need to make additional efforts to sell their products on the EU market. Additionally, RoHS compliance could be seen as a competitive advantage by customers even on markets outside the EU.

Regarding additional costs, technical costs would be limited for already compliant manufacturers. However, additional administrative costs (preparing technical files and declarations of conformity) would occur and could be significant given the many different cable types. Some stakeholders estimate that the CE marking will require a significant amount of additional work and jobs, which would have a negative impact on competitiveness. Furthermore, Europacable estimate that around 235 European companies will have to include RoHS specific aspects in the conformity declarations; R&D departments will be required to provide information for the conformity declarations; purchasing services will have to include RoHS compliance in the specifications to suppliers and carry out follow-up procedures. As the resources needed depend on the company considered and the variety of cables produced, it is not possible to provide a quantitative estimate of these additional costs.

Given the claims by some manufacturers that they are already RoHS compliant, no impact on innovation and research is expected for EU manufacturers in case of RoHS II implementation. Even for possible non-compliant manufacturers, substitutes should be well-known and are available.

1.4.3 Social impacts

Europacable member companies employ over 55000 people across Europe[30]. As they represent approximately 85% of the EU market, the total number of jobs in the EU related to the cable sector should be around 65 000 people. Additional jobs may be created due to the added administrative burden for RoHS II compliance. No negative impact (due to a decrease of the market size for instance) is expected. The current trend to increasingly source from China may be limited by RoHS II if users are more confident that EU-manufactured cables will be RoHS compliant although the extent of this is unknown and may be negligible.

Similarly to the environmental impacts during the end-of-life treatment processes, the emissions of RoHS substances to the environment result in negative health effects. In particular, workers in extra-EU manufacturing countries and those involved in end-of-life treatment processes outside the EU may be particularly exposed to these substances. The health impacts for Option 2 compared to the baseline scenario could not be quantified. They depend on the quantities of RoHS substances still used in cable manufacturing outside the EU (under the assumption that RoHS substances are no longer used in EU manufacturing processes).

Cables are also subject to important safety and security considerations, the main one being related to accidental fires. The plastics fraction of cables represents a potential source of combustible material in specific conditions, which could facilitate fire propagation. As a result, plastics have to

[30] http://www.europacable.com/about-main/key-facts.html, accessed in June 2012

be protected from fire, first of all to keep them functioning for as long as possible (e.g. for critical applications), but also to avoid feeding the fire. On the other hand, they may also be the source of fires, via short circuits. To ensure the reliability and safety of cables, flame retardants are used in PVC (which has good intrinsic fire safety characteristics) and PE resins. Testing standards and national regulatory specifications have been development in the field of fire resistance. The formulation of flame retardants is usually specific to each defined application. Replacement of lead based stabilisers by calcium / zinc and other alternatives will not change the types and quantities of flame retardants added to PVC cable insulation or the high level of flame resistance. PVC itself is not combustible but plasticisers are needed for flexibility and these are combustible and so antimony oxide is a common flame retardant in PVC although short and medium chain chlorinated paraffins are used in Asian countries as a combined plasticiser / flame retardant. Polyethylene insulation does rarely contain PBDE nowadays and alternative flame retardants are widely available and can achieve the same high level of fire protection.

1.4.4 Comparison of options

As a conclusion, an accurate quantitative assessment was not feasible for cables, given the lack of data on RoHS substances used in such products and the remaining lack of clarity of what types of cables are newly in scope. No specific recommendation concerning cables in scope of RoHS can therefore be made. However, the considerations about the 'EEE' and 'cable' definitions (respectively given in Art. 3.1 and Art. 3.5) may need to be clarified.

The possible benefits of RoHS II implementation are uncertain: depending on the RoHS substances still used in cables by extra-EU manufacturers, positive environmental and health effects may occur, particularly during the end-of-life treatment processes. On the other hand, RoHS II implementation would certainly result in additional costs and administrative burdens for manufacturers, especially due to CE marking requirements.

Annex

The EPA (2008) provides a first overview of environmental impacts related to hazardous substances in cables. The study performed comparative Life Cycle Assessments (LCA) between three types of cables (containing lead stabilisers)[31] and their lead free alternatives (using calcium-zinc based stabilisers), over their full life cycle. According to the study, these products contain materials common to many wire and cable applications, typically contain materials for which alternatives are being sought (situation in 2008), and represent a significant share of the wire and cable market. The system considered in the assessment included only materials and processes where the cables might be substantially different, i.e. the plastics fraction of the cables (called the resin), which is why copper was excluded from the analysis[32].

Across all cable types examined in the study, the lead-free cable formulations had lower environmental impacts for the majority of impact categories. However, for most impacts the overall disparities between cable alternatives after factoring in of parameter uncertainties were small to minimal. The study also demonstrated that the end-of-life stage generates the most sizeable impact differences between baseline leaded cables and lead-free cables. For two of the three cable types, the difference between the leaded cable and its lead-free version was most pronounced in the potential public chronic non-cancer and potential aquatic ecotoxicity impacts, with lead-free cables displaying much lower impacts in these categories (between 62% and 99% reduction[33]). Potential public non-cancer toxicity and potential aquatic ecotoxicity impact results are extremely sensitive to the ability of lead to leach out of cable jacketing and then escape landfills linings and drainage systems. An opportunity for improvement that is stated is consequently the reduction of the quantities of lead entering the landfills (while recognizing potential trade-offs if alternatives are needed to replace the reduced amounts of lead) or management of municipal solid waste and construction and demolition landfills, by ensuring that permeation of lead-containing landfill leachate is minimised.

[31] Riser-rated communication wire (CMR), plenum-rated communication wire (CMP) and non-metallic sheathed low-voltage power cable (NM-B)

[32] In another study, copper wire was found to be the largest single contributor to most environmental impact categories for CMR and CMP cables (Krieger, T., S. Barr, J. Hoover, F. Dawson. 2007. New Fire Hazard and Environmental Burden Evaluations of Electrical Cable Installations Utilizing ISO 14040 Environmental Methodologies. DuPont.)

[33] Note: this figure is related to the studied object (resin) which excludes copper.

Combustion-engine powered garden equipment

Important note: In this factsheet, the product group combustion-engine powered garden equipment will always refer to such products having at least one electric or electromagnetic function.

1.1 Key issues

Combustion-engine powered garden equipment was not in scope of the COM recast proposal but it is understood that it would fall in the scope of the final text of the Directive due to the new and broader definition of EEE in RoHS II[1] even if the only electrical function of such a product is the electric spark ignition system. This issue is being discussed further by stakeholders as part of the FAQ consultation process. In this factsheet it will be explored what the impact of this change is and whether the benefits of the inclusion of combustion-engine powered garden equipment in RoHS II outweigh the potential costs.

Only those products will be assessed that are destined for non-professional or dual use. Professional equipment of this kind would be excluded from the scope by Art. 2.4(g).

1.2 Background

Due to the diversity of activities in the garden sector, there is a wide range of products that can be considered within the combustion-engine powered garden equipment group. Combustion engines used in garden equipment can be of two types: either spark ignited, or combustion ignited (diesel engines). Stakeholders estimate that diesel engines represent 3% of the total EU market for garden equipment in 2010 and 2011 in terms of sales numbers. Because combustion ignited engines are usually fitted in bigger equipment and as these engines are 30 to 40% more expensive than petrol engines, the market share may be more important in terms of its monetised value but no accurate estimate could be made. **The following analysis has been primarily made in regards to spark ignition combustion engines, but overall conclusions are estimated to be also valid for diesel engines equipment**.

Most types of equipment have non-professional and professional lines. The design can but does not necessarily define the application: a professional device can be used for domestic purposes while professionals can also use non-professional equipment. Therefore, even if labelled as 'professional', all products available for general purchase through general consumer distribution channels, without, e.g. a license/professional training requirement, can be bought and used either by individual consumers or by professionals. These products destined for either non-professional or dual use represent the products in the scope of this analysis. Only products made exclusively

[1] Art. 3.2: 'needing [electricity] to fulfil at least one intended function'

available to professionals are not considered, as they are excluded by Art. 2.4 (g) of RoHS II. Professional use means that products are not sold to consumers but to businesses for a specific use (under controlled conditions) by qualified users (e.g. fairway mowers). Access through license is an example of exclusive professional use, e.g. top handle chainsaws can only be used by a licensed user. Furthermore, specific service contracts can be provided to professionals. Professional devices, whether designed for exclusively professional or dual use are designed for a much longer lifetime resulting in a higher price. There is no current legal / reference definition of 'professional use'. However, products that are specifically designed and intended for professional use but occasionally purchased by consumers should be considered professional products and excluded from the scope by Art. 2.4 (g). According to stakeholders, the professional appliances market represents approximately 10% of the total market, in terms of quantity.

The major products belonging to combustion-engine powered garden equipment include:

- Lawn mowers: A walk-behind or ride-on grass cutting machine or a machine with grass-cutting attachment(s) where the cutting device operates in a plane approximately parallel to the ground and which uses the ground to determine the height of cut by means of wheels, air cushion or skids, etc., and which uses an engine or an electric motor for a power source. The cutting devices are either rigid cutting elements, or non-metallic filament line(s) or freely pivoting non-metallic cutter(s) with a kinetic energy of more than 10 J each.[2]

  Also included are walk-behind or ride-on grass cutting machines or machines with grass-cutting attachment(s) where the cutting device is rotating about a horizontal axis to provide a shearing action with a stationary cutter bar or knife (cylinder mower).

- Brushcutters and grass trimmers (or 'trimmers'): A combustion-engine driven portable hand-held unit fitted with a rotating blade made of metal or plastic intended to cut weeds, brush, small trees and similar vegetation. The cutting device operates in a plane approximately parallel to the ground.
- Hedge trimmers: hand-held powered equipment, integrally driven by a combustion engine which is designed for use by one operator for trimming hedges and bushes utilising one or more linear reciprocating cutter blades.
- Chain saws: a saw driven by a combustion engine, usually portable, in which the cutting teeth form links in a continuous chain. It is mainly used in applications such as tree felling and limbing. It consists of an engine, a drive mechanism, a guide bar and a cutting chain having small sharp blades. These tools operate at high engine speeds to propel the chain through a wood surface and make a quick cut.
- Garden cultivators: a gardening tool driven by a combustion engine to stir and pulverize the soil, either before planting (to aerate the soil) or after the crop has begun growing.
- Cleaning equipment:

[2] The kinetic energy is determined using EN 786:1997, Annex B

   - Blowers: A combustion engine driven machine appropriate to clear lawns, paths, ways, streets, etc. of leaves and other material by means of a high velocity air flow. It may be portable (hand-held) or mobile.
   - Leaf collector: A combustion engine driven machine suitable for collecting leaves and other debris using a suction device which produces a vacuum inside the machine and a suction nozzle and a container for the collected material. It may be portable (hand-held) or mobile.
   - High-pressure cleaner;
   - etc.
- Other miscellaneous products: earth/ice augers, cut-off saws, cutting wheels, log splitters, multipurpose garden machinery, etc.

Many of these products have manual or electric alternative designs, where the combustion engine is replaced by an electric motor. Stakeholders estimate that electric devices represent approximately 44% of the total garden equipment. Electric motors are quieter and do not emit combustion by-products while combustion powered equipment can be more powerful and are not limited by the length of an electrical cord. Given that electric tools are in scope of RoHS I, manufacturers that produce both combustion engine and electric motor designs should already be familiar with RoHS considerations. Many manufacturers, however, produce only combustion-engine driven products.

Important requirements of these products are high safety and air emission standards. Besides the possibility of a spark ignition system or the fuel pre-heating system (in diesel engines), the most common electric features that can be found in combustion powered garden equipment have been introduced because of safety or comfort reasons (e.g. electrically heated handles). For instance, hedge trimmers are usually designed with safety devices so that they work only when both of the operator's hands are placed on the handles. These safety features are designed to prevent operator injury and are often mandated by international/EU regulations and standards.

1.2.1 Legal background

Electrical and electronic tools constitute Category 6 of the WEEE Directive (2002/96/EC)[3]. As a result, electric powered garden equipment was already included in scope of RoHS I. Due to the European Commission / Member States authorities' interpretation of the enlarged scope of RoHS II at the time of writing of this report, all combustion-engine powered garden equipment that requires electricity, even if only for a minor function, will fall within Category 6 (Annex I) of the Directive from July 2019. The RoHS II substance restrictions will apply to all components, also non-electrical ones, on the homogeneous material level.

Some electrical functions (such as the ignition sparking system) may be subject to exemptions from RoHS II depending on their voltage (Art. 3.1). However, even if the electric spark function, which requires a high voltage to be produced, may be affected by Art. 3.1, it is normally obtained from a

[3] http://www.weeeregistration.com/categories-of-electrical-and-electronic-equipment-covered-by-WEEE-directive.html

lower voltage source via an ignition coil which is not subject to Article 3.1. This assessment will consider the strictest possible definition of the product group: all combustion-engine powered garden equipment with at least one electric or electromagnetic function, even if this is only the electric spark.

Due to Article 2.4(g) of RoHS II, combustion-engine powered garden equipment that can be defined as non-road mobile machinery made available exclusively for professional use is exempted from RoHS II and is therefore not considered within the scope of this assessment. Being 'made available exclusively for professional use' refers to the intended use of a product as well as how it is marketed.

1.2.2 Quantities and hazardous substances

There is no official collection of garden equipment data at European level. The European Garden Machinery Federation (EGMF), representing 16 European manufacturers and eight National associations[4] estimates that Europe represents around 35% of the world market for these products, with the major producing countries being the UK, Germany, France, Sweden and Italy. One of the specificities of this market is that it is dependent on the climate conditions influencing the growth of plants and trees, so that annual sales may vary from one year to another, more significantly than in other industrial sectors. More than six million lawnmowers, four and a half million chainsaws, three million brushcutters and three million hedgetrimmers are sold each year in Europe[5]. These figures do not differentiate products by energy source (electric, combustion engine), nor by use (non-professional, professional), and are thus not restricted to products considered in this assessment.

Table 1 shows sales figures (in quantities and values) for categories containing products potentially within the scope of combustion-engine powered garden equipment (not intended for professional use), extracted from the PRODCOM database, for the EU-27 in 2010. Product categories containing exclusively non powered hand tools, electric tools or equipment intended for professional use are consequently not included. No specific product categories for some of the garden equipment (brush cutters, hedge trimmers, etc.) have been identified. PRODCOM codes of the product categories presented are given in Annex.

The apparent consumption in the EU-27 is also calculated from PRODCOM figures. "Mowers for lawns, parks or sports grounds, powered non-electrically, with the cutting device rotating in a horizontal plane" and "Chainsaws with a self-contained non-electric motor" appear as the most sold product categories. These figures have to be considered with caution given the data gaps in some Member States.

[4] http://www.egmf.org/en/members
[5] http://www.egmf.org/en/economic-information/

Table 1: PRODCOM market figures for non-electric garden/outdoor/etc. equipment, sorted by EU-27 Apparent Consumption Value (EU-27, 2010)[6]

Product category[7]	Production		Imports		Exports		EU-27 Apparent Consumption[8]	
	Quantity (in p/st)	Value (in €)	Quantity (in p/st)	Value (in €)	Quantity (in p/st)	Value (in €)	Quantity (in p/st)	Value (in €)
Mowers for lawns, parks or sports grounds, powered non-electrically, with the cutting device rotating in a horizontal plane	3 441 137	920 173 070	2 114 646	398 094 530	426 144	79 884 820	5 129 639	1 238 382 780
Chainsaws with a self-contained non-electric motor	2 337 564	563 459 130	2 797 798	191 640 460	96 208	12 679 600	5 039 154	742 419 990
Handtools, hydraulic or with a self-contained non-electric motor (excluding chainsaws)	1 982 085	191 003 780	n.a.	266 656 670	n.a.	162 504 810	n.a.	295 155 640
Scarifiers and cultivators	131 947	288 211 011	867 435	45 380 980	35 653	57 843 470	963 729	275 748 521
Motor mowers for lawns, parks or sports grounds, powered non-electrically, with the cutting device rotating in a vertical plane or with cutter bars	26 539	40 091 124	530 709	99 173 750	9 897	9 987 130	547 351	129 277 744
Motor mowers (excluding for lawns, parks, golf courses or sports grounds)	92 940	81 294 413	20 584	6 445 120	27 269	11 260 610	86 255	76 478 923
Rotovators	240 000	89 869 363	141 001	19 343 500	122 304	33 127 570	258 697	76 085 293
Mowers (excluding those with motors, for lawns, parks, golf courses or sports grounds, those designed to be hauled or carried by a tractor)	2 217	12 841 146	36 399	5 687 870	106 200	14 554 070	-67 584	3 974 946
Mowers designed to be hauled or carried by a tractor, with cutting device rotating in a horizontal plane (excluding those with a motor, for lawns, parks, golf courses or sports grounds)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Mowers designed to be carried or hauled by a tractor (excluding those with a motor, for lawns, parks, golf courses/sports grounds, with cutting device rotating in a horizontal plane)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

[6] Extracted on 1st February 2012. Database available at: http://epp.eurostat.ec.europa.eu/portal/page/portal/prodcom/data/database
[7] Not all products within a presented category are systematically included within the scope of this impact assessment but some of them always are: for instance, motor mowers for parks may be exclusively for professional use but motor mowers for lawns are considered in this analysis.
[8] Apparent Consumption = Production + Imports - Exports

A JRC-IES study[9] presents market data of spark ignition engines in the EU-15, based on EUROMOT data (see Table 2). Hobby applications are dominating the market (professional products are not presented in the table below, as they are not considered in this analysis).

Table 2: Market figures for domestic combustion-engine powered garden equipment in the EU-15, in 2005[9,10]

Engine type (for hobby use only)	Annual sales in volume	Stock in volume	Average power (in kW)	Engine class
Lawn mowers	2 317 032	23 170 320	2.5	SN 3
Chainsaws	1 022 220	8 177 760	1.8	SH 2
Trimmers	681 480	5 451 840	1	SH 2
Others	397 530	3 180 240	1	SH 2
Riding mowers	263 506	2 635 056	10	SN 4
Total EU-15	4 681 768	42 615 216	-	-
Total, scaled to EU-27 based on population[11], and market share[12]	7 150 000	65 000 000	-	-

These figures are approximately in line with PRODCOM estimates. EGMF also estimates a total EU-27 market of 8 650 000 units in 2010, for combustion-engine powered garden equipment (both hobby and professional).

The combustion engines used in this equipment are almost exclusively spark ignition engines (97% of the market sales), so that the products can be all considered within the scope of the analysis (as the products contain at least one electric function). Combustion powered products with diesel engines are in general not used for the consumer market. **Consequently, the annual sales of combustion-engine powered garden equipment, not intended for professional use and with at least one electric function probably represent approximately eight million units per year, for a stock of 65 million units.** According to EGMF, the percentage of combustion powered lawnmowers with an additional electric function (other than the spark ignition system) in annual sales varies depending on the type of lawnmower: from 20 to 100 % for professional devices, less than 5% for smaller ones[13].

Regarding international trade, manufacturers estimate that approximately 70% of the EU-27 production is exported to non-EU countries. EU manufacturers dominate the world market of

[9] 2007 Technical Review of the NRMM Directive 1997/68/EC as amended by Directives 2002/88/EC and 2004/26/EC (2008), DG JRC-IES. Available at:
http://ec.europa.eu/enterprise/sectors/mechanical/files/nrmm/final_report_nrmm_review_part_ii_en.pdf
[10] Engine class categories SH1, SN1 and SN2 are not presented because they represent a negligible share of the market volume, compared to the other classes.
[11] 381 781 620 inhabitants in the EU-15 in 2004, and 494 296 878 in the EU-27 in 2007, i.e. 29.5% increase by neglecting the evolution in Member States within that period. Source:
http://en.wikipedia.org/wiki/Statistics_relating_to_enlargement_of_the_European_Union
[12] Imports from manufacturers not members of Euromot are not accounted for. The figures presented constitute approximately 85% of the market.
[13] Data with high uncertainty.

handheld products (e.g. chainsaws, hedge trimmers) with approximately 75% of the global market share. In particular, products are exported to the USA, Russia and South America, especially Brazil. For wheeled products (e.g. lawnmowers) however, the US industry accounts for 70% of the global market share. It is estimated that 80% of the EU-27 lawnmower sales come from extra-EU imports (in particular from the USA, as well as from Japan and China) while for the other product groups, imports represent around 35% of sales.

According to several manufacturers, combustion-engine powered garden equipment does not currently comply with RoHS II. Table 3 lists the presence of the different hazardous substances considered by RoHS II.

Table 3: RoHS substances in combustion-engine powered garden equipment

Substance	Presence in combustion-engine powered garden equipment
Lead	Yes, in solder, metal alloys and ceramic. Estimation: 0.74 g in solder per product
Mercury	No
Cadmium	Unlikely
Hexavalent Chromium	Yes, on screws and other steel parts for corrosion protection. Estimation: up to 200 µg per product[14]
Polybrominated biphenyls (PBB)	Unlikely
Polybrominated diphenyl ethers (PBDE)	Unlikely

Source: Stakeholders enquiry

According to stakeholders, most non-compliant materials that can be replaced without a relevant technical trade-off have already been replaced by RoHS compliant alternatives to reduce the complexity in purchasing and manufacturing. Some manufacturers state that the only RoHS substance contained in their products is lead: all other components were made RoHS compliant when RoHS I was implemented for the electric devices. In particular, coatings and surface treatments have been replaced by Cr VI-free substitutes. Other manufacturers, particularly those who produce goods intended for longer life spans and outdoor storage, have researched but not identified a proven alternative for Cr VI corrosion resistant coatings and surface treatments. For cadmium, PBB and PBDE, their use is unlikely: to manufacturers' best knowledge, they have been phased out in garden equipment. They are not expected to be found in the products but manufacturers do not control the whole supply chain. It is assumed that they are not present for the assessment. Lead is used in:

- Solder in the ignition module and wiring harnesses: a rough estimation of 0.74 g per product is given in the table above according to stakeholder feedback.
- Aluminium, steel and copper alloys (for shafts and casing): these uses are covered by exemptions under RoHS II (6(b), 6(a) and 6(c) respectively). These uses shall

[14] One EGMF member manufacturer estimated that a specific lawnmower contained approximately 0.00036% hexavalent chromium by weight in the entire product. Because no detailed information was available on the product, this share could not be estimated representative of the market.

therefore not be considered in the analysis. Stakeholders indicate that they may represent approximately 0.5 g of lead in a typical 5 kg product.

- Ceramic lead oxide: these uses may be covered by an exemption under RoHS II (7(c)-I). No quantitative estimation could be made.

Therefore, only the lead contained in solder will be considered as affected by the scope change between the RoHS recast proposal and RoHS II in this product group. The situation might be different for some manufacturers on the market but no feedback was received indicating that other hazardous substances could be found and in which quantities.

Substitute-soldering of motor electronics in air cooled engines turns out to be a technical barrier for a number of products of this product group. According to some stakeholders, proven alternatives to lead solder used to ensure quality and performance levels do not exist. The rationale for this is that the electronic boards and wiring harnesses containing lead solder are directly connected to the combustion engine. They are therefore subject to high levels of vibration and high temperatures, which is not the case in devices with electric motors[15]. These products are also stored and used in very low temperature environments. The service temperature range is likely to be from -20 to +150 °C. Consequently, according to manufacturers, a substitution by lead-free solder would reduce the reliability and durability of the combustion-engine powered garden equipment as lead free solder differs in terms of porosity, process temperature and adhesion on components. This risk of a decrease in durability has not been documented, however, as no reliable data on the use of lead free solder exists. Lead-free solders are either tin/copper or tin/silver/copper. Both have higher melting points and tin/silver/copper solder has a significantly higher cost due to its silver content. In garden equipment, it can be assumed that tin/silver/copper solder is used as this is easier to use. According to stakeholders, the lead solder substitutes will however have to be further investigated by the industry, and the chosen solder may vary depending on the product type (e.g. tin/silver/copper for heavy duty machines subject to heavier constraints, tin/copper which is less reliable for cheaper products).

Hexavalent chromium is used in:

- Fastener plating;
- Hydraulic hard-line and fitting plating; and
- Bracket and retainer plating.

Hexavalent chromium plating is required for corrosion resistance and wear resistance to increase the lifetime. According to some stakeholders, no viable alternative exists to hexavalent chromium that will meet the corrosion resistance required to protect lawn and garden equipment that is often stored outdoors. It is argued that even if trivalent chromium coatings now show equivalent corrosion protection performance to hexavalent chromium coatings[16], they do not benefit from the same self healing properties which are important for long-term protection. However, hexavalent chromium has been eliminated from all EEE previously within the scope of RoHS I without any exemption (including electric garden equipment), as well as from the automotive sector where

[15] These combustion engines can go up to 18 000 rpm (e.g. for chain saws).

[16] Gardner, A. and Scharf, J., "High Performance Alternative to Hexavalent Chromium Passivation of Plated Zinc and Zinc Alloys," SAE Technical Paper 2001-01-0644, 2001, doi:10.4271/2001-01-0644.

vehicles can also be exposed to severe environmental conditions. It is consequently likely that alternative substances will be found for combustion-powered garden equipment as well, but the time and effort required to do so are still uncertain.

1.2.3 Policy objectives and options

The objective of both, the RoHS recast proposal (COM (2008) 809 final) as well as RoHS II (2011/65/EU) is to contribute 'to the protection of human health and the environment, including the environmentally sound recovery and disposal of waste EEE'[17].

The purpose of this work is to look at the impacts of combustion-engine powered garden equipment falling under the scope of RoHS II compared to combustion-engine powered garden equipment being excluded from the COM recast proposal. Policy options will then be evaluated according to their effectiveness, efficiency and coherence in reaching the above-mentioned overall objective of the RoHS Directive. The policy options analysed are the following:

OPTION 1 (baseline scenario): The COM recast proposal. Combustion-engine powered garden equipment is not in scope of the proposed recast Directive.

OPTION 2: RoHS II. Combustion-engine powered garden equipment is included in the scope of the recast Directive.

[17] 2011/65/EU, Article 1

1.3 Impacts of policy options

1.3.1 Impact indicators

The following impact indicators have been chosen as relevant for this product group (see Table 4).

Table 4: Impact indicators for the product group combustion-engine powered garden equipment

Impact indicators		
Environmental	Economic	Social
Energy use	Functioning of the internal market and competition	Employment
Air quality	Competitiveness	Health
Renewable or non-renewable resources	Costs and administrative burdens	Social impacts in third countries
Waste production / generation / recycling	Innovation and research	
Noise emissions	Consumers and households	
International environmental impacts		

The following legend will be used in summarising the impacts:

Legend	
+++	Very beneficial effect
++	Substantial beneficial effect
+	Slight beneficial effect
=	No effect
-	Negative effect
--	Substantial negative effect
---	Very negative effect
?	Unknown effect

1.3.2 Environmental impacts

The most important stakes regarding the environmental impacts in the context of RoHS are related to the quantities of hazardous substances used in the equipment. The mere quantity of a substance is however not sufficient to estimate what the actual impacts of the substance on the environment and health will be. These depend upon numerous factors such as the effective treatment of products at the end-of-life, their design for the use phase or their potential emissions during the production phase. The impact of the substances released to the environment is also determined by case-specific and complex dose-response relationships.

It is therefore not straightforward to predict environmental impacts due to hazardous substances found in products. Where possible, the following subsections will make the link between the quantities of hazardous substances and their potential environmental impacts.

1.3.2.1 Energy use

Given the definition of this product group, all products are expected to consume energy during their operation. Manufacturers are continuously trying to improve the efficiency of engines, in order to reduce the energy use. One manufacturer states a 15% reduction over the period 2004-2010[18].

Combustion-engine powered garden equipment usually has motors belonging to the power range of 1.5 -20 kW (see Table 5).

Table 5: Indicative power bands of some combustion powered garden equipment

Product	Indicative Power Band[19], in kW	Engine durability period[20], in hours	Estimated energy consumption over lifetime, per device, in kWh
Brushcutter	1.5	50	75
Chain saw	2.5	50	125
Lawn mower	4	125	500
Riding mower	15	250	3 750

Stakeholders indicate that the presence of the hazardous substances considered in RoHS II does not have any direct influence on the energy use and efficiency of the devices. They mention, however, that the combustion optimisation has been the result of a substantial and continuous R&D process and that it is possible thanks to the engine electronics control. Effects of possible lead substitutions in these parts are not certain, and will not be before practical tests are carried out.

The European Commission impact assessment accompanying the RoHS recast proposal[21] states that the substitution of lead solder by lead-free solder might lead to an increase in energy

[18] http://www.egmf.org/scripts/tinyMCE/plugins/filemanager/files/Husqvarna_Life_cycle_thinking_important.pdf
[19] http://www.euromot.org/download/8b9081fd-6913-4c71-906b-b6c4a28972be/Engine_Power_Bands.pdf
[20] 2007 Technical Review of the NRMM Directive 1997/68/EC as amended by Directives 2002/88/EC and 2004/26/EC (2008), DG JRC-IES. Available at:
http://ec.europa.eu/enterprise/sectors/mechanical/files/nrmm/final_report_nrmm_review_part_ii_en.pdf
[21] European Commission (2008), SEC(2008) 2930. Available at:

consumption during the production phase because of a higher melting point. The additional energy consumption will vary widely depending on the solder type, the equipment specifications and process operating parameters employed by the facility. Nevertheless, it is generally accepted that lead-free soldering requires approximately 15% more energy than tin/lead (SnPb) soldering when comparing equivalent soldering technology for the two types of alloy and the following calculations will be based on this assumption. Based on a typical solder reflow oven to make the small PCBs on which lead is found in garden equipment, the total additional energy required for lead-free solders represents 65.9 MWh per year. [22] Compared to a total EU final energy consumption of 13.6 million PWh[23], this impact of additional energy required is regarded as negligible for this environmental impact indicator. The additional energy consumption will have an extra cost of 6 125 €[24], which is negligible compared to other technical costs (see section 1.3.3.3). Additional CO_2 emissions due to a change from tin/lead solder to lead-free solder represent 25.7 tonnes CO_2 eq[25].

Consequently, even if lead-free solder would require more energy during the production phase, this effect is expected to be quite low over a life cycle given the high energy use during the use phase of the device. Thus, the inclusion of combustion-engine powered garden equipment within the scope of RoHS II should have no significant impact on this environmental indicator.

1.3.2.2 Air quality

Because of their energy use during operation, combustion-engine powered garden equipment induces emissions of pollutants to the air. These exhaust emissions are dependent upon the type of fuel and motor used and are regulated at the European level by the Directive on emissions from non-road mobile machinery (2002/88/EC), amending Directive (97/68/EC), for spark ignited engines up to 18 kW for engines installed in handheld and non-handheld equipment. It sets limits for emissions of pollutants (CO, HC, NOx) and defines the test procedures to be used (see Table 6). According to stakeholders, electrically controlled components are required to respect this EU legislation. Features such as catalysts can be used in order to limit the exhaust emissions.

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http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=SEC:2008:2930:FIN:EN:PDF

[22] A typical solder reflow oven operates 16 hours per day, 5 days a week, 49 weeks per year and on average consumes 13.9 kWh for SnPb and 16kWh for lead-free. It is assumed that one oven can produce 300 PCBs per hour or 1 million per year (25 PCBs made in a panel every 5 minutes) as these PCBs are small. The total number of units to be made are approximately 8 million.

[23] 1168.63 Mtoe, European Commission, *EU transport in figures, statistical pocketbook 2011*, accessed at http://ec.europa.eu/transport/publications/statistics/doc/2011/pocketbook2011.pdf

[24] Average EU industrial electricity price = 0.093 €/kWh in 2011 according to Eurostat.

[25] Based on 0.39 kg CO_2 eq/kWh from Eurelectric

Table 6: Pollutants emission limits for spark ignition engines with a net power ≤ 19 kW, by class, stage II (2007)

Class	Products	Carbon monoxide (CO) (g/kWh)	Sum of hydrocarbons and oxides of nitrogen (HC + NO_x) (g/kWh)[26]
SH :1 (<20cc)	Hand-held machinery (e.g. trimmers)	805	50
SH :2 (20 to <50cc)		805	50
SH :3 (50cc or more)		603	72
SN :1 (<66cc)	Non-hand-held machinery (e.g. lawn mowers)	610	50.0
SN :2 (66 to < 100cc)		610	40.0
SN :3 (100 to < 225cc)		610	16.1
SN :4 (225cc or more)		610	12.1

Source: Directive 2002/88/EC

In this context, pollutant emissions from combustion-engine powered garden equipment have been decreasing in the past years, in line with an improvement in energy efficiency (see section 1.3.2.1). One manufacturer states that emissions of hydrocarbons and other substances from their products have been reduced by 40% since 2001[27]. Stakeholders indicate that in order to comply with the existing and future exhaust emissions limits in the EU and other parts of the world, it is foreseen that comprehensive electric sensors and control units will need to be added to combustion ignited engines. These motor management systems will be highly computerized and contain additional printing circuits to control the engine, which would need to be RoHS compliant.

As for energy use, the presence of the hazardous substances considered in RoHS II does not have any direct influence on the emission levels of the devices. The inclusion of combustion-engine powered garden equipment within the scope of RoHS II should therefore have no impact on this environmental indicator.

1.3.2.3 Renewable or non-renewable resources

This section focuses on the use phase of the equipment as the most significant use of non-renewable resources is the consumption of fossil fuels during the operation of garden equipment.[28]

Different fuels can be used in small spark ignition engines for combustion-engine powered garden equipment. Currently, the most commonly used is petrol or a petrol/oil mixture which is a non-renewable resource. Manufacturers mention that the regular petrol engines can also use a petrol/ethanol mixture[29]. Ethanol being a biofuel, a certain share of the combustible comes from

[26] The NO_x emissions for all engine classes must not exceed 10 g/kWh.
[27] EGMF online, "Life cycle thinking important when Husqvarna develops outdoor products": http://www.egmf.org/scripts/tinyMCE/plugins/filemanager/files/Husqvarna_Life_cycle_thinking_important.pdf
[28] Please note that this is based on petrol engines only.
[29] E10, i.e. up to 10% ethanol, in standard motors, and E25, i.e. up to 25% ethanol, in the most advanced ones.

renewable resources in this case. There are products exclusively functioning with Liquefied Petroleum Gas (LPG), or biofuels (like Pure Vegetable Oil[30]), the latter being a renewable resource. These products are not yet commonly sold though.

No information was found regarding the presence of hazardous substances depending on the type of fuels, and of engines, used. It is assumed that the presence of the hazardous substances considered in RoHS II is not linked to the type of fuel consumed. The inclusion of combustion-engine powered garden equipment within the scope of RoHS II should therefore have no impact on this environmental indicator.

1.3.2.4 *Waste production / generation / recycling*

The lifetime of combustion-engine powered garden equipment can be very variable depending on the type of device considered, its application and its context of use. According to stakeholders, the lifetime may be segmented between a professional use during the first years of usage (2-4 years), and private use as spare equipment or within farming afterwards, typically by a private owner. Stakeholders talk of an estimated lifetime of 10 years[31], as an order of magnitude. A study by the United Nations University[32] uses the same value for lawn mowers and other garden tools. Table 7 presents average figures estimated for the USA: these figures give ranges slightly lower than 10 years but the source also mentions that Australian turnover of equipment is probably lower than the American one and leads to an average lifespan of 10-12 years. **10 years is consequently estimated as an acceptable average for the EU.**

Table 7: USA Average Usage and Lifespan of Outdoor Garden Equipment[33]

Equipment (for general consumers)	Lifespan (years)
Walk-behind mowers	6-7
Rear engine ride on mowers	6-7
Chainsaws	5-9
Leaf blowers	5-9
Trimmers	5-9

In terms of end-of-life management, recycling markets exist for the high value materials from the recovered products such as metals (sold to scrap metal dealers), while complex plastic parts and electronic components are given to existing recycling schemes. In addition, a business (not controlled by the manufacturers) of second hand and specially re-conditioned parts/components, but also complete products does exist, especially in Eastern Europe. Manufacturers are not responsible for the end-of-life management of their products outside of the scope of the WEEE Directive (2002/96/EC). According to stakeholders, at least 80% of combustion-engine powered garden equipment is recycled at the end-of-life, either through dealers (50% of all products are

[30] http://www.etesia.com/bio-concept.html

[31] From 7 to 20 years for private use.

[32] United Nation University (2007), 2008 Review of Directive 2002/96 on Waste Electrical and Electronic Equipment (WEEE) – Final Report.

[33] Adapted from: http://www.environment.gov.au/atmosphere/airquality/publications/pubs/outdoor-garden-equipment.pdf

returned) or individual users bringing their product to a collection site. Given that printed circuit boards contain high value metals, they are almost always recovered through recycling schemes. Thus, a recycling rate of 80% for the lead solder will be assumed even if it is not part of the most valuable material on a printed circuit board. The remaining 20% are assumed to be disposed of in landfills with the rest of the product (see Table 8).

Depending on the quality of the end-of-life operations, a certain share of the substances (called the leaching potential) is always lost to the environment. According to BIO (2008)[34], process control of landfills and incinerators, alongside mineralization mechanisms in landfills, are some of the options to reduce this share. But there is limited quantitative data about the fate of hazardous substances going through land filling or incineration processes, in particular their leaching potential.

Policy Option 2 (including this type of equipment in the scope of RoHS II) would progressively (over a 10 year period, between 2019 and 2029[35]) decrease the quantities of hazardous substances from combustion-engine powered garden equipment found in the waste streams, compared to the baseline scenario. The reduction of these substances may have a beneficial effect on their end-of-life treatment. This effect is dependent on the development of the waste management sector as a whole.

On the other hand, according to stakeholders, a replacement of lead-containing solder by lead-free solder would be a trade-off in regards to durability of the products and reliability of the safety features for which such solder is required. Stakeholders indicate that the ignition modules are difficult to recycle because of the epoxy resin sealing. The substitution by lead free solder may result in a reduction of the lifespan of the entire product (and an increase of the waste generated) but this is not documented yet and will therefore be neglected in the following analysis. Similarly, substituting hexavalent chromium with other already identified and available corrosion protection methods, e.g. trivalent chromium, may reduce the lifespan, durability and reliability of the entire product, including safety features, due to premature corrosion. Again, no conclusive documentation has been found or received on this and the issue will therefore be disregarded in this assessment.

Table 8 shows the estimations used to calculate the environmental impacts of RoHS hazardous substances released into the environment at the end-of-life. The assessment is likely to contain high uncertainties, because of the assumptions made to model the end-of-life options.

[34] BIO (2008), Study to support the impact assessment of the RoHS review – Final Report, for DG ENV.
[35] Possibly earlier if manufacturers take early measures.

Table 8: Heavy metal emissions, by end-of-life management options

End-of-life process	Share of total end-of-life products (in %)	Emissions to air during end-of-life process	Emissions to water during end-of-life process	Source of the emissions estimates
Recycling	80%[36]	0.001%	0.059%	COWI (2002)[37],
Incineration	0%	0.5%	2.49%	ERM (2006)[38]
Landfill	20%	-	5%[39]	ERM (2006)

By considering the annual sales and RoHS substance quantities presented in section 1.2.2, it is estimated that 5.92 tonnes of lead from solder and 1.6 kg of hexavalent chromium would be sent annually into the end-of-life management circuit from 2029[40] if the product group was not included within the scope of RoHS II. For Option 2, it is assumed that all lead in solder and all Cr VI coatings would be removed from the products from 2019, so that none of these substances would go to the waste streams from 2029.

Based on these assumptions, the ecotoxicity freshwater midpoint indicator was calculated[41] in order to illustrate the avoided impacts for the end-of-life, of the inclusion of combustion-engine powered garden equipment within the scope of RoHS II, in 2029. This indicator was chosen because the release of RoHS hazardous substances in the environment has an influence on its value (this is not the case for Global Warming Potential for instance).

Table 9: Avoided freshwater ecotoxicity impacts by Option 2, compared to Option 1

Year[42]	Ecotoxicity freshwater midpoint (CTUe[43])
2029	2.50E+04

This result represents 0.000000002% of the overall freshwater ecotoxicity annual impact in 2029 in the EU-27 (USEtox™ normalisation values). Details of the calculations are given in Annex.

In theory, end-of-life impacts also depend on the possible substitutes that would replace the six hazardous substances. A similar quantitative analysis could not be done by considering the impact of the substitution of lead solder by lead-free solder, as the most suitable substitutes are not known yet. Still, some substitutes are likely to leach hazardous substances into the environment too, even if lead is the most toxic alloying element: silver or antimony represent a potential source of toxicity in leachates when used in alloys, while bismuth, indium and copper are regarded as less dangerous[44]. Obviously, the levels of emissions depend on the specific environmental conditions

[36] At least, i.e. 80% is a worst case scenario.
[37] COWI (2002), Heavy Metals in Waste – Final Report, for European Commission DG ENV. Applicable to lead, assumed to be the same for other heavy metals.
[38] ERM (2006), Battery Waste Management Life Cycle Assessment – Final Report.
[39] Please note that this estimate may be high because all circuit boards have to be sealed with epoxy resin.
[40] 10 years (the lifetime of the product) after the effective implementation of RoHS II for this product group..
[41] According to USEtox™ methodology.
[42] RoHS II coming into force for this product group (2019), plus one product lifetime (10 years)
[43] Comparative Toxicity Unit ecotoxicity, equivalent to PAF.m3.day
[44] Edwin B. Smith III, Environmental Impacts and Toxicity of Lead Free Solders: http://leadfree.ipc.org/files/RoHS_16.pdf

the waste will be exposed to during the end-of-life management. Another source[45] builds a comparative analysis of lead-free solder, by taking into account toxicity, availability and environmental impact of extraction of substitutes to lead in solder alloys. Based on this, only tin and copper appear to have a lower overall impact than lead. These outcomes have to be considered with caution given the subjective assessment grid. Finally, a comparative life cycle assessment[46] also illustrates that depending on the environmental impact considered, either lead solder or one substitute (bismuth-tin-silver or copper-tin) can be best performing..

1.3.2.5 *Noise emissions*

Noise emissions from combustion powered garden equipment are regulated by Directive 2000/14/EC on the noise emission in the environment by equipment for use outdoors (amended by Directive 2005/88/EC). According to stakeholders, electrically controlled components are required to respect this EU legislation.

Table 10: Noise emissions limits by equipment for use outdoors

Type of equipment	Cutting width L in cm	Permissible sound power level in dB/1 pW	
		Stage I as from 3 January 2002	Stage II as from 3 January 2006
Lawnmowers, lawn trimmers/lawn-edge trimmers	L ≤ 50	96	94*
	50 < L ≤ 70	100	98
	70 < L ≤ 120	100	98*
	L > 120	105	103*

*The figures for stage II are merely indicative. Definitive figures depend on an amendment of the Directive following the report required by Article 20(1). In the absence of any such amendment, the figures for stage I will continue to apply for stage II. Source: Directive 2000/14/EC

Hexavalent chromium may be used as plating on fasteners that hold mufflers in place on machinery. Requiring the substitution of hexavalent chromium might reduce the durability of mufflers, potentially causing an increase in noise emissions, but no conclusive documentation was found or received on this issue. It is thus assumed that the presence of the hazardous substances considered in RoHS II does not have any influence on the noise levels of the devices. The inclusion of combustion-engine powered garden equipment within the scope of RoHS II should therefore have no impact on the noise emissions of these products.

1.3.2.6 *International environmental impacts*

Given the stakeholder feedback on the waste management options of end-of-life products, there does not seem to be significant treatment (recycling or landfilling) of combustion-engine powered garden equipment outside the EU-27. Regional and national recycling markets exist and second-

[45] Anna Kua, Prof. Oladele Ogunseitanb, Prof. Jean-Daniel Saphoresc. Lead-Free Solders: Issues of Toxicity, Availability and Impacts of Extraction:
http://trs-new.jpl.nasa.gov/dspace/bitstream/2014/6388/1/03-0222.pdf
[46] EPA (2005), Solders in electronics: a life-cycle assessment. Available at:
http://www.epa.gov/dfe/pubs/solder/lca/lfs-lca-final.pdf

hand markets mostly concern Eastern European countries. As a consequence, international environmental impacts are expected to be negligible.

However, concerning the production phase, most electronics components are manufactured outside the EU-27 (e.g. in China) so that the ban of the hazardous substances might have positive effects in extra-EU countries involved in component manufacturing. The overall effect is expected to be relatively low, given the limited amount of electronics in garden equipment, but it nonetheless contributes to an improvement of the supply chain in general.

1.3.2.7 Overview of environmental impacts until 2029

Based on the above, some positive environmental impacts can be expected from combustion-engine powered garden equipment falling in the scope of RoHS II, in particular during the end-of-life phase, where less hazardous substances would be released to the environment.

Table 11: Estimated environmental impacts

Estimated environmental impacts until 2029[47]		
	2012	**2029**
Energy use	=	=
Air emissions	=	=
Renewable or non-renewable resources	=	=
Waste production / generation / recycling	=	+
Noise emissions	=	=
International environmental impacts	=	=/+

1.3.3 Economic impacts

The market of combustion-engine powered garden equipment is being described by stakeholders as a mature market.

1.3.3.1 Functioning of the internal market and competition

RoHS II should affect all manufacturers of combustion-engine powered garden equipment in the EU equally, which means that no competitive pressures within the European Union should be expected. Provided there is a common interpretation between Member States on the spark ignition question and suitable market surveillance, no distortion of the internal market is expected.

[47] RoHS II coming into force for this product group (2019), plus one product lifetime (10 years)

1.3.3.2 Competitiveness

In theory, the implementation of RoHS II for combustion-engine powered garden equipment should have no impact on the competitiveness of EU companies on the EU market, as all products sold are subject to the same regulations. Still, according to stakeholders the combustion-engine powered garden equipment is a competitive market with many products from China and Taiwan not being compliant with European laws and safety standards. Non RoHS-compliant manufacturers (inside or outside the EU) could therefore benefit from an implementation of RoHS II, in case that market surveillance is not properly implemented.

Another possible negative impact for RoHS-compliant manufacturers is that a replacement of lead-containing solder by lead-free solder may be a trade-off regarding durability and reliability of the products according to stakeholders. As discussed above, combustion engines are subject to heavier constraints (vibrations, temperature) than electric motors, and lead-free solder might not provide the same durability. A study conducted by ERA[48] confirms that lead-free solders have been shown to be less reliable than tin-lead solders at high acceleration forces in the direction perpendicular to printed circuit boards. At the time, research and comparison regarding the thermal stress was not conclusive, and no complementary information has been found or provided by manufacturers on this issue, which remains uncertain. According to stakeholders, substituting hexavalent chromium with other identified and available corrosion protection methods e.g. trivalent chromium may also reduce the durability and reliability of the product, due to premature corrosion. Again, no conclusive documentation has been found or received on this and the issue will therefore be disregarded in this assessment.

Market estimations provided by manufacturers highlight that there is substantial trade of combustion-engine powered garden equipment with extra-EU countries. As stated before, EU manufacturers dominate the world market of handheld products (e.g. chainsaws, hedge trimmers) with approximately 75% of the global market share, while the US industry accounts for 70% of the global market share for non hand-held products. Therefore, the implementation of RoHS II in the EU-27 is very likely to have impacts on manufacturers outside the EU as well, given their share on the EU-27 market. Outside the EU-27, the more expensive RoHS compliant products are likely to be less competitive and manufacturers would probably need two versions of the products and loose economies of scale. Again, this effect should not be limited to EU manufacturers but extra-EU manufacturers not exporting to the EU market may benefit from a competitive advantage.

Finally, there could be a small market distortion towards electric garden equipment if additional costs due to RoHS II implementation are reflected in purchase prices of combustion-engine powered garden equipment. This effect should be very limited because electric products are also RoHS compliant (implying the same additional costs), and electric and combustion powered equipment differ substantially by their intended uses.

[48] ERA (2008), Review of Directive 2002/95/EC (RoHS) Categories 8 and 9 –Final Report, for DG ENV.

1.3.3.3 Costs and administrative burdens

It is very difficult to estimate additional costs due to RoHS II implementation. Important discrepancies have been found between estimations from manufacturers. One manufacturer mentions the following costs, for each manufacturer:

- One-off compliance costs: 200-250 k€
- One-off technical costs: 150 k€ for tooling, 100 k€ for testing
- Future yearly costs: 120 k€ for one additional employee

Another provides estimations 20% higher, while a third one states that the one-off technical costs would represent almost €1.5 million.

According to the 2008 Impact Assessment accompanying the Commission's recast proposal[49], there is little experience of actual compliance costs for industry. For products currently included in RoHS, estimates are it would vary from 1-4% of turnover. Other surveys give an average overall cost related to RoHS of 1.9% of turnover (past cost and one-off future costs). Assuming an average price of 500 € for a typical product and 8 million annual sales, the annual turnover of the whole sector is 4 billion €. Applying the 1-4% range, compliance costs would represent between 40 million € and 160 million € for all manufacturers. The estimations from manufacturers seem lower than the overall estimate, which may be due to the fact that most of them are already familiar with RoHS and have already included RoHS compliant components where possible.

Technical costs could arise due to additional research to come up with new compliant components and to the fact that changed components would have to undergo extensive field testing before being implemented in products, in order to minimise the risk of a decrease in durability. Such costs could be reasonably supported by large manufacturers, but could be more problematic for SMEs of the sector. Furthermore, the situation may be different between manufacturers: some of them already voluntarily changed all RoHS non-compliant components where possible in order to simplify the production processes and the supply chain.

The replacement of lead-solder by lead-free solder would also result in additional costs due to raw material requirements. With a quantity of lead in solders of 0.74 g per product, and annual sales representing 8 million products, lead solder constitutes 10.08 tonnes of tin and 5.92 tonnes of lead per year. Assuming that 50% of the lead solder is replaced by tin/silver/copper solder, and 50% is replaced by tin/copper solder, 5.68 additional tonnes of tin and 0.24 tonnes of silver would be required to replace the lead. Additional costs would therefore amount to approximately 244 k€ annually for all manufacturers of this type of garden equipment[50].

Stakeholders indicate that suppliers of ignition modules have little experience with lead-free solders, partly because the automotive industry, which is the other most important application of

[49] European Commission (2008), SEC(2008) 2930. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=SEC:2008:2930:FIN:EN:PDF

[50] Under the following assumptions: composition of tin/lead solder is 63%/37%; composition of tin/silver/copper solder is 97%/3%/0% (copper is neglected); composition of tin/copper solder is 99.3%/0.7%; prices of metals (LME): 1590€/tonne for lead, 16210 €/tonne for tin; 674000 €/tonne for silver; price of copper neglected; 1 g of tin/lead solder is assumed to be replaced by 1 g of tin/silver/copper solder or 1 g of tin/copper solder.

small combustion engines, is not concerned by these issues. Therefore, a ban of lead solder in combustion-engine powered garden equipment may result in important additional costs for them (e.g. separate production lines), if requirements between the two sectors are not the same.

1.3.3.4 Innovation and research

Research and development is relatively important in this industrial sector given the energy and emission stakes of combustion-engine powered garden equipment. To simplify the procedures along the supply chain, some manufacturers mention that they have already substituted the RoHS substances, where possible, in their products (even if until now not under the scope of RoHS). However, components produced for electrically driven machines that are RoHS compliant may not be used for combustion-engine driven equipment. The entire chain of combustion-engine driven equipment will have to be re-assessed and made RoHS compliant. The combustion engines industry should be the sector primarily concerned and involved in R&D in order to make the electric and electronic features of the motors RoHS compliant, but for the many companies not producing electrical products, a full inventory and research must be done (in-house as well as external). Furthermore, research concerning lead-free solder is not restricted to the garden equipment and combustion engine industry, but concerns the whole EEE sector: joining forces would certainly boost research for this technical stake.

1.3.3.5 Consumers and households

There is no average retail price for combustion-engine powered garden equipment as such, as prices vary from 20 € to 55 000 € and above. This wide range is due to the variety of products, models and sizes, and no realistic average can be calculated. It is difficult to predict the possible increase effect that RoHS II implementation would have on the final purchase prices. Given the estimated additional costs and administrative burdens (see section 1.3.3.3), even if they are fully supported by the purchaser in the end, the negative effect is estimated to be limited.

1.3.3.6 Overview of economic impacts until 2029

Based on the above, economic impacts from combustion-engine powered garden equipment falling in scope of RoHS II are expected to be limited. Potentially, there could be some distortion in the internal market while innovation and research could increase in order to find new substitutes.

Table 12: Estimated economic impacts

Estimated economic impacts until 2029		
	2012	**2029**
Functioning of the internal market and competition	=	=
Competitiveness	=	-
Costs and administrative burdens	=/-	-
Innovation and research	=	+
Consumers and households	=	=/-

1.3.4 Social impacts

1.3.4.1 Jobs

Statistics regarding jobs directly and indirectly linked to the combustion-engine powered garden equipment industry are sparse. Manufacturers' estimates indicate 200 000 jobs (direct and indirect) for the whole non-road mobile machinery sector, and 60 000 jobs (direct and indirect) in the small spark ignition engine sector. Given the fact that there are not many professional appliances exclusively available to professionals, these overall job estimates are almost all related to products within the scope of this assessment (i.e. domestic and dual use equipment).On the one hand, the impacts of RoHS II on the jobs in the industrial sector could be detrimental because of the possible phase-out of some products with electric functions for which no substitutes can be found. On the other hand, the needs from customers for combustion-engine powered garden equipment is not expected to change in the future so that the demand for these products is expected to remain constant, even if some functions are lost. Furthermore, the development of R&D to find substitutes could stimulate job creation.

1.3.4.2 Health

The overall impacts of hazardous substances on health are difficult to quantify. It needs to be differentiated between possible impacts during the production phase, on users during the actual product's lifetime and at the end-of-life.

First, exposure to these substances during the production phase may represent a risk for the facility workers, who are a population group at greatest risk of exposure to lead, especially through air. This risk is very much dependent upon the type of exposure (time, frequency, pathway, etc.). It can be expected that generally EU manufacturers already respect the related legislation and implement the necessary precaution to ensure their workers' well-being. The production of most of the electronics containing lead solder takes place outside the EU-27 thanks to lower labour costs. Manufacturers mention that workers should have no contact with the solder in normal operation. However, a ban of the six hazardous substances under RoHS in combustion-engine powered garden equipment would certainly reduce the health impacts in case of accidental situations. This phenomenon is also dependent on possible developments in the other industrial sectors, because of the complex structure of supply chains. The importance of these health effects also depends on the potential effects of the substitutes to the six banned substances, if any. Therefore, a quantification of these impacts could not be made.

Impacts on the health of users are also difficult to quantify. In normal operation, the products represent a very low risk to the user's health, as this is taken into account in the design phase. Like in the production chain, people can be affected by accidents/maloperation though but no conclusive information could be found on this issue. According to stakeholders, no direct contact with these components is possible: the ignition module is sealed with epoxy resin in order to protect it from water, oil, fuel, broad temperature range, and high vibrations and to ensure a suitable dielectric strength. RoHS II might have an influence on reliability in terms of functioning of electric safety features so that slight negative health effect could occur for the user in case of higher risk of accident. However, no conclusive documentation has been found on this issue. The health risks to the user are thus assumed to be negligible.

Finally, the end-of-life management of the equipment can result in important impacts to the environment and health. These impacts are dependent upon the management options followed by products, which have already been presented (see section 1.3.2.4). Based on the same assumptions regarding the emissions to air and water of the substances during recycling, incineration and disposal (see Table 8), health impacts can be quantified via the human toxicity indicators[51]: assuming the ban of RoHS hazardous substances in combustion-engine powered garden equipment from 2019 (Option 2), a human toxicity impact of 2.01E-04 CTUh (cancer effects) and 7.88E-03 CTUh (non-cancer effects) would be avoided in 2029 (0.000001% and 0.000002% respectively of the overall impacts in the EU-27 annually), compared to Option 1, due to the removal of lead in solder and chromium VI in coatings.

Table 13: Human toxicity indicators

Year[52]	Human toxicity midpoint, cancer effects (CTUh[53])	Human toxicity midpoint, non-cancer effects (CTUh)
2029	2.01E-04	7.88E-03

A major concern of lead solders is the harm to health caused by unsuitable and dangerous recycling practices that are used in some developing countries. Despite legislation aimed at preventing illegal WEEE exports, some European WEEE is shipped to developing countries for recycling. According to stakeholders, garden machinery is not expected to be much exported as WEEE for recycling.

The monetised cost has been calculated by Defra (UK)[54] which looked at the costs in terms of health impacts of options for management of waste containing hazardous substances including lead. The study estimated health impacts from mathematical models of landfill and incineration and estimates of pollution from these disposal options. Applying these results to the heavy metal

[51] USEtox™ method.
[52] RoHS II coming into force for this product group (2019), plus one product lifetime (10 years)
[53] Comparative Toxicity Unit human, equivalent to cases
[54] Enviros Consulting Ltd. For Defra, *Valuation of the external costs and benefits to health and environment of waste management options*, December 2004, table 3.2 and page 82)

emissions per end-of-life treatment options (see Table 8), gives a monetised health benefit from not using lead of between €87,000 and €2,072,000[55].

1.3.4.3 Social impacts in third countries

Given the stakeholder feedback on the waste management options of end-of-life products, there does not seem to be significant treatment (recycling or landfilling) of combustion-engine powered garden equipment outside the EU-27. A minor share may, however, be exported for recycling, sometimes illegally by shipping it to developing countries where unsafe processes are used. The overall effect is expected to be relatively limited though, as low quantities are estimated to be exported.

1.3.4.4 Overview of social impacts until 2029

The social impacts of combustion-engine powered garden equipment falling in the scope of RoHS II can be expected to be slightly positive given the health benefits, especially during the end-of-life phase of the products.

Table 14: Estimated social impacts

Estimated social impacts until 2029		
	2012	**2029**
Employment	=	=
Health	=	+
Social impacts in third countries	=	=

1.3.5 Comparison of options

The inclusion of combustion-engine powered garden equipment in the scope of RoHS II is expected to result in relatively limited impacts, both positive and negative. Due to the decrease of the use of the banned substances, environmental and health benefits are expected all along the lifecycle of the products, especially at the end-of-life. Please note that the current assessment assumes that lead in solder and chromium VI are nowadays the only hazardous substances left in the products that would be affected by the scope change. While this was the case for the participating stakeholders, it may not be true for all manufacturers so that the quantitative impacts calculated may be underestimated (high uncertainty figures). Another important point is the current lack of technical documentation of the use of lead solder versus lead-free solder in small combustion engines. Further research may be needed in view of possible specific exemptions for lead and hexavalent chromium in case important technical limitations were proven.

[55] Based on a monetised impact of lead between €1.46 million/tonne and €35 million/tonne, and assuming a 1% leakage rate of lead at the end-of-life.

Table 15: Comparison of options

Impact indicators	Option 1 : Combustion-engine powered garden equipment excluded in COM recast proposal	Option 2: Combustion-engine powered garden equipment in scope of RoHS II
Environmental impact indicators		
Energy use	=	=
Air quality	=	=
Renewable or non-renewable resources	=	=
Waste production / generation / recycling	=	+
Noise emissions	=	=
International environmental impacts	=	=/+
Economic impact indicators		
Functioning of the internal market and competition	=	=
Competitiveness	=	-
Costs and administrative burdens	=	-
Innovation and research	=	+
Consumers and households	=	=/-
Social impact indicators		
Employment	=	=
Health	=	+
Social impacts in third countries	=	=

In relation to the overall policy objective of RoHS II, namely to contribute 'to the protection of human health and the environment, including the environmentally sound recovery and disposal of waste EEE'[56], the discussion above shows that including combustion-engine powered garden equipment in RoHS II does contribute to this objective, even if slightly. The issues of a potential loss in durability and reliability of products because of the substitution of lead solder and hexavalent

[56] 2011/65/EU, Article 1

chromium that some stakeholders argue is important are not well documented and could not be taken into account in the calculations of this assessment.

Table 16: Policy objectives and options

Policy options in relation to overall policy objectives			
	Effectiveness	**Efficiency**	**Coherence**
Option 1: Combustion-engine powered garden equipment excluded in COM recast proposal	Slightly negative: Hinders the objectives	Efficiency cannot be evaluated as the option does not contribute to the overall objectives	No unintended impacts
Option 2: Combustion-engine powered garden equipment in scope of RoHS II	Slightly positive: Does contribute to the effectiveness of the Directive	Limited: None of the positive impacts are significant	Unintended impacts are limited

Annex

Table 17: PRODCOM codes for non-electric garden/outdoor/etc. equipment

PRODCOM Code	Product category
28241260	Chainsaws with a self-contained non-electric motor
28241280	Handtools, hydraulic or with a self-contained non-electric motor (excluding chainsaws)
28303210	Scarifiers and cultivators
28303250	Rotovators
28304030	Mowers for lawns, parks or sports grounds, powered non-electrically, with the cutting device rotating in a horizontal plane
28304050	Motor mowers for lawns, parks or sports grounds, powered non-electrically, with the cutting device rotating in a vertical plane or with cutter bars
28305130	Motor mowers (excluding for lawns, parks, golf courses or sports grounds)
28305153	Mowers designed to be hauled or carried by a tractor, with cutting device rotating in a horizontal plane (excluding those with a motor, for lawns, parks, golf courses or sports grounds)
28305155	Mowers designed to be carried or hauled by a tractor (excluding those with a motor, for lawns, parks, golf courses/sports grounds, with cutting device rotating in a horizontal plane)
28305170	Mowers (excluding those with motors, for lawns, parks, golf courses or sports grounds, those designed to be hauled or carried by a tractor)

Table 18: Quantities of RoHS substances released to the environment in 2029 without RoHS II implementation, due to end-of-life management options

Substance	Released to	Quantity (in kg)
Cadmium	Air	0
Chromium VI		0.0000128
Lead		0.04736
Mercury		0
Cadmium	Water	0
Chromium VI		0.0167552
Lead		61.99424
Mercury		0

Table 19: Characterisation factor of the RoHS substances (USEtox™ method)

Substance	Type of emissions	Human toxicity midpoint, cancer effects (in CTUh/kg)	Human toxicity midpoint, non-cancer effects (in CTUh/kg)	Ecotoxicity freshwater midpoint (in CTUe/kg)
Lead	Emissions to air, unspecified	2.69E-05	9.44E-03	1.75E+02
	Emissions to water, unspecified	3.42E-07	1.20E-04	3.75E+02
Mercury	Emissions to air, unspecified	7.06E-03	8.35E-01	1.22E+04
	Emissions to water, unspecified	1.20E-04	1.42E-02	2.21E+04
Chromium VI	Emissions to air, unspecified	4.45E-03	4.16E-04	4.20E+04
	Emissions to water, unspecified	1.06E-02	2.40E-05	1.05E+05
Cadmium	Emissions to air, unspecified	2.17E-04	4.55E-02	3.94E+03
	Emissions to water, unspecified	1.59E-06	4.27E-04	9.71E+03

Table 20: Impact assessment results (USEtox™ method)

Impact indicator (unit)	Avoided impacts in 2029 in EU-27, with RoHS II implementation (in impact indicator unit)	Avoided impacts in 2029 in EU-27, with RoHS II implementation (in % of annual EU-27 impacts)	USEtox™ normalisation factors (in impact indicator unit per person per year)
Human toxicity midpoint, cancer effects (in CTUh)	2.01E-04	0.000001%	3.25E-05
Human toxicity midpoint, non-cancer effects (in CTUh)	7.88E-03	0.000002%	8.14E-04
Ecotoxicity freshwater midpoint (in CTUe)	2.50E+04	0.000000002%	3.18E+06

An EU-27 population estimate of 502m inhabitants in 2011 is used for the normalisation (source: Eurostat, in March 2012).

AC systems

1.1 Key issues

Complex AC systems not in scope of RoHS I or the COM recast proposal now fall within the scope of RoHS II. In this factsheet it will be explored what the impact of this change is and whether the benefits of the inclusion in RoHS II outweigh the potential costs.

Chiller; source: www.acairsystems.co.uk

1.2 Background

Complex air conditioners not in scope of RoHS I or the COM proposal but in scope of RoHS II are the following:

- Air handling units (AHUs): Designed to condition and circulate air and to perform the following primary functions: air supply, air exhaust, filtration, heat recovery. Additional functions comprising heating, cooling, circulation, (de)humidifying, and mixing may be integrated as well. An air handling unit is part of the heating, ventilating, and air-conditioning (HVAC) system. In 95% of cases an air handling unit is combined with heating and/or cooling functions.[1]
- Chillers: A device that withdraws heat from a liquid by compression or absorption. Once circulated through a heat exchanger this can be used to cool air or equipment.
- Condensing units: In air conditioning systems, a condensing unit is a device that usually condenses water from air by cooling it.
- Rooftop units (RTUs): Air handling units that usually include a gas-fired or electric air heater, a cooling coil and other functional equipment like fans, economizers and filters. They are especially designed for outdoor use, mainly on rooftops.[2]
- Variable refrigerant flow systems (VRFs): A special type of a multi-split system including one or more external unit(s) connected by refrigerant pipes with several indoor units that can operate independently in a cooling or heating mode.[2]

[1] European Commission DG ENTR Lot 6 Ventilation (Task 1), accessed at http://www.ecohvac.eu/downloads/Task%201%20Lot%206%20Ventilation%20Draft%202May%202011.pdf

[2] European Commission DG ENER Lot 21 Preparatory Study (Task 4), accessed at http://www.ecoheater.org/lot21/open_docs/BIO_EuP_Lot21_draft_Task4_v2.pdf

1.2.1 Legal background

Air conditioning equipment was included in scope of RoHS I as long as they would either qualify as large household appliances (Category 1) or small household appliances (Category 2) and this situation would not have changed under the COM recast proposal. Due to the enlarged scope of RoHS II, systems that are larger, more complex, and not made for residential applications will now fall in Category 11 of this Directive unless excluded as a large-scale fixed installation.

AC systems could be excluded from the scope of RoHS II through the 'large-scale fixed installation' exclusion of Article 2.4(e). No officially agreed definition of the term 'large-scale' exists at the time of writing of this report and it remains unclear what percentage of systems could be excluded as such. The final draft of the RoHS 2 FAQ document of 15 May 2012 states as an example of a large-scale fixed installation: "Larger fixed installed cooling, air conditioning and refrigerating systems of more than 12 kW nominal cooling capacity [...] insofar as they are not for domestic use." At the point of writing of this report, it remains unclear whether the above means that those systems of more than 12 kW nominal cooling capacity are automatically large-scale or can be large-scale, i.e. whether all such systems over 12kW are excluded as large-scale or not. This interpretation seems unlikely because systems of over1 MW are installed and these are much more likely to be regarded as 'large-scale'.

For this assessment it is assumed that all complex air conditioners not in scope of RoHS I and the COM recast proposal will be in scope of RoHS II unless they are 'large-scale' according to the ISO 20 foot container criterion outlined in previous draft versions of the RoHS II FAQ document: "If, when de-installing the tool, the tool is too large to be removed in ISO 20 foot containers because the individual machines, equipment and/or components are larger than 6,10 m x 2,44 m x 2,59 m, then the equipment can be considered large scale." Based on these parameters industry provided data for this assessment and this could not be updated following the final draft of the FAQ document and the open definition issues this has not been able to clarify. **It should be noted that the impact calculated below is likely to be higher than it will turn out in practice as according to the current FAQ document, many more air conditioners might be excluded from the scope of RoHS II than assumed for this analysis.**

1.2.2 Quantities and hazardous substances

Table 1 shows 2008 sales figures in units and 2010 stock figures for the types of AC systems assessed as part of this work.

Table 1: Information on sales and stock[3]

Type of system	Sales 2008 in units In thousand	Stock in 2010 EU-27 In thousand
Chillers for air conditioning	85	1,325
Chillers for refrigeration	32	405
Air handling units for air conditioning and fan coil units	13,240	n/a
Air handling units in ventilation	18	1,751
Rooftops	9	200
VRFs	20	634
Condensing units	600	5,243

Based on the above, the annual sales of AC systems assessed in this factsheet amounts to 14 million units.

According to the results of the stakeholder consultation, all six RoHS substances are potentially used in this type of AC system equipment: However, no information was received on exact uses or quantities. The most likely and important uses are:

- **Lead** solders are still likely to be used in at least the larger systems. These will have complex PCBs so the quantity per system is likely to be at least 20 grams and could be over 100 grams for the most complex. For this assessment, 50 grams per system are assumed as an average.
- **Hexavalent chromium** is estimated to be commonly used in this type of equipment, mostly for corrosion and surface treatment. The amounts used will vary depending on the exact application but are likely to range between 20 mg and 200 mg. For this assessment an average of 80 mg will be assumed.
- **Cadmium** might be used in brazing alloys and plastics but these uses are already banned by REACH and the implementation of RoHS II should therefore have no additional impact. It could also be used in unusual solders but this is unlikely.
- The use of **mercury** is unlikely as most components containing mercury are no longer widely available. In the absence of further information it will be disregarded in this assessment. The occurrence of flame retardants **PBB and PBDE** is possible but rather uncommon nowadays due to the effects of RoHS.

Table 2 lists the presence of the different hazardous substances considered by RoHS II as well as quantity estimations.

[3] First stakeholder consultation, January 2012; ENTR Lot 6 and ENTR Lot 1. Figures are irrespective of whether imported, manufactured in EU-27 or assembled within EU-27 from imported components.

Table 2: RoHS substances in AC systems affected by scope changes

Substance	Presence in AC systems
Lead	Yes, estimation of 50 grams per system
Mercury	Unlikely
Cadmium	Potentially in brazing alloys and plastics – banned by REACH
Hexavalent Chromium	Yes, estimation of 80 mg per system
Polybrominated biphenyls (PBB)	Unlikely
Polybrominated diphenyl ethers (PBDE)	Unlikely

Source: Own estimations

The situation regarding RoHS substances is likely to vary between the different manufacturers on the market. While some offer RoHS compliant designs already today, partly because other equipment they produce presently falls in scope of RoHS I, others do not. It has, however, not been possible to gather information on the percentage of the market that is already RoHS compliant.

1.2.3 Policy objectives and options

The objective of both, the RoHS recast proposal (COM (2008) 809 final) as well as RoHS II (2011/65/EU) is to contribute 'to the protection of human health and the environment, including the environmentally sound recovery and disposal of waste EEE'[4].

The purpose of this work is to look at the impacts of the inclusion of AC systems not already in scope of RoHS I or the COM proposal in scope of RoHS II. Policy options will then be evaluated according to their effectiveness, efficiency and coherence in reaching the above-mentioned overall objective of the RoHS Directive. The policy options analysed are the following:

OPTION 1 (baseline scenario): The COM recast proposal. AC systems not already in scope of RoHS I are also not in scope of the proposed recast Directive.

OPTION 2: RoHS II. AC systems not in scope of ROHS I are now included in scope of RoHS II unless excluded as large-scale fixed installation according to the ISO 20 foot container size criterion.

[4] 2011/65/EU, Article 1

1.3 Impacts of policy options

1.3.1 Impact indicators

The following impact indicators have been chosen as relevant for this product group (see Table 3).

Table 3: Impact indicators for the product group AC systems

Impact indicators		
Environmental	Economic	Social
Energy use	Functioning of the internal market and competition	Employment
Waste production / generation / recycling	Competitiveness	Health
International environmental impacts	Costs and administrative burdens	Social impacts in third countries
	Innovation and research	
	Consumers and households	

The following legend will be used in summarising the impacts:

Legend	
+++	Very beneficial effect
++	Substantial beneficial effect
+	Slight beneficial effect
=	No effect
-	Negative effect
--	Substantial negative effect
---	Very negative effect
?	Unknown effect

1.3.2 Environmental impacts

The most important stakes regarding the environmental impacts in the context of RoHS are related to the quantities of hazardous substances used in the equipment. The mere quantity of a substance is however not sufficient to estimate what will be the actual impacts of the substance on the environment and health. These depend upon numerous factors such as the effective treatment of products at the end-of-life, their design for the use phase or their potential emissions during the production phase. The impact of the substances released to the environment is also determined by case-specific and complex dose-response relationships.

It is therefore not straightforward to predict environmental impacts due to hazardous substances found in products. Where possible, the following subsections will make the link between the quantities of hazardous substances and their potential environmental impacts.

1.3.2.1 Energy use

Given the definition of this product group, all products are expected to consume energy during their operation. It can be assumed, however, that the presence of the hazardous substances considered in RoHS II does not have any direct influence on the energy use and efficiency of the devices.

The European Commission impact assessment accompanying the RoHS recast proposal[5] states that the substitution of lead solder by lead-free solder might lead to an increase in energy consumption during the production phase because of a higher melting point. The additional energy consumption will vary widely depending on the solder type, the equipment specifications and process operating parameters employed by the facility. Nevertheless, it is generally accepted that lead-free soldering requires approximately 15% more energy than tin/lead (SnPb) soldering when comparing equivalent soldering technology for the two types of alloy and the following calculations will be based on this assumption. The most common lead-free solders are either tin/copper (SnCu) or tin/silver/copper (SnAgCu) alloys. Both have higher melting points and SnAgCu has a significantly higher cost due to its silver content. The most likely replacement solder in AC systems will be tin/silver/copper as it is easier to use and ensures higher reliability. Nevertheless, it is assumed that 30% of all lead solder is replaced by tin/copper solder due to its lower costs. Based on a typical solder reflow oven to make the PCBs on which lead is found in this type of AC system, the total additional energy required for lead-free solders represents 98.7 MWh per year[6]. Compared to a total EU final energy consumption of 13.6 million PWh[7], this impact of additional energy required is regarded as negligible on this environmental impact indicator. The additional energy consumption translates into an extra cost of 9 187 €[8], which is negligible compared to other technical costs (see section 1.3.3.3). Additional CO_2 emissions due to the change from tin/lead solder to lead-free solder represent 38.5 tonnes CO_2 eq[9]. In relation to the overall CO_2 emissions of 4 088.8 million tonnes of the EU-27 in 2008[10], this increase would also be considered negligible.

Consequently, even if lead-free solder would require more energy during the production phase, this effect is expected to be low over a life cycle given the high energy use during the use phase of the

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[5] European Commission (2008), SEC(2008) 2930. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=SEC:2008:2930:FIN:EN:PDF

[6] A typical solder reflow oven operates 16 hours per day, 5 days a week, 49 weeks per year and on average consumes 13.9 kWh for SnPb and 16kWh for lead-free. It is assumed that one oven can produce 300 PCBs per hour or 1 million per year (25 PCBs made in a panel every 5 minutes) as these PCBs are small. The total number of units to be made is approximately 14 million.

[7] 1168.63 Mtoe, European Commission, *EU transport in figures, statistical pocketbook 2011*, accessed at http://ec.europa.eu/transport/publications/statistics/doc/2011/pocketbook2011.pdf

[8] Average EU industrial electricity price = 0.093 €/kWh in 2011 according to Eurostat.

[9] Based on 0.39 $kgCO_2$ eq/kWh from Eurelectric

[10] 4 186.7 million tonnes. European Commission, *EU transport in figures, statistical pocketbook 2011*, accessed at http://ec.europa.eu/transport/publications/statistics/doc/2011/pocketbook2011.pdf

device. Thus, the inclusion of this type of AC systems within the scope of RoHS II should have no significant impact on this environmental indicator.

1.3.2.2 Waste production / generation / recycling

The lifetime of the type of AC systems assessed here will vary depending on the type of device considered, its application and its context of use. Table 4 presents average figures for the different types of equipment. Based on this information, an **average lifetime of 17 years is assumed for this assessment.**

Table 4: Average lifetime per type of equipment[11]

Type of system	Average lifetime in years
Small and medium capacity chillers	15
Large capacity chillers	20-30
Air handling units	17
Rooftops	15
VRFs	15
Condensing units	8

In terms of end-of-life management, this type of equipment is installed and de-installed by professionals and recycling rates should be high. In line with the results of the Lot 21 preparatory study for DG ENER[12], it is assumed that 83% of all equipment is recycled, 12% incinerated and 5% landfilled. Depending on the quality of the end-of-life operations, a certain share of the substances, called the leaching potential, is always lost to the environment. According to BIO (2008)[13], process control of landfills and incinerators, alongside mineralization mechanisms in landfills, are some of the options to reduce this share. But there is limited quantitative data about the fate of hazardous substances going through land filling or incineration processes, in particular their leaching potential.

Policy Option 2 (including this type of equipment in the scope of RoHS II) would progressively (over a 10 year period, between 2019 and 2029[14]) decrease the quantities of hazardous substances from these types of air conditioning equipment found in the waste streams, compared to the baseline scenario. The reduction of these substances may have a beneficial effect on their end-of-life treatment. This effect is dependent on the development of the waste management sector as a whole. On the other hand, a replacement of lead-containing solder by lead-free solder is often seen as a trade-off regarding durability and reliability of the products and hence reduce the product's lifetime. This is, however, not well documented and will therefore be neglected in the following analysis. Similarly, substituting hexavalent chromium with other available corrosion protection methods e.g. trivalent chromium may reduce the lifespan, durability and reliability of the entire

[11] Adapted from: http://www.environment.gov.au/atmosphere/airquality/publications/pubs/outdoor-garden-equipment.pdf
[12] European Commission DG ENER Lot 21 Preparatory Study (Task 4), accessed at http://www.ecoheater.org/lot21/open_docs/BIO_EuP_Lot21_draft_Task4_v2.pdf
[13] BIO (2008), Study to support the impact assessment of the RoHS review – Final Report, for DG ENV.
[14] Possibly earlier if manufacturers take early measures.

product due to premature corrosion. Again, no documentation has been found or received on this and the issue will therefore be disregarded in this assessment.

Table 5 shows the estimations used to calculate the environmental impacts of RoHS hazardous substances released into the environment at the end-of-life. The assessment is likely to contain high uncertainties, because of the assumptions made to model the end-of-life options.

Table 5: Heavy metal emissions, by end-of-life management options

End-of-life process	Share of total end-of-life products (in %)	Emissions to air during end-of-life process	Emissions to water during end-of-life process	Source of the emissions estimates
Recycling	83%	0.001%	0.059%	COWI (2002)[15]
Incineration	12%	0.5%	2.49%	ERM (2006)[16]
Landfill	5%	-	5%[17]	ERM (2006)

By considering the annual sales and RoHS substance quantities presented in section 1.2.2, it is estimated that 700 tonnes of lead and 1.12 tonnes of hexavalent chromium would be sent annually into the end-of-life management circuit from 2036[18] if the product group was not included within the scope of RoHS II. For Option 2, it is assumed that all lead and hexavalent chromium would be removed from the products from 2019, so that none of these substances would go to the waste streams from 2036.

Based on these assumptions, the ecotoxicity freshwater midpoint indicator was calculated[19] in order to illustrate the avoided impacts for the end-of-life, of the inclusion of this type of AC systems within the scope of RoHS II in 2036. This indicator was chosen because the release of RoHS hazardous substances in the environment has an influence on its value (this is not the case for Global Warming Potential for instance).

Table 6: Avoided freshwater ecotoxicity impacts by Option 2, compared to Option 1

Year[20]	Ecotoxicity freshwater midpoint (CTUe[21])
2036	2.37E+06

This result represents 0.000054% of the overall freshwater ecotoxicity annual impact in the EU-27 (USEtox™ normalisation values). Details of the calculations are given in Annex.

In theory, end-of-life impacts also depend on the possible substitutes that would replace the six hazardous substances. A similar quantitative analysis could not be done by considering the impact of the substitution of lead solder by lead-free solder, as the most suitable substitutes are not known yet. Still, some substitutes are likely to leach hazardous substances into the environment too, even

[15] COWI (2002), Heavy Metals in Waste – Final Report, for European Commission DG ENV. Applicable to lead, assumed to be the same for other heavy metals
[16] ERM (2006), Battery Waste Management Life Cycle Assessment – Final Report.
[17] Please note that this estimate may be high because all circuit boards have to be sealed with epoxy resin.
[18] 17 years (the lifetime of the product) after the effective implementation of RoHS II.
[19] According to USEtox™ methodology.
[20] RoHS II coming into force for this product group (2019), plus one product lifetime (17 years)
[21] Comparative Toxicity Unit ecotoxicity, equivalent to PAF.m3.day

if lead is the most toxic alloying element: silver or antimony represent a potential source of toxicity in leachates when used in alloys, while bismuth, indium and copper are regarded as less dangerous[22]. Obviously, the levels of emissions depend on the specific environmental conditions the waste will be exposed to during the end-of-life management. Another source[23] builds a comparative analysis of lead-free solder, by taking into account toxicity, availability and environmental impact of extraction of substitutes to lead in solder alloys. Based on this, only tin and copper appear to have a lower overall impact than lead. These outcomes have to be considered with caution given the subjective assessment grid. Finally, a comparative life cycle assessment[24] also illustrates that depending on the environmental impact considered, either lead solder or one substitute (bismuth-tin-silver or copper-tin) can be best performing and it is not possible to determine which alloy type has the greatest negative impact overall.

1.3.2.3 International environmental impacts

Given the end-of-life considerations in section 1.3.2.2, it is not expected that end-of-life treatment of this type of AC systems occurs outside the EU-27. Either the products will be recovered by professionals and mainly re-used or recycled, or they may be mixed with the demolition waste, in which case they are not likely to be exported.

Concerning the production phase, the electronics components (mainly the PCBs) are probably manufactured outside the EU-27 (e.g. in China) so that the ban of the hazardous substances might have positive effects in extra-EU countries involved in components manufacturing. The overall effect is expected to be relatively low but it nonetheless contributes to an improvement of the supply chain in general.

1.3.2.4 Overview of environmental impacts until 2036

Based on the above, limited positive environmental impacts can be expected from these types of AC systems falling in the scope of RoHS II, in particular during the end-of-life phase.

Table 7: Estimated environmental impacts

Estimated environmental impacts until 2036[25]		
	2012	**2036**
Energy use	=	=
Waste production / generation / recycling	=	+
International environmental impacts	=	=/+

[22] Edwin B. Smith III, Environmental Impacts and Toxicity of Lead Free Solders: http://leadfree.ipc.org/files/RoHS_16.pdf

[23] Anna Kua, Prof. Oladele Ogunseitanb, Prof. Jean-Daniel Saphoresc. Lead-Free Solders: Issues of Toxicity, Availability and Impacts of Extraction: http://trs-new.jpl.nasa.gov/dspace/bitstream/2014/6388/1/03-0222.pdf

[24] EPA (2005), Solders in electronics: a life-cycle assessment. Available here: http://www.epa.gov/dfe/pubs/solder/lca/lfs-lca-final.pdf

[25] RoHS II coming into force for this product group (2019), plus one product lifetime (17 years)

1.3.3 Economic impacts

Table 8 provides an overview of market trends for the types of AC systems assessed as part of this work. What becomes evident is that the trend is highly variable depending on the specific system type. The market for rooftops, for example, is expected to shrink by 63% between 2005 and 2015 while the market for VRFs is predicted to grow by approximately 240% over the same period.

Table 8: Market trends[26]

Type of system	Units sold in 2005/2006	Units expected to be sold in 2020	Units expected to be sold in 2025
Chillers for air conditioning	83000	116000	137000
Chillers for refrigeration	28222	40525	44743
Air handling units	n/a	n/a	n/a
Rooftops	16000	110000	6000
VRFs	63000	179000	216000
Condensing units	632100	502614	458608

The types of AC systems analysed as part of this work are not normally residential applications and tend to be order based. Table 9 presents average retail prices for the different types of equipment ranging from € 4800 for a small air handling unit in ventilation to € 77 000 for large chillers for air conditioning. **For this assessment an average retail price of € 10 000 is assumed reflecting the fact that air handling units is by far the largest of the system categories.**

Table 9: Average retail prices[27]

Type of system	Average retail price in thousand €
Chillers for air conditioning	Air cooled : 49.2 Water cooled : 77.4
Chillers for refrigeration	55-70
Air handling units for air conditioning and fan coil units	n/a
Air handling units in ventilation	4.8-21
Rooftops	12.4
VRFs	32.3
Condensing units	4.9-5.9

[26] First stakeholder consultation, January 2012; ENTR Lot 6 and ENTR Lot 1

[27] First stakeholder consultation, January 2012; ENTR Lot 6 and ENTR Lot 1. Figures are irrespective of whether imported, manufactured in EU-27 or assembled within EU-27 from imported components.

1.3.3.1 Functioning of the internal market and competition

RoHS II should affect all manufacturers of these types of AC systems in the EU equally, which means that no competitive pressures within the European Union should be expected. Provided there is suitable market surveillance, no distortion of the internal market is expected.

1.3.3.2 Competitiveness

No market information on imports and exports was received or found specific to the types of AC systems assessed in this work so there is high uncertainty regarding the effect of RoHS II implementation for this indicator. In theory, the implementation of RoHS II for this type of equipment should have no impact on the competitiveness of EU companies on the EU market, as all products sold are subject to the same regulations. However, non RoHS-compliant manufacturers (inside or outside the EU) selling on the EU market could benefit from an implementation of RoHS II in case that market surveillance is not properly implemented.

The impact on competitiveness can be expected to be limited because of two main reasons: RoHS compliant designs currently exist and those products already falling in scope of RoHS I were successfully made RoHS compliant without major effects on competitiveness. Additional technical costs should therefore either be limited or counterbalanced by other benefits, such as a 'green' visibility for instance. For products for which technical limitations may exist, RoHS implementation may reduce their competitiveness for exportations in countries where such substances requirements are not compulsory, due to additional costs. Depending on the possible substitutes, RoHS II implementation might also result in technical issues, such as a loss of reliability. This effect is however estimated very limited given that it only concerns a limited range of products.

1.3.3.3 Costs and administrative burdens

The inclusion of new products in RoHS II will increase the costs and administrative burdens for those companies that do not yet offer RoHS compliant products as well as for those who do as they will need to provide CE markings for their products.

According to the 2008 Impact Assessment accompanying the Commission's recast proposal[28], there is little experience of actual compliance costs for industry. For products currently included in RoHS estimates are it would vary from 1-4% of turnover. Other surveys give an average overall cost related to RoHS of 1.9% of turnover (past cost and one-off future costs). Assuming an average price of € 10 000 per unit and 14 million annual sales, the annual turnover of the whole sector is € 140 billion. Applying the 1-4% range, compliance costs would represent between € 1.4 billion and € 5.6 billion for all EU manufacturers combined. Given that some manufacturers already offer RoHS compliant products and most already have experience with RoHS compliance, banned substances and their substitutes because other products they manufacture presently fall in scope of RoHS I, this

[28] European Commission (2008), SEC(2008) 2930. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=SEC:2008:2930:FIN:EN:PDF

estimate is likely to be high. On-going demonstration of compliance costs are typically 0.1% of turnover and so would be expected to be €140 million per year[29].

The replacement of lead solder by lead-free solder would also result in additional costs due to raw material requirements. With a quantity of lead in solders of 50 g per system, and annual sales representing 14 million units, lead solder constitutes 358 tonnes of tin and 210 tonnes of lead per year, based on the assumption that none of the products are already RoHS compliant. Assuming that lead solder is replaced by 70% tin/silver/copper and 30% tin/copper solder, 674 additional tonnes of tin, 17 tonnes of silver, and 9 tonnes of copper would be required to replace the lead. Additional costs would therefore amount to approximately € 17.4 million annually for all manufacturers combined[30]. Given that those manufacturers that already offer RoHS compliant products would not be subject to any additional technical costs, this estimate is likely to be high. Nevertheless, as some of the complex AC systems are order-based products, the percentage increase in technical costs might be higher than usual if only a very limited number of components are bought and these do not yet exist in a RoHS compliant design.

Overall, additional costs and administrative burdens for industry due to the inclusion of complex AC systems in RoHS II are expected to be incurred, albeit to a limited extent.

1.3.3.4 Innovation and research

The influence of RoHS II implementation on innovation and research will vary for each manufacturer. It seems that many manufacturers already provide RoHS compliant products so that they have already successfully carried out R&D to substitute RoHS substances. It could be, however, that reliable substitutes are still to be found for some products with specific properties or requirements. Overall, R&D might be slightly boosted but only to a very limited extent. For those manufacturers not selling RoHS compliant designs already, R&D activities could be highly facilitated by the work already carried out by the sector, which shows that no major technical limitation is present.

In any case, the impact on innovation and research is estimated as positive but negligible compared to the business-as-usual activities.

1.3.3.5 Consumers and households

According to stakeholders, prices for products that were already in scope of RoHS I were increased by approximately 3% as a result of technical and administration costs incurred by the industry in order to ensure compliance. Assuming the average product price of € 10 000 discussed above, this would be an increase of € 3000. It could, however, be assumed that the increase would be lower for products now falling in scope of RoHS II as industry has already become familiar with the Directive and substitutes have been identified and become available for most if not all products. Most importantly, the types of AC system discussed in this assessment are not destined for residential applications and should therefore not affect consumers or households directly.

[29] Based on a survey carried out by the Consumer electronics association.

[30] Under the following assumptions: composition of tin/lead solder is 63%/37%; composition of tin/copper solder is 99.3%/0.7%; prices of metals (LME): 1590€/tonne for lead, 16210 €/tonne for tin; price of copper neglected; 1 g of tin/lead solder is assumed to be replaced by 1 g of tin/copper solder.

1.3.3.6 *Overview of economic impacts until 2036*

Based on the above, economic impacts of the types of AC systems assessed here falling in the scope of RoHS II are expected to be limited.

Table 10: Estimated economic impacts

Estimated economic impacts until 2036[31]		
	2012	**2036**
Functioning of the internal market and competition	=	=
Competitiveness	=	=/-
Costs and administrative burdens	=/-	-
Innovation and research	=	=
Consumers and households	=	=

1.3.4 Social impacts

1.3.4.1 *Jobs*

Statistics regarding jobs directly and indirectly linked to the specific types of AC systems assessed in this work have not been found or provided by stakeholders. Given the limited expected impact of RoHS II implementation on competitiveness, costs and R&D, no significant impact on jobs is expected for this industry either.

1.3.4.2 *Health*

The impacts of hazardous substances on health can be differentiated between possible impacts during the production phase, on users during the actual product's lifetime and at the end-of-life.

First, exposure to these substances during the production phase represents a risk for facility workers, who are the population group at greatest risk of exposure to lead, especially through air. This risk is very much dependent upon the type of exposure (time, frequency, pathway, etc.). It is assumed that the production of the electronics containing the lead solder takes predominantly place outside the EU-27. A ban of the use of the six RoHS substances in these types of AC systems would certainly reduce the health impacts during the production phase, in particular in case of accidental situations. During the use phase, the possible RoHS substances in these types of AC systems are estimated to represent a very low risk in normal operation: the product design takes these considerations into account and direct contact is not expected to occur. Finally, the management during the end-of-life can result in important impacts for the environment and health. These impacts are dependent upon the management options followed by products, which have already been presented (see section 1.3.2.2). Based on the same assumptions regarding the

[31] RoHS II coming into force for this product group (2019), plus one product lifetime (17 years)

emissions to air and water of the substances during recycling, incineration and disposal (see Table 5), health impacts can be quantified via the human toxicity indicators[32]: assuming the ban of RoHS hazardous substances in these AC systems from 2019 (Option 2), a human toxicity impact of 8.72E-02 CTUh (cancer effects) and 4.52E+00 CTUh (non-cancer effects) would be avoided in 2039 compared to Option 1. This translates to 0.000534% and 0.0011% of the overall annual impacts in the EU-27 respectively.

Table 11: Human toxicity indicators

Year[33]	Human toxicity midpoint, cancer effects (CTUh[34])	Human toxicity midpoint, non-cancer effects (CTUh)
2039	8.72E-02	4.52E+00

The monetised cost of this impact has been calculated by Defra (UK)[35] which looked at the costs in terms of health impacts of options for management of waste containing hazardous substances including lead. The study estimated health impacts from mathematical models of landfill and incineration and estimates of pollution from these disposal options. Applying these results to the heavy metal emissions per end-of-life treatment options (see Table 5), gives a monetised health benefit from not using lead of between € 6.8 million and € 162 million[36].

1.3.4.3 Social impacts in third countries

A major concern of lead solders is the harm to health caused by unsuitable and dangerous recycling practices that are used in some developing countries. Despite legislation aimed at preventing illegal WEEE exports, some European WEEE is shipped to developing countries for recycling. AC systems, because they are dismantled by professionals and can be part of the construction and demolition waste, are not expected to be exported as WEEE for recycling. Consequently, impacts outside the EU are estimated as negligible.

1.3.4.4 Overview of social impacts until 2036

The social impacts of these AC systems falling in scope of RoHS II can be expected to be slightly positive given the health benefits, especially during the end-of-life phase of the products.

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[32] USEtox™ method.

[33] RoHS II coming into force for this product group (2019), plus one product lifetime (17 years)

[34] Comparative Toxicity Unit human, equivalent to cases

[35] Enviros Consulting Ltd. For Defra, *Valuation of the external costs and benefits to health and environment of waste management options*, December 2004, table 3.2 and page 82)

[36] Based on a monetised impact of lead between €1.46 million/tonne and €35 million/tonne, and assuming a 0.66% leakage rate of lead at the end-of-life.

Table 12: Estimated social impacts

Estimated social impacts until 2036[37]		
	2012	2036
Employment	=	=
Health	=	+
Social impacts in third countries	=	=

1.3.5 Comparison of options

The inclusion of AC systems not already in scope of RoHS I in the scope of RoHS II is expected to result in slightly positive impacts. Due to the decrease in the use of lead and hexavalent chromium environmental and health benefits are expected particularly at the end-of-life. Additional technical and administrative costs are expected to be incurred by industry but these should limited given that many manufacturers already carry out R&D activities and are familiar with the Directive.

Table 13: Comparison of options

Impact indicators	Option 1 : AC systems not already in scope of RoHS I not in scope of COM recast proposal either	Option 2: AC systems not already in scope of RoHS I in scope of RoHS II unless LSFI[38]
Environmental impact indicators		
Energy use	=	=
Waste production / generation / recycling	=	+
International environmental impacts	=	=/+
Economic impact indicators		
Functioning of the internal market and competition	=	=
Competitiveness	=	=/-
Costs and administrative burdens	=	-
Innovation and research	=	=
Consumers and households	=	=
Social impact indicators		
Employment	=	=
Health	=	+
Social impacts in third countries	=	=

[37] RoHS II coming into force for this product group (2019), plus one product lifetime (17 years)
[38] According to ISO 20 foot size criterion

In relation to the overall policy objective of RoHS II, namely to contribute 'to the protection of human health and the environment, including the environmentally sound recovery and disposal of waste EEE'[39], including these types of AC systems in RoHS II does contribute to this objective.

Table 14: Policy objectives and options

Policy options in relation to overall policy objectives			
	Effectiveness	**Efficiency**	**Coherence**
Option 1: AC systems not already in scope of RoHS I not in scope of COM recast proposal	Slightly negative: Hinders the objectives of the Directive	Efficiency cannot be evaluated as the option does not contribute to the overall objectives	No unintended impacts
Option 2: AC systems not already in scope of RoHS I in scope of RoHS II[40]	Slightly positive: Contributes to the effectiveness of the Directive	Efficient in reaching the objectives of the Directive, albeit to a limited extent	Unintended impacts are limited

[39] 2011/65/EU, Article 1

[40] Unless excluded as LSFI according to ISO 20 foot container size criterion

Annex

Table 15: Quantities of RoHS substances released to the environment in 2036 without RoHS II implementation, due to end-of-life management options

Substance	Released to	Quantity (in kg)
Cadmium	Air	0
Chromium VI		0.68
Lead		426
Mercury		0
Cadmium	Water	0
Chromium VI		6.7
Lead		4184
Mercury		0

Table 16: Characterisation factor of the RoHS substances (USEtox™ method)

Substance	Type of emissions	Human toxicity midpoint, cancer effects (in CTUh/kg)	Human toxicity midpoint, non-cancer effects (in CTUh/kg)	Ecotoxicity freshwater midpoint (in CTUe/kg)
Lead	Emissions to air, unspecified	2.69E-05	9.44E-03	1.75E+02
	Emissions to water, unspecified	3.42E-07	1.20E-04	3.75E+02
Mercury	Emissions to air, unspecified	7.06E-03	8.35E-01	1.22E+04
	Emissions to water, unspecified	1.20E-04	1.42E-02	2.21E+04
Chromium VI	Emissions to air, unspecified	4.45E-03	4.16E-04	4.20E+04
	Emissions to water, unspecified	1.06E-02	2.40E-05	1.05E+05
Cadmium	Emissions to air, unspecified	2.17E-04	4.55E-02	3.94E+03
	Emissions to water, unspecified	1.59E-06	4.27E-04	9.71E+03

Table 17: Impact assessment results (USEtox™ method)

Impact indicator (unit)	Avoided impacts in 2036 in EU-27, with RoHS II implementation (in impact indicator unit)	Avoided impacts in 2036 in EU-27, with RoHS II implementation (in % of annual EU-27 impacts)	USEtox™ normalisation factors (in impact indicator unit per person per year)
Human toxicity midpoint, cancer effects (in CTUh)	8.72E-02	0.00053%	3.25E-05
Human toxicity midpoint, non-cancer effects (in CTUh)	4.52E+00	0.0011%	8.14E-04
Ecotoxicity freshwater midpoint (in CTUe)	2.37E+06	0.000054%	3.18E+06

An EU-27 population estimate of 502m inhabitants in 2011 is used for the normalisation (source: Eurostat, in March 2012).

Fuseboxes

1.1 Key issues

Fuseboxes were not in scope of the COM recast proposal but do fall within the scope of RoHS II. In this factsheet it will be explored what the impact of this change is and whether the benefits of the inclusion of fuseboxes in RoHS II outweigh the potential costs.

Please note that for this product group, it has been difficult to establish any productive contact with industry or their representatives. It should be stressed that insufficient data led to the assessment being based on a number of assumptions.

1.2 Background

Fuseboxes (also called consumer units) are part of the electricity installations in buildings. Electrical power is distributed by networks of cables that are connected to the power source. The fusebox is necessary for safety reasons (to ensure protection against accidents/faults) and to protect the power generator. It is placed between the distributed electricity network within a building or installation and the electricity supply source.

Fuseboxes are usually composed of three main components:

- The main switch: it allows the user to turn the electricity supply to the building/flat on or off.
- The Residual Current Device (RCD): is a switch that disconnects a circuit when the current is not balanced between the energized conductor and the return neutral conductor. Thus, the RCD provides protection against current imbalance (earth faults), which may be caused by a person accidentally touching the electric circuit. The disconnection is quick in order to prevent/limit the potential injury due to the electric shock. An RCD in a fusebox can provide protection to individual or groups of circuits. An electric installation is not necessarily linked to one single RCD: this situation is common in the UK and favours 'nuisance' trips, i.e. disconnection of all appliances because of earth leakage which may come from a malfunctioning device (instead of an electric shock). An RCD is characterised by the following main parameters: its rated current (chosen depending on the maximum sustained load current it will carry), its sensitivity (rated residual operating current which will trigger the trip) that can range from 6 mA to 30 A[1], and its break time (instantaneous or with a short time delay). The RCD can normally be tested thanks

[1] 6 mA – 30 mA for direct-contact / life injury protection, 100 – 1000 mA for fire protection, 3 – 30 A for protection of machines.

to a test button. RCD protection is particularly important whilst using mains-powered electrical equipment outdoors, where there is an increased risk of electric shock2. To provide additional protection against electric shock, an RCD must have a rated tripping current of no more than 30 mA.

- The fuses or circuit breakers: they ensure over-current and short-circuit protection for the electric circuits which are designed to carry an expected load: when the demand for current exceeds the rating of the protective device the circuit is disconnected. When a fault or overload current flows through the fuse wire, it will become hot and melt, thus disconnecting the faulty circuit. The fuse then needs to be replaced. In case there is no such protection, over-current results in excessive heat in the wiring which may cause a fire. Fuses can be used in a variety of applications (e.g. integrated in products), and not only in a consumer unit. They differ by their ampere/voltage ratings, the way they are mounted (e.g. on a surface, on a PCB, on a strap), their body (e.g. glass, ceramic, sand filled), their fuse holder (e.g. clip, base, block, in-line holder), their breaking capacity (maximum current that can safely be interrupted) or their speed. Circuit breakers are similar in size to fuses, but give more precise protection. They are more sophisticated than fuses as they monitor the circuit and switch of power if a fault is detected. Furthermore, when they trip, the switch can simply be reset according to different modes (e.g. automatic reset, modified reset, manual reset) while a fuse has to be changed. Today, traditional fuses have been replaced by several designs of circuit breakers (although fuses are still used in some types of commercial electrical equipment) and households often have a series of miniature circuit breakers (MCB) in a distribution board that is still sometimes referred to as a fusebox.

Households tend to have separate circuits for lighting, with one circuit for each floor and for wall power sockets, also with one circuit per floor. One fuse or circuit breaker is used for each circuit and is rated so that sufficient power will pass in normal use but the fuse / circuit breaker should rapidly open and cut off the power should a fault occur.

Devices combining the over-current protection of the fuses/circuit breakers and the leakage detection of the RCD exist. They are called Residual Current Circuit Breaker with Overload protection (RCBO). The circuits ensuring the two functions are usually separated, but the interrupting mechanism is shared. RCDs also exist as separate devices, i.e. not part of the fusebox. For instance, they can be integrated in electrical socket-outlets, on which appliances more likely to represent a potential hazard will be plugged. Alternatively, portable RCDs can plug into any standard socket-outlet and an appliance can then be plugged into the RCD [2]. This level of protection only protects the circuit within the appliance.

As part of the electric installation, the adequate operation of fuseboxes depends on the design of the whole electric distribution system. In particular, wire size and fuse/circuit breaker must be properly co-ordinated. For instance, if circuit breakers trip frequently with no specific reason, it indicates that the circuit capacity is inadequate for the load and it should be re-wired with a cable of a larger conductor cross-sectional area. This phenomenon may be due to the changing use of the

[2] http://www.esc.org.uk/public/home-electrics/rcds-explained/

electric installation (e.g. new/more appliances). Similarly, increasing the rating of the protective device is sometimes permissible, but only after a complete appraisal of the conductor size and lengths installed[3]. When renovating the electrical system of a dwelling, the first area that should be examined is the consumer unit. Often, units have been installed in the 50s and 60s and may have too few circuits (only 2 or 3), or be mounted on wood, which is not allowed under current standards[3].

Electricity installations widely vary from country to country (e.g. voltage, frequency, outlets). The International Standard series IEC 60364 governs electrical installations and is an attempt to harmonise national standards given the significant differences in the national codes[3]. The European equivalent is CENELEC HD384 but there are still significant differences between international and national standards[4] implementation. As a result of this diversity, the installations and common deficiencies found vary from Member State to Member State. Some of the critical problems include:

- Mains supply not protected by an RCD (often the case in dwellings over 20 years old);
- No protection by an RCD for bathroom and wet areas; and
- No protection by an RCD for circuits supplying power to appliances used outdoors[5].

1.2.1 Legal background

Fuseboxes were not previously included within the scope of RoHS I or of the COM proposal. Due to the enlarged scope of RoHS II, they will fall within category 11 (Annex I) of the Directive from July 2019: "Fuseboxes meet the definition of EEE as set out in Article 3(1), and do not benefit from any exclusion"[6]. The RoHS II substance restrictions will apply to all components, also non-electrical ones, on the homogeneous material level. According to Article 3(1), some fuseboxes may be exempted from RoHS II because of high voltage: if exceeding 1 000 V for alternating current and 1 500 V for direct current.

1.2.2 Quantities and hazardous substances

Table 1 shows market figures (in quantities and values) for categories containing products potentially related to fuseboxes, extracted from the PRODCOM database, for the EU-27 in 2010. PRODCOM codes of the product categories presented are given in Annex.

The apparent consumption in the EU-27 is also calculated from PRODCOM figures. "Automatic circuit breakers for a voltage <= 1 kV and for a current <= 63 A" appear as the most sold product

[3] Towards improved electrical installations in European homes (2004), European Copper Institute, European Association of Electrical Contractors, Europacable, International Union of Electricity Applications and International Federation for the Safety of Electricity Users.
[4] Example include AREI/RGIE in Belgium, VDE100 in Germany, REBT in Spain, NF C 15-100 in France, CEI 64-8 in Italy, NN 1010 in Netherlands, BS 7671 in the UK.
[5] http://www.aie.eu/files/PDF%20stand%20&%20safety/Feeds_report%20def.pdf
[6] European Commission, DG ENV, RoHS 2 FAQ, Final Draft 15 May 2012.

categories, both in terms of quantities (production figures only) and value. Sales of fuses seem important as well, although these products have a much lower unit value than circuit breaker.

These figures have to be considered with caution given the data gaps in some Member States, which may be the reason for the negative apparent consumption for "Fuses for a voltage <= 1 kV and for a current <= 10 A".

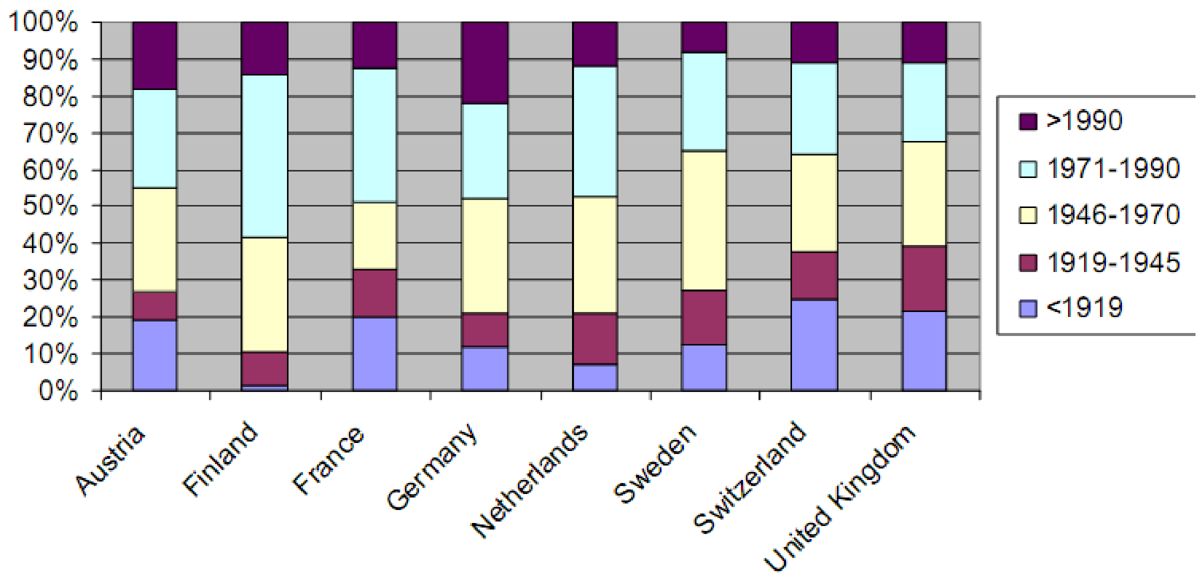
Table 1: PRODCOM market figures for fuseboxes, sorted by EU-27 Apparent Consumption Value (EU-27, 2010)[7]

Product category[8]	Production		Imports		Exports		EU-27 Apparent Consumption[9]	
	Quantity (in p/st)	Value (in €)	Quantity (in p/st)	Value (in €)	Quantity (in p/st)	Value (in €)	Quantity (in p/st)	Value (in €)
Automatic circuit breakers for a voltage <= 1 kV and for a current <= 63 A	511 216 614	1 785 243 782	n.a	130 421 830	n.a.	510 652 250	n.a.	1 405 013 362
Automatic circuit breakers	4 500 000	1 400 000 000	n.a	70 406 330	n.a.	547 261 900	n.a.	923 144 430
Automatic circuit breakers for a voltage <= 1 kV and for a current > 63 A	63 042 641	946 373 445	n.a	96 970 120	n.a.	512 318 830	n.a.	531 024 735
Lightning arresters, voltage limiters and surge suppressors for a voltage > 1 kV	3 000 000	222 447 779	n.a	47 250 350	n.a.	118 327 950	n.a.	151 370 179
Fuses for a voltage <= 1 kV and for a current > 10 A but <= 63 A	206 904 796	95 212 266	n.a	45 068 390	n.a.	48 954 730	n.a.	91 325 926
Fuses for a voltage <= 1 kV and for a current > 63 A	150 871 107	106 527 276	n.a	31 046 640	n.a.	68 307 100	n.a.	69 266 816
Fuses for a voltage > 1 kV	54 000 000	88 899 123	n.a.	11 060 750	n.a.	49 792 400	n.a.	50 167 473
Fuses for a voltage <= 1 kV and for a current <= 10 A	193 722 894	65 089 636	n.a	61 219 650	n.a.	131 690 130	n.a.	-5 380 844

[7] Extracted in May 2012. Database available at: http://epp.eurostat.ec.europa.eu/portal/page/portal/prodcom/data/database
[8] Not all products within a presented category are systematically included within the scope of this impact assessment but some of them always are. For instance, fuses for a voltage > 1 kV can be included or excluded from RoHS II, depending on the current (alternative or direct).
[9] Apparent Consumption = Production + Imports - Exports

According to a survey on electrical safety in Europe, an average of 67% of dwellings did not have mains protection by RCD in 2004, while this safety device had been available for over 20 years. This is partly due to the fact that existing buildings do not require to be made compliant with new standards that come into force after the building has been constructed (see Figure 1) except when non-compliance to the new standard represents a safety hazard (e.g. in the following MS: CZ, D, I)[10]. Important differences can be observed: in Italy, for example, only 7% of dwellings do not have RCD protection compared to 68% in France[11]. In the UK, more than half of homes (i.e. 13 million) do not yet have any, or an adequate level of such RCD protection[12]. Still, in 2008, a new edition of the UK standard for the safety of electrical installations, BS 7671, came into effect and calls for virtually all electrical circuits installed in homes since then to be provided with additional protection by means of an RCD.

Figure 1: Age of the residential building stock



Source: Building Renovation and Modernisation in Europe: State of the art review (2008), ERABUILD.

Therefore, as the composition of consumer units is varying both regarding the presence of an RCD and the number of fuses/circuit breakers, it is difficult to estimate a number of fuseboxes from the PRODCOM figures.

A simpler estimation could be obtained from the buildings stock in the EU. In 2003, the European stock represented 263 million dwellings[13]. According to another source, a total number of dwellings of 221 million is estimated in the EU-27 (see Table 2). Consequently, **an estimation of 250 million fuseboxes installed in residential buildings** in the EU-27 seems reasonable (assuming one fusebox per dwelling).

[10] Towards improved electrical installations in European homes (2004), European Copper Institute, European Association of Electrical Contractors, Europacable, International Union of Electricity Applications and International Federation for the Safety of Electricity Users.
[11] In particular, the installation of a differential switch of not more than 30 mA in case of absence of an earth protection circuit was imposed.
[12] http://www.esc.org.uk/public/home-electrics/rcds-explained/
[13] EU housing stock, Economist World in Figures (2003).

Table 2: Dwelling stock in the EU-27, by Member State

Member State	Dwelling stock (in thousand)	Year of reference : 2009 unless specified below
Austria	3 598	-
Belgium	5 043	-
Bulgaria	n.a.	-
Cyprus	288	2001
Czech Republic	3 828	2001
Denmark	2 680	-
Estonia	651	-
Finland	2 784	-
France	31 264	2006
Germany	39 268	-
Greece	5 465	2000
Hungary	4 303	-
Ireland	1 619	2004
Italy	27 269	2002
Latvia	1 042	2005
Lithuania	1 308	-
Luxembourg	188	2005
Malta	139	2005
Netherlands	7 107	-
Poland	13 150	2005
Portugal	5 537	2006
Romania	8 329	2005
Slovak Republic	1 767	2008
Slovenia	798	2004
Spain	25 129	-
Sweden	4 503	2008
United Kingdom	23 500	2004
Total – EU-27	**220 557**	**-**

Source: Housing Statistics in the European Union 2010, OTB Research Institute for the Built Environment, Delft University of Technology[14].

Non-residential buildings include commercial, industrial, health and educational buildings. They represent approximately half of the surface of residential buildings in the EU-27, but this proportion is much lower in terms of units. For instance, in the UK, there are 1.84 million non-residential

[14] http://abonneren.rijksoverheid.nl/media/dirs/436/data/housing_statistics_in_the_european_union_2010.pdf

buildings and 26.2 million dwellings[15]. By assuming a similar composition of the building stock in the EU-27, an estimation of 15 million non-residential buildings can be made. In these buildings, it is likely that several fuseboxes are installed given their larger surface on average, but some of them are also expected to exceed the voltage limit of RoHS[16] or could be considered as part of a large scale fixed installation. In the end, it is difficult to obtain a reliable estimate but a range of **10 to 50 million installed fuseboxes affected by RoHS scope changes in non-residential buildings** seems acceptable.

The annual sales of fuseboxes, not exceeding 1 000 V or not considered as a large scale fixed installation are estimated to represent approximately 11 million units per year[17], for a stock of 260 to 300 million units in the EU-27.

No information regarding RoHS substances in fuseboxes was obtained directly from stakeholders. According to several manufacturers' websites, a wide range of fuseboxes, RCDs and circuit breakers are already available in RoHS compliant designs. Some manufacturers/distributors indeed display declarations of RoHS compliance: Belfuse[18], Fuzetec[19], Cooper Bussmann[20], Eska[21], Littelfuse[22], Swe-check[23], ABB[24], Schurter[25]. The main reason for that may be that fusebox components can also be included in other products within the scope of RoHS I as components. The above is also the case for some extra-EU manufacturers, e.g. LSIS[26]. Regarding circuit breakers, some products can also be found in RoHS compliant designs[27].

Certain types of fuses contain solder, which can be lead-based[28]. The main materials are plastics as insulators with copper and brass conductors and connectors. The enclosure (box) is usually made of steel although some designs have polycarbonate covers. Inside there are often rails on which the MCB or fuses are held. The steel enclosure, rails and fasteners may have chromate passivation coatings. MCBs[29] contain steel or brass terminals, copper conductors, a solenoid (copper wire) and electrical contacts which could be silver-cadmium oxide (RoHS exemption 8b) although silver /nickel is more likely, in a plastic case. RCDs also contain a small Printed Circuit Board (PCB) which could contain lead solder and also have power switch contacts which could be silver-cadmium

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[15] Building Renovation and Modernisation in Europe: State of the art review (2008), ERABUILD.
[16] 1 000 V for alternating current and 1 500 V for direct current (Art. 3.1)
[17] Assuming a lifetime of 25 years, Average annual sales = stock / average lifetime
[18] http://belfuse.com/Data/UploadedFiles/DecofRoHScomp-CP.pdf
[19] http://www.fuzetec.com/Lead-Free%20&%20RoHS%20Compliant%20Products.pdf
[20] http://www.cooperindustries.com/content/dam/public/bussmann/Resources/RoHS/RoHS_Commitment.pdf
[21] http://eska-fuses.de/RoHS_142.html
[22] https://www.littelfusebusinesscenter.com/LFWeb/DesktopDefault.aspx?tabindex=4&tabid=37&guid=07cb8a4c-3f0b-4160-b4c2-674c132a8366&action=0
[23] http://www.swecheck.com.au/pdfs/swecheck_rohs_policy.pdf
[24] http://www05.abb.com/global/scot/scot209.nsf/veritydisplay/3d3c413f678d2e86c12572a50040c76f/$file/RoHS%20Eng%20DS9-2CSC422001K0201.pdf
[25] http://www.schurter.com/Components/Circuit-Protection/Fuses-Fuseholder/Fuseholders
[26] http://stuff.morek.eu/CATALOGUES/LS_INDUSTRIAL/LOW_VOLTAGE/MINIATURE_CIRCUIT_BREAKERS_&_RESIDUAL_CURRENT_DEVICES/Miniature_Circuit_Breakers_&_Residual_Current_Devices_2011(ENG).pdf
[27] http://www.sensata.com/klixon/circuit-breaker-thermal-rohs.htm
[28] http://www.schurter.com/Company/Environment/RoHS
[29] http://en.wikipedia.org/wiki/Circuit_breaker

oxide[30]. PBB and PBDE may be used as flame retardants in circuit breakers as well, according to a previous study[31].

Table 3 lists the presence of the different hazardous substances considered by RoHS II as well as quantity estimations.

Table 3: RoHS substances in fuseboxes

Substance	Presence in fuseboxes
Lead	Yes, in solder Estimation: 0.5 g per product
Mercury	No
Cadmium	Unlikely (excluding exemption 8b for silver cadmium oxide)
Hexavalent Chromium	Possible
Polybrominated biphenyls (PBB)	Possible
Polybrominated diphenyl ethers (PBDE)	Possible

Source: Own estimations

The situation regarding RoHS substances is likely to vary between the different manufacturers on the market.

1.2.3 Policy objectives and options

The objective of both, the RoHS recast proposal (COM (2008) 809 final) as well as RoHS II (2011/65/EU) is to contribute 'to the protection of human health and the environment, including the environmentally sound recovery and disposal of waste EEE'[32].

The purpose of this work is to look at the impacts of fuseboxes falling under the scope of RoHS II compared to fuseboxes being excluded from the COM recast proposal. Policy options will then be evaluated according to their effectiveness, efficiency and coherence in reaching the above-mentioned overall objective of the RoHS Directive. The policy options analysed are the following:

OPTION 1 (baseline scenario): The COM recast proposal. Fuseboxes are not in scope of the proposed recast Directive.

OPTION 2: RoHS II. Fuseboxes are included in the scope of the recast Directive.

[30] http://en.wikipedia.org/wiki/Residual-current_device
[31] Arcadis Eolas & RPA (2008), Study on RoHS and WEEE Directives - Final Report, for DG ENTR.
[32] 2011/65/EU, Article 1

1.3 Impacts of policy options

1.3.1 Impact indicators

The following impact indicators have been chosen as relevant for this product group (see Table 4).

Table 4: Impact indicators for the product group fuseboxes

Impact indicators		
Environmental	Economic	Social
Energy use	Functioning of the internal market and competition	Employment
Waste production / generation / recycling	Competitiveness	Health
International environmental impacts	Costs and administrative burdens	Social impacts in third countries
	Innovation and research	
	Consumers and households	

The following legend will be used in summarising the impacts:

Legend	
+++	Very beneficial effect
++	Substantial beneficial effect
+	Slight beneficial effect
=	No effect
-	Negative effect
--	Substantial negative effect
---	Very negative effect
?	Unknown effect

1.3.2 Environmental impacts

The most important stakes regarding the environmental impacts in the context of RoHS are related to the quantities of hazardous substances used in the equipment. The mere quantity of a substance is however not sufficient to estimate what will be the actual impacts of the substance on the environment and health. These indeed depend upon numerous factors such as the effective treatment of products at the end-of-life, their design for the use phase or their potential emissions during the production phase. The impact of the substances released to the environment is also determined by case-specific and complex dose-response relationships.

It is therefore not straightforward to predict environmental impacts due to hazardous substances found in products. Where possible, the following subsections will make the link between the quantities of hazardous substances and their potential environmental impacts.

1.3.2.1 Energy use

In a previous study, it was estimated that 5% of annual electricity consumption can be saved through electric installation upgrade, i.e. 200 kWh/year per dwelling[33]. This estimation is not specific to fuseboxes but highlights the electricity losses (not an electricity consumption per se) that occur along the distribution network. Concerning the substitution of the RoHS substances, no information was found regarding its influence on the energy efficiency of fuseboxes. As some manufacturers already provide RoHS compliant products of equivalent quality[34], it is estimated that no significant influence should be expected during the use phase.

Regarding the production phase, the European Commission impact assessment accompanying the RoHS recast proposal[35] states that the substitution of lead solder by lead-free solder might lead to an increase in energy consumption because of a higher melting point. The additional energy consumption will vary widely depending on the solder type, the equipment specifications and process operating parameters employed by the facility. Nevertheless, it is generally accepted that lead-free soldering requires approximately 15% more energy than tin/lead (SnPb) soldering when comparing equivalent soldering technology for the two types of alloy and the following calculations will be based on this assumption. Based on a typical solder reflow oven to make the small PCBs on which lead is found in circuit breakers, the total additional energy required for lead-free solders represents 82 MWh per year [36]. This represents a high-end estimate based on the assumption that none of the current RCD PCBs are RoHS compliant. Compared to a total EU final energy consumption of 13.6 million PWh[37], this impact of additional energy required is regarded as negligible on this environmental impact indicator. The additional energy consumption will have an additional cost of 7 656 €[38], which is negligible compared to other technical costs (see section 1.3.3.3). Additional CO_2 emissions due to change from tin/lead solder to lead-free solder represent

[33] Towards improved electrical installations in European homes (2004), European Copper Institute, European Association of Electrical Contractors, Europacable, International Union of Electricity Applications and International Federation for the Safety of Electricity Users.
[34] http://www.schurter.com/Company/Environment/RoHS
[35] European Commission (2008), SEC(2008) 2930. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=SEC:2008:2930:FIN:EN:PDF
[36] A typical solder reflow oven operates 16 hours per day, 5 days a week, 49 weeks per year and on average consumes 13.9 kWh for SnPb and 16kWh for lead-free. It is assumed that one oven can produce 300 PCBs per hour or 1 million per year (25 PCBs made in a panel every 5 minutes) as these PCBs are small. The total number of units to be made are approximately 11 million units.
[37] 1168.63 Mtoe, European Commission, *EU transport in figures, statistical pocketbook 2011*, accessed at http://ec.europa.eu/transport/publications/statistics/doc/2011/pocketbook2011.pdf
[38] Average EU industrial electricity price = 0.093 €/kWh in 2011 according to Eurostat.

32.1 tonnes CO_2 eq[39]. In relation to the overall CO_2 emissions of 4 088.8 million tonnes of the EU-27 in 2008[40], this increase would also be considered negligible.

1.3.2.2 *Waste production / generation / recycling*

Electrical installations may last several decades, depending on the building they are installed in. Reliability and safety are key features of fuseboxes. However, an installation built over 30 years ago will typically be subject to deterioration issues (e.g. due to moisture), as well as changing needs so that the functionality provided may not be optimal anymore. Consequently, maintenance and upgrade activities are required for fuseboxes within the existing buildings stock, besides new products that are installed in new buildings. UK studies[41] estimated that of the 46% of households which make some improvement to their home each year, only 4.5% of them improve the electrical installation[42]. According to an internet source, the life expectancy of a fusebox is maximum 30 years[43], if maintained in proper working conditions. For this assessment, an **average lifetime of 25 years** will be assumed for fuseboxes.

In most cases, the upgrades are carried out by professionals who are expected to take back products at the end-of-life. No information on the end-of-life treatment was found or received from stakeholders. However, the average reuse and recycling rate of professional EEE in France was 90% in 2010, the remaining shares being 3% for incineration and 7% for disposal[44]. In absence of more specific data, this repartition will be considered as representative of the EU-27 situation, even if important discrepancies can exist regarding these rates between Member States (see Table 5).

Depending on the quality of the end-of-life operations, a certain share of the substances (called the leaching potential) is always lost to the environment. According to BIO (2008)[45], process control of landfills and incinerators, alongside mineralization mechanisms in landfills, are some of the options to reduce this share. But there is limited quantitative data about the fate of hazardous substances going through land filling or incineration processes, in particular their leaching potential.

Policy Option 2 (including this type of equipment in the scope of RoHS II) would progressively (over a 25 year period, between 2019 and 2044[46]) decrease the quantities of hazardous substances from fuseboxes found in the waste streams, compared to the baseline scenario. The reduction of these substances may have a beneficial effect on their end-of-life treatment. This effect is dependent on the development of the waste management sector as a whole.

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[39] Based on 0.39 kgCO_2 eq/kWh from Eurelectric

[40] 4 186.7 million tonnes. European Commission, *EU transport in figures, statistical pocketbook 2011*, accessed at http://ec.europa.eu/transport/publications/statistics/doc/2011/pocketbook2011.pdf

[41] Samuelson-Brown, G,Thornton, M, Repair, maintenance & improvement in housing - electrical supply, the supply side, BSRIA, 1997.
The GB Private Home Improvement Market - the demand side for electrical & security system improvements, Construction Forecasting and Research Limited, 1998.

[42] Towards improved electrical installations in European homes (2004), European Copper Institute, European Association of Electrical Contractors, Europacable, International Union of Electricity Applications and International Federation for the Safety of Electricity Users.

[43] http://www.popselectric.com/services/56.html

[44] ADEME (2010), Équipement électriques et électroniques - Rapport annuel.

[45] BIO (2008), Study to support the impact assessment of the RoHS review – Final Report, for DG ENV.

[46] Possibly earlier if manufacturers take early measures.

Table 5 shows the estimations used to calculate the environmental impacts of RoHS hazardous substances released into the environment at the end-of-life. The assessment is likely to contain high uncertainties, because of the assumptions made to model the end-of-life options.

Table 5: Heavy metal emissions, by end-of-life management options

End-of-life process	Share of total end-of-life products (in %)	Emissions to air during end-of-life process	Emissions to water during end-of-life process	Source of the emissions estimates
Recycling	90%	0.001%	0.059%	COWI (2002)[47]
Incineration	3%	0.5%	2.49%	ERM (2006)[48]
Landfill	7%	-	5%	ERM (2006)

By considering the annual sales and lead quantities presented in section 1.2.2, it is estimated that 5.5 tonnes of lead from solder would be sent annually into the end-of-life management circuit from 2044[49] if the product group was not included within the scope of RoHS II. For Option 2, it is assumed that all lead in solder would be removed from the products from 2019, so that none of these substances would go to the waste streams from 2044.

Based on these assumptions, the ecotoxicity freshwater midpoint indicator was calculated[50] in order to illustrate the avoided impacts for the end-of-life, of the inclusion of fuseboxes within the scope of RoHS II, in 2044. This indicator was chosen because the release of RoHS hazardous substances in the environment has an influence on its value (this is not the case for Global Warming Potential for instance).

Table 6: Avoided freshwater ecotoxicity impacts by Option 2, compared to Option 1

Year[51]	Ecotoxicity freshwater midpoint (CTUe[52])
2044	1.00E+04

This result in 2044 represents 0.0000000007% of the overall freshwater ecotoxicity annual impact in the EU-27 (USEtox™ normalisation values). Details of the calculations are given in Annex.

In theory, end-of-life impacts also depend on the possible substitutes that would replace the six hazardous substances. A similar quantitative analysis could not be done by considering the impact of the substitution of lead solder by lead-free solder, as the most suitable substitutes are not known yet. Still, some substitutes are likely to leach hazardous substances into the environment too, even if lead is the most toxic alloying element: silver or antimony represent a potential source of toxicity in leachates when used in alloys, while bismuth, indium and copper are regarded as less dangerous[53]. Obviously, the levels of emissions depend on the specific environmental conditions the

[47] COWI (2002), Heavy Metals in Waste – Final Report, for European Commission DG ENV. Applicable to lead, assumed to be the same for other heavy metals
[48] ERM (2006), Battery Waste Management Life Cycle Assessment – Final Report.
[49] 25 years (the lifetime of the product) after the effective implementation of RoHS II.
[50] According to USEtox™ methodology.
[51] RoHS II coming into force for this product group (2019), plus one product lifetime (25 years)
[52] Comparative Toxicity Unit ecotoxicity, equivalent to PAF.m3.day
[53] Edwin B. Smith III, Environmental Impacts and Toxicity of Lead Free Solders: http://leadfree.ipc.org/files/RoHS_16.pdf

waste will be exposed to during the end-of-life management. Another source[54] builds a comparative analysis of lead-free solder, by taking into account toxicity, availability and environmental impact of extraction of substitutes to lead in solder alloys. Based on this, only tin and copper appear to have a lower overall impact than lead. These outcomes have to be considered with caution given the subjective assessment grid. Finally, a comparative life cycle assessment[55] also illustrates that depending on the environmental impact considered, either lead solder or one substitute (bismuth-tin-silver or copper-tin) can be best performing.

1.3.2.3 International environmental impacts

Given the end-of-life considerations in section 1.3.2.2, it is not expected that end-of-life treatment of fuseboxes occur outside the EU-27. Either the products will be recovered by professionals and mainly re-used or recycled, or they may be mixed with the demolition waste, in which case they are not likely to be exported.

Concerning the production phase, the electronics components (mainly the PCBs) are probably manufactured outside the EU-27 (e.g. in China) so that the ban of the hazardous substances might have positive effects in extra-EU countries involved in components manufacturing. The overall effect is expected to be relatively low, given the low amount of electronics in fuseboxes, but it nonetheless contributes to an improvement of the supply chain in general.

1.3.2.4 Overview of environmental impacts until 2044

Based on the above, limited positive environmental impacts can be expected from fuseboxes falling in the scope of RoHS II, in particular during the end-of-life phase.

Table 7: Estimated environmental impacts

Estimated environmental impacts until 2044[56]		
	2012	2044
Energy use	=	=
Waste production / generation / recycling	=	=/+
International environmental impacts	=	=/+

[54] Anna Kua, Prof. Oladele Ogunseitanb, Prof. Jean-Daniel Saphoresc. Lead-Free Solders: Issues of Toxicity, Availability and Impacts of Extraction:
http://trs-new.jpl.nasa.gov/dspace/bitstream/2014/6388/1/03-0222.pdf

[55] EPA (2005), Solders in electronics: a life-cycle assessment. Available at:
http://www.epa.gov/dfe/pubs/solder/lca/lfs-lca-final.pdf

[56] RoHS II coming into force for this product group (2019), plus one product lifetime (25 years)

1.3.3 Economic impacts

1.3.3.1 Functioning of the internal market and competition

RoHS II should affect all manufacturers of fuseboxes in the EU equally, which means that no competitive pressures within the European Union should be expected. Provided there is suitable market surveillance, no distortion of the internal market is expected.

1.3.3.2 Competitiveness

No specific market information on imports and exports were received or found so there is high uncertainty regarding the effect of RoHS II implementation for this indicator. In theory, the implementation of RoHS II for fuseboxes should have no impact on the competitiveness of EU companies on the EU market, as all products sold are subjected to the same regulations. However, non RoHS-compliant manufacturers (inside or outside the EU) selling on the EU market could benefit from an implementation of RoHS II, in case that market surveillance is not properly implemented.

The fact that many manufacturers already propose RoHS compliant fuseboxes implies that they did not suffer from a lack of competitiveness for these products and that the additional technical costs were either not significant or counterbalanced by other benefits, such as a 'green' visibility for instance. For products for which technical limitations may exist, RoHS implementation may reduce their competitiveness for exportations in countries where such substances requirements are not compulsory, due to additional costs. Depending on the possible substitutes, RoHS II implementation might also result in technical issues, such as a loss of reliability. This effect is however estimated very limited given that it only concerns a limited range of products.

1.3.3.3 Costs and administrative burdens

The reliability and safety of fuseboxes (and of the whole electrical distribution installation within buildings) is of primary importance in terms of costs, when looking at the overall picture. According to a report[57], the following benefits to society are brought by electric installations inspections and renovations: up to €14 billion per year saved due to reduced property damage, injuries, casualties and fire fighting; up to €3 billion per year in emission reductions and reduced energy costs; and net employment creation. It is therefore important that RoHS II does not result in any loss of reliability or functionality of fuseboxes to avoid these societal costs. The fact that many manufacturers already propose RoHS compliant products implies that no major technical limitations exist. However, it could be that products with specific properties are not yet available in RoHS compliant design, due to a lack of suitable substitutes. Technical costs might be due to additional research to come up with new compliant components for these products and to the fact that changed components would have to undergo extensive field testing before being implemented in products, in order to minimise the risk of durability decrease.

[57] Towards improved electrical installations in European homes (2004), European Copper Institute, European Association of Electrical Contractors, Europacable, International Union of Electricity Applications and International Federation for the Safety of Electricity Users.

According to the 2008 Impact Assessment accompanying the Commission's recast proposal[58], there is little experience of actual compliance costs for industry. For products currently included in RoHS estimates are it would vary from 1-4% of turnover. Other surveys give an average overall cost related to RoHS of 1.9% of turnover (past cost and one-off future costs). Assuming an average price of 100 € for a consumer unit[59] and 11 million annual sales, the annual turnover of the whole sector is 1.1 billion €. Applying the 1-4% range, compliance costs would represent between 11 million € and 44 million € for all manufacturers. Given that those manufacturers that already offer RoHS compliant would be significantly less affected, this estimate is likely to be high.

The replacement of lead solder by lead-free solder would also result in additional costs due to raw material requirements. With a quantity of lead in solders of 0.5 g per product, and annual sales representing 11 million products, lead solder constitutes 9.4 tonnes of tin and 5.5 tonnes of lead per year, based on the assumption that none of the products are already RoHS compliant. Assuming that all lead solder is replaced by tin/copper solder for reliability reasons, 5.4 additional tonnes of tin and 0.1 tonnes of copper would be required to replace the lead. Additional costs would therefore amount to approximately 79 k€ annually for all manufacturers of fuseboxes[60]. Given that those manufacturers that already offer RoHS compliant products would not be subject to any addition technical costs, this estimate is likely to be high.

1.3.3.4 Innovation and research

The influence of RoHS II implementation on innovation and research will vary for each manufacturer. It seems that many manufacturers already provide RoHS compliant products so that they have already successfully carried out R&D to substitute RoHS substances. It could be, however, that reliable substitutes are still to be found for some products with specific properties or requirements. Overall, R&D might be slightly boosted but only to a very limited extent. For those manufacturers not selling RoHS compliant fuseboxes already, R&D activities could be highly facilitated by the work already carried out by the sector, which shows that no major technical limitation is present.

In any case, the impact on innovation and research is estimated as positive but negligible, compared to the business-as-usual activities.

1.3.3.5 Consumers and households

Compared to the purchase price of a fusebox (approx. €50 for the largest ones), the total cost for the installation of a fusebox by a professional (which is almost always the case) is much more important: a typical average cost of renovation is €300 for upgrading a consumer unit[61]. Even if the additional technical and administrative costs of manufacturers are fully supported by the consumer

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[58] European Commission (2008), SEC(2008) 2930. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=SEC:2008:2930:FIN:EN:PDF

[59] Purchase prices may range from 15 € for a plug-in RCD to several hundred Euros for more sophisticated distribution boards.

[60] Under the following assumptions: composition of tin/lead solder is 63%/37%; composition of tin/copper solder is 99.3%/0.7%; prices of metals (LME): 1590€/tonne for lead, 16210 €/tonne for tin; price of copper neglected; 1 g of tin/lead solder is assumed to be replaced by 1 g of tin/copper solder.

[61] http://www.aie.eu/files/PDF%20stand%20&%20safety/Feeds_report%20def.pdf

in the end, it is not likely that this price increase will have an influence on the market: firstly because of the minor share represented by the device in itself during installation; secondly, because it is absolutely necessary to always have a functional fusebox. Given the long lifetime (25 years), this impact will be negligible on the consumer's wallet.

1.3.3.6 *Overview of economic impacts until 2044*

Based on the above, economic impacts from fuseboxes falling in the scope of RoHS II are expected to be limited, given the fact that many manufacturers already offer RoHS compliant products, but administrative costs would occur, whatever the extent of the technical modifications of the products.

Table 8: Estimated economic impacts

Estimated economic impacts until 2044[62]		
	2012	**2044**
Functioning of the internal market and competition	=	=
Competitiveness	=	=/-
Costs and administrative burdens	=/-	=/-
Innovation and research	=	=
Consumers and households	=	=

1.3.4 Social impacts

1.3.4.1 *Jobs*

Maintenance and upgrade of the electric installations of buildings is a key issue to ensure safety and suitable operation. For most EU countries, there are no periodic inspection regimes for existing dwellings. In some MS (Czech Republic, Hungary, and Poland) and Russia, periodic inspection regimes at a 5 to 9 year interval officially exist but, due to a lack of enforcement, do not achieve their goal. In 1990, Italy made inspection - and renovation where required - statutory for all dwellings built before 1999[63]. The same source estimates that about three quarters of the European housing stock is in need of inspection and about half would require renovation. The maintenance and upgrade activities should, however, not be affected by RoHS II implementation.

Statistics regarding jobs directly and indirectly linked to the fuseboxes industry are sparse. Given the limited impact of RoHS II implementation on competitiveness, costs and R&D, no significant impact on jobs is expected for manufacturers either. The demand for fuseboxes is not expected to

[62] RoHS II coming into force for this product group (2019), plus one product lifetime (25 years)
[63] Towards improved electrical installations in European homes (2004), European Copper Institute, European Association of Electrical Contractors, Europacable, International Union of Electricity Applications and International Federation for the Safety of Electricity Users.

be altered by the technical characteristics of the products as it is a necessary device in each dwelling.

1.3.4.2 Health

The impacts of hazardous substances on health can be differentiated between possible impacts during the production phase, on users during the actual product's lifetime and at the end-of-life.

First, exposure to these substances during the production phase represents a risk for facility workers, who are the population group at greatest risk of exposure to lead, especially through air. This risk is very much dependent upon the type of exposure (time, frequency, pathway, etc.). It is assumed that the production of the electronics containing the lead solder takes predominantly place outside the EU-27. A ban of the use of the six RoHS substances in fuseboxes would certainly reduce the health impacts during the production phase, in particular in case of accidental situations.

During the use phase, the possible RoHS substances in fuseboxes are estimated to represent a very low risk in normal operation: the product design takes these considerations into account and direct contact is not expected to occur. Electricity in buildings is a source of two potential hazards, which are fire and electric shocks. Electrical fires represent 10% of total domestic fires in the UK[64], and 25% in France[65], and they result in a disproportionate amount of the associated injuries (20 to 30%). Related casualties in Eastern Europe are higher than the European average[63]. In the UK, about 4 000 fires caused by electricity in homes might have been prevented each year if RCD protection had been fitted in the consumer unit[66]. Regarding electric shocks, their consequences range from transitory discomfort to death, depending on the severity, timing and duration of the shock. There are few statistics available but the ANAH (French National Agency for Dwelling Improvement[67]) estimated that in France about 200 000 individuals suffer burns in their homes each year and that electric shock is a major cause of these accidents[63]. In the UK, around 70 people die and 350 000 are injured as a result of electrical accidents at home every year[68]. Therefore, if RoHS substances substitutions have an influence on the functionality of fuseboxes, they could result in negative impacts on health through an increase of electric shocks and fires. However, no data was found or received from stakeholders on this topic and based on the available information it assumed that the substitutes will enable to maintain an equivalent functionality of the products. The fact the RoHS compliant fuseboxes are already available tend to confirm this. The health risks to the user are thus assumed to be negligible.

Finally, the management during the end-of-life can result in important impacts for the environment and health. These impacts are dependent upon the management options followed by products, which have already been presented (see section 1.3.2.2). Based on the same assumptions regarding the emissions to air and water of the substances during recycling, incineration and disposal (see Table 5), health impacts can be quantified via the human toxicity indicators[69]: assuming the ban of

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[64] Aust, R, Fires in the home: findings from the 2000 British Crime Survey, UK Department for Transport, Local Government and Regions, 2001
[65] According to Centre National de Prévention et de Protection
[66] http://www.esc.org.uk/public/home-electrics/rcds-explained/
[67] Agence Nationale pour l'Amélioration de l'Habitat
[68] http://www.esc.org.uk/public/home-electrics/rcds-explained/
[69] USEtox™ method.

RoHS hazardous substances in fuseboxes from 2019 (Option 2), a human toxicity impact of 3.25E-05 CTUh (cancer effects) and 1.14E-02 CTUh (non-cancer effects) would be avoided in 2044 (0.0000002% and 0.000003% respectively of the overall impacts in the EU-27 annually), compared to Option 1, due to the removal of lead in solder.

Table 9: Human toxicity indicators

Year[70]	Human toxicity midpoint, cancer effects (CTUh[71])	Human toxicity midpoint, non-cancer effects (CTUh)
2044	3.25E-05	1.14E-02

The monetised cost of this impact has been calculated by Defra (UK)[72] which looked at the costs in terms of health impacts of options for management of waste containing hazardous substances including lead. The study estimated health impacts from mathematical models of landfill and incineration and estimates of pollution from these disposal options. Applying these results to the heavy metal emissions per end-of-life treatment options (see Table 5), gives a monetised health benefit from not using lead of between €40 260 and €962 500[73].

1.3.4.3 *Social impacts in third countries*

A major concern of lead solders is the harm to health caused by unsuitable and dangerous recycling practices that are used in some developing countries. Despite legislation aimed at preventing illegal WEEE exports, some European WEEE is shipped to developing countries for recycling. Fuseboxes, because they are dismantled by professionals and can be part of the construction and demolition waste, are not expected to be exported as WEEE for recycling. Consequently, impacts outside the EU are estimated as negligible.

1.3.4.4 *Overview of social impacts until 2044*

The social impacts of fuseboxes falling in the scope of RoHS II can be expected to be slightly positive given the health benefits, especially during the end-of-life phase of the products.

[70] RoHS II coming into force for this product group (2019), plus one product lifetime (25 years)
[71] Comparative Toxicity Unit human, equivalent to cases
[72] Enviros Consulting Ltd. For Defra, *Valuation of the external costs and benefits to health and environment of waste management options*, December 2004, table 3.2 and page 82)
[73] Based on a monetised impact of lead between €1.46 million/tonne and €35 million/tonne, and assuming a 0.5% leakage rate of lead at the end-of-life.

Table 10: Estimated social impacts

Estimated social impacts until 2044[74]		
	2012	2044
Employment	=	=
Health	=	=/+
Social impacts in third countries	=	=

1.3.5 Comparison of options

The inclusion of fuseboxes in the scope of RoHS II is expected to result in very limited impacts, both positive and negative. Due to the slight decrease of the use of the banned substances, environmental and health benefits are expected mostly at the end-of-life. Technical costs are expected to be limited given that many manufacturers already carry out R&D activities but administrative costs will represent an additional burden, albeit to a limited extent.

Table 11: Comparison of options

Impact indicators	Option 1 : Fuseboxes excluded in COM recast proposal	Option 2: Fuseboxes in scope of RoHS II
Environmental impact indicators		
Energy use	=	=
Waste production / generation / recycling	=	=/+
International environmental impacts	=	=/+
Economic impact indicators		
Functioning of the internal market and competition	=	=
Competitiveness	=	=/-
Costs and administrative burdens	=	-
Innovation and research	=	=
Consumers and households	=	=
Social impact indicators		
Employment	=	=
Health	=	=/+
Social impacts in third countries	=	=

[74] RoHS II coming into force for this product group (2019), plus one product lifetime (25 years)

In relation to the overall policy objective of RoHS II, namely to contribute 'to the protection of human health and the environment, including the environmentally sound recovery and disposal of waste EEE'[75], including fuseboxes in RoHS II does contribute to this objective, even if very slightly.

Table 12: Policy objectives and options

Policy options in relation to overall policy objectives			
	Effectiveness	**Efficiency**	**Coherence**
Option 1: Fuseboxes excluded in COM recast proposal	Slightly negative: Hinders the objectives to a limited extent	Efficiency cannot be evaluated as the option does not contribute to the overall objectives	No unintended impacts
Option 2: Fuseboxes in scope of RoHS II	Slightly positive: Does contribute to the effectiveness of the Directive	Very limited: None of the positive impacts are significant	Unintended impacts are limited

[75] 2011/65/EU, Article 1

Annex

Table 13: PRODCOM codes for fuseboxes

PRODCOM Code	Product category
27121010	Fuses for a voltage > 1 kV
27121020	Automatic circuit breakers
27121040	Lightning arresters, voltage limiters and surge suppressors for a voltage > 1 kV
27122130	Fuses for a voltage <= 1 kV and for a current <= 10 A
27122150	Fuses for a voltage <= 1 kV and for a current > 10 A but <= 63 A
27122170	Fuses for a voltage <= 1 kV and for a current > 63 A
27122230	Automatic circuit breakers for a voltage <= 1 kV and for a current <= 63 A
27122250	Automatic circuit breakers for a voltage <= 1 kV and for a current > 63 A

Table 14: Quantities of RoHS substances released to the environment in 2044 without RoHS II implementation, due to end-of-life management options

Substance	Released to	Quantity (in kg)
Cadmium	Air	0
Chromium VI		0
Lead		0.8745
Mercury		0
Cadmium	Water	0
Chromium VI		0
Lead		26.279
Mercury		0

Table 15: Characterisation factor of the RoHS substances (USEtox™ method)

Substance	Type of emissions	Human toxicity midpoint, cancer effects (in CTUh/kg)	Human toxicity midpoint, non-cancer effects (in CTUh/kg)	Ecotoxicity freshwater midpoint (in CTUe/kg)
Lead	Emissions to air, unspecified	2.69E-05	9.44E-03	1.75E+02
	Emissions to water, unspecified	3.42E-07	1.20E-04	3.75E+02
Mercury	Emissions to air, unspecified	7.06E-03	8.35E-01	1.22E+04
	Emissions to water, unspecified	1.20E-04	1.42E-02	2.21E+04
Chromium VI	Emissions to air, unspecified	4.45E-03	4.16E-04	4.20E+04
	Emissions to water, unspecified	1.06E-02	2.40E-05	1.05E+05
Cadmium	Emissions to air, unspecified	2.17E-04	4.55E-02	3.94E+03
	Emissions to water, unspecified	1.59E-06	4.27E-04	9.71E+03

Table 16: Impact assessment results (USEtox™ method)

Impact indicator (unit)	Avoided impacts in 2044 in EU-27, with RoHS II implementation (in impact indicator unit)	Avoided impacts in 2044 in EU-27, with RoHS II implementation (in % of annual EU-27 impacts)	USEtox™ normalisation factors (in impact indicator unit per person per year)
Human toxicity midpoint, cancer effects (in CTUh)	3.25E-05	0.00000020%	3.25E-05
Human toxicity midpoint, non-cancer effects (in CTUh)	1.14E-02	0.00000279%	8.14E-04
Ecotoxicity freshwater midpoint (in CTUe)	1.00E+04	0.00000000063%	3.18E+06

An EU-27 population estimate of 502m inhabitants in 2011 is used for the normalisation (source: Eurostat, in March 2012).

Gas water heaters

Important note: In this factsheet, the product group gas water heaters will always refer to such products having at least one electric or electromagnetic function that are not part of a large-scale fixed installation.

1.1 Issues to explore

Gas water heaters were not in scope of the COM recast proposal but do fall within the scope of RoHS II. In this factsheet, it will be explored what the impact of this change is and whether the benefits of the inclusion of gas water heaters in RoHS II outweigh the potential costs.

1.2 Background

A water heater is defined as an appliance designed to provide hot sanitary water. It may (but need not) be designed to provide space heating or other functions as well[1]. Hence, a distinction can be made between **dedicated water heaters**, specifically designed and used to provide hot sanitary water, and **water heaters part of combi-boilers** (also referred to as "combination heaters"). A combination boiler is a space heating boiler with the capability to provide domestic hot water directly, in some cases containing an internal hot water store. **The electronics and RoHS substances content of these boilers is likely to be similar to the designs used for dedicated gas water heaters.** Water heaters that are part of combi-boilers are not considered in the following analysis and it is estimated that similar conclusions would apply to them.

Dedicated water heaters can use different types of energy, the main ones being: electricity[2]; gas; oil; coal; and biomass. Oil-fired, coal-fired and biomass dedicated water heaters are very rare in Europe[3,1].

Two main types of technology are available for gas-fired water heaters[1] (either dedicated or part of combi-boiler):

- Direct/instantaneous gas water heaters: A water heater without an internal hot water store or with an internal hot water store of capacity less than 15 litres (for gas- or oil-fired heaters). Water is heated on demand. They can be segmented according to water flow rate (5-10 L/min, 10-13 L/min, >13 L/min). Truly instantaneous dedicated water heaters are typically used as single-point

[1] Preparatory study on water heaters in the context of the Ecodesign Directive (2009/125/EC), VHK (2007). Available at: www.ecohotwater.org

[2] Electric water heaters are already in the scope of RoHS I and are therefore not further analysed in this impact assessment

[3] Almost non-existing for coal-fired.

appliances, dedicated to a kitchen or bathroom (especially with a flow rate of <10 L/min).

- Storage water heater: A water heater with an internal hot water store with a capacity of at least 15 litres. Storage water heaters are typically multi-point appliances although single-point variations do occur. They offer high domestic hot water performance (in l/min) and recovery rates (l/hr at given temperature difference). Most storage water heaters are essentially storage cylinders with a burner/heat exchanger built into the appliance. The basic principle is fairly simple and robust and the product may last for decades with adequate maintenance (i.e. corrosion protection for storage tank).

Gas being the primary energy of gas water heaters, not all of these products do necessarily include electric or electromagnetic functions. Table 1 describes the most common electric/electronic functions that they may contain. The presence of these functions can be dependent on the type of gas water heater considered:

- Type A gas water heaters are systems that do not use chimneys for flue gases;
- Type B devices use a chimney for the flue gases and take the combustion air from the indoor water heater room;
- Type C gas water heaters ('room-sealed') use a chimney too but take the combustion air from the outdoors.

Instantaneous water heaters are still available in a type A configuration (which emits flue gases in installed space), although type B or C are recommended by legislators and installers for health, safety and efficiency reasons.

Regarding ignition, two technological options exist: electronic (through glowing plug or spark plug) or pilot flame. Except in some dedicated instantaneous gas water heaters, the pilot flame for ignition is almost extinct in new water heaters.

Table 1: Description of the electric/electronic functions found in different types of gas water heaters

	Instantaneous gas water heaters	Storage gas water heater
Without electric/electronic functions (not within the scope of this impact assessment)	Only possible in types A-B: The simplest gas-fired water heaters (type A or B, with pilot flame and hydraulic control) do not use auxiliary energy (pilot flame left aside at ignition). They can be powered by a small water turbine, driven by the flow of the water.	Only possible in types A-B: Simple types A-B gas storage water heaters equipped with a pilot flame (ignited manually) and a gas valve operated by the thermostat do not require electricity.
With electric/electronic functions (within the scope of this impact assessment)	Type C water heaters use electronic (piezo) ignition and require electric mains connection or batteries to ignite. Also, fan-assisted water heaters are always connected to the electric mains. These belong to types B or C.	In type C heaters (all fan-assisted, requiring electricity), typical electric/electronic functions are: - Burner control, including connection to ionization electrode (to detect ignition); - Gas valve (operates gas supply, works with solenoid valve); - Pressure differential sensor (checks airflow); - Fan (controlled by burner control); - Thermostat (temperature thermostat and safety thermostat). - Switches, control lights, etc. Also, type B heaters can be fan-assisted and consequently require electricity.

Source: based on Preparatory study on water heaters in the context of the Ecodesign Directive (2009/125/EC), VHK (2007)

Consequently, all type C gas water heaters and a certain share of types A-B gas water heaters (in particular, all those with fans or electronic ignition functions) contain at least one electric or electronic function and are considered within the scope of RoHS II and this impact assessment.

1.2.1 Legal background

Large household appliances constitute category 1 of the WEEE Directive (2002/96/EC). As a result, electric water heaters were already included within the scope of RoHS I. Due to the new and broader definition of EEE in RoHS II[4], as from 22 July 2019, gas water heaters that require electricity for any of their functions will fall in the scope of the RoHS II Directive[5]. The RoHS II substance restrictions will apply to all components, also non-electrical ones, on the homogeneous material level.

[4] Art. 3.2: 'needing [electricity] to fulfil at least one intended function'
[5] In Category 1 of Annex I

Some electrical functions (such as the spark plug ignition system) may be subject to exemptions from RoHS II depending on their voltage (Art. 3.1). However, even if the electric spark function, which requires a high voltage to be produced, may be affected by Art. 3.1, it is normally obtained from a lower voltage source via an ignition coil which is not subject to Art 3.1. This assessment will consider the strictest possible definition of the product group: all gas water heaters equipment with at least one electric or electromagnetic function, even if this is only the spark plug ignition system.

1.2.2 Quantities and hazardous substances

Regarding market figures, Eurostat indicates 6 millions of products sold in 2010[6], for the category 27521400 "Non-electric instantaneous or storage water heaters". However, figures are lacking for some large Member States, such as Germany or the UK and no figures are available providing import and export quantities. The preparatory study on water heaters[7] stressed the limited reliability of this data and relied on other estimates. It provides the following figures for the EU-22 in 2005: the total sales of water heaters were 17.2 million units, of which 10.4 million dedicated water heaters. Amongst these dedicated water heaters representing a stock of 146 million appliances in 2005, 8.3 million were electric while 2.1 million were gas-fired. These dedicated gas-fired water heater sales were split into:

- 1.85 million gas instantaneous types; and
- 0.23 million gas storage types.

Table 2 shows a more detailed split of storage type sales, according to the flue type. Figures in 2010 were estimated by the preparatory study (published in 2007) based on market trends.

Table 2: Gas water heaters sales in thousand units, in EU-22

	2000	2005	2010
Gas instantaneous	1 972	1 849	1 734
Gas storage	291	234	208
Open Flue	216	126	69
Fan Flue	69	97	118
Total gas water heaters	2 263	2 083	1 942

Source: Preparatory study on water heaters in the context of the Ecodesign Directive (2009/125/EC), VHK (2007).

Despite the long term annual growth rate of 1.5% for the water heaters sales (over 1990-2005), the market for dedicated gas water heaters was in decline in 2005. At the time the preparatory study was carried out, it was expected that this trend would be a lasting one: dedicated gas water heaters represented 12.7% of the water heater market in 2005 while a decreased share of 9.1% was

[6] Extracted on 8th March 2012, at: http://epp.eurostat.ec.europa.eu/portal/page/portal/prodcom/data/database

[7] Preparatory study on water heaters in the context of the Ecodesign Directive (2009/125/EC), VHK (2007). Available at: www.ecohotwater.org

expected for 2010[8]. Only the very small group of condensing storage water heaters was expected to increase its market share between 2005 and 2010.

Based on these EU-22 figures (excluding Cyprus, Malta, Luxembourg, Romania and Bulgaria) and on the slight decline of the dedicated gas water heater market still ongoing, the Association of the European Heating Industry (EHI) estimated that the current annual sales of dedicated gas water heaters represent approximately 2 million units in the EU-27 in 2010.

Table 3 and Table 4 give an additional breakdown of the dedicated gas water heater sales by capacity.

Table 3: Storage gas water heaters sales in 2005, by storage volume

Typical Storage volume (in L)	80	120	150	250
Sales (in thousand units)	112	54	33	35

Source: Preparatory study on water heaters in the context of the Ecodesign Directive (2009/125/EC), VHK (2007).

Table 4: Instantaneous gas water heaters sales in 2005, by flow rate

Flow rate at ΔT 40°C (in L/min)	5-10	10-13	>13
Sales (in thousand units)	266	1 253	330

Source: Preparatory study on water heaters in the context of the Ecodesign Directive (2009/125/EC), VHK (2007).

According to stakeholders, traditionally the great majority of instantaneous gas water heaters are type B[9] . However, fanned flues were progressively introduced during the 1990s and the situation differs significantly depending on Member States: e.g. 30-40% of water heaters were type C in Italy in 2006, while Type C was predominant in the UK at the time. Regarding storage water heaters in particular, Table 2 shows that at least 118 out of 208 thousand products (i.e. 56%) have an electric function (fan) in 2010. No other specific information was received so far on the share of dedicated water heaters including electric and electronic functions. Given these minimum percentages and the fact that only the simplest gas water heaters (belonging to types A-B, without fans or electronic ignition function) do no present any electric function, this work will be based on the assumption that **80% of all dedicated water heaters are considered within the scope of RoHS II. Consequently, the current annual sales of dedicated gas water heaters with an electric or electronic function represent approximately 1.6 million units in the EU-27 in 2010.** Please note that this figure presents high uncertainty.

Concerning the hazardous substances found in these products, EHI indicated that some manufacturers are already RoHS I compliant, which means there does not seem to be particular technical limitations to substitute the six hazardous substances.

Table 5 lists the presence of the different hazardous substances considered by RoHS II. The total quantity of lead is assumed to be used in solder. Lead-free solders are either tin/copper or

[8] Preparatory study on water heaters in the context of the Ecodesign Directive (2009/125/EC), VHK (2007). Available at: www.ecohotwater.org
[9] Type B devices use a chimney for the flue gases and take the combustion air from the indoor water heater room.

tin/silver/copper. Both have higher melting points and tin/silver/copper solder has a significantly higher cost due to its silver content.

Table 5: RoHS substances in gas water heaters

Substance	Presence in gas water heaters
Lead	2 g in solder, per product[10]
Mercury	No
Cadmium	Unknown, but not expected (most likely uses already banned by REACH)
Hexavalent Chromium	Yes, on screws and other steel parts for corrosion protection. Estimation: up to 200 µg per product
Polybrominated biphenyls (PBB)	No
Polybrominated diphenyl ethers (PBDE)	Possible but amount unknown

1.2.3 Policy options

The objective of both, the RoHS recast proposal (COM (2008) 809 final) as well as RoHS II (2011/65/EU) is to contribute 'to the protection of human health and the environment, including the environmentally sound recovery and disposal of waste EEE'[11].

The purpose of this work is to look at the impacts of gas water heaters falling under the scope of RoHS II compared to gas water heaters being excluded from the COM recast proposal. Policy options will then be evaluated according to their effectiveness, efficiency and coherence in reaching the above-mentioned overall objective of the RoHS Directive. The policy options analysed are the following:

OPTION 1 (baseline scenario): The COM recast proposal. Gas water heaters are not in scope of the recast Directive.

OPTION 2: RoHS II. Gas water heaters are included in the scope of the recast Directive.

[10] Typical Printed Circuit Boards (PCBs) in gas water heaters are intermediate in size and a complexity between printer and PC PCBs. The VHK Lot 2 preparatory study (2007) found that electronics is between 94 g and 117 g for storage gas water heaters, and 144 g and 335 g for instantaneous gas water heaters: we assume an average of 200 g. Several publications indicate that the lead content of PCBs ranges from ~0.2% to 2% so we estimate that the average lead content for gas water heater electronics is 1%, i.e. 2 g.

[11] 2011/65/EU, Article 1

1.3 Impacts of policy options

1.3.1 Impact indicators

The following impact indicators have been chosen as relevant for this product group (see Table 6).

Table 6: Impact indicators for the product group gas water heaters

Impact indicators		
Environmental	Economic	Social
Energy use	Functioning of the internal market and competition	Employment
Air quality	Competitiveness	Health
Renewable or non-renewable resources	Costs and administrative burdens	Social impacts in third countries
Waste production / generation / recycling	Innovation and research	
Likelihood or scale of environmental risks	Consumers and households	
International environmental impacts		

The following legend will be used in summarising the impacts:

Legend	
+++	Very beneficial effect
++	Substantial beneficial effect
+	Slight beneficial effect
=	No effect
-	Negative effect
--	Substantial negative effect
---	Very negative effect
?	Unknown effect

1.3.2 Environmental impacts

The most important stakes regarding the environmental impacts in the context of RoHS are related to the quantities of hazardous substances used in the equipment. The mere quantity of a substance is however not sufficient to estimate what will be the actual impacts of the substance on the environment and health. These depend upon numerous factors such as the effective treatment of products at the end-of-life, their design for the use phase or their potential emissions during the production phase. The impact of the substances released to the environment is also determined by case-specific and complex dose-response relationships.

It is therefore not straightforward to precisely estimate the environmental impacts due to the hazardous substances found in the products. Where possible, the following subsections will make the link between the quantities of hazardous substances in gas water heaters and their potential environmental impacts.

1.3.2.1 Energy use

Given the definition of this product group, all products are expected to consume energy during their operation. Gas-fired instantaneous water heaters are available in a wide capacity range, ranging from small 'geysers' of less than 10 kW, to bath water heaters of 40 kW, to very large industrial type water heaters of over 1000 kW[12]. The lower end of the range is intended for 'kitchen-sink only' whereas the higher end is found in wash down and process use in the food industry, hotels, sports and leisure centres, universities, colleges and hospitals, etc.

Gas-fired storage water heaters are produced with a wide range of burner output power (from < 5 kW to > 180 kW), and storage volumes[12]. The average recommended storage temperature is 60ºC, although higher temperatures can be supported but result in higher energy consumption.

Storage and instantaneous dedicated gas water heaters account together for 16.4% of the net energy use in households of all types of water heaters. Table 7 and Table 8 show the typical total energy consumption of gas water heaters over their use phase, by capacity.

Table 7: Energy consumption of instantaneous gas water heaters due to the use phase, over the product lifetime

Max heat power output (in kW)	9.4	17.5	21 - 27	40
Gross Energy requirement (in GJ)	3 785	1 809	2 217 – 5 164	5 770
Overall efficiency[13]	12%	25%	37%	44%

Source: Preparatory study on water heaters in the context of the Ecodesign Directive (2009/125/EC), VHK (2007).

[12] Preparatory study on water heaters in the context of the Ecodesign Directive (2009/125/EC), VHK (2007). Available at: www.ecohotwater.org

[13] Ratio between the energy contained in the primary energy source, and the energy actually contained in the heated water.

Table 8: Energy consumption of storage gas water heaters due to the use phase, over the product lifetime

Typical Storage volume (in L)	80	120	150	250
Gross Energy requirement (in GJ)	7 418	8 889	11 227	13 266
Overall efficiency	17%	29%	37%	41%

Source: Preparatory study on water heaters in the context of the Ecodesign Directive (2009/125/EC), VHK (2007).

In absence of specific data or feedback from stakeholders on this point, it is assumed that the presence of the hazardous substances considered in RoHS II does not have any influence on the energy use and efficiency of the gas water heaters.

The European Commission impact assessment accompanying the RoHS recast proposal[14] states that the substitution of lead solder by lead-free solder might lead to an increase in energy consumption during the production phase because of a higher melting point. The additional energy consumption will vary widely depending on the solder type, the equipment specifications and process operating parameters employed by the facility. Nevertheless, it is generally accepted that lead-free soldering requires approximately 15% more energy than tin/lead (SnPb) soldering when comparing equivalent soldering technology for the two types of alloy and the following calculations will be based on this assumption. Based on a typical solder reflow oven to make the small PCBs on which the lead is found in gas water heaters, the total additional energy required for lead-free solders represents 16.5 MWh per year [15]. Compared to a total EU final energy consumption of 13.6 million PWh[16], this impact of additional energy required is regarded as negligible on this environmental impact indicator. The additional energy consumption will have an additional cost of 1 500 €[17], which is negligible compared to other technical costs (see section 1.3.3.3). Additional CO_2 emissions due to a change from tin/lead solder to lead-free solder represent 6.5 tonnes CO_2 eq[18].

The inclusion of gas water heaters within the scope of RoHS II should therefore have no impact on the energy use indicator.

1.3.2.2 Air quality

For type A gas water heaters, combustion gases may come inside the house as there is an open connection between the burner and the room. Emissions of air pollutants from the combustion process are carbon dioxide (CO_2), nitrogen oxides (NO_x), carbon monoxide (CO) and partially burnt hydrocarbons (HC). CO_2 emissions (as well as water vapour) are unavoidable products from the combustion reaction. The other carbon-containing compounds are a consequence of incomplete

[14] European Commission (2008), SEC(2008) 2930. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=SEC:2008:2930:FIN:EN:PDF

[15] A typical solder reflow oven operates 16 hours per day, 5 days a week, 49 weeks per year and on average consumes 13.9 kWh for SnPb and 16kWh for lead-free. It is assumed that one oven can produce 300 PCBs per hour or 1 million per year (25 PCBs made in a panel every 5 minutes) as these PCBs are small. The total number of units to be made are approximately 1.6 million units.

[16] 1168.63 Mtoe, European Commission, *EU transport in figures, statistical pocketbook 2011*, accessed at http://ec.europa.eu/transport/publications/statistics/doc/2011/pocketbook2011.pdf

[17] Average EU industrial electricity price = 0.093 €/kWh in 2011 according to Eurostat.

[18] Based on 0.39 kgCO_2 eq/kWh from Eurelectric

combustion (in particular due to the lack of sufficient air/oxygen) while NO_x comes from chemical reactions between air molecules triggered by the specific combustion conditions.

Despite the existence of European harmonised standards, there are currently no mandatory measures regarding indoor emissions of water heaters, neither at the EU level, nor at Member State level for individual products (apart from some national type approval requirements on NO_x-levels)[12].

In absence of specific data or feedback from stakeholders on this point, it is assumed that the presence of these hazardous substances does not have any influence on the emission levels of the devices, as the substances have not been explicitly found in emission-limiting features. The inclusion of gas water heaters within the scope of RoHS II should therefore have no impact on this environmental indicator.

1.3.2.3 Renewable or non-renewable resources

Gas water heaters can function with natural gas, LPG (Liquified Petroleum Gas), or biogas even if rare. The two first combustibles are coming from non-renewable resources while the latter one comes from renewable resources. The analysis of the RoHS substances in gas water heaters does not establish a link between the presence of the six hazardous substances and the type of combustible. Therefore, the implementation of RoHS II is not expected to have an influence on the types of gas used, and on the renewable or non-renewable resource use.

As presented in section 1.2, different sources of energy can be used in water heaters. Electricity and gas are by far the most commonly used sources in the EU-27. Solar energy can also be used through solar thermal technologies. In case of possible market distortion following the implementation of RoHS II for gas water heaters, the balance between the different energy sources may slightly change (e.g. if electric water heaters benefit from a purchase price increase of gas water heaters). At this point, it is difficult to assess what changes would occur in terms of renewable versus non-renewable resource consumption: This depends on future market shares of each energy source and the share of electricity coming from renewable sources is country (and even region) dependent, so that no obvious trend can be drawn.

1.3.2.4 Waste production / generation / recycling

According to the Ecodesign preparatory study, there is a considerable spread in product life per type, but **the estimated average product life is 15 years for dedicated water heaters**[12].

Furthermore, a default scenario from the simplified LCA tool (called EcoReport) is used for the end-of-life management. This scenario assumes that 5% of the products are landfilled, that 95% of metals and glass are recycled, and that a certain share of plastics and Printed Wiring Boards (PWB) not re-used/recycled are incinerated. No specific information on the end-of-life management of gas water heaters was found or received from stakeholders. Given the fact that gas water heaters are large appliances normally installed and removed by professionals[19], a high recycling rate is indeed

[19] Due to the local regulations governing the safety of gas supplies

very likely. Because of the high metal content in water heaters, most of the metals are likely to be recovered with a high yield. A small proportion will probably be landfilled and as they are too large to be disposed of in municipal waste, very few will be sent to municipal incinerators. The analysis will assume the following end-of-life rates (see Table 9): 90% recycling, 2% incineration and 8% landfill.

Depending on the quality of the end-of-life operations, a certain share of the substances (called the leaching potential) is always lost to the environment. According to BIO (2008)[20], process control of landfills and incinerators, alongside mineralization mechanisms in landfills, are some of the options to reduce this share. But there is limited quantitative data about the fate of hazardous substances going through land filling or incineration processes, in particular their leaching potential.

Policy Option 2 (including this type of equipment in the scope of RoHS II) would progressively (over a 15 year period[21], between 2019 and 2034[22]) decrease the quantities of hazardous substances from gas water heaters found in the waste streams, compared to the baseline scenario. The reduction of these substances may have a beneficial effect on their end-of-life treatment. This effect is dependent on the development of the waste management sector as a whole.

Table 9 shows the estimations used to calculate the environmental impacts of RoHS hazardous substances released into the environment at the end-of-life. The assessment is likely to contain high uncertainties because of the assumptions made to model the end-of-life options.

Table 9: Heavy metal emissions, by end-of-life management options

End-of-life process	Share of total end-of-life products (in %)	Emissions to air during end-of-life process	Emissions to water during end-of-life process	Source of the emissions estimates
Recycling	90%	0.001%	0.059%	COWI (2002)[23]
Incineration	2%	0.5%	2.49%	ERM (2006)[24]
Landfill	8%	-	5%	ERM (2006)

By considering the annual sales and substance quantities presented in section 1.2.2, it is estimated that 3.2 tonnes of lead and 0.32 kg of hexavalent chromium would be sent annually into the end-of-life management circuit from 2034[25] if the product group was not included within the scope of RoHS II. For Option 2, it is assumed that all lead and all Cr VI coatings would be removed from the products from 2019, so that none of these substances would go to the waste streams from 2034. For those water heaters manufactured in the EU-27, the use of Cr VI may decline prior to 2019 because of authorisation requirements for the use of Cr VI chemicals under the REACH Regulation.

[20] BIO (2008), Study to support the impact assessment of the RoHS review – Final Report, for DG ENV.
[21] Estimated lifetime of the equipment
[22] Possibly earlier if manufacturers take early measures.
[23] COWI (2002), Heavy Metals in Waste – Final Report, for European Commission DG ENV. Applicable to lead, assumed to be the same for other heavy metals
[24] ERM (2006), Battery Waste Management Life Cycle Assessment – Final Report.
[25] 15 years (the lifetime of the product) after the effective implementation of RoHS II.

Based on these assumptions, the ecotoxicity freshwater midpoint indicator was calculated[26] in order to illustrate the avoided impacts for the end-of-life, of the inclusion of gas water heaters within the scope of RoHS II, in 2034. This indicator was chosen because the release of RoHS hazardous substances in the environment has an influence on its value (this is not the case for Global Warming Potential for instance).

Table 10: Avoided freshwater ecotoxicity impacts by Option 2, compared to Option 1

Year[27]	Ecotoxicity freshwater midpoint (CTUe[28])
2034	6.26 E+03

This result in 2034 represents 0.0000000004% of the overall freshwater ecotoxicity annual impact in the EU-27 (USEtox™ normalisation values). Details of the calculations are given in Annex.

In theory, end-of-life impacts also depend on the possible substitutes that would replace the six hazardous substances. A similar quantitative analysis could not be done by considering the impact of the substitution of lead solder by lead-free solder, as the most suitable substitutes are not known yet. Still, some substitutes are likely to leach hazardous substances into the environment too, even if lead is the most toxic alloying element: silver or antimony represent a potential source of toxicity in leachates when used in alloys, while bismuth, indium and copper are regarded as less dangerous[29]. Obviously, the levels of emissions depend on the specific environmental conditions the waste will be exposed to during the end-of-life management. Another source[30] builds a comparative analysis of lead-free solder, by taking into account toxicity, availability and environmental impact of extraction of substitutes to lead in solder alloys. Based on this, only tin and copper appear to have a lower overall impact than lead. These outcomes have to be considered with caution given the subjective assessment grid. Finally, a comparative life cycle assessment[31] also illustrates that depending on the environmental impact considered, either lead solder or one substitute (bismuth-tin-silver or copper-tin) can be best performing.

1.3.2.5 Likelihood or scale of environmental risks

In absence of specific data or feedback from stakeholders on the presence of RoHS substances in safety feature components of gas water heater, RoHS II implementation is not expected to have any influence on the likelihood of accidents during the functioning of gas water heaters. Impacts of RoHS II implementation on this environmental indicator are consequently expected to be negligible.

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[26] According to USEtox™ methodology.
[27] RoHS II coming into force for this product group (2019), plus one product lifetime (15 years)
[28] Comparative Toxicity Unit ecotoxicity, equivalent to PAF.m3.day
[29] Edwin B. Smith III, Environmental Impacts and Toxicity of Lead Free Solders: http://leadfree.ipc.org/files/RoHS_16.pdf
[30] Anna Kua, Prof. Oladele Ogunseitanb, Prof. Jean-Daniel Saphoresc. Lead-Free Solders: Issues of Toxicity, Availability and Impacts of Extraction: http://trs-new.jpl.nasa.gov/dspace/bitstream/2014/6388/1/03-0222.pdf
[31] EPA (2005), Solders in electronics: a life-cycle assessment. Available here: http://www.epa.gov/dfe/pubs/solder/lca/lfs-lca-final.pdf

1.3.2.6 International environmental impacts

Most gas water heaters will be removed from buildings by professionals and most will be sent on to metal recyclers because of their high metal content. These organisations may, however, export this waste for recycling, sometimes illegally by shipping it to developing countries where unsafe processes are used. Concerning the production phase, electronic components are mostly manufactured outside the EU-27 (e.g. in China) so that the ban of the hazardous substances might have positive effects in extra-EU countries involved in components manufacturing. The overall effect is expected to be relatively low, given the limited amount of electronics in gas water heaters, but it nonetheless contributes to an improvement of the supply chain in general.

1.3.2.7 Overview of environmental impacts until 2034 and beyond

Based on the above, positive environmental impacts can be expected from gas water heaters falling in the scope of RoHS II, even if rather limited.

Table 11: Estimated environmental impacts

Estimated environmental impacts until 2034[32]		
	2012	**2034**
Energy use	=	=
Air quality	=	=
Renewable or non-renewable resources	=	=
Waste production / generation / recycling	=	+
Likelihood or scale of environmental risks	=	=
International environmental impacts	=	=/+

[32] RoHS II coming into force for this product group (2019), plus one product lifetime (15 years)

1.3.3 Economic impacts

Table 12 indicates average product prices by type of gas water heater and by size. Prices range from € 240 to € 1250.

Table 12: Typical weights and prices of dedicated gas water heaters

	XS	S	M	L	XL	XXL	Average[33]
Gas storage water heaters							
Storage volume (in L)			80	120	150	250	
Weight (in kg)			50	75	95	120	
Price (in €)			400	600	750	1 250	661
Gas instantaneous water heaters							
Max test flow rate (ΔT 45°C) (in L/min)	4	5	6	10			
Weight (in kg)	9.5	13	16-20	22			
Price (in €)	240	240	350	600			358

Source: Preparatory study on water heaters in the context of the Ecodesign Directive (2009/125/EC), VHK (2007)

1.3.3.1 Functioning of the internal market and competition

There are numerous manufacturers and brand names of gas water heaters. RoHS II should affect all gas water heater manufacturers in the EU-27 equally, which means that no competitive pressures within the European Union should be expected.

1.3.3.2 Competitiveness

No specific figures were found or received from stakeholders regarding international trade (imports and exports) of gas water heaters.

For non-RoHS compliant manufacturers, the ban of the RoHS hazardous substances in gas water heaters may result in some additional costs that could be passed on to the consumer in the end. Given the absence of technical limitations, or of important R&D to carry out, these consequences are not expected to represent a significant advantage to non-EU manufacturers outside the EU, all the more that RoHS compliance might be regarded as an advantage by consumers. As within the EU market, all appliances will have to comply with RoHS, the same possible burden would apply to non-EU manufacturers willing to export to the EU market and it could be that these manufacturers would then manufacture and sell RoHS compliant products outside the EU as well. Assuming appropriate market surveillance, RoHS II implementation would not have any impact on international competition, as it is expected that the EU market represents a major market share for EU manufacturers.

[33] Based on sales percentages.

1.3.3.3 Costs and administrative burdens

Costs and administrative burdens will differ from manufacturer to manufacturer. Those who are already RoHS compliant will not suffer from any additional technical or operating costs. Only administrative burdens for RoHS compliance would be added.

According to the 2008 Impact Assessment accompanying the Commission's recast proposal[34], there is little experience of actual compliance costs for industry. For products currently included in RoHS, estimates are it would vary from 1-4% of turnover. Other surveys give an average overall cost related to RoHS of 1.9% of turnover (past costs and one-off future costs). The Consumer Electronics Association surveyed its members after they had converted their products to comply with RoHS by 2006. This survey found that transition costs were 1.1% for each of the previous 3 or 4 years leading up to 1 July 2006 and annual compliance costs have been on average 0.1% of turnover since. As these costs affect all manufacturers and importers equally, there is nothing to prevent them eventually passing on these costs to consumers as higher prices.

Assuming an average price of 661 € and annual sales of 166 400 (80% of 208 000 units) for typical storage gas water heaters, and an average price of 358 € and annual sales of 1 387 200 units (80% of 1 734 000 units) for typical instantaneous gas water heaters (see Table 2 and Table 12), the annual turnover of the whole sector is approximately 607 million €. Applying the 1-4% range, compliance costs would represent between 6.1 million € and 24.3 million € for all manufacturers.

The replacement of lead-solder by lead-free solder would also result in additional costs due to raw materials prices. With a quantity of lead in solders of 2 g per product, and annual sales representing 1.6 million products, lead solder constitute 5.45 tonnes of tin and 3.2 tonnes of lead per year. Assuming that 50% of the lead solder is replaced by tin/silver/copper solder, and 50% is replaced by tin/copper solder, 3.07 additional tonnes of tin and 0.13 tonnes of silver would be required to replace lead. Additional costs would then represent approximately 132 k€[35].

1.3.3.4 Innovation and research

The household appliances sector has been one of the most innovative sectors over the past decades. The fact that some manufacturers are already RoHS compliant shows that there are no fundamental functional limitations that would require the presence of hazardous substances in gas water heaters. The importance of continuous R&D in this very competitive sector is likely to facilitate the potential RoHS compliance of gas water heaters. In some instances, RoHS compliance was adopted by manufacturers producing both electric and gas-fired water heaters in order to reduce the complexity of the supply chain and of their production processes. Based on these facts,

[34] European Commission (2008), SEC(2008) 2930. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=SEC:2008:2930:FIN:EN:PDF

[35] Under the following assumptions: composition of tin/lead solder is 63%/37%; composition of tin/silver/copper solder is 97%/3%/0% (copper is neglected); composition of tin/copper solder is 99.3%/0.7%; prices of metals (LME): 1590€/tonne for lead, 16210 €/tonne for tin; 674000 €/tonne for silver; price of copper neglected; 1 g of tin/lead solder is assumed to be replaced by 1 g of tin/silver/copper solder or 1 g of tin/copper solder.

the inclusion of gas water heaters within the scope of RoHS II is expected to have a very limited positive, if any, impact on innovation and research.

1.3.3.5 *Consumers and households*

Table 12 shows the average purchase prices for gas water heaters by type and capacity. The ranges are 240 - 600 € for instantaneous water heaters and 400 – 1250 € for storage water heaters. It is difficult to predict the possible increase effect that RoHS II implementation would have on the final purchase prices. Given the estimated additional costs and administrative burdens (see section 1.3.3.3), if they are fully supported by the purchaser in the end, prices could be increased by around 15 € per product (2-4% of average product price).

1.3.3.6 *Overview of economic impacts until 2034*

Based on the above, economic impacts from gas water heaters falling in the scope of RoHS II are expected to be slightly negative in terms of costs and administrative burdens, which may also impact consumers and households.

Table 13: Estimated economic impacts

Estimated economic impacts until 2034		
	2012	**2034**
Functioning of the internal market and competition	=	=
Competitiveness	=	=
Costs and administrative burdens	=/-	-
Innovation and research	=	=/+
Consumers and households	=	-

1.3.4 Social impacts

1.3.4.1 *Jobs*

No data regarding people directly or indirectly employed by gas water heater manufacturers and installers in the EU was found or received by stakeholders.

The impacts of RoHS II on the jobs in the industrial sector could potentially be adverse, either because of a slight loss of competitiveness of gas water heaters versus electric water heaters (see section 1.3.3.2), or because of the possible phase-out of some products with electric functions for which no substitutes can be found. The latter is, however, not likely as some manufacturers are already RoHS compliant. Given that a number of manufacturers produce both electric and gas water heaters, this effect is expected to be limited, as the overall water heater sector follows an annual growth of 1.5%. Still, SMEs or exclusively gas water heaters manufacturers may suffer from more important impacts than larger companies.

1.3.4.2 Health

Water heaters deal with several health and safety considerations during their use phase given their primary functionality of providing hot sanitary water[36]:

- They play a role in scalding (a specific type of burning that is caused by hot fluids or gases);
- They are a potential source of thermophylic bacteria and legionellosis. In practice, this is however rarely the case and instantaneous water heaters are not concerned by this risk;
- Type A gas-fired water heaters placed inside the house are a potential source of CO-intoxication; and

The third bullet point has been addressed under section 1.3.2.2. Regarding the other bullet points, they are assumed not to be affected by the presence of RoHS substances as no specific information was found or provided by stakeholders on this issue.

Finally, the management during the end-of-life can result in important impacts on the environment and health. These impacts are dependent upon the management options followed by products, which have already been presented (see section 1.3.2.4). Based on the same assumptions regarding the emissions to air and water of the substances during recycling, incineration and disposal (see Table 9), health impacts can be quantified via the human toxicity indicators[37]: assuming the ban of RoHS hazardous substances in gas water heaters from 2019 (Option 2), a human toxicity impact of 3.22 E-05 CTUh (cancer effects) and 5.22 E-03 CTUh (non-cancer effects) would be avoided in 2034 (respectively 0.0000002% and 0.000001% of overall impacts in EU-27 annually), compared to Option 1, due to the removal of lead and chromium VI in coatings.

Table 14: Avoided human toxicity impacts by Option 2, compared to Option 1

Year[38]	Human toxicity midpoint, cancer effects (CTUh[39])	Human toxicity midpoint, non-cancer effects (CTUh)
2034	3.22 E-05	5.22 E-03

The monetised cost has been calculated by Defra (UK)[40] which looked at the costs in terms of health impacts of options for management of waste containing hazardous substances including lead. The

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[36] Preparatory study on water heaters in the context of the Ecodesign Directive (2009/125/EC), VHK (2007). Available at: www.ecohotwater.org

[37] USEtox™ method.

[38] RoHS II coming into force for this product group (2019), plus one product lifetime (15 years)

[39] Comparative Toxicity Unit human, equivalent to cases

[40] Enviros Consulting Ltd. For Defra, *Valuation of the external costs and benefits to health and environment of waste management options*, December 2004, table 3.2 and page 82)

study estimated health impacts from mathematical models of landfill and incineration and estimates of pollution from these disposal options. Applying these results to the heavy metal emissions per end-of-life treatment options (see Table 9), gives a monetised health benefit from not using lead of between €23,500 and €560,000[41].

1.3.4.3 *Social impacts in third countries*

Most gas water heaters will be removed from buildings by professionals and most will be sent on to EU metal recyclers because of their high metal content. These organisations may, however, export this waste for recycling, sometimes illegally by shipping it to developing countries where unsafe processes are used. The overall effect is expected to be relatively limited though, as low quantities are estimated to be exported.

1.3.4.4 *Overview of social impacts until 2034*

The social impacts of gas water heaters falling in the scope of RoHS II can be expected to be slightly positive given the health benefits, especially during the end-of-life phase of the products.

Table 15: Estimated social impacts

Estimated social impacts until 2034[42]		
	2012	**2034**
Employment	=	=/-
Health	=	+
Social impacts in third countries	=	=

1.3.5 Comparison of options

The inclusion of gas water heaters in the scope of RoHS II is expected to result in relatively limited impacts, both positive and negative. Due to the decrease of the use of the banned substances, environmental and health benefits are expected all along the lifecycle of the products, especially at the end-of-life. On the other hand, negative impacts are likely to occur due to additional costs, both for manufacturers and customers. Please note that the quantitative assessment of such impacts is highly uncertain and would be very variable for each manufacturer.

[41] Based on a monetised impact of lead between €1.46 million/tonne and €35 million/tonne, and assuming a 0.5% leakage rate of lead at the end-of-life.

[42] RoHS II coming into force for this product group (2019), plus one product lifetime (15 years)

Table 16: Comparison of options

Impact indicators	Option 1 : Gas water heaters excluded in COM recast proposal	Option 2: Gas water heaters in scope of RoHS II
Environmental impact indicators		
Energy use	=	=
Air quality	=	=
Renewable or non-renewable resources	=	=
Waste production / generation / recycling	=	+
Likelihood or scale of environmental risks	=	=
International environmental impacts	=	=/+
Economic impact indicators		
Functioning of the internal market and competition	=	=
Competitiveness	=	=
Costs and administrative burdens	=/-	-
Innovation and research	=	=/+
Consumers and households	=	-
Social impact indicators		
Employment	=	=/-
Health	=	+
Social impacts in third countries	=	=

In relation to the overall policy objective of RoHS II, namely to contribute 'to the protection of human health and the environment, including the environmentally sound recovery and disposal of waste EEE'[43], the discussion above shows that including gas water heaters in RoHS II does contribute to this objective, even if slightly:

[43] 2011/65/EU, Article 1

Table 17: Policy objectives and options

Policy options in relation to overall policy objectives			
	Effectiveness	**Efficiency**	**Coherence**
Option 1: Gas water heaters excluded in COM recast proposal	Negative: Hinders the objectives	Efficiency cannot be evaluated as the option does not contribute to the overall objectives	No unintended impacts
Option 2: Gas water heaters in scope of RoHS II	Positive: Contributes to reaching the objectives although amounts of RoHS substances are limited	Efficient as costs are expected to be limited.	Limited unintended impacts

Annexes

Table 18: Quantities of RoHS substances released to the environment in 2034 without RoHS II implementation, due to end-of-life management options

Substance	Released to	Quantity (in kg)
Cadmium	Air	0
Chromium VI		0.00003488
Lead		0.3488
Mercury		0
Cadmium	Water	0
Chromium VI		0.00160928
Lead		16.0928
Mercury		0

Table 19: Characterisation factor of the RoHS substances (USEtox™ method)

Substance	Type of emissions	Human toxicity midpoint, cancer effects (in CTUh/kg)	Human toxicity midpoint, non-cancer effects (in CTUh/kg)	Ecotoxicity freshwater midpoint (in CTUe/kg)
Lead	Emissions to air, unspecified	2.69E-05	9.44E-03	1.75E+02
	Emissions to water, unspecified	3.42E-07	1.20E-04	3.75E+02
Mercury	Emissions to air, unspecified	7.06E-03	8.35E-01	1.22E+04
	Emissions to water, unspecified	1.20E-04	1.42E-02	2.21E+04
Chromium VI	Emissions to air, unspecified	4.45E-03	4.16E-04	4.20E+04
	Emissions to water, unspecified	1.06E-02	2.40E-05	1.05E+05
Cadmium	Emissions to air, unspecified	2.17E-04	4.55E-02	3.94E+03
	Emissions to water, unspecified	1.59E-06	4.27E-04	9.71E+03

Table 20: Impact assessment results (USEtox™ method)

Impact indicator (unit)	Avoided impacts in 2034 in EU-27, with RoHS II implementation (in impact indicator unit)	Avoided impacts in 2034 in EU-27, with RoHS II implementation (in % of annual EU-27 impacts)	USEtox™ normalisation factors (in impact indicator unit per person per year)
Human toxicity midpoint, cancer effects (in CTUh)	3.22E-05	0.0000002%	3.25E-05
Human toxicity midpoint, non-cancer effects (in CTUh)	5.22E-03	0.000001%	8.14E-04
Ecotoxicity freshwater midpoint (in CTUe)	6.26E+03	0.0000000004%	3.18E+06

An EU-27 population estimate of 502 477 005 inhabitants in 2011 is used for the normalisation (source: Eurostat, in March 2012).

Electric Bicycles

Important note: In this factsheet, the product group electric bicycles will always refer to such two-wheel products that are not type approved.

1.1 Key issues

Electric bicycles were not considered in scope of RoHS I or the COM recast proposal by many stakeholders although some Member States did already require compliance under RoHS I. Article 2.4(f) of RoHS II excludes all means of transport for persons or goods, excluding electric two-wheel vehicles which are not type-approved. In other words, electric two-wheel vehicles that are not type-approved are now explicitly included in the Directive. In this factsheet it will be explored what the impact of this change is and whether the benefits of the inclusion of electric bicycles in RoHS II outweigh the potential costs.

Source: PRESTO Cycling Policy Guide, 2010

1.2 Background

Electric bicycles are a rapidly growing product group in Europe. They use a small electric motor with a rechargeable battery to assist the user in his effort. There are two main types of electric bicycles:[1]

- Pedelecs: The user needs to pedal for the motor to assist. A sensor is integrated in the vehicle and determines how much assistance to provide. The motor stops assisting automatically at 25 km/h and when the cyclist stops pedalling. The European market of electric bicycles consists almost exclusively (95%) of pedelecs and of these approximately 95% are two-wheeled.
- E-bikes: The user does not necessarily need to pedal for the motor to assist. The cyclist determines how much assistance is required and can operate this with a separate throttle on the handle bar.

Only pedelecs with a motor of a maximum continuous rated power of 0.25 kW whose output is continually reduced and finally cut off at a speed of 25 km/h is considered as a bicycle and does not have to be type-approved. As only non-type approved electric bicycles are in scope of RoHS II, it will only be these two-wheeled pedelecs that are subject to this assessment. This group includes approximately 95% of all electrically assisted bicycles. Only 5% of the market consists of more

[1] Why Cycle? Online, Electric Bikes, 2012, accessed at http://www.whycycle.co.uk/bike_styles/electric_bikes/

powerful and/or faster electrically assisted bicycles, bicycles with an auxiliary motor or other light electric vehicle that are subject to type-approval.[2]

Approximately 95% of pedelecs use a so-called hub motor located in the hub of either the front or the rear wheel. This is a space that is not normally used in conventional bicycles, which means that little engineering or design changes are needed and assembly and sourcing processes remain similar. Manufacturers of hub motors are largely based in Europe, Asia and North America.[3] Other electrical and electronic equipment in electric bicycles are the battery, display, sensors, controllers, and in some cases also the gear system.[4] According to manufacturers, all these electronic components are already RoHS compliant.

Research has shown that the majority of pedelecs users are those over 65 years old and commuters. The average age of pedelec buyers is, however, decreasing. Pedelec users cycle faster, more often and over longer distances while the use of conventional bicycles is generally limited to seven kilometre distances. Cargo bicycles are also on the increase, i.e. bicycles used not only to transport people but also goods, which suggests that these bicycles get other larger vehicles off the road.[5]

According to the Electric Bikes Worldwide Report (EBWR) 2011, the predominant drivers for buying electric bicycles are the following:

- Rising fuel and hence transportation costs
- Parking congestion in most urban areas in the world
- Increased urbanisation
- Increased government support

The last point, government support for electric bicycles, is increasing significantly. One example is the German 'electro-mobility model regions' (Modellregionen Elektromobilität) programme launched in 2009. As part of the programme the German Transport Ministry supports eight regions in the introduction of electric vehicles. Of these eight regions, four have planned activities involving pedelecs.[3] Another example is the Paris Council extension of subsidies on the purchase of electric scooters to electric bicycles in order to increase mobility and public health while decreasing air pollution and noise.

1.2.1 Legal background

Electric bicycles were not considered in scope of RoHS I or the COM recast proposal by many stakeholders although some Member States did already require compliance under RoHS I. No compliance tests have been carried out in the past, however, so that no data exists on actual compliance.

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[2] Stakeholder consultation contribution by ETRA, January 2012

[3] PRESTO Cycling Policy Guide, Give Cycling a Push, 2010, accessed at http://www.presto-cycling.eu/images/policyguides/presto_cycling%20policy%20guide%20electric%20bicycle.pdf

Electric bicycles with a motor of a maximum continuous rated power of 0.25 kW whose assistance is cut off at a maximum speed of 25 km/h are subject to the Machinery Directive 2006/42/EC, the Electromagnetic Compatibility (EMC) Directive 2004/108/EC, the Battery Directive 2006/66/EC and the CEN technical standard EN 15194.[6]

1.2.2 Quantities and hazardous substances

In 2011, an estimated 1.3 million electric bicycles were sold in the EU with an average retail price of €1,500. As a result, turnover was €1.95 billion. As a comparison, the EU market for conventional bicycles in 2010 was around 22 million bicycles sold at an estimated average value of €450, which results in a turnover of €9 billion.[7] Germany and the Netherlands are the biggest markets in electric bicycles while in a number of Member States, notably in Eastern Europe, they remain virtually inexistent.[8] The average product life of an electric bicycle is estimated at five to seven years[9] compared to approximately 15 years for a conventional bicycle. [10]

Regarding imports and exports, there are no exact statistics available. As Table 1, below, illustrates, China is by far the largest market worldwide with 31 million electric bicycles estimated to be sold in 2012, compared to 1.6 million in Europe.

Table 1: Worldwide electric bike sales (in thousands, estimates)

Year	2009	2010	2011	2012	2013
China	24,000	27,000	29,000	31,000	34,000
India	60	70	120	150	200
Japan	325	390	400	425,000	450,000
Europe	754	1,021	1,294	1,632	1,839
Taiwan	11	12	14	15	15
SE Asia	50	60	70	85	100
USA	70	80	100	120	150
TOTAL	**25,270**	**28,563**	**30,998**	**33,427**	**36,754**

Source: EBWR Global Volume Projections 2011

The large sales figures in China are, at least partially, due to the fact that a number of Chinese cities have legally banned petrol engine mopeds and scooters. The Chinese electric bicycle market is not dominated by pedelecs, like the European one, but by e-bikes that do not necessarily require the user to pedal to assist.[8]

Although some Member States already require compliance under RoHS I, no compliance tests have been carried out in the past. Therefore, no data has been gathered on the actual compliance of

[6] Stakeholder consultation contribution by ETRA, January 2012
[7] ETRA Statement on electric bicycles excluded from the type-approval falling in the scope of 2011/65/EU
[8] PRESTO Cycling Policy Guide, Give Cycling a Push, 2010, accessed at http://www.presto-cycling.eu/images/policyguides/presto_cycling%20policy%20guide%20electric%20bicycle.pdf
[9] Stakeholder consultation contribution by ETRA, January 2012
[10] Dave, Shreya, *Life Cycles Assessment of Transportation Options for Commuters*, 2010, Massachusetts Institute of Technology (MIT)

these products and which, if any, RoHS substances are actually present. According to the stakeholder enquiry, the six RoHS substances are not on the bill of materials list for electric bicycles in Europe so the focus would have to be on the supply chain. Even if not the final product is imported, many European producers source their parts in Asia, notably China, and only assemble the final product in Europe. As discussed above, electrical and electronic equipment in electric bicycles are the motor, battery[11], display, sensors, controllers, and in some cases also the gear system.[12] According to manufacturers, all these electronic components are already RoHS compliant.

Very little if no information exists on RoHS substances in the non-electric components of electric bicycles. Manufacturers have pointed out that electric bicycles are covered by REACH and that all substances are therefore covered. It is important to point out, however, that whilst REACH defines the regulation of substances, their use in preparations and in articles, their placement on the market and the assessment of risks, it does only ban the general use of substances in a few cases. RoHS is more specific in its application by restricting certain hazardous substances (a total of six as of June 2012) in electrical and electronic equipment. The fact that substances used in the non-electric components of electric bicycles are covered by REACH does therefore not mean that RoHS substances are non-existent in these components. In case of electric bicycles, two potential applications of cadmium have been banned under REACH, which are its use in brazing alloys and plastics.

Manufacturers contacted by ETRA (European Twowheel Retailers' Association) in this context stated that they are aware of RoHS and produce electric bicycles free of RoHS substances. This could not be verified within the scope of this work but it shows that even if none or not all manufacturers produce RoHS compliant electric bicycles, this kind of production is believed to be possible. Not one of the stakeholders mentioned that producing without RoHS substances would be impossible or even very costly.

As discussed above, with most electric bicycles the motor sits in the hub of either the front or the rear wheel. This means that very little design change is required from a conventional to an electric bicycle. It is therefore assumed that non-electric components of electric bicycles should be rather similar in nature to their conventional counterparts. Cadmium could be believed to be found in brazing alloys or plastic parts. Both applications have been banned under REACH though and RoHS II is therefore not believed to have a further impact on the use of this substance in electric bicycle components. Hexavalent chromium might be thought to be found in coatings to avoid rusting but bicycles tend to be either chromium metal plated or painted and in both applications hexavalent chromium is not used. It is, however, possible to find it in screws. Finally, lead might be found in solder in the wiring of electrical components, but manufacturers repeatedly assured that all electrical components are already RoHS compliant. Table 2, below, summarises this:

[11] The issue of hazardous substances in electric bicycle batteries is covered by the Battery Directive 2006/66/EC
[12] Stakeholder consultation contribution by ETRA, January 2012

Table 2: RoHS substances in electric bicycles

Substance	Presence in electric bicycles
Lead	No
Mercury	No
Cadmium	Potentially in brazing alloys and plastics – banned under REACH
Hexavalent Chromium	Possibly on screws for corrosion protection Estimation: 100 µg per product[13]
Polybrominated biphenyls (PBB)	No
Polybrominated diphenyl ethers (PBDE)	No

Source: Stakeholders enquiry; own estimations

1.2.3 Policy options

The objective of both, the RoHS recast proposal (COM (2008) 809 final) as well as RoHS II (2011/65/EU) is to contribute 'to the protection of human health and the environment, including the environmentally sound recovery and disposal of waste EEE'[14].

The purpose of this work is to look at the impacts of electric bicycles falling in scope of RoHS II compared to the prior situation where MS treated this product group differently. Policy options will then be evaluated according to their effectiveness, efficiency and coherence in reaching the above-mentioned overall objective of the RoHS Directive. The policy options analysed are the following:

OPTION 1 (baseline scenario): The COM recast proposal. No changes to RoHS I regarding electric bicycles, which means that Member States could be expected to treat this product group as they did under RoHS I.

OPTION 2: RoHS II. Electric bicycles that are not type-approved are included in the scope of the recast Directive.

[13] Based on information provided by stakeholders for petrol engine powered garden equipment, for which up to 200 µg are assumed. Due to less use of screws in electric bicycles and no use in the other steel parts 100 µg is assumed here.
[14] 2011/65/EU, Article 1

1.3 Impacts of policy options

1.3.1 Impact indicators

The following impact indicators have been chosen as relevant for this product group:

Table 3: Impact indicators for electric bicycles

Impact indicators		
Environmental	Economic	Social
The climate	Functioning of the internal market and competition	Employment
Transport and energy use	Competitiveness	Health
Air quality	Costs and administrative burdens	Social impacts in third countries
Renewable or non-renewable resources	Public authorities	
Waste production / generation / recycling	Innovation and research	
Noise emissions	Consumers and households	
International environmental impacts		

The following legend will be used in summarising the impacts:

Legend	
+++	Very beneficial effect
++	Substantial beneficial effect
+	Slight beneficial effect
=	No effect
-	Negative effect
--	Substantial negative effect
---	Very negative effect
?	Unknown effect

1.3.2 Environmental impacts

The most important stakes regarding the environmental impacts in the context of RoHS are related to the quantities of hazardous substances used in the equipment. The mere quantity of a substance is however not sufficient to estimate what will be the actual impacts of the substance on the environment and health. These depend upon numerous factors such as the effective treatment of products at the end-of-life, their design for the use phase or their potential emissions during the production phase. The impact of the substances released to the environment is also determined by case-specific and complex dose-response relationships. It is therefore not straightforward to estimate the environmental impacts due to the hazardous substances found in products. Where possible, the following subsections will make the link between the quantities of hazardous substances and their potential environmental impacts.

1.3.2.1 Transport and energy use

According to the European Commission's Statistical Pocketbook 'EU Energy and Transport in Figures', every European makes circa three trips a day of which approximately half are up to three kilometres long. Of all car trips, approximately half are six kilometres or shorter.[15] The average speed of an electric bicycle is 24 km/h compared to 17 km/h for a conventional bicycle. While conventional bicycle users tend to limit their trips to a seven kilometre maximum, 15 kilometres are a reasonable distance using an electric bicycle. Many of the shorter car trips could therefore be undertaken on an electric bicycle instead of a car. Different studies have shown the decrease in car kilometres by pedelecs users. The Swiss study 'Electric Two-Wheelers – Effects on Mobility' shows that the use of pedelecs resulted in 5.2% less car kilometres, for example.[15]

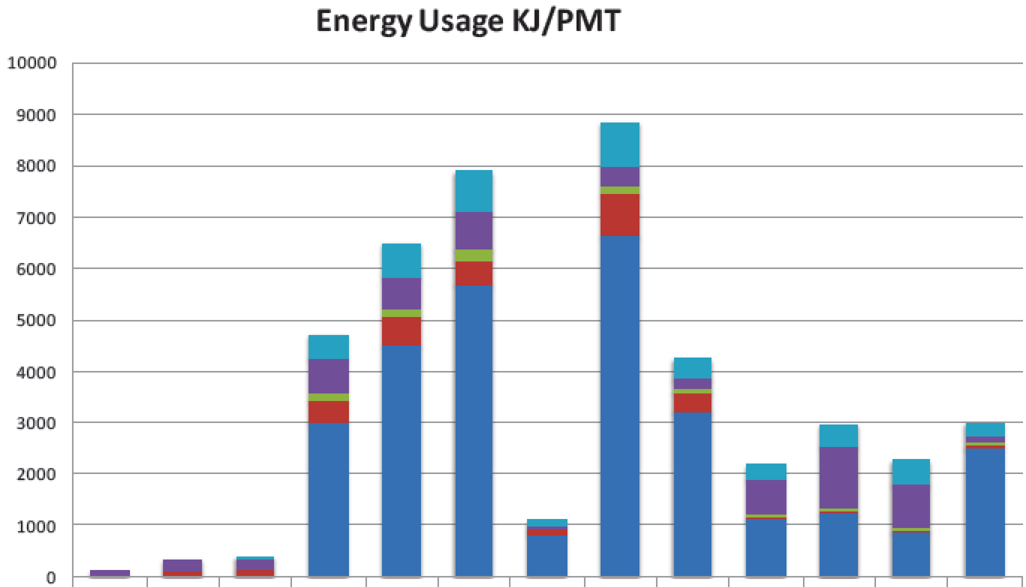
In the context of this work, a discussion on energy use of electric bicycles has to take into account other transport modes that would be the alternatives to electric bicycles. According to research conducted at the Massachusetts Institute for Technology (MIT), electric bicycles use less than 10% of the energy required to power a saloon car for each mile travelled.[16] This assessment takes into account the total energy input over a life of a vehicle including manufacturing and assembling as well as the construction and maintenance of the required infrastructure. It does not, however, take into account disposal at the end-of-life of the bicycle or vehicle. In another comparison of energy use of electric bicycles compared to cars, it is estimated that the 500,000 pedelecs sold in the EU in 2008 prevented the use of 38.25 million litres of petrol and saved 3.4 billion kWh electricity. While the fuel cost per kilometre for pedelecs would be € 0.00055 in 2009, it would be approximately €0.095 for a four-wheel combustion engine vehicle. [15]

Dave (2010), estimates that compared to a conventional bicycle, the energy usage over the product life cycles is 12% higher. She does, however, state that available data on this is limited and only little significance can be attributed to this result.[17] As an estimate this shows, however, that in terms of energy use conventional bicycles and electric bicycles are not expected to be significantly different.

[15] PRESTO Cycling Policy Guide, Give Cycling a Push, 2010, accessed at http://www.presto-cycling.eu/images/policyguides/presto_cycling%20policy%20guide%20electric%20bicycle.pdf

[17] Dave, Shreya, *Life Cycles Assessment of Transportation Options for Commuters*, 2010, Massachusetts Institute of Technology (MIT)

Figure 1: Energy usage of different transport modes



	Walking	Bicycling	Ebike	Sedan	SUV	Pickup	Bus on peak	Bus off peak	Bus Avg	BART	MUNI	Green Line	Boeing 737
Total	102	319	356	4694	6474	7914	1108	8837	4260	2187	2970	2270	2996
Fuel Production	0	0	2	430	640	810	110	840	400	274	418	487	250
Infrastructure	102	204	204	667	607	728	51	406	189	700	1233	829	119
Maintenance	0	9	9	184	180	208	18	144	68	41	51	54	56
Manufacturing	0	106	141	413	547	468	101	827	393	37	38	21	49
Operation	0	0	0	3000	4500	5700	828	6620	3210	1136	1230	879	2522

Source: Dave, Shreya, *Life Cycles Assessment of Transportation Options for Commuters*, 2010

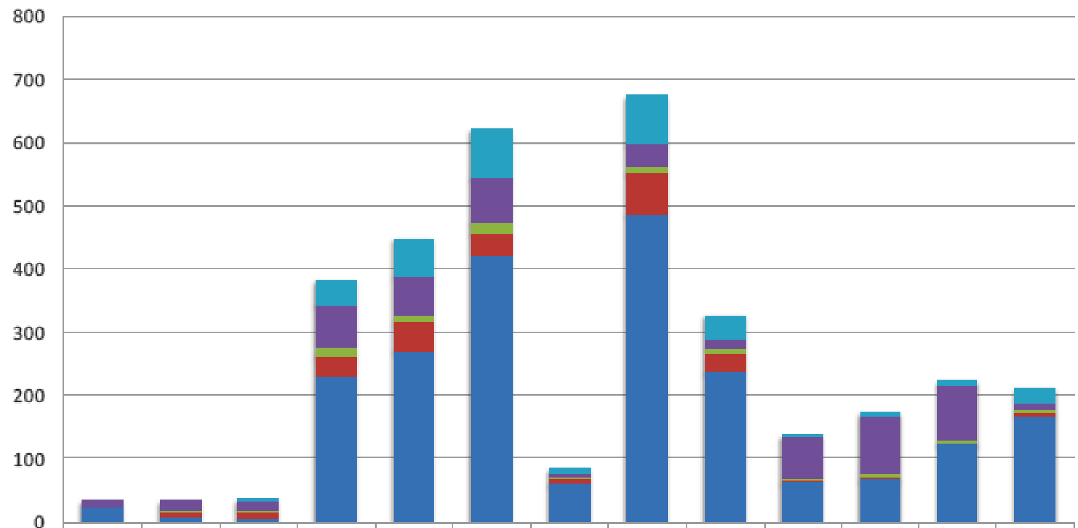
Using only 10% of the energy to power a saloon car, electric bicycles have significant potential in decreasing the energy consumed by the transport sector. Given the market development of electric bicycles in Europe, this influence is expected to become more significant over time. For this assessment, however, the question is whether the inclusion of electric bicycles in the scope of RoHS II would have an influence on this indicator. As the electric components in these bicycles are already RoHS compliant, no changes to these components would be required. As these are the components influencing the energy use of the electric bicycle, no impact is therefore expected. Another way of influencing this indicator would be if electric bicycles were sold in significantly lower numbers because of RoHS II, which would reduce the potential of this transport mode to contribute to an overall reduction in energy use by the transport sector. It is, however, not expected that RoHS II will lead to a significant reduction in the sales of electric bicycles in Europe (please see 'Economic impacts' below for more details). Overall, this indicator is therefore not expected to be influenced by the inclusion of electric bicycles in the scope of RoHS II.

1.3.2.2 *The climate*

Compared to a conventional bicycle, over the production and operation stage of the product the electric bicycle is not estimated to emit more greenhouse gases. While the electric bicycle requires more energy in its production and operation stage and emits the associated greenhouse gases, a conventional bicycle requires the user to breathe harder when cycling at a reasonable rate of 16 miles per hour. This breathing rate will be much higher than for an electric bicycle where the user is assisted in its effort by the motor.[18] Figure 2 presents greenhouse gas emissions in kg per passenger mile travelled.

Figure 2: Energy usage of different transport modes

Greenhouse gas emissions in kg GGE/PMT



	Walking	Bicycling	Ebike	Sedan	SUV	Pickup	Bus on Peak	Bus off Peak	Bus Average	BART	MUNI	Green Line	Boeing 737
Total	33	33	33	382	446	619	85	674	326	136	173	224	210
Fuel Production	0	0	0.33	39	58	74	10	77	36	3	4	8	23
Infrastructure	9	17	17	65	59	71	4	34	16	64	94	87	11
Maintenance	0	1	1	15	14	17	1	12	6	2	4	4	4
Manufacturing	0	8	11	34	45	38	8	66	31	2	2	1	4
Operation	24	7	4	230	270	420	61	486	237	64	69	123	168

Source: Dave, Shreya, *Life Cycles Assessment of Transportation Options for Commuters*, 2010

According to a study by New Ride, every electric bicycle on the road results in 900 less car kilometres per year. Even if the European Union goal of 120 g/km of CO_2 for new passenger cars is reached and all cars conform to this in the future, this would translate into a saving of 108 kg of CO_2 for each electric bicycle on the road.[19] For all 1.63 million bicycles estimated to be sold in Europe in 2012, this would come to a total of 176,000 tonnes of saved CO_2. In relation to the overall CO_2 emissions of the EU-27 in 2007[20], this translates to a total of 0.0004% of these emissions.

Regarding CO_2 emissions linked to the electricity needs of electric bicycles, this depends on the power supply used. According to a study, producing the energy to supply a 200 watt-hour battery allowing for a 60 km range will lead to zero CO_2 emissions in the best case scenario where only biomass is used to 0.17-0.2 kg CO_2 in the worst case scenario where coal is used instead. In case of

[18] Dave, Shreya, *Life Cycles Assessment of Transportation Options for Commuters*, 2010, Massachusetts Institute of Technology (MIT)
[19] PRESTO Cycling Policy Guide, Give Cycling a Push, 2010, accessed at http://www.presto-cycling.eu/images/policyguides/presto_cycling%20policy%20guide%20electric%20bicycle.pdf
[20] 4186.7 million tonnes. European Union, *EU Energy and Transport in Figures*, 2010, accessed at http://ec.europa.eu/energy/publications/statistics/doc/2010_energy_transport_figures.pdf

the latter, the electric bicycle will cause 0.333 kg of CO_2 for a 100 km trip. Even this worst-case scenario compares well to a car that emits 12 kg of CO_2 per 100 kilometres. [21]

Even though electric bicycles could contribute positively to a reduction in the emission of greenhouse gases, the impact indicator 'climate' in this assessment is not expected to be influenced by the inclusion of electric bicycles in the scope of RoHS II. This would only be the case if electric bicycles would be sold in significantly lower numbers because of this scope change or if the components influencing the electricity used would need to be changed because of RoHS II. Neither of these scenarios is to be expected.

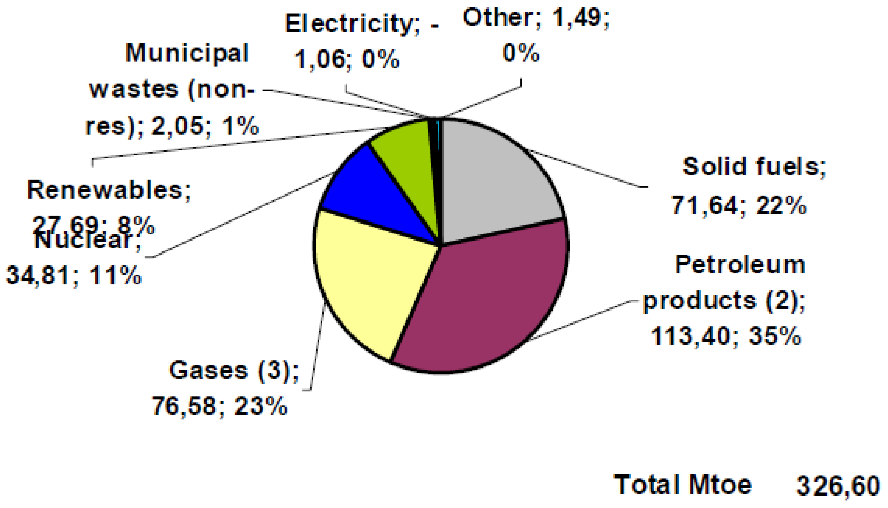
1.3.2.3 Air quality

According to research conducted at the Massachusetts Institute for Technology (MIT), electric bicycles emit 90% less pollutants than a bus operating off-peak. [22] As for the impact indicator 'climate' above, electric bicycles could therefore contribute to an improvement in air quality. However, this improvement is not expected to be significantly furthered or hindered by electric bicycles being included in the scope of RoHS II.

1.3.2.4 Renewable or non-renewable resources

Whether renewable or non-renewable resources are used for the electricity demands of an electric bicycle depend on the electricity mix consumed in the country in question as well as by the energy provider in particular. Figure 3 and Figure 4, below, show the energy mix in 2009 for Germany and the Netherlands, the two biggest electric bicycle markets in Europe.

Figure 3: Energy mix in Germany, 2009[23]

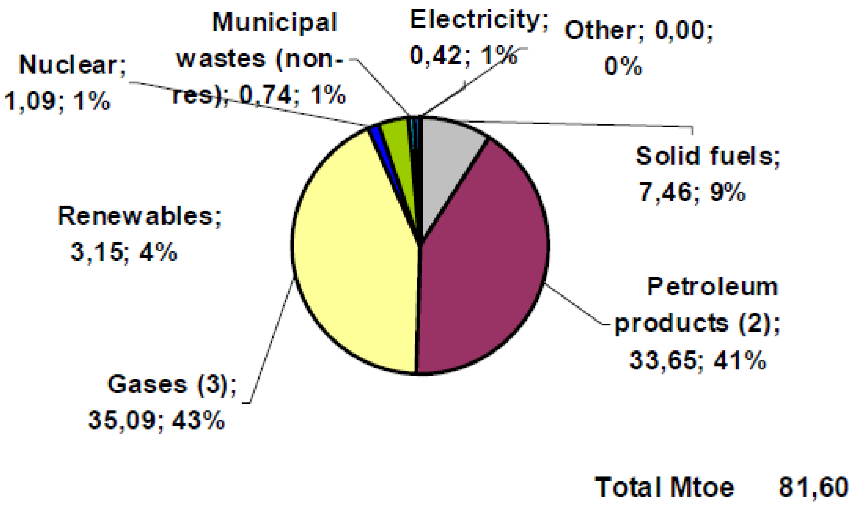


[21] PRESTO Cycling Policy Guide, Give Cycling a Push, 2010, accessed at http://www.presto-cycling.eu/images/policyguides/presto_cycling%20policy%20guide%20electric%20bicycle.pdf

[22] Dave, Shreya, *Life Cycles Assessment of Transportation Options for Commuters*, 2010, Massachusetts Institute of Technology (MIT)

[23] Source: European Commission, DG Energy, EU Energy in figures and factsheets (revision 2011), Country Fiches, Netherlands. Accessed at http://ec.europa.eu/energy/publications/statistics/statistics_en.htm

Figure 4: Energy mix in the Netherlands, 2009[24]



As can be seen from the above, energy mixes vary widely from Member State to Member State. While Germany still depended on nuclear energy for 11% of its total consumption in 2009, this was only 1% for the Netherlands. On the other hand, renewables stood at 8% in Germany, while this was 4% in the Netherlands.

It can be assumed, however, that the presence of the hazardous substances considered in RoHS II does not have an impact on the type of energy source used. Whether electric bicycles are in scope of RoHS II or not does therefore not have an impact on the electricity mix used and hence the use of renewable or non-renewable resources used for the electricity consumption of these bicycles.

1.3.2.5 Waste production / generation / recycling

The average product life of an electric bicycle is estimated to be five to seven years[25] compared to approximately 15 years for a conventional bicycle.[26] Table 4 shows the estimations used to calculate the environmental impacts of RoHS hazardous substances released into the environment at the end-of-life. The assessment is likely to contain high uncertainties, because of the assumptions made to model the end-of-life options. No figures on past end-of-life treatment for electric bicycles were available at the time of writing of this report. In line with RoHS II, the WEEE recast proposal adopted by the European Parliament on 19 January 2012, explicitly includes two-wheel vehicles which are not type-approved in its scope.[27] This means that electric bicycles owners have to be able

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[24] Source: European Commission, DG Energy, EU Energy in figures and factsheets (revision 2011), Country Fiches, Netherlands. Accessed at http://ec.europa.eu/energy/publications/statistics/statistics_en.htm

[25] Stakeholder consultation contribution by ETRA, January 2012

[26] Dave, Shreya, *Life Cycles Assessment of Transportation Options for Commuters*, 2010, Massachusetts Institute of Technology (MIT)

[27] Art. 2.4(d), European Parliament legislative resolution of 19 January 2012 on the Council position at first reading with a view to the adoption of a directive of the European Parliament and the Council on waste electrical and electronic equipment(WEEE) (Recast) (07906/2/2011 – C7-0250/2011 – 2008/0241(COD)). Accessed at http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//TEXT+TA+P7-TA-2012-0009+0+DOC+XML+V0//EN

to return these at the end-of-life free of charge. For this assessment it is assumed that 65%[28] of end-of-life electric bicycles will be recycled by 2019 with the remainder going to landfill.

Table 4: Heavy metal emissions, by end-of-life management options

End-of-life process	Share of total end-of-life products (in %)	Emissions to air during end-of-life process	Emissions to water during end-of-life process	Source of the emissions estimates
Recycling	65%	0.001%	0.059%	COWI (2002)[29]
Incineration	0%	0.5%	2.49%	ERM (2006)[30]
Landfill	35%	-	5%	ERM (2006)

By assuming an annual sales volume of 3.26 million electric bicycles in Europe by 2019 and 5.77 million by 2025[31], it is estimated that 0.33 kg of hexavalent chromium would be sent into the end-of-life management circuit by 2019 and 0.59 kg by 2025[32] if the product group was not included within the scope of RoHS II. For Option 2, it is assumed that all hexavalent chromium would be removed from the products from 2019, so that none of these substances would go to the waste streams from 2025.

Based on these assumptions, the ecotoxicity freshwater midpoint indicator was calculated[33] in order to illustrate the avoided impacts for the end-of-life of the inclusion of electric bicycles in the scope of RoHS II, in 2025. This indicator was chosen because the release of RoHS hazardous substances in the environment has an influence on its value (this is not the case for Global Warming Potential for instance).

Table 5: Avoided freshwater ecotoxicity impacts by Option 2, compared to Option 1

Year[34]	Ecotoxicity freshwater midpoint (CTUe[35])
2025	6.10E+02

This result represents 0.00000001% of the overall freshwater ecotoxicity annual impact in the EU-27 (USEtox™ normalisation values). It can hence be assumed that the use of hexavalent chromium on screws in electric bicycles has a negligible environmental impact. Details of the calculations are provided in the Annex.

[28] In line with new WEEE recycling target from 2019 of 65t for every 100t put on the market in the three preceding years
[29] COWI (2002), Heavy Metals in Waste – Final Report, for European Commission DG ENV. Applicable to lead, assumed to be the same for other heavy metals
[30] ERM (2006), Battery Waste Management Life Cycle Assessment – Final Report.
[31] Based on an annual growth rate of 10% from 2013, the last year for which sales estimates exist
[32] 6 years (average lifetime of the product) after the effective implementation of RoHS II
[33] According to USEtox™ methodology.
[34] RoHS II coming into force for this product group (2019), plus one product lifetime (6 years)
[35] Comparative Toxicity Unit ecotoxicity, equivalent to PAF.m3.day

Regarding the other RoHS substances, they are not expected to be found in electric bicycles, or, if they are, they are already banned under REACH (cadmium in brazing alloys and plastics). The inclusion of electric bicycles in RoHS II is therefore not expected to have an impact on this indicator.

1.3.2.6 Noise emissions

Electric bicycles produce very little or no noise. In the UK, for example, the noise level limit for cars used on a public road is 74 decibel (db(A)) although most vehicles produce lower levels than that.[36] Every car ride avoided due to an electric bicycle would therefore also lead to avoided noise emissions.

Noise emitted by an electric bicycle is, however, not linked to the RoHS substances found in them as all electronic components are already RoHS compliant. Including electric bicycles in the scope of RoHS II would therefore not have an impact on this environmental indicator.

1.3.2.7 International environmental impacts

As discussed above, there are no exact statistics for European imports and exports of electric bicycles. Even though China is the biggest electric bicycle market in the world, it is not dominated by pedelecs, like the European one, but by e-bikes that do not necessarily require the user to pedal to assist. It can therefore be assumed that European exports of electric bicycles are limited. End-of-life considerations that are relevant in Europe, are therefore less relevant for third countries.

Even though the import of final product electric bicycles might also be limited, most European manufacturers source their parts in Asia, mostly China, and only assemble the bicycles in Europe. ETRA estimates that 80-85% of parts are imported from Asia. The use of hazardous substances at the production stage is therefore relevant for third countries. However, as no or very limited amounts of RoHS substances are expected to be used at the production state, or, if they are, their use is already banned under REACH, no impact of the inclusion of electric bicycles in the scope of RoHS II is expected on this indicator.

1.3.2.8 Overview of environmental impacts until 2025

No environmental impacts are expected from the inclusion of electric bicycles in the scope of RoHS II for two main reasons: First, no or very limited amounts of RoHS substances are expected to be found in electric bicycles or, if they are, they are already banned under REACH (cadmium in brazing alloys and plastics). And secondly, the number of electric bicycles sold on the European market is not expected to decrease because of RoHS II (please see the section on economic impacts below for more details). Potential environmental benefits stemming from electric bicycle use are therefore not expected to be undermined by RoHS II.

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[36] Directgove Online, Transport noise pollution, 2012, accessed at http://www.direct.gov.uk/en/TravelAndTransport/Usingmotorwaysandroads/Reducingroadcongestionandpollution/DG_10025601

Table 6: Estimated environmental impacts

Estimated environmental impacts until 2025[37]		
	2012	2025
Transport and energy use	=	=
The climate	=	=
Air quality	=	=
Renewable or non-renewable resources	=	=
Waste production / generation / recycling	=	=
Noise emissions	=	=
International environmental impacts	=	=

1.3.3 Economic impacts

The electric bicycle industry consists of a small number of large companies and many SMEs. Many companies are still in their R&D phase while those that are already producing still tend to have high R&D costs.[38] In 2011, an estimated 1.3 million electric bicycles were sold in the EU with an average retail price of €1,500. As a result, turnover was € 1.95 billion.

1.3.3.1 Functioning of the internal market and competition

While in the past Member State authorities have not been in agreement regarding the inclusion of electric bicycles in the scope of RoHS I, the recast Directive is very clear in its inclusion of this product group in its scope. It should be noted that as no compliance checks were carried out in the past, manufacturers across the EU were not actually affected by this lack of agreement. Still, the clear inclusion of electric bicycles in the scope of RoHS II should have a positive impact on the internal market as all manufacturers have to comply with the same rules.

1.3.3.2 Competitiveness

As discussed above, European import and export data for electric bicycles is not available[39], which makes an analysis of potential impacts on competitiveness difficult. However, as exports are expected to be very limited, no major impact is expected. Imports would have to comply with RoHS II just as European products do, which again means no impact on competitiveness of European firms.

[37] RoHS II coming into force for this product group (2019), plus one product lifetime (6 years)
[38] PRESTO Cycling Policy Guide, Give Cycling a Push, 2010, accessed at http://www.presto-cycling.eu/images/policyguides/presto_cycling%20policy%20guide%20electric%20bicycle.pdf
[39] On 28 October 2011, the new code 8711 89 10 for pedal assisted bikes 25 km/h - 250W in the combined Nomenclature was created. As a result, import and export data will become available in the future. Stakeholder consultation contribution by ETRA, June 2012

Another aspect of competitiveness is that stemming from health benefits of increased electric bicycle use. This improvement would affect all companies whose employees use electric bicycles, not just electric bicycle manufacturers. Research has shown that the Dutch average sick leave among cycling employees is on average 7.4 days per year as opposed to 8.7 days for those who do not cycle. Furthermore, the longer the distance cycled and the more frequent, the higher the decrease in sick leave. [40] This could lead to gains in competitiveness for companies if more and more commuters opt for an electric bicycle as their transport medium.

An impact on competitiveness (in terms of a lost opportunity to increase competitiveness) would only be expected if the inclusion of electric bicycles in the scope of RoHS II would lead to less electric bicycles being sold. As this is not expected, this indicator is not assumed to be impacted.

1.3.3.3 Costs and administrative burdens

Data on costs and administrative burdens is difficult to collect and manufacturers consulted as part of this assessment were not in agreement on this subject. One manufacturer, for example, pointed out that no additional costs are expected due to the inclusion of electric bicycles in the scope of RoHS II. They only consider the actual electrical or electronic components to be EEE and as these are already RoHS compliant, no additional costs, neither technical nor administrative, would be incurred. Another stakeholder, on the other hand, pointed out that additional compliance costs are the major worry of industry. Still, no estimates of actual compliance costs were received. Manufacturers contacted by ETRA (European Twowheel Retailers' Association) in this context stated that they are aware of RoHS and produce electric bicycles free of RoHS substances. This could not be verified within the scope of this work but it shows that even if none or not all manufacturers produce RoHS compliant electric bicycles, this kind of production is apparently believed to be possible. Not one of the stakeholders mentioned that substituting RoHS substances would be impossible or even very costly.

The industry considers itself under already a significant administrative burden due to obligations resulting from the Machinery Directive, EMC Directive, EN standards, Battery Directive, the WEEE Directive, REACH, UN Regulations of transport on batteries, etc. It should be noted, however, that the familiarity with these regulations can also be an advantage in this context. The Machinery Directive, for example, does already require CE marking for pedelecs. Manufacturers should therefore be familiar with this process and implementing RoHS requirements should be less time consuming than if they had never worked with this type of regulation before.

According to the 2008 Impact Assessment accompanying the Commission's recast proposal[41], there is little experience of actual compliance costs for industry. For products currently included in RoHS, estimates are it would vary from 1-4% of turnover. Other surveys give an average overall cost related to RoHS of 1.9% of turnover. Based on the 2011 figures of 1.3 million electric bicycles being sold in Europe at an average retail price of €1,500, the annual turnover was €1.95 billion. Applying

[40] PRESTO Cycling Policy Guide, Give Cycling a Push, 2010, accessed at http://www.presto-cycling.eu/images/policyguides/presto_cycling%20policy%20guide%20electric%20bicycle.pdf
[41] European Commission (2008), SEC(2008) 2930. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=SEC:2008:2930:FIN:EN:PDF

the 1-4% range, compliance costs could range from €20 million to €78 million for all European manufacturers combined.

The electric bicycle industry consists of a number of large companies and many SMEs. While the larger companies can be expected to have a designated employee working on regulatory issues and also being better able and equipped to cover these additional costs, for SMEs the additional effort required might be larger. Another point raised by industry is that ensuring compliance is not necessarily just a question of costs but also of feasibility. As approximately 85% of parts come from Asia, ensuring compliance might be a difficult task for European manufacturers.

Overall, with very limited data availability it is difficult to make precise estimations of additional compliance costs for the electric bicycle industry due to RoHS II. Still, based on the discussion above it can be assumed that costs will be incurred albeit to a limited extent. These costs will be easier to assimilate for the large players in the market than for the many SMEs.

1.3.3.4 Public authorities

Public authorities can be affected by a growing electric bicycle market as infrastructure might need to be adapted. Here it needs to be differentiated between segregated and integrated cycling infrastructure. For many electric bicycle users, especially commuters, speed is the main factor. Fast and comfortable segregated cycling lanes might convince even doubtful car users to commute by electric bicycle. Furthermore, an adaptation of cycling infrastructure might be necessary for safety reasons if the number of electric bicycle users increases significantly. Regarding integrated cycling, traffic calming and speed management of motorised transport might be required. Another issue for public authorities might be that of secure and sheltered parking facilities if the number of electric bicycles continues to increase significantly. [42] In terms of overall costs for public authorities these should remain limited. It will also be integrated in a more general rethinking of transport infrastructure in cities, which already focuses on facilitating bicycle traffic. Furthermore, spending on electric bicycle parking should, at the same time, free up funds from reduced spending on car parking facilities, which require significantly more space.

Regarding this assessment, the indicator would only be affected by electric bicycles falling in the scope of RoHS II if this lead to a decrease in the number of electric bicycles being sold. As this is not expected, the indicator can be assumed to be unaffected by the scope change.

1.3.3.5 Innovation and research

Many electric bicycle manufactures are still in their R&D phase while those that are already producing generally tend to have high R&D costs. [43] Innovation and research is therefore an important topic for these manufacturers. However, as no or very little RoHS substances are expected to be found in electric bicycles or, if they are, they already need to be substituted because of REACH obligations, no impact on innovation and research because of RoHS II can be expected.

[42] PRESTO Cycling Policy Guide, Give Cycling a Push, 2010, accessed at http://www.presto-cycling.eu/images/policyguides/presto_cycling%20policy%20guide%20electric%20bicycle.pdf
[43] PRESTO Cycling Policy Guide, Give Cycling a Push, 2010, accessed at http://www.presto-cycling.eu/images/policyguides/presto_cycling%20policy%20guide%20electric%20bicycle.pdf

1.3.3.6 Consumers and households

An increase in both technical as well as administrative costs for electric bicycle manufacturers might lead to an increase in prices for consumers. However, a number of manufacturers already state that their electric bicycles are RoHS-substance free while these bicycles are not sold at a premium. At the same time, without RoHS II prices of electric bicycles were expected to decrease in the future because of increased economies of scale and a reduction in R&D costs, which are still substantial for many manufacturers at this early stage. Even if manufacturers did increase prices due to costs related to RoHS, it would therefore rather be a future price decrease foregone than an actual price increase. Overall, the impact on consumers and households is therefore expected to be negligible.

1.3.3.7 Overview of economic impacts until 2025

Based on the above, economic impacts from electric bicycles falling in the scope of RoHS II are expected to be negligible.

Table 7: Estimated economic impacts

Estimated economic impacts until 2025[44]		
	2012	**2025**
Functioning of the internal market and competition	=	+
Competitiveness	=	=
Costs and administrative burdens	=/-	-
Public authorities	=	=
Innovation and research	=	=
Consumers and households	=	=

1.3.4 Social impacts

1.3.4.1 Employment

Official employment figures for the electrical bicycle sector in Europe do not exist. However, it is known that in 2011 a total of 17 million conventional bicycles were sold compared to 1.25 million electric bicycles. Based on a total of 90,000 people employed in manufacturing and distribution of bicycles in general in the EU, this would correspond to a total of 6300 jobs linked to the manufacturing and distribution of electric bicycles in Europe.[45] Based on turnover instead of bicycle numbers, this figure would increase to 16,200 jobs.

[44] RoHS II coming into force for this product group (2019), plus one product lifetime (6 years)
[45] Email exchange with ETRA, March 2012

As electric bicycles would not need to be adapted because of RoHS II and as potential compliance costs are not expected to be significant, no job losses in the electric bicycle market is expected as a result of the scope changes of RoHS II.

1.3.4.2 Health

An increase in the number of pedelecs on the street is widely believed to have a positive impact on public health. The Swiss study 'Evaluation of the impact on health of the promotion of pedelecs' concludes that the use of these electric bicycles helps to prevent cardiovascular diseases, hypertension, diabetes II and colon cancer. Furthermore, it also helps people suffering from chronic diseases such as multiple sclerosis. As a result, electric bicycle use helps to reduce the overall cost of national health systems. In addition, the WHO report 'Transport, environment and health' states that the greatest benefits from physical activity come when people who have been minimally active engage in moderate activity.[46] Electric bicycles can be an ideal means of getting minimally active people to engage in physical activity as their users are still supported in their effort. Nevertheless, as no impact on the numbers of electric bicycles being sold is expected from them falling in scope of RoHS II, this is not expected to have an impact on public health.

Regarding the impact of the use of hexavalent chromium on screws in electric bicycles, this is difficult to quantify. It needs to be differentiated between possible impacts during the production phase, on users during the actual product's lifetime and at the end-of-life. First, exposure to these substances during the production phase represents a risk for the facility workers, who are a population group at greatest risk of exposure to lead, especially through air. This risk is very much dependent upon the type of exposure (time, frequency, pathway, etc.). It can be expected that generally EU manufacturers already respect the related legislation and implement the necessary precaution to ensure their workers' well-being. Whether this is the case outside the EU is more difficult to determine and as approximately 85% of electronic bicycle parts are imported from outside the EU some form of workers' exposure to this RoHS substance can be assumed. This phenomenon is also dependent on possible developments in the other industrial sectors, because of the complex structure of supply chains. The importance of these health effects also depends on the potential effects of the substitutes, if any. Therefore, a quantification of these impacts could not be made. Impacts on the health of users are also difficult to quantify but under normal operation it can be assumed to be negligible.

Finally, the management during the end-of-life can result in important impacts to the environment and health. These impacts are dependent upon the management options followed by products, which have already been presented (see section 1.3.2.5). Based on the same assumptions regarding the emissions to air and water of the substances during recycling, incineration and disposal (see Table 4), health impacts can be quantified via the human toxicity indicators[47]: Assuming the RoHS ban of hexavalent chromium in electric bicycles from 2019 (Option 2), a human toxicity impact of 6.20E-03 CTUh (cancer effects) and 1.44E-05 CTUh (non-cancer effects) would be avoided in 2025.

[46] 'Evaluation d'impact sur la santé Promotion du vélo à assistance électrique', PRESTO Cycling Policy Guide, Give Cycling a Push, 2010, accessed at http://www.presto-cycling.eu/images/policyguides/presto_cycling%20policy%20guide%20electric%20bicycle.pdf

[47] USEtox™ method.

This represents 0.00000038% of the overall human toxicity (cancer effects) impact in the EU-27 in 2025. For non-cancer human toxicity effects this translates into 0.00%.

Table 8: Human toxicity indicators

Year[48]	Human toxicity midpoint, cancer effects (CTUh[49])	Human toxicity midpoint, non-cancer effects (CTUh)
2025	6.20E-05	1.40^{E}-07

Based on the above, the positive health effects of a ban of chromium VI in electric bicycles can be regarded as very limited.

1.3.4.3 *Social impacts in third countries*

A possible positive social impact in third countries because of electric bicycles falling in the scope of RoHS II would be based on the occurrence of hexavalent chromium in screws in these products. Given that approximately 85% of electric bicycle parts are imported into the EU, a ban could also have positive health impacts in these manufacturing countries. However, the quantity used of this substance is low and, as discussed in the section on health impacts above, the impact is therefore expected to be very limited.

1.3.4.4 *Overview of social impacts until 2025*

Based on the above, no employment impacts and very limited positive health and social impacts in third countries are expected from electric bicycles falling in the scope of RoHS II.

Table 9: Estimated social impacts

Estimated social impacts until 2025[50]		
	2012	**2025**
Employment	=	=
Health	=	=/+
Social impacts in third countries	=	=/+

1.3.5 Comparison of options

Overall, the inclusion of electric bicycles in the scope of RoHS II is expected to have very limited impacts, whether that is in environmental, economic or social terms. While the internal market could benefit from the inclusion, the electric bicycle manufacturers will face additional compliance costs and administrative burdens. Socially, very slight health benefits within and outside of the EU could be the result. None is expected to be significant though. Table 10, below, provides a comparison of the two policy options.

[48] RoHS II coming into force for this product group (2019), plus one product lifetime (6 years)
[49] Comparative Toxicity Unit human, equivalent to cases
[50] RoHS II coming into force for this product group (2019), plus one product lifetime (6 years)

Table 10: Comparison of options

Impact indicators	Option 1 : Unclear whether electric bicycles in scope of COM recast proposal	Option 2: Not type-approved electric bicycles in scope of RoHS II
Environmental impact indicators		
The climate	=	=
Transport and energy use	=	=
Air quality	=	=
Renewable or non-renewable resources	=	=
Waste production / generation / recycling	=	=
Noise emissions	=	=
International environmental impacts	=	=
Economic impact indicators		
Functioning of the internal market and competition	=	+
Competitiveness	=	=
Costs and administrative burdens	=/-	-
Public authorities	=	=
Innovation and research	=	=
Consumers and households	=	=
Social impact indicators		
Employment	=	=
Health	=	=/+
Social impact in third countries	=	=/+

In relation to the overall policy objective of RoHS II, namely to contribute 'to the protection of human health and the environment, including the environmentally sound recovery and disposal of waste EEE'[51], the discussion above shows that including electric bicycles in RoHS II does not hinder this although it does not significantly contribute to it either. While a slightly positive health impact can be expected, no environmental benefit is expected from these bicycles falling in the scope of RoHS II. Electric bicycle use can have a number of positive impacts and can contribute to the overall European goal of a reduction in greenhouse gas emissions. The inclusion of electric bicycles in RoHS II is not incoherent with this goal as the overall number of these bicycles is not expected to decrease as a result of the scope change. Table 11, below, provides an overview of the policy options in relation to the overall objectives of RoHS II.

[51] 2011/65/EU, Article 1

Table 11: Policy objectives and options

Policy options in relation to overall policy objectives			
	Effectiveness	**Efficiency**	**Coherence**
Option 1: Unclear whether electric bicycles in COM recast proposal	Neutral: Does not contribute to reaching the objectives but does not hinder them either	Efficiency cannot be evaluated as option does not contribute to the objectives	None or very limited unintended impacts
Option 2: Electric bicycles in scope of RoHS II	Neutral: Does not contribute to reaching the objectives but does not hinder them either	Efficiency cannot be evaluated as option does not contribute to the objectives	Very limited unintended impacts

Annex

Table 12: Quantities of RoHS substances released to the environment in 2025 without RoHS II implementation, due to end-of-life management options

Substance	Released to	Quantity (in kg)
Cadmium	Air	0
Chromium VI		0.000002
Lead		0
Mercury		0
Cadmium	Water	0
Chromium VI		0.0058
Lead		0
Mercury		0

Table 13: Characterisation factor of the RoHS substances (USEtox™ method)

Substance	Type of emissions	Human toxicity midpoint, cancer effects (in CTUh/kg)	Human toxicity midpoint, non-cancer effects (in CTUh/kg)	Ecotoxicity freshwater midpoint (in CTUe/kg)
Lead	Emissions to air, unspecified	2.69E-05	9.44E-03	1.75E+02
	Emissions to water, unspecified	3.42E-07	1.20E-04	3.75E+02
Mercury	Emissions to air, unspecified	7.06E-03	8.35E-01	1.22E+04
	Emissions to water, unspecified	1.20E-04	1.42E-02	2.21E+04
Chromium VI	Emissions to air, unspecified	4.45E-03	4.16E-04	4.20E+04
	Emissions to water, unspecified	1.06E-02	2.40E-05	1.05E+05
Cadmium	Emissions to air, unspecified	2.17E-04	4.55E-02	3.94E+03
	Emissions to water, unspecified	1.59E-06	4.27E-04	9.71E+03

Table 14: Impact assessment results 2025 (USEtox™ method)

Impact indicator (unit)	Avoided impacts in 2025 in EU-27, with RoHS II implementation (in impact indicator unit)	Avoided impacts in 2025 in EU-27, with RoHS II implementation (in % of annual EU-27 impacts)	USEtox™ normalisation factors (in impact indicator unit per person per year)
Human toxicity midpoint, cancer effects (in CTUh)	6.20E-05	0.00000038%	3.25E-05
Human toxicity midpoint, non-cancer effects (in CTUh)	1.40E-07	0.00%	8.14E-04
Ecotoxicity freshwater midpoint (in CTUe)	6.10E+02	0.00%	3.18E+06

A EU-27 population estimate of 502 477 005 inhabitants in 2011 is used for the normalisation (source: Eurostat, in March 2012).

Furniture with secondary electrical functions

1.1 Key issues

Furniture with electrical functions was not in scope of RoHS I as long as its primary function of being a piece of furniture could be fulfilled without the electrical function. Because of the new definition of 'dependent' in RoHS II, furniture with any electrical function, whether primary or secondary, falls in scope of the Directive. In this factsheet it will be explored what the impact of this change is and whether the benefits of the inclusion of electric bicycles in RoHS II outweigh the potential costs.

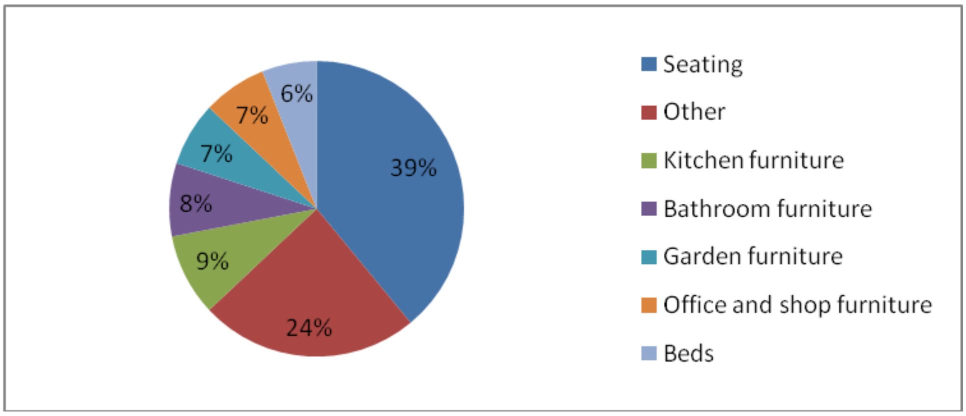
Source: Fads.co.uk

Regarding this factsheet, it should be noted that no information has been received from stakeholders despite several attempts to establish contact. The information presented is therefore based on secondary research and derived estimations only and results should be considered with caution.

1.2 Background

Furniture is a diverse product group, which includes items with primary, secondary or no electrical functions. The largest percentage of furniture will have no electrical functions at all. Figure 1 provides an overview of different furniture categories placed on the French market in 2007.

Figure 1: Types of furniture, France 2007

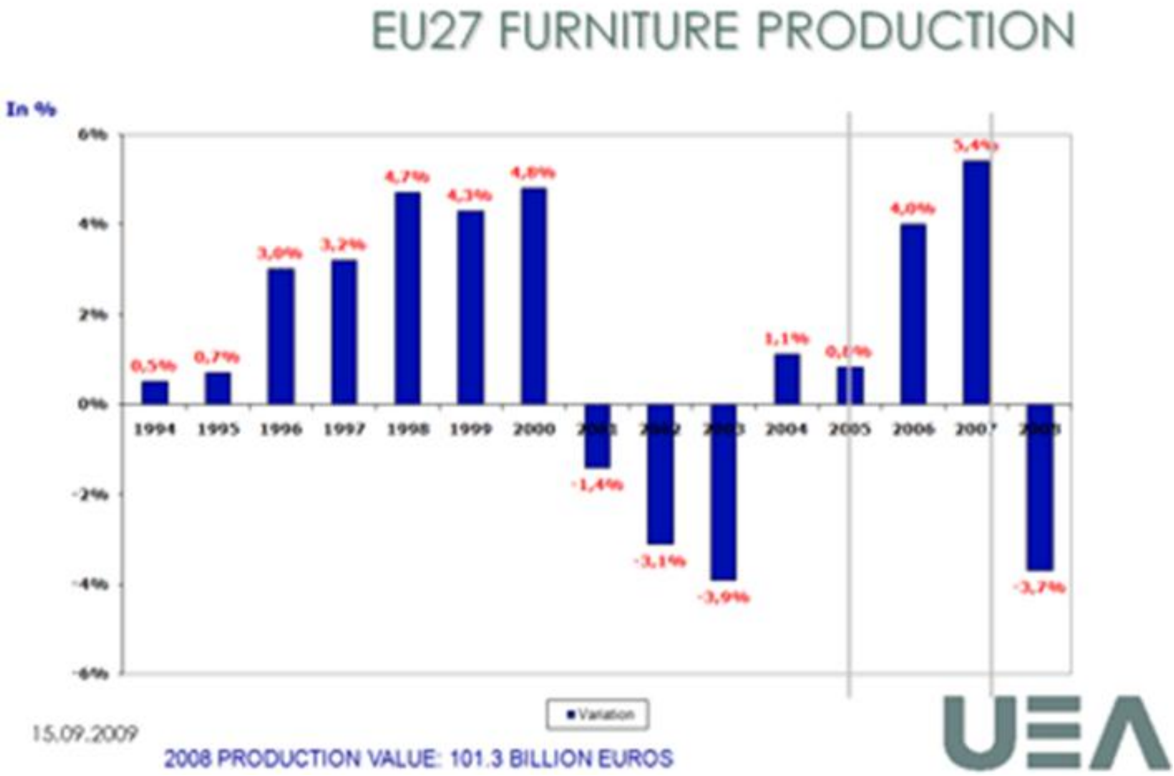


Source :Ademe (2010)[1]

[1]Ademe, *Dimensionnement et cadrage de filieres pour la gestion de mobiliers menagers et professionnels usages*, 2010, accessed at : http://www2.ademe.fr/servlet/getDoc?cid=96&m=3&id=73566&p1=02&p2=05&ref=17597

In 2004, the EU-15 total furniture consumption amounted to €68 billion or €162 per capita. Within the EU, the four major markets are the UK, Italy, France and Germany. Together, these four countries represented 64% of total consumption, 60% of total production and 70% of total imports of household furniture in the EU.[2] Total EU-27 furniture production value in 2008 was €101.3 billion, see Figure 2. According to Eurostat, the total number of furniture units sold in the EU-27 in 2007 was 277 million.[3]

Figure 2: Furniture production in EU-27, 2008



Source: European Federation of Furniture Manufacturers (UEA)[4]

According to European Federation of Furniture Manufacturers (UEA) statistics, the European Union furniture industry accounted for 19% of world exports in 2007[5].The European furniture market has been under pressure over recent years because of increased and more diversified competition, especially from China. China is the main extra-EU trade partner of furniture in terms of imports with a total value of €6.2 billion of furniture imported into the EU-27 from China in 2008. Imports from China have increased from a 15% share in 2000 to a 50.7% share in 2008. Regarding extra-EU exports, the most important trading partners are the USA, Switzerland, Russia and Norway.[6] Overall, the trade balance has decreased from a surplus of almost €3 billion in 2002 to a deficit of €1.2 billion in 2008.

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[2] USAID, *EU Furniture Market Study – Summary*, 2006
[3]Eurostat, *European Business - Facts and figures*, 2009, accessed in May 2012 at: http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-BW-09-001/EN/KS-BW-09-001-EN.PDF
[4] http://www.ueanet.com/uea-extranet/-THE-FURNITURE-INDUSTRY-
[5] By value, excluding intra-EU trade
[6] European Federation of Furniture Manufacturers online, accessed April 2012 at http://www.ueanet.com/uea-extranet/-THE-FURNITURE-INDUSTRY-

No data was found or received from stakeholders on the percentage of furniture with secondary (or any) electrical functions of the total European furniture market. Given the restrictive nature of the product group definition (see section 1.2.1), this can, however, be expected to be very low. For this assessment it is assumed that furniture with secondary electrical functions, such was wardrobes and beds with integrated lights or tie rotators, do not exceed 1% of the overall European furniture market.[7] The actual figure is likely to be lower, but in order to assess the strongest possible impact the scope inclusion might have, 1% will be assumed.

1.2.1 Legal background

Furniture with minor electrical functions was not considered in scope of RoHS I in most cases as it could perform its primary function of being a piece of furniture without the electrical function as well. In some cases, for example reclining chairs, it was argued that the primary function was to recline and not just to be a chair. The UK, for example, regard adjusting beds, massage chairs, gamer chairs with built-in speakers and chairs that facilitate standing as being in scope of RoHS I. In contrast to RoHS I and the COM recast proposal, according to Article 3.2 of RoHS II electricity is only needed for 'at least one intended function' for the equipment to be categorised as EEE. In other words, the electric function no longer has to be primary but can also be secondary for the equipment to qualify as EEE and this can also be the case for furniture. Hence furniture with any electrical function is now included in Category 11 'Other EEE' of RoHS II, Annex I (unless they are in Category 7 as leisure equipment).

The Draft Final RoHS 2 FAQ document of 15 May 2012 details that for a product to be EEE, its dependent electrical functions must in principle be integrated. Regarding furniture, the document provides an example of a wardrobe with lights, saying that "[...] even if sold as a single unit, a distinction between the piece of furniture and the electric/electronic device the piece is or can be equipped with has to be drawn. If the lighting is EEE itself and both the lighting and the wardrobe can be separated and used by the end user as fully functional separate products, it is only the electric/electronic equipment (the lighting) [that] is in the RoHS 2 scope. The furniture itself would then be outside the scope."[8]Regarding this factsheet, it will therefore need to be differentiated between fully integrated EEE components, in which case the piece of furniture with integral electrical components would be in scope of RoHS 2 and types of furniture with modular EEE components that could be removed as functional EEE, in which case the furniture would be out of scope but the removable electrical part in scope.

Other European environmental legislation affecting the manufacture of furniture includes, amongst others, the IPPC Directive on Integrated Pollution Prevention and Control (96/61/EC) regarding surface treatments; the VOC Solvents Emissions Directive (2004/42/EC) also regarding surface treatments; the Waste Directive (2008/98/EC) and REACH which also has obligations on sellers of furniture and professional users.

[7] Please note that this excludes furniture with primary electrical functions, such as reclining beds or chairs that were already in scope of RoHS I and are therefore not part of this assessment. See section 1.2.1 for more details.
[8] European Commission, DG ENV, *RoHS 2 FAQ, Final Draft 15 May 2012*, p.21

1.2.2 Quantities and hazardous substances

Furniture in general comprises a number of different materials, the most important of which being wood, glass, metal, resin, fabrics, and foam.[9]Some of these materials, such as fabrics and foam, are, however, not considered as important for this assessment as they are most likely to be found in furniture with primary electrical functions, such as reclining chairs. No information related to the presence of RoHS substances in furniture with secondary electrical functions was found or received from stakeholders. Table 1lists the estimations of the different hazardous substances, which should be considered with caution given the high uncertainty. As presented in section 1.2, the total number of furniture units sold in the EU-27 in 2007 was 277 million.[10] If it is assumed that furniture with secondary electrical functions represents 1% of the total market, this comes to 2.77 million units.

It can be assumed that **lead** is found in the solder and some may also be used as PVC stabilisers of the electrical components of furniture with secondary electrical functions. Lead solders are estimated to be used only in very small amounts, if any. If the secondary electrical function is a mains voltage lamp or tie rotator motor, then connections may be crimped and so no solder would be used at all. If LED lighting is used, which is more likely, there will need to be a very small PCB to power the LEDs. Low voltage LEDs or tie rotator motors will also need an external power supply unit. These are usually made in China and most are already made with lead-free solders because approximately 95% of their uses in the EU require RoHS compliance. There will be PVC wires and cables but lead PVC stabilisers are now extremely uncommon because of the effect of RoHS. Based on the above, it is estimated that, on average, the total amount of lead in furniture with secondary functions is less thano.5 grams.

Mercury might be found in lamps integrated into this type of furniture. These lamps would have, however, already been covered by RoHS I and the inclusion in RoHS II is not expected to have an additional impact. The potential presence of mercury is therefore disregarded in this assessment. Wooden furniture may have wood screws and other fasteners and some of these could contain **CrVI** coatings, which would be estimated at no more than 50 µg.

Finally, **Deca-BDE** might be expected to be used to protect furniture cushions and upholstery textiles. As discussed above, these materials are expected to be predominantly used in furniture with primary electrical functions that was already in scope of RoHS and will therefore be disregarded in this assessment.

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[9]Ademe, *Dimensionnement et cadrage de filieres pour la gestion de mobiliers menagers et professionnels usages*, 2010, accessed at : http://www2.ademe.fr/servlet/getDoc?cid=96&m=3&id=73566&p1=02&p2=05&ref=17597

[10] Eurostat, *European Business - Facts and figures*, 2009, accessed in May 2012 at: http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-BW-09-001/EN/KS-BW-09-001-EN.PDF

Table 1: RoHS substances in furniture with secondary electrical functions

Substance	Presence in furniture with secondary electrical functions
Lead	Yes, in solder and PVC stabilisers Estimated at <0.5 grams
Mercury	Yes, in lamps (already covered by RoHS I)
Cadmium	No (most uses already restricted by REACH)
Hexavalent Chromium	Potentially in coatings on wood screws Estimated at 50 µg
Polybrominated biphenyls (PBB)	No
Polybrominated diphenyl ethers (PBDE)	Deca-BDE for protection of upholstery (most already in scope of RoHS I)

Source: Own estimations

Compliance testing experience in the UK for furniture with primary electrical functions, e.g. a reclining chair, shows that compliance ranged from full to no compliance. No further information has been available on this issue, but this experience importantly shows that full compliance of this type of furniture is possible.

1.2.3 Policy objectives and options

The objective of both, the RoHS recast proposal (COM (2008) 809 final) as well as RoHS II (2011/65/EU) is to contribute 'to the protection of human health and the environment, including the environmentally sound recovery and disposal of waste EEE'[11].

The purpose of this work is to look at the impacts of furniture with electrical functions falling in scope of RoHS II compared to the prior situation where MS treated this product group differently. Policy options will then be evaluated according to their effectiveness, efficiency and coherence in reaching the above-mentioned overall objective of the RoHS Directive. The policy options analysed are the following:

OPTION 1 (baseline scenario): The COM recast proposal. Furniture with secondary electrical functions not in scope of the proposed recast Directive.

OPTION 2: RoHS II. Furniture with secondary electrical functions included in the scope of the recast Directive.

[11] 2011/65/EU, Article 1

1.3 Impacts of policy options

1.3.1 Impact indicators

The following impact indicators have been chosen as relevant for this product group (see Table 2).

Table 2: Impact indicators for the product group automatic doors and gates

Impact indicators		
Environmental	Economic	Social
Energy use	Functioning of the internal market and competition	Employment
Renewable or non-renewable resources	Competitiveness	Health
Waste production / generation / recycling	Costs and administrative burdens	Social impacts in third countries
International environmental impacts	Innovation and research	
	Consumers and households	

The following legend will be used in summarising the impacts:

Legend	
+++	Very beneficial effect
++	Substantial beneficial effect
+	Slight beneficial effect
=	No effect
-	Negative effect
--	Substantial negative effect
---	Very negative effect
?	Unknown effect

1.3.2 Environmental impacts

The most important impacts regarding the environmental impacts in the context of RoHS are related to the quantities of hazardous substances used in the equipment. The mere quantity of a substance is however not sufficient to estimate what will be the actual impacts of the substance on the environment and health. These depend upon numerous factors such as the effective treatment of products at the end-of-life, their design for the use phase or their potential emissions during the production phase. The impact of the substances released to the environment is also determined by case-specific and complex dose-response relationships.

It is therefore not straightforward to predict environmental impacts due to hazardous substances found in products. Where possible, the following subsections will make the link between the quantities of hazardous substances and their potential environmental impacts.

1.3.2.1 Energy use

Given the definition of this product group, all products are expected to consume energy during their operation. Still, the energy consumption of a piece of furniture with secondary electrical functions is assumed to be low and, most importantly, is not expected to be influenced by the RoHS substances used in the product.

The European Commission impact assessment accompanying the RoHS recast proposal[12] states that the substitution of lead solder by lead-free solder might lead to an increase in energy consumption during the production phase because of a higher melting point. The additional energy consumption will vary widely depending on the solder type, the equipment specifications and process operating parameters employed by the facility. Nevertheless, it is generally accepted that lead-free soldering requires approximately 15% more energy than tin/lead (SnPb) soldering when comparing equivalent soldering technology for the two types of alloy and the following calculations will be based on this assumption.

The most common lead-free solders are either tin/copper (SnCu) or tin/silver/copper (SnAgCu) alloys. Both have higher melting points and SnAgCu has a significantly higher cost due to its silver content. The most likely replacement solder in furniture with secondary electrical functions will be cheaper Sn0.7%Cu as this is expected to be sufficiently reliable for this type of equipment. Based on a typical solder reflow oven to make the small PCBs on which the lead is found in furniture with secondary electrical function if an LED lamp is used, the total additional energy required for lead-free solders represents 19.39 MWh per year [13]. Compared to a total EU final energy consumption of 13.6 million PWh[14], this impact of additional energy required is regarded as negligible on this environmental impact indicator. The additional energy consumption will have an extra cost of approximately € 1803€[15]. Additional CO_2 emissions due to change from tin/lead solder to lead-free solder represent 7.56 tonnes CO_2eq[16]. In relation to the overall CO_2 emissions of 4088.8 million tonnes of the EU-27 in 2008[17], this increase would be negligible.

[12] European Commission (2008), SEC(2008) 2930. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=SEC:2008:2930:FIN:EN:PDF

[13] A typical solder reflow oven operates 16 hours per day, 5 days a week, 49 weeks per year and on average consumes 13.9 kWh for SnPb and 16kWh for lead-free. It is assumed that one oven can produce 300 PCBs per hour or 1 million per year (25 PCBs made in a panel every 5 minutes) as these PCBs are small. Based on the assumption that the total number of units to be made are approximately 2.77 million. The true number is likely to be significantly less as not all furniture with secondary electrical functions will have LED lights.

[14] 1168.63 Mtoe, European Commission, *EU transport in figures, statistical pocketbook 2011*, accessed at http://ec.europa.eu/transport/publications/statistics/doc/2011/pocketbook2011.pdf

[15] Average EU industrial electricity price = 0.093 €/kWh in 2011 according to Eurostat.

[16] Based on 0.39 kg CO_2eq/kWh from Eurelectric

[17] 4186.7 million tonnes. European Commission, *EU transport in figures, statistical pocketbook 2011*, accessed at http://ec.europa.eu/transport/publications/statistics/doc/2011/pocketbook2011.pdf

Thus, the inclusion of furniture with secondary electrical functions in the scope of RoHS II should have no significant impact on this environmental indicator.

1.3.2.2 Renewable or non-renewable resources

Wood is the most important single material used in furniture production. Approximately 90% of the European woodworking industries' wood raw material comes from sustainable EU forests, the rest is imported.[18]Based on the available information, neither the amount of wood used nor its source is expected to be influenced by the use of RoHS substances in furniture with secondary electrical functions. The inclusion of this type of equipment in RoHS II is therefore not expected to have an impact on this indicator.

1.3.2.3 Waste production / generation / recycling

The average product life of furniture with secondary electrical functions will depend highly on the exact product in question but can generally be assumed to be long. This is partly because re-use plays an important role in the furniture sector, which increases the lifetime of the product. A study[19] shows that with 35 years interior furniture made of solid wood has the longest expected lifetime of all furniture types. The electronic components in furniture with secondary electrical functions can be expected to slightly decrease this lifetime of the furniture, although this is not certain, as the furniture may continue to be used after secondary electrical functions cease to work. Furthermore, not all of this type of equipment is necessarily made of solid wood. **An average lifetime of 25 years will therefore be assumed for furniture with secondary electrical functions.**

According to European Federation of Furniture Manufacturers (UEA) statistics, furniture waste accounts for more than 4% of the total municipal waste in the EU with 8-10 million tonnes. Of this amount, 80-90% is incinerated or dumped in landfills and only 10% is recycled in wood transforming industries.[20] As discussed above, the main components of furniture are wood, foam and textiles and as these materials tend to be co-mingled, recycling has not been profitable and is not a well-established end-of-life option.[21]It can be assumed that this situation is not fundamentally different for furniture with secondary electrical functions as the small electric components are unlikely to make the recycling process profitable. However, re-use and recycling of furniture does become an issue in the industry. IKEA, for example, now takes back old furniture for re-use or recycling, albeit for a fee.[22]Figure 3 shows that a total of 54% of hard furniture would be recyclable or re-usable. Easily recycled within those products are the wood, board materials (MDF and MFC), metals, some plastics and cardboard.

[18]European Commission, DG ENTR, *Wood, Paper, Printing - Woodworking Industries*, accessed May 2012 at http://ec.europa.eu/enterprise/sectors/wood-paper-printing/wood/index_en.htm

[19]Ademe, *Dimensionnement et cadrage de filieres pour la gestion de mobiliers menagers et professionnels usages*, 2010, accessedat : http://www2.ademe.fr/servlet/getDoc?cid=96&m=3&id=73566&p1=02&p2=05&ref=17597

[20] http://ec.europa.eu/environment/ecolabel/documents/furnitureext_finalreport_1004.pdf

[21] Contribution to stakeholder consultation (phone), April 2012

[22] IKEA, *We want your old furniture*, April 2012, accessed at http://www.ikea.com/ms/en_GB/customer_service/ikea_services/furniture_take_back.html

Figure 3: Recycable/re-usable bulky waste

			Mean Percentage					
		No. of LAs sampled	A: Re-usable in current condition	B: Slight repair but in good	A + B: 'Easy Re-use'	E: Remaining recyclable after all re-use is removed	A+ B+E: Re-use + recyclable	Potential recycling if no items are re-used
Hard furniture	Method 1	4	33%	15%	**48%**	**6%**	**54%**	**n/a**
	Method 2	3	21%	30%	**51%**	**n/a**	**n/a**	**25%**
Soft furniture	Method 1	5	16%	17%	**33%**	**8%**	**41%**	**n/a**
	Method 2	3	17%	10%	**27%**	**n/a**	**n/a**	**3%**
Other furnishings	Method 1	4	5%	1%	**6%**	**1%**	**7%**	**n/a**
	Method 2	3	19%	30%	**49%**	**n/a**	**n/a**	**1%**
General	Method 1	4	41%	8%	**49%**	**18%**	**67%**	**n/a**
	Method 2	3	38%	23%	**61%**	**n/a**	**n/a**	**79%**
Large WEEE	Method 1	4	30%	n/a[10]	**30%**	**53%**	**83%**	**82%**
Other WEEE	Method 1	4	36%	n/a	**36%**	**27%**	**63%**	**42%**

Source :Defra (2005)[23]

Based on the above, the following analysis will be carried out considering that 60% of furniture with secondary electrical functions is landfilled, 30% incinerated and 10% recycled (see Table 3).

Depending on the quality of the end-of-life operations, a certain share of the substances (called the leaching potential) is always lost to the environment. According to BIO (2008)[24], process control of landfills and incinerators, alongside mineralization mechanisms in landfills are some of the options to reduce this share. But there is limited quantitative data about the fate of hazardous substances going through land filling or incineration processes, in particular their leaching potential.

Policy Option 2 (including this type of equipment in the scope of RoHS II) would progressively (over a 25 year period, between 2019 and 2044[25]) decrease the quantities of hazardous substances from furniture with secondary electrical functions found in waste streams, compared to the baseline scenario. The reduction of these substances may have a beneficial effect on their end-of-life treatment. This effect is dependent on the development of the waste management sector as a whole.

Table 3 shows the estimations used to calculate the environmental impacts of RoHS hazardous substances released into the environment at the end-of-life. The assessment is likely to contain high uncertainties because of the assumptions made to model the end-of-life options.

[23]Defra, *Bulky Waste Collections – Maximising Re-use and Recycling*, 2005

[24]BIO (2008), Study to support the impact assessment of the RoHS review – Final Report, for DG ENV.

[25] One estimated product lifetime after this type of equipment falling in scope of RoHS II. Possibly earlier if manufacturers take early measures.

Table 3: Heavy metal emissions, by end-of-life management options

End-of-life process	Share of total end-of-life products (in %)	Emissions to air during end-of-life process	Emissions to water during end-of-life process	Source of the emissions estimates
Recycling	10%	0.001%	0.059%	COWI (2002)[26]
Incineration	30%	0.5%	2.49%	ERM (2006)[27]
Landfill	60%	-	5%	ERM (2006)

By considering the annual sales and lead quantities presented in section 1.2.2, it is estimated that 1.39 tonnes of lead and 0.14 kg of hexavalent chromium would be sent annually into the end-of-life management circuit from 2044[28] if the product group was not included within the scope of RoHS II. For Option 2, it is assumed that all lead in solder and all Cr VI coatings would be removed from the products from 2019, so that none of these substances would go to the waste streams from2044.

Based on these assumptions, the ecotoxicity freshwater midpoint indicator was calculated[29] in order to illustrate the avoided impacts for the end-of-life of furniture with secondary electrical functions within the scope of RoHS II, in 2044.This indicator was chosen because the release of RoHS hazardous substances in the environment has an influence on its value (this is not the case for Global Warming Potential, for instance).

Table 4: Avoided freshwater ecotoxicity impacts by Option 2, compared to Option 1

Year[30]	Ecotoxicity freshwater midpoint (CTUe[31])
2044	2.04E+04

This result in 2039 represents 0.000000001% of the overall freshwater ecotoxicity annual impact in the EU-27 (USEtox™ normalisation values). Details of the calculations are given in Annex.

In theory, end-of-life impacts also depend on the possible substitutes that would replace the six hazardous substances. A similar quantitative analysis could not be carried out by considering the impact of the substitution of lead solder by lead-free solder, as the most suitable substitutes are not yet known. Still, some substitutes are likely to leach hazardous substances into the environment too, even if lead is the most toxic alloying element: silver or antimony represent a potential source of toxicity in leachates when used in alloys, while bismuth, indium and copper are regarded as less dangerous[32]. Obviously, the levels of emissions depend on the specific environmental conditions the waste will be exposed to during the end-of-life management. Another source[33] builds a comparative analysis of lead-free solder, by taking into account toxicity, availability and

[26] COWI (2002), Heavy Metals in Waste – Final Report, for European Commission DG ENV. Applicable to lead, assumed to be the same for other heavy metals.
[27]ERM (2006), Battery Waste Management Life Cycle Assessment – Final Report.
[28] 25 years (the lifetime of the product) after the effective implementation of RoHS II.
[29]According to USEtox™ methodology.
[30] RoHS II coming into force for this product group (2019), plus one product lifetime (25 years)
[31]Comparative Toxicity Unit ecotoxicity, equivalent to PAF.m3.day
[32] Edwin B. Smith III, Environmental Impacts and Toxicity of Lead Free Solders: http://leadfree.ipc.org/files/RoHS_16.pdf
[33] Anna Kua, Prof. Oladele Ogunseitanb, Prof. Jean-Daniel Saphoresc. Lead-Free Solders: Issues of Toxicity, Availability and Impacts of Extraction: http://trs-new.jpl.nasa.gov/dspace/bitstream/2014/6388/1/03-0222.pdf

environmental impact of extraction of substitutes to lead in solder alloys. Based on this, only tin and copper appear to have a lower overall impact than lead. These outcomes have to be considered with caution given the subjective assessment grid. Finally, a comparative life cycle assessment[34] also illustrates that depending on the environmental impact considered, either lead solder or one substitute (bismuth-tin-silver or copper-tin) can be best performing.

Based on the discussion above, the inclusion of furniture with secondary electrical functions in the scope of RoHS II is not expected to have an impact on this indicator.

1.3.2.4 International environmental impacts

Given the waste management options of end-of-life products, international environmental impacts are expected to be negligible. Concerning the production phase, many of the components that are largely made in China already tend to be RoHS compliant because of their use in other equipment currently in scope of RoHS or could be made in a compliant form. Overall there is hence no impact on this indicator to be expected.

1.3.2.5 Overview of environmental impacts until 2044

Based on the above, no environmental impacts are to be expected from furniture with secondary electrical functions, whether positive or negative.

Table 5: Estimated environmental impacts

Estimated environmental impacts until 2044[35]		
	2012	**2044**
Energy use	=	=
Renewable or non-renewable resources	=	=
Waste production / generation / recycling	=	=
International environmental impacts	=	=

1.3.3 Economic impacts

According to Eurostat[36], in 2006 the EU-27 furniture industry represented a turnover of € 125.7 billion for the production of 277 million units. This suggests an average product price of approximately € 454. Assuming that furniture with secondary electrical functions accounts for

[34] EPA (2005), Solders in electronics: a life-cycle assessment. Available here: http://www.epa.gov/dfe/pubs/solder/lca/lfs-lca-final.pdf

[35] RoHS II coming into force for this product group (2019), plus one product lifetime (25 years)

[36] Eurostat, *European Business - Facts and figures*, 2009, accessed in May 2012 at: http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-BW-09-001/EN/KS-BW-09-001-EN.PDF

approximately 1% of this sector, this suggests a turnover of € 1.26 billion for this segment of the market.

According to European Federation of Furniture Manufacturers (UEA) statistics, the European furniture market has been under pressure over recent years because of increased and more diversified competition, especially from China. In 2008, European furniture production shrunk by 3.7%.

1.3.3.1 *Functioning of the internal market and competition*

In the past, Member State authorities have not been in agreement regarding the inclusion of furniture with electrical functions in the scope of RoHS I. Decisions tended to be made on a case-by-case basis, which did not provide manufacturers with the required legal certainty. Very limited data has been received regarding past compliance checks so that it remains unclear whether manufacturers were in practice experiencing diverse compliance regimes in different Member States.

Accompanied by an FAQ document agreed on by both the Commission and MS authorities , RoHS II should clarify the situation. As discussed in section 1.2.1, the Final Draft RoHS 2 FAQ of 15 May 2012 states that for a product to be EEE under RoHS II, its electricity dependent function must in principle be integrated. If it is interpreted differently by Member State authorities whether the EE component of a piece of furniture is fully integrated or not, manufacturers might have to comply with different rules depending on the MS. It is hence unclear whether with regard to the functioning of the internal market, the inclusion of furniture with secondary electrical functions would have an impact.

1.3.3.2 *Competitiveness*

Limited compliance testing experience in the UK for furniture with primary electrical functions, e.g. a reclining chair, has shown that compliant products do exist. If compliance is possible for products with primary electrical functions, it can be assumed that this should also be possible for products with secondary electrical functions.

As presented in section 1.2, key export markets for furniture with secondary electrical functions produced in the EU are the USA and Switzerland and to a lesser extent Russia and Norway. As most of the key export markets are countries with stringent environmental legislation in place, the impact of this type of furniture falling in the scope of RoHS II is likely to be limited. Imports would have to comply with RoHS II just as European products do, which again means no impact on competitiveness of European firms.

1.3.3.3 *Costs and administrative burdens*

According to the 2008 Impact Assessment accompanying the Commission's recast proposal[37], there is little experience of actual compliance costs for industry. For products currently included in RoHS,

[37]European Commission (2008), SEC(2008) 2930. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=SEC:2008:2930:FIN:EN:PDF

estimates are it would vary from 1-4% of turnover. Other surveys give an average overall cost related to RoHS of 1.9% of turnover (past cost and one-off future costs). Applying the 1-4% range on the annual turnover of the segment of the market of approximately € 1.25 billion, compliance costs would represent between € 12.6 million and € 50 million for all manufacturers combined. Due to a lack of stakeholder contact it has not been possible to assess whether manufacturers of furniture with secondary electrical functions would be specialised or whether these products would generally be manufactured by those who also produce furniture with no or primary electrical functions. It is hence impossible to determine by how many manufacturers these added costs would be shared.

Technical costs will also increase due to the substitution of lead-free solder for lead solder. Based on a maximum lead content of 0.5 grams per piece of furniture with secondary electrical functions, the total amount of lead would be 1.39 tonnes produced in the EU per year. As discussed above, in furniture with secondary electrical functions the tin/lead solder is most likely to be replaced by tin/copper solder. Given the cost difference between lead and tin, the total additional solder metal cost would approximately be € 12,300.[38] Given that this cost is calculated for the entire industry and would therefore be shared by many manufacturers, this is not regarded as significant. EU importers of furniture with secondary electrical functions will also incur compliance costs ensuring that Chinese products are compliant, including the audit of suppliers, selective analyses, etc. Based on previous surveys of RoHS compliance, this is likely to be approximately 0.1% of turnover[39] and will therefore have a limited impact.

1.3.3.4 Innovation and research

As no specific technical information was found or received on the use and functions of RoHS substances in furniture with secondary electrical functions and their possible substitutes, it is difficult to forecast possible needs or costs regarding innovation and research. It seems that no electric function or component used in furniture with secondary electrical functions is specific to this sector, i.e. they can also be found in other products. Therefore, manufacturers would probably not be directly in charge of R&D, but would instead look for alternative RoHS compliant components. These are likely to already exist for other product groups in scope of the Directive. Consequently, the impact on this indicator is considered negligible.

1.3.3.5 Consumers and households

An average retail price for furniture with secondary electrical functions has been previously estimated at € 454 (see section 1.3.3.5). However, prices will vary significantly depending on the product in question. Most products will be sold in the price range of €70 to €2000. It is also important to note that that furniture prices within the EU are very variable.[40]

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[38]Assuming that SnPb will contain 37% of lead. One tonne of lead replaced by 645 kg of tin. Value of lead not used subtracted from extra costs. Metal prices: Lead €1590/tonne; tin €16210/tonne. London Metal Exchange prices, April 2012

[39] Dr. Goodman, P., email exchange April 2012

[40] USAID, *EU Furniture Market Study – Summary*, 2006

[40] Eurostat, *European Business - Facts and figures*, 2009, accessed in May 2012 at: http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-BW-09-001/EN/KS-BW-09-001-EN.PDF

Given the lack of information, it is difficult to predict the possible increase effect that RoHS II implementation would have on final purchase prices. However, as it is assumed that RoHS compliant products do exist, consumers should not be restricted in their product choice because of RoHS II. Furthermore, as discussed in section 1.3.3.3, the additional costs and administrative burdens for this sector because of RoHS II are expected to be limited. This also means that price increases directly linked to a RoHS II implementation should be little, if any.

Overall, the impact of the inclusion of furniture with secondary functions in the scope of RoHS II on consumers and households is expected to be negligible.

1.3.3.6 Overview of economic impacts until 2044

Based on the above, economic impacts from furniture with secondary electrical functions falling in scope of RoHS II are expected to be limited.

Table 6: Estimated economic impacts

Estimated economic impacts until 2044[41]		
	2012	**2044**
Functioning of the internal market and competition	=	=/?
Competitiveness	=	=
Costs and administrative burdens	=/-	-
Innovation and research	=	=
Consumers and households	=	=

1.3.4 Social impacts

1.3.4.1 Jobs

According to Eurostat, a total of 1.35 million people were employed in the EU furniture industry in 2006.[42] Based on the assumption that a maximum of 1% of all furniture will have secondary electrical functions, approximately 13,500 people will be employed by this segment of the market. As discussed above, no information has been received on the type of employers in this particular segment of the market, especially whether they are larger companies or SMEs. As there is also very limited information on the additional costs and administrative burdens, it is difficult to say to what extent the labour market would be affected by furniture with secondary electrical functions falling in scope of RoHS II. If any, the impact is expected to be negative but only slightly so.

[41] RoHS II coming into force for this product group (2019), plus one product lifetime (25 years)
[42] Eurostat, *European Business - Facts and figures*, 2009, accessed in May 2012 at: http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-BW-09-001/EN/KS-BW-09-001-EN.PDF

1.3.4.2 Health

The overall impacts of hazardous substances on health are difficult to quantify. It needs to be differentiated between possible impacts during the production phase, on users during the actual product's lifetime and at the end-of-life.

First, exposure to these substances during the production phase represents a risk for the facility workers, who are a population group at greatest risk of exposure to lead,especially through air. This risk is very much dependent upon the type of exposure (time, frequency, pathway, etc.). It can be expected that generally EU manufacturers already respect the relevant legislation and implement the necessary precaution to ensure their workers' well-being. The production of the electronics is mostly carried out outside the EU-27 thanks to lower labour costs. However, a ban of the six RoHS substances would be likely to reduce the health impacts during the production phase, in particular in case of accidental situations. This phenomenon is also dependent on possible developments in other industrial sectors because of the complex structure of supply chains. The importance of these health effects furthermore depends on the potential effects of the substitutes to the six banned substances, if any. Therefore, a quantification of these impacts could not be made.

Impacts on the health of users during the use phase are expected to be negligible because no RoHS substances are emitted during use. In normal operation, the product represents a very low or no risk to the user's health, as this is taken into account in the design phase. Direct contact with hazardous substances is not expected.

Finally, the management during the end-of-life can result in important impacts to the environment and health. These impacts are dependent upon the management options followed by products, which have already been presented (see section1.3.2.3). Based on the same assumptions regarding emissions to air and water of the substances during recycling, incineration and disposal (see Table 3), health impacts can be quantified via the human toxicity indicators[43]: Assuming the ban of RoHS hazardous substances in furniture with secondary electrical functions from 2019 (Option 2), a human toxicity impact of1.30E-04 CTUh (cancer effects) and 2.59E-02 CTUh (non-cancer effects) would be avoided in 2044(0.000001% and 0.000006% respectively of overall impacts in the EU-27 annually), compared to Option 1, due to the removal of lead and chromium VI.

Table 7: Human toxicity indicators

Year[44]	Human toxicity midpoint, cancer effects (CTUh[45])	Human toxicity midpoint, non-cancer effects (CTUh)
2044	1.30E-04	2.59E-02

The monetised benefit of this has been calculated by Defra (UK)[46] which looked at the costs in terms of health impacts of options for management of waste containing hazardous substances including lead. The study estimated health impacts from mathematical models of landfill and incineration and estimates of pollution from these disposal options. Applying these results to the

[43]USEtox™ method.
[44] RoHS II coming into force for this product group (2019), plus one product lifetime (25 years)
[45]Comparative Toxicity Unit human, equivalent to cases
[46]Enviros Consulting Ltd. For Defra, *Valuation of the external costs and benefits to health and environment of waste management options*, December 2004, table 3.2 and page 82)

heavy metal emissions per end-of-life treatment options (see Table 3), gives a monetised health benefit from not using lead of between €79,000 and € 1.9 million[47].

Based on the above, health benefits, albeit limited, can be expected from the inclusion of furniture with secondary electrical functions in the scope of RoHS II.

1.3.4.3 Social impacts in third countries

Given the waste management options of end-of-life products, international health impacts are expected to be negligible. Concerning the production phase, the components that are largely made in China are generally already RoHS compliant because of their use in other equipment currently in scope of RoHS. Overall there is hence no impact on this indicator to be expected.

1.3.4.4 Overview of social impacts until 2044

The social impacts of furniture with secondary electrical functions falling in the scope of RoHS II can be expected to be slightly positive given the health benefits, especially during the end-of-life phase of the products.

Table 8: Estimated social impacts

Estimated social impacts until 2044[48]		
	2012	**2044**
Employment	=	?/-
Health	=	+
Social impacts in third countries	=	=

1.3.5 Comparison of options

The inclusion of furniture with secondary electrical functions in scope of RoHS II is expected to have very limited impacts on the relevant indicators. This is mostly due to the limited number of products assumed to be affected by this scope change as well as the limited amount of RoHS substances in these products. While there are no environmental impacts expected, overall health impacts are estimated to be beneficial. Economic impacts are limited to a possible increase in costs and administrative burdens for industry although this should not be significant.

Please note that the current assessment is based on many assumptions and that detailed information on the RoHS substances specifically used in these products were not found or received from stakeholders. Therefore, results should be considered with caution.

[47] Based on a monetised impact of lead between €1.46 million/tonne and €35 million/tonne, and assuming a 3.9% leakage rate of lead at the end-of-life.
[48] RoHS II coming into force for this product group (2019), plus one product lifetime (25 years)

Table 9: Comparison of options

Impact indicators	Option 1 : Furniture with secondary electrical functions not in scope of COM recast proposal	Option 2: Furniture with secondary electrical functions in scope of RoHS II
Environmental impact indicators		
Energy use	=	=
Renewable or non-renewableresources	=	=
Waste production / generation / recycling	=	=
International environmental impacts	=	=
Economic impact indicators		
Functioning of the internal market and competition	=	=/?
Competitiveness	=	=
Costs and administrative burdens	=	-
Innovation and research	=	=
Consumers and households	=	=
Social impact indicators		
Employment	=	?/-
Health	=	+
Social impacts in third countries	=	=

In relation to the overall policy objective of RoHS II, namely to contribute 'to the protection of human health and the environment, including the environmentally sound recovery and disposal of waste EEE'[49], the discussion above shows that including furniture with secondary electrical functions in RoHS II does contribute to this objective, but only slightly:

[49] 2011/65/EU, Article 1

Table 10: Policy objectives and options

Policy options in relation to overall policy objectives			
	Effectiveness	**Efficiency**	**Coherence**
Option 1: Furniture with secondary electrical functions not in scope of COM recast proposal	Slightly negative: Hinders the objectives to a limited extent	Efficiency cannot be evaluated as the option does not contribute to the overall objectives	No unintended impacts
Option 2: Furniture with secondary electrical functions in scope of RoHS II	Slightly positive: Contributes to reaching the objectives although limited	Limited: None of the positive impacts are significant	Limited unintended impacts

Annex

Table 11: Quantities of RoHS substances released to the environment in 2044 without RoHS II implementation, due to end-of-life management options

Substance	Released to	Quantity (in kg)
Cadmium	Air	0
Chromium VI		0.0002
Lead		2.0789
Mercury		0
Cadmium	Water	0
Chromium VI		0.0052
Lead		51.9777
Mercury		0

Table 12: Characterisation factor of the RoHS substances (USEtox™ method)

Substance	Type of emissions	Human toxicity midpoint, cancer effects (in CTUh/kg)	Human toxicity midpoint, non-cancer effects (in CTUh/kg)	Ecotoxicity freshwater midpoint (in CTUe/kg)
Lead	Emissions to air, unspecified	2.69E-05	9.44E-03	1.75E+02
	Emissions to water, unspecified	3.42E-07	1.20E-04	3.75E+02
Mercury	Emissions to air, unspecified	7.06E-03	8.35E-01	1.22E+04
	Emissions to water, unspecified	1.20E-04	1.42E-02	2.21E+04
Chromium VI	Emissions to air, unspecified	4.45E-03	4.16E-04	4.20E+04
	Emissions to water, unspecified	1.06E-02	2.40E-05	1.05E+05
Cadmium	Emissions to air, unspecified	2.17E-04	4.55E-02	3.94E+03
	Emissions to water, unspecified	1.59E-06	4.27E-04	9.71E+03

Table 13: Impact assessment results (USEtox™ method)

Impact indicator (unit)	Avoided impacts in 2044 in EU-27, with RoHS II implementation (in impact indicator unit)	Avoided impacts in 2044 in EU-27, with RoHS II implementation (in % of annual EU-27 impacts)	USEtox™ normalisation factors (in impact indicator unit per person per year)
Human toxicity midpoint, cancer effects (in CTUh)	1.30E-04	0.000001%	3.25E-05
Human toxicity midpoint, non-cancer effects (in CTUh)	2.59E-02	0.000006%	8.14E-04
Ecotoxicity freshwater midpoint (in CTUe)	2.04E+04	0.000000001%	3.18E+06

An EU-27 population estimate of 502m inhabitants in 2011 is used for the normalisation (source: Eurostat, in March 2012).

Light and power switches, power wall sockets

1.1 Key issues

Light and power switches and power wall sockets were not in scope of the COM recast proposal but fall in Category 11 of RoHS II. In this factsheet, it will be explored what the impact of this change is and whether the benefits of the inclusion of light and power switches and power wall sockets in RoHS II outweigh the potential costs.

1.2 Background

1.2.1 Definition of the products

- Electrical switches for light and power

The role of an electrical switch is to regulate the flow of current that travels in an electrical circuit, between the load (i.e. a lamp, a television) and the power source (i.e. the fuse box). In order for an electrical switch to work, it has to be connected to the fuse box (or circuit breaker units) and the load. There are different types of electrical switches designed for lighting and mains power and they come in a variety of styles and designs. There are three or four main types of electrical switches: a toggle switch, a rocker switch, a silent switch and a dimmer switch. They differ by the way of establishing contact between the contact points, as explained below:

- Toggle switch: The popular toggle switch has an arrow-shaped armature that floats between the contact points when the switch is in the off position. This armature comes in contact with both terminals when the switch is flipped to the on position, thus providing a continuous flow of electrical current to the light or appliance.
- Rocker switch: It is an alternative design to the toggle switch that is commonly used in the European Union.
- Silent switch: The silent switch has a steel spring armature that is pressed away from the bottom terminal when the switch is turned off. Flipping the switch lever to the on position moves the steel spring back against the contact point, thus establishing contact in the circuit.
- Dimmer switches: These are used for room lighting to control the level of lighting. There are various designs used, some use thyristors, triacs or rheostats but commercial non-domestic dimmers use more complex designs.

Lighting switches in buildings switch mains circuits usually single phase at 230 ± 10% volts AC. The lighting circuit current of buildings in European countries is typically 5A, 6A or 10A.

- Power wall sockets

A power wall socket is fixed on equipment or a building structure. It provides power to an electrical product by using a plug designed to mate with the socket. The plug is attached to a wire to take power from the socket to the electrical equipment. A socket is also called a receptacle, outlet, or power point. Electrical sockets have three major parts: the faceplate, the receptacle and the mounting box. The sockets that are used in European Members States are compatible with plugs in line with European standards (i.e. 220–240 volts at 50 Hz). Standard plugs used in European Member States are all compatible with the CEE 7/16 Europlug except for the UK, which uses a different design defined by BS 1363. 3-phase sockets are used in commercial buildings and factories. These have a different design to single phase sockets.

1.2.2 Legal background

Light and power switches and power wall sockets were not considered in scope of RoHS I or the COM recast proposal but will fall in Category 11 of RoHS II. The RoHS II substance restrictions will apply to all components, also non-electrical ones, on the homogeneous material level.

The use of cadmium and its compounds in electrical contacts is currently exempt from RoHS by exemption 8b of Annex III.

1.2.3 Quantities and hazardous substances

1.2.3.1 Electrical power and light switches

In the PRODCOM database[1], switches are included in several product categories:

- Time switches, with clock or watch movement or with synchronous motor (including switches for making and breaking the circuit supplying electrical apparatus) (PRODCOM code 26522870);
- Isolating switches and make-and-break switches (PRODCOM code 27121030);
- Electrical apparatus for switching electrical circuits for a voltage <= 1 kV (including push-button and rotary switches) (excluding relays) (PRODCOM code 27331100) ; and
- Other apparatus for switching... electrical circuits > 1000 V (PRODCOM code 27121090).

Table 1 shows production and trade figures (in quantities and values) for categories containing products potentially within the scope of light and power switches, extracted from the PRODCOM database, for the EU-27 in 2010. The table includes figures on the apparent consumption in the EU-27 which is calculated from PRODCOM figures. No specific product category including all light and power switches within the scope of the study has been identified

[1] Statistics on the production of manufactured goods Value ANNUAL 2010, updated 04/05/2012

Table 1: PRODCOM market figures for switches, sorted by EU-27 Apparent Consumption Value (EU-27, 2010)[2]

Product category[3]	Production		Imports		Exports		EU-27 Apparent Consumption[4]	
	Quantity (in '000 p/st)	Value (in k€)	Quantity (in '000 p/st)	Value (in k€)	Quantity (in '000 p/st)	Value (in k€)	Quantity (in '000 p/st)	Value (in k€)
Time switches, with clock or watch movement or with synchronous motor (including switches for making and breaking the circuit supplying electrical apparatus	9,017	121,774	21,012	47,115	6,658	47,952	23,371	120,937
Isolating switches and make-and-break switches	5,998	503,431	n.a	137,857	n.a	239,358	n.a	401,930
Electrical apparatus for switching electrical circuits for a voltage <= 1 kV (including push-button and rotary switches) (excluding relays)	2,814,270	4,232,574	n.a	1,270,747	n.a	1,645,594	n.a	3,857,727
Other apparatus for switching... electrical circuits > 1000V	27,712	1,205, 606	n.a	236,841	n.a.	1,117,715	n.a.	324,732

In the absence of further information from industry, it is **estimated that approximately 30% of the combined equipment of the four above-mentioned PRODCOM categories are relevant for this analysis**. Based on an EU-27 total apparent consumption or EU sales of 2.77 billion units[5], this translates into **921.5 million units of sales per year**.

Power switches are made from hard plastics as an electrical insulator with copper and brass conductors, brass connectors and have switching contacts that are made of various materials depending on the type of switch. Silver containing **cadmium oxide** is used in some types of switch, others use silver / nickel alloy, silver with tin oxide and other materials. The use of cadmium oxide in electric contacts is currently exempt from RoHS by exemption 8b of Annex III. Some types of power switches will be attached to a receptacle using screws that may have a chromate passivation coating (i.e. **hexavalent chromium**). The receptacle itself is usually made of a hard plastic or galvanised steel and may also have a chromate passivation coating to prevent corrosion. **For this assessment it is estimated that approximately 10 µg of CrVI can be found in cases where it is used. In the absence of further information from industry, it is assumed that CrVI can be found in 30% of switches assessed as part of this works, which means in approximately 307 million units per year.**

[2] Database available at: http://epp.eurostat.ec.europa.eu/portal/page/portal/prodcom/data/database. Last update on: 19/09/2011

[3] Not all products within a presented category are systematically included within the scope of this impact assessment.

[4] Apparent Consumption = Production + Imports - Exports

[5] Assuming the same unit/value relation as in 'Production'

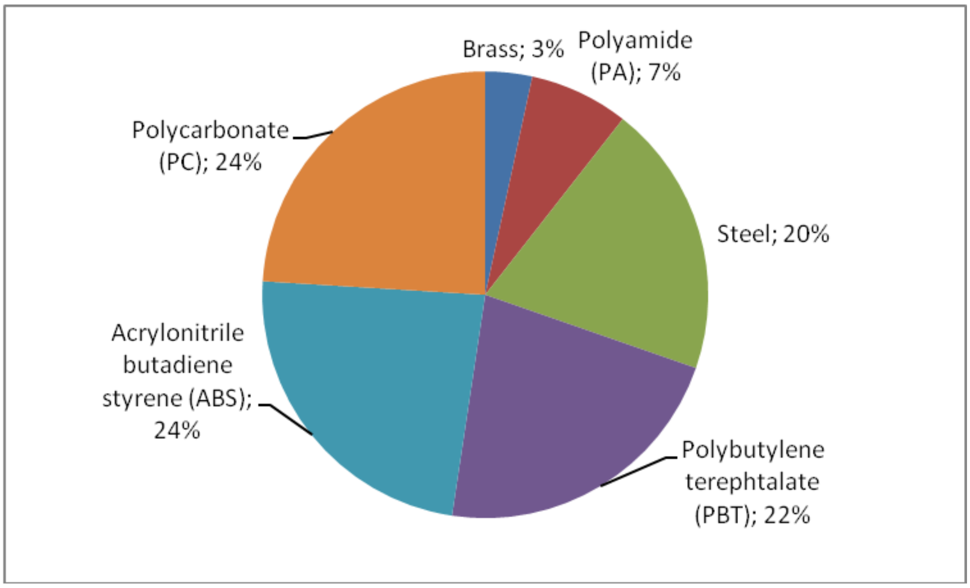
Light switches consist of similar materials but as they tend to switch lower currents, silver-cadmium oxide electric contacts are much less likely to be used. Some designs of dimmer switches will include small electrical circuits that may use solder.

Mercury switches are rarely used today. They were used in the past as switches that were integral parts of equipment as level sensors, safety cut-outs and for telecommunications and in thermostats. Most uses have been replaced by mercury free switches and mercury switches are no longer used as power switches and are not used for lighting. **PBDE** might be found as a flame retardant in the hard plastic that switches are made of. **For this assessment it is estimated that PBDE is used in 5% of all switches analysed as part of this work, which equals to 46 million units, in a quantity of approximately 1 gram.**

Lead and PBB are not expected to be found in electrical light and power switches with the possible exception of small amounts of lead in thyristors (currently exempt) and in solders used in some types of dimmer switches. Given the small amount of lead expected as well as the small amount of affected switches, lead will be disregarded in this analysis.

The share of each constituent material in the total is given as an example for a 3-position switch for shutters representative of the group of products "switches and buttons with or without claws fixing". The main constituent materials are: Steel (20%) and hard plastics: Polybutylene terephthalate (PBT) (22%), Acrylonitrile butadiene styrene (ABS) (24%) and PC (Polycarbonate) (24%). Other materials are: Brass (3%) and another type of plastic, being Polyamide (PA) (7%). The weight of this product line is ranged between 75g and 80g, excluding packing. The item studied is around 77.4g.

Figure 0-1: Constituent materials of a 3-position switch for shutters (weight: 77.4 g) (Schneider Electric)[6]



[6] Complete Environmental Profile Product available at: http://www.global-download.schneider-electric.com/85257689000007EE/all/3817F771FCABD16E852578BE005CF443/$File/envpep110401fr.pdf

The table below presents the ROHS substances contained in electrical power and light switches.

Table 2: RoHS substances in electrical light and power switches

Substance	Presence in electrical light and power switches
Lead	No (only small amounts (<0.5grams) in some types of dimmer switch (probably <1% of switches)). Some lead may be used in copper alloys but this use is exempt.
Mercury	No
Cadmium	Yes but use of cadmium oxide in electrical contacts currently exempt from RoHS by exemption 8b of Annex III.
Hexavalent Chromium	Potentially on the receptacle and screws Estimation: ~10µg where used
Polybrominated biphenyls (PBB)	No
Polybrominated diphenyl ethers (PBDE)	Potentially in PBT and in ABS Estimation: ~1 g where used

Source: Own estimations

It should be noted that a number of manufacturers already offer light and power switches that are RoHS compliant but no data has been identified specifying the percentage of the market that is currently compliant.

1.2.3.2 *Power wall sockets*

In the PRODCOM database[7], power wall sockets of the type considered here are contained in the following category:

- Plugs and sockets for a voltage <= 1 kV (excluding for coaxial cables, for printed circuits) (PRODCOM code 27331350).

The table below shows production and trade figures (in quantities and values) for this category although it should be stressed that not all products in the category will be of relevance for this assessment.

[7] Statistics on the production of manufactured goods Value ANNUAL 2010

Table 3: PRODCOM market figures for power wall sockets, sorted by EU-27 Apparent Consumption Value (EU-27, 2010)[8]

Product category[9]	Production		Imports		Exports		EU-27 Apparent Consumption[10]	
	Quantity (in '000 p/st)	Value (in k€)	Quantity (in '000 p/st)	Value (in k€)	Quantity (in '000 p/st)	Value (in k€)	Quantity (in '000 p/st)	Value (in k€)
Plugs and sockets for a voltage <= 1 kV (excluding for coaxial cables, for printed circuits)	20,000,000	3,046,724	n.a.	1,133,785	n.a.	1,056,350	n.a.	3,124,159

In the absence of further information from industry, it is **estimated that approximately 50% of the equipment of the above-mentioned PRODCOM category are relevant for this analysis**. Based on an EU-27 total apparent consumption or EU sales of 20.5 billion units[11], this translates into **10.3 billion units of sales per year**.

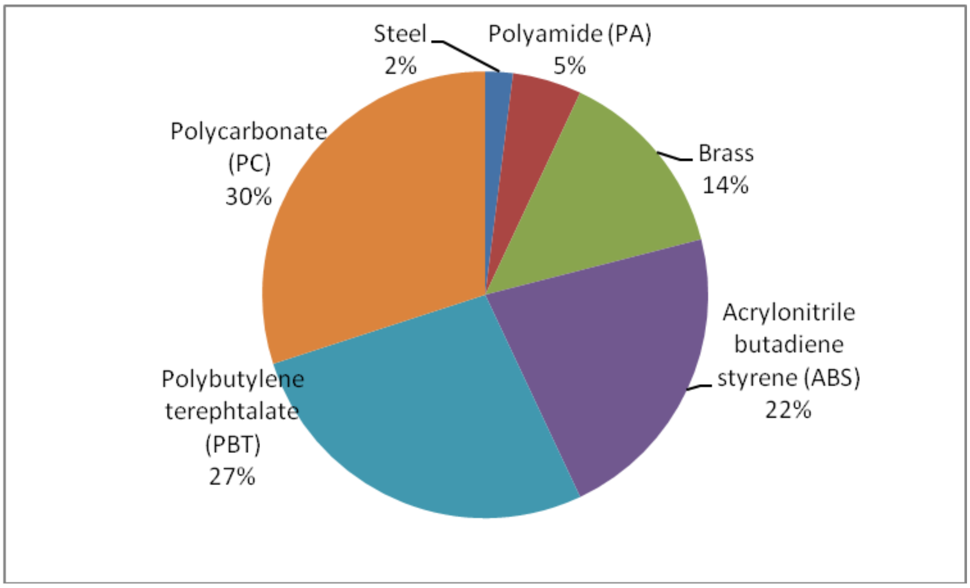
Power sockets are made of a hard type of plastic as an electrical insulator such as polybutylene terephthalate (PBT) with copper and brass conductors and brass or bronze clips that hold the plug pins. PBT is one of the types of plastics that have used deca-BDE flame retardant in the past. Penta- and deca-BDE were also used in ABS. The deca-BDE flame retardant is included in the family of Polybrominated diphenyl ethers (**PBDE**). For this assessment it is estimated that PBDE is used in 5% of all sockets analysed as part of this work, which equals to 513 million units, in a quantity of approximately 1 gram.

There are also brass connectors to connect to the power circuit. Some power sockets incorporate a mains switch (see above). The power socket will be attached to a receptacle using screws that may have a chromate passivation coating (i.e. **Hexavalent Chromium**). The receptacle itself is made of either a hard plastic or galvanised steel which may also have a chromate passivation coating to prevent corrosion. **For this assessment it is estimated that approximately 10 µg of CrVI can be found in case it is used. In the absence of further information from industry, it is assumed that CrVI can be found in 50% of sockets assessed as part of this works, which means in approximately 5.2 billion units per year.**

The share of each constituent material is given for a wall power socket in line with the German standard, 2P + earth side, 16 A plug, with screwless terminals. This item is representative of the product line "power wall sockets, 2P + earth side and 2P + E, with terminals with screws or without screws, with or without retaining claws". The main constituent materials are: ABS (22%), PBT (27%), and PC (30%). Other materials are: Steel (2%), PA (5%), and brass (14%).

[8] Database available at: http://epp.eurostat.ec.europa.eu/portal/page/portal/prodcom/data/database. Last update on 19/09/2011
[9] Not all products within a presented category are systematically included within the scope of this impact assessment.
[10] Apparent Consumption = Production + Imports - Exports
[11] Assuming the same unit/value relation as in 'Production'

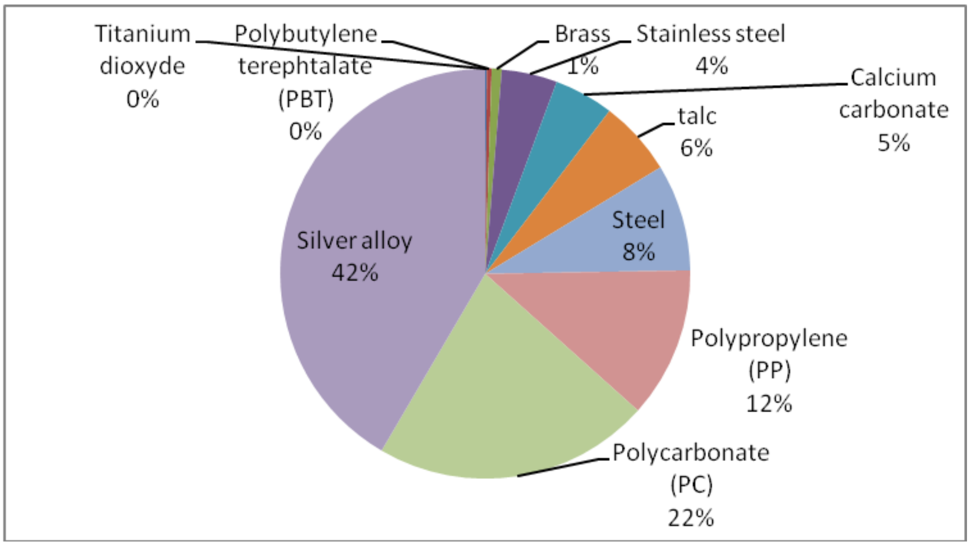
Figure 0-2: Constituent materials of a power wall socket in line with the German standard, 2P + earth side, 16 A plug, with screwless terminals



Source: Schneider Electric[12]

Another example is provided for a surface mounted NF-USE sockets 16 A – 250 V. This item is representative of the product line "power wall sockets, 2P+T-(VDE) 16 A – 250 V". The main constituent materials are: Silver alloy (42%), PC (22%) and Polypropylene (PP) (11.9%). Other materials are between 5% and 10%: Elastomere, Steel, Talc, and Brass. Stainless steel, Fiberglass, Titanium dioxide, and PBT are less than 1%.

Figure 0-3: Constituent materials of a surface mounted NF-USE sockets 16 A – 250 V



Source: Schneider Electric[13]

[12] Complete Environmental Profile of the product available at: http://www.global-download.schneider-electric.com/85257689000007EE/all/B44AA0359F39D49785257864006442 9A/$File/envpep101111fr.pdf

[13] Complete Environment Profile of the product available at : http://www.global-download.schneider-electric.com/852577A4005D7372/all/2BBA5D50AD29A166852577EC0068A03F/$File/fiche-pep-mureva_socket%20nf_en.pdf

Table 4 indicates whether the hazardous substances covered by the RoHS Directive are expected to be present in power wall sockets.

Table 4: RoHS substances in power wall sockets

Substance	Presence in power wall sockets
Lead	No
Mercury	No
Cadmium	Unlikely
Hexavalent Chromium	Potentially on the receptacle and screws Estimation: ~10µg where used
Polybrominated biphenyls (PBB)	No
Polybrominated diphenyl ethers (PBDE)	Potentially in PBT and ABS Estimation: ~ 1 gram where used

Source: Own estimations

1.2.4 Policy objectives and options

The objective of both, the RoHS recast proposal (COM (2008) 809 final) as well as RoHS II (2011/65/EU) is to contribute 'to the protection of human health and the environment, including the environmentally sound recovery and disposal of waste EEE'[14].

The purpose of this work is to look at the impacts of light and power switches and power wall sockets falling in scope of RoHS II compared to light and power switches and power wall sockets being excluded from the COM recast proposal. Policy options will then be evaluated according to their effectiveness, efficiency and coherence in reaching the above-mentioned overall objective of the RoHS Directive. The policy options analysed are the following:

- OPTION 1 (baseline scenario): The COM recast proposal. Light and power switches and power wall sockets are not in scope of the proposed recast Directive.
- OPTION 2: RoHS II. Light and power switches and power wall sockets are included in the scope of the recast Directive.

[14] 2011/65/EU, Article 1

1.3 Impacts of policy options

1.3.1 Impact indicators

The following impact indicators have been chosen as relevant for this product group (see Table 5).

Table 5: Impact indicators for the product group of switches and sockets

Impact indicators		
Environmental	Economic	Social
Energy use	Functioning of the internal market and competition	Employment
Waste production / generation / recycling	Competitiveness	Health
International environmental impacts	Costs and administrative burdens	Social impacts in third countries
	Innovation and research	
	Consumers and households	

The following legend will be used in summarising the impacts:

Legend	
+++	Very beneficial effect
++	Substantial beneficial effect
+	Slight beneficial effect
=	No effect
-	Negative effect
--	Substantial negative effect
---	Very negative effect
?	Unknown effect

1.3.2 Environmental impacts

The most important stakes regarding the environmental impacts in the context of RoHS are related to the quantities of hazardous substances used in the equipment. The mere quantity of a substance is however not sufficient to estimate what will be the actual impacts of the substance on the environment and health. These indeed depend upon numerous factors such as the effective treatment of products at the end-of-life, their design for the use phase or their potential emissions during the production phase. The impact of the substances released to the environment is also determined by case-specific and complex dose-response relationships.

It is therefore not straightforward to predict environmental impacts due to hazardous substances found in products. Where possible, the following subsections will make the link between the quantities of hazardous substances and their potential environmental impacts.

1.3.2.1 Energy use

Switches and power wall sockets are products by which passes electricity; their manufacturing, distribution and use entail energy depletion. For a 3-position switch, representative of this product group, the life cycle analysis performed by a manufacturer by using the EIME software indicates that energy use is highest during the distribution phase and negligible during the use phase.[15] Regarding a surface mounted NF-USE socket 16 A – 250 V, the life cycle analysis performed shows that the phase of highest energy use is the manufacturing one.[16]

Neither the use of hexavalent chromium, nor of PBDE, which are the RoHS substances of interest regarding switches and sockets as outlined in section 1.2.3, are expected to have an impact on the energy use during any of the life cycles stages of the equipment. This indicator is therefore not expected to be impacted by the equipment falling in scope of RoHS II.

1.3.2.2 Waste production / generation / recycling

The main constituent materials of switches and power wall sockets are hard plastics: PBT, ABS, PC and PA. These materials can be recycled by common processes of end-of-life management. Apart from recycling and disposal to landfill, waste plastic can be incinerated at end-of-life with or without energy recovery. As BIO intelligence Service (2009) stated, 21% of waste plastic generated was recycled mechanically in 2008 in the EU and 0.3% through feedstock recycling. The requirement for mechanical recycling is that the discarded plastics are collected as far as possible in single types and/or sorted into individual types[17]. When contaminated, in limited quantity or with a varied composition, the material is not suitable for this type of process. For instance, the deca-BDE flame retardant, included in the family of Polybrominated diphenyl ethers (PBDE) might limit the potential of recycling of a material as recycled plastics containing this substance cannot be re-used in new EEE in scope of RoHS. In theory, feedstock recycling is appropriate for all qualities and types of waste plastic, as long as requirements are met. Furthermore, the potential of recycling of materials will depend highly on the level of waste plastic recovery in a determined country. As

[15] Schneider Electric (2010a), Interrupteur à bascule 3 positions ODACE pour volets roulants avec griffes de fixation – Profil Environnement Produit (in French). Available at: http://www.global-download.schneider-electric.com/85257689000007EE/all/3817F771FCABD16E852578BE005CF443/$File/envpep110401fr.pdf. Energy depletion in the distribution phase:. 31.1 MJ and around 3.7E+02 MJ during the production phase.

[16] Calculated by using the software EIME (Environmental Impact and Management Explorer) version 4.0 and its database version 10.0. Results in an energy depletion equal to around 1.7E+01 MJ in total. The most impacting phase is the manufacturing one with an energy use of approximately 1.4E+01 MJ. During the distribution phase, it is about 6.7E-01 and during the use phase 2.1E+00 MJ. Source: Mureva surface mounted wiring devices, Product Environmental Profile. Available at: http://www.global-download.schneider-electric.com/852577A4005D7372/all/2BBA5D50AD29A166852577EC0068A03F/$File/fiche-pep-mureva_socket%20nf_en.pdf

[17] OECD, Plastic from the commercial and private household sectors, 2009

indicated in BIO Intelligence Service (2009), significant differences in the levels of waste plastic recovery[18] can be observed across Member States in 2008**Erreur ! Signet non défini.**: Nordic countries (Norway, Sweden, Germany, Denmark, Belgium) have the highest recovery rates (over 85%), France (54.7%) and Italy (44.4%) have a rate close to the EU average, Spain (32.7%), Portugal (27.6%) and the UK (25.3%) have relatively low recovery rates, others Member States have even lower levels.

The potential for recycling of a surface mounted socket 16 A – 250 V (NF-USE) was estimated at 77%[19], which is high. Conversely, the calculation of the potential for recycling of both a 3-position switch for shutters and a power wall socket shows that these product lines do not contain recyclable materials, due to the absence of a specific recycling program for the plastics used although they can be dismantled or grounded to make better use of different materials.[20] In the absence of further information by industry, it is assumed that **20% of all switches and sockets assessed in this work will be recycled, with another 30% being incinerated and 50% going to landfill** (see Table 6). Furthermore, based on environmental product profiles of relevant products developed by Schneider Electric, an **average lifetime of 20 years** will be assumed for switches and sockets.[15,16]

Depending on the quality of the end-of-life operations, a certain share of the substances (called the leaching potential) is always lost to the environment. According to BIO (2008)[21], process control of landfills and incinerators, alongside mineralization mechanisms in landfills, are some of the options to reduce this share. But there is limited quantitative data about the fate of hazardous substances going through land filling or incineration processes, in particular their leaching potential.

Policy Option 2 (including this type of equipment in the scope of RoHS II) would progressively (over a 20 year period, between 2019 and 2039[22]) decrease the quantities of hazardous substances from light and power switches and power wall sockets found in the waste streams, compared to the baseline scenario. The reduction of these substances may have a beneficial effect on their end-of-life treatment. This effect is dependent on the development of the waste management sector as a whole.

Table 6 shows the estimations used to calculate the environmental impacts of RoHS hazardous substances released into the environment at the end-of-life. The assessment is likely to contain high uncertainties, because of the assumptions made to model the end-of-life options.

[18] The term 'recovered' in the context of waste plastic is frequently used to cover both recycling and energy recovery incineration of waste plastic.
[19] Schneider Electric (2010), Prise de courant ODACE au standard allemand, 2P + T latérale, 16 A, à obturateur, avec bornes sans vis – Profil Environnement Produit (in French). Available at: http://www.global-download.schneider-electric.com/85257689000007EE/all/B44AA0359F39D497852578640064429A/$File/envpep101111fr.pdf
[20] Complete Environmental Profile of the product available at: http://www.global-download.schneider-electric.com/85257689000007EE/all/B44AA0359F39D497852578640064429A/$File/envpep101111fr.pdf
[20] Complete Environment Profile of the product available at : http://www.global-download.schneider-electric.com/852577A4005D7372/all/2BBA5D50AD29A166852577EC0068A03F/$File/fiche-pep-mureva_socket%20nf_en.pdf
[21] BIO (2008), Study to support the impact assessment of the RoHS review – Final Report, for DG ENV.
[22] Possibly earlier if manufacturers take early measures.

Table 6: Heavy metal emissions, by end-of-life management options

End-of-life process	Share of total end-of-life products (in %)	Emissions to air during end-of-life process	Emissions to water during end-of-life process	Source of the emissions estimates
Recycling	20%	0.001%	0.059%	COWI (2002)[23]
Incineration	30%	0.5%	2.49%	ERM (2006)24
Landfill	50%	-	5%	ERM (2006)

By considering the annual sales and quantities of hexavalent chromium presented in section 1.2.3, it is estimated that 52 kg of hexavalent chromium would be sent annually into the end-of-life management circuit from 2039[25] for sockets and 3.07 kg for switches if these product groups were not included within the scope of RoHS II. For Option 2, it is assumed that all hexavalent chromium would be removed from the products from 2019, so that none of these substances would go to the waste streams from 2039.

Based on these assumptions, the ecotoxicity freshwater midpoint indicator was calculated[26] in order to illustrate the avoided impacts of the inclusion of light and power switches and power wall sockets within the scope of RoHS II at the end-of-life 2039. This indicator was chosen because the release of RoHS hazardous substances in the environment has an influence on its value (this is not the case for Global Warming Potential for instance).

Table 7: Avoided freshwater ecotoxicity impacts by Option 2, compared to Option 1

Product	Ecotoxicity freshwater midpoint (CTUe[27]) in 2039[28]
Light and power switches	1.07E+04
Power wall sockets	1.81E+05

This result represents 0.00000024% for light and power switches and 0.000004% for power wall sockets of the overall freshwater ecotoxicity annual impact in the EU-27 (USEtox™ normalisation values) in 2039. Details of the calculations are given in Annex.

Furthermore, based on the assumptions made in section 1.2.3 a total of 46 tonnes[29] of PBDE could be saved annually from the ban of this substance in light and power switches and 513 tonnes[30] from

[23] COWI (2002), Heavy Metals in Waste – Final Report, for European Commission DG ENV. Applicable to lead, assumed to be the same for other heavy metals
[24] ERM (2006), Battery Waste Management Life Cycle Assessment – Final Report.
[25] 20 years (the lifetime of the product) after the effective implementation of RoHS II.
[26] According to USEtox™ methodology.
[27] Comparative Toxicity Unit ecotoxicity, equivalent to PAF.m3.day
[28] RoHS II coming into force for this product group (2019), plus one product lifetime (20 years)
[29] Based on the assumption of 1 g being used in 46 million units annually
[30] Based on the assumption of 1 g being used in 513 million units annually

its ban in power wall sockets. However, it could not be assessed as part of this study to what amounts of saved PBDE this would translate in the waste stream and what the final environmental benefit would be.

Overall, the ban of the use of hexavalent chromium and PBDE in light and power switches and power wall sockets can be expected to have a positive impact on this environmental indicator. Nevertheless, it should be stressed that this analysis is characterised by a lack of data and high uncertainties. In theory, end-of-life impacts also depend on the possible substitutes that would replace the hazardous substances. A similar quantitative analysis could not be carried out for the impact of the substitutions of CrVI and PBDE.

1.3.2.3 International environmental impacts

The above-mentioned environmental benefits could also affect third countries that export this type of equipment to the EU-27. However, no information has been available on the main exporters and hence no further conclusions can be drawn.

Given the end-of-life treatment options of light and power switches and power wall sockets presented in section 1.3.2.2, it is estimated unlikely that illegal shipment of this type of equipment is significant.

1.3.2.4 Overview of environmental impacts until 2039

The environmental impacts of light and power switches and power wall sockets falling in the scope of RoHS II can be expected to be positive mainly because of the reduction of hexavalent chromium and PBDE in the waste stream.

Table 8: Estimated environmental impacts

Estimated environmental impacts until 2039[31]		
	2012	**2039**
Energy use	=	=
Waste production / generation / recycling	=	+
International environmental impacts	=	?

[31] RoHS II coming into force for this product group (2019), plus one product lifetime (20 years)

1.3.3 Economic impacts

1.3.3.1 Functioning of the internal market and competition

RoHS II should affect all EU manufacturers of light and power switches and power wall sockets equally, which means that no competitive pressures within the European Union should be expected. Provided there is suitable market surveillance, no distortion of the internal market is expected.

1.3.3.2 Competitiveness

No specific market information on imports and exports was received or found so there is high uncertainty regarding the effect of RoHS II implementation for this indicator. In theory, the implementation of RoHS II for light and power switches and power wall sockets should have no impact on the competitiveness of EU companies on the EU market, as all products sold are subject to the same regulations. However, non RoHS-compliant manufacturers (inside or outside the EU) selling on the EU market could benefit from an implementation of RoHS II, in case that market surveillance is not properly implemented.

The fact that RoHS compliant designs are already widely available on the EU market implies that their manufacturers did not suffer from a lack of competitiveness for these products and that the additional technical costs were either not significant or counterbalanced by other benefits, such as a 'green' visibility for instance. This assumption is supported by the fact that where RoHS compliant products are on offer, being considered as a marketing advantage, this compliance is widely communicated by suppliers and distributors to clients.

For products for which technical limitations may exist, RoHS implementation may reduce their competitiveness for exportations to countries where such substance requirements are not compulsory, due to additional costs. Furthermore, according to stakeholders, substituting hexavalent chromium with other identified and available corrosion protection methods e.g. trivalent chromium may also reduce the durability and reliability of the product, due to premature corrosion. However, no further information supporting this information has been received and the fact that numerous RoHS compliant designs exist, implies that there are means to ensure durability and reliability without the use of RoHS substances.

1.3.3.3 Costs and administrative burdens

The inclusion of new products in RoHS II will increase the costs and administrative burdens for those companies that do not yet offer RoHS compliant products as well as for those who do as they will need to provide CE markings for their products.

According to the 2008 Impact Assessment accompanying the Commission's recast proposal[32], there is little experience of actual compliance costs for industry. For products currently included in RoHS estimates are it would vary from 1-4% of turnover. Other surveys give an average overall cost

[32] European Commission (2008), SEC(2008) 2930. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=SEC:2008:2930:FIN:EN:PDF

related to RoHS of 1.9% of turnover (past cost and one-off future costs). No information on the turnover of the market analysed as part of this work has been received or available, but based on the estimated annual sales figures presented in section 1.2.3 and an average product price of €4 for standard sockets and €5 for switches[33], an annual turnover of € 4.6 billion for switches and € 41 billion for sockets assessed here can be estimated. Applying the 1-4% range, compliance costs would represent between € 46 million and € 184 million for the switch sector and between € 410 million and € 1.6 billion the socket sector. However, given that those manufacturers that already offer RoHS compliant designs would be significantly less affected and that substitutes are identified and available, this estimate is likely to be high.

1.3.3.4 Innovation and research

The influence of RoHS II implementation on innovation and research will vary for each manufacturer. It seems that many manufacturers already provide RoHS compliant products so that they have already successfully carried out R&D to substitute RoHS substances. It could be, however, that reliable substitutes are still to be found for some products with specific properties or requirements. Overall, R&D might be slightly boosted but only to a very limited extent. For those manufacturers not currently offering RoHS compliant light and power switches and power wall sockets, R&D activities would be highly facilitated by the work already carried out by the sector, which shows that no major technical limitation is present.

Overall, the impact on innovation and research is estimated as positive but negligible compared to business-as-usual activities.

1.3.3.5 Consumers and households

Given the availability of RoHS compliant designs of light and power switches and power wall sockets on the EU market, no significant impact of the scope inclusions of these products in RoHS II is expected. Manufacturers that would be required to change their designs would be careful to remain competitive with currently available RoHS compliant products and would be unlikely to transfer incurred administrative costs onto the consumer.

1.3.3.6 Overview of economic impacts until 2039

The economic impacts of light and power switches and power wall sockets falling in the scope of RoHS II can be expected to be slightly negative due to additional costs and administrative burdens incurred by companies in this sector.

[33] Prices for both product types vary widely depending on the exact application, finish, etc. Switch prices, for example are significantly higher for a dimmer switch than for a standard light switch.

Table 9: Estimated economic impacts

Estimated economic impacts until 2039[34]		
	2012	2039
Functioning of the internal market	=	=
Competitiveness	=	=
Costs and administrative burdens	=/-	-
Innovation and research	=	=
Consumers and households	=	=

1.3.4 Social impacts

1.3.4.1 Employment

Statistics regarding jobs directly and indirectly linked to the switches and sockets industry are sparse. Given the limited impact of RoHS II implementation on competitiveness, costs and R&D, no significant impact on jobs is expected for manufacturers either. The demand for these products is not expected to be altered by the technical characteristics of the products as it is a necessary device in each private and public building.

1.3.4.2 Health

The impacts of hazardous substances on health can be differentiated between possible impacts during the production phase, on users during the actual product's lifetime and at the end-of-life.

First, exposure to these substances during the production phase represents a risk for facility workers, who are the population group at greatest risk of exposure to lead, especially through air. This risk is very much dependent upon the type of exposure (time, frequency, pathway, etc.). A ban of the use of the six RoHS substances in light and power switches and power wall sockets would certainly reduce the health impacts during the production phase, particularly in case of accidental situations and concerning hexavalent chromium.

During the use phase, the possible RoHS substances in light and power switches and power wall sockets are estimated to represent a very low risk in normal operation: the product design takes these considerations into account and direct contact is not expected to occur. In the absence of further information from stakeholders it is also deemed unlikely that the substitution of hexavalent chromium and PBDE would result in greater health risks for consumers, such as electric shocks and fires. The fact the RoHS compliant designs are already available tends to confirm this. The health risks to the user are thus assumed to be negligible.

[34] RoHS II coming into force for this product group (2019), plus one product lifetime (20 years)

Finally, the management during the end-of-life can result in important impacts for the environment and health. These impacts are dependent upon the management options followed by products, which have already been presented (see section 1.3.2.2). Based on the same assumptions regarding the emissions to air and water of the substances during recycling, incineration and disposal (see Table 6), health impacts can be quantified via the human toxicity indicators[35]: assuming the ban of RoHS hazardous substances in light and power switches and power wall sockets from 2019 (Option 2), a human toxicity impact of 1.09E-03 CTUh (cancer effects) and 4.31E-06 CTUh (non-cancer effects) would be avoided for switches and 1.84E-02 CTUh (cancer effects) and 7.31E-05 CTUh (non-cancer effects) for sockets in 2039. Regarding cancer effects this represents 0.000007% for switches and 0.000113% for sockets of the overall EU-27 annual impacts compared to Option 1 due to the ban on the use of hexavalent chromium in these products. For non-cancer effects, both results represent 0.00% of the overall EU-27 annual impacts.

Table 10: Human toxicity indicators

Product	Human toxicity midpoint, cancer effects (CTUh[36]) in 2039[37]	Human toxicity midpoint, non-cancer effects (CTUh) in 2039
Light and power switches	1.09E-03	4.31E-06
Power wall sockets	1.84E-02	7.31E-05

Furthermore, based on the assumptions made in section 1.2.3 a total of 46 tonnes[38] of PBDE could be saved annually from the ban of this substance in light and power switches and 513 tonnes[39] from its ban in power wall sockets. Clear health benefits are expected from this although based on the lack of data these could not be qualitatively evaluated as part of this work.

1.3.4.3 Social impacts in third countries

The above-mentioned environmental benefits could also affect third countries that export this type of equipment to the EU-27. However, no information has been available on the main exporters and hence no further conclusions can be drawn.

Given the end-of-life treatment options of light and power switches and power wall sockets presented in section 1.3.2.2, it is estimated unlikely that illegal shipment of this type of equipment is significant and therefore health impacts in third countries due to end-of-life treatment of this type of product is expected to be negligible.

[35] USEtox™ method.
[36] Comparative Toxicity Unit human, equivalent to cases
[37] RoHS II coming into force for this product group (2019), plus one product lifetime (20 years)
[38] Based on the assumption of 1 g being used in 46 million units annually
[39] Based on the assumption of 1 g being used in 513 million units annually

1.3.4.4 *Overview of social impacts until 2039*

The social impacts of light and power switches and power wall sockets falling in the scope of RoHS II can be expected to be slightly positive given the health benefits, especially during the end-of-life phase of the products.

Table 11: Estimated social impacts

Estimated social impacts until 2039[40]		
	2012	**2039**
Employment	=	=
Health	=	+
Social impacts in third countries	=	?

1.3.5 Comparison of options

The inclusion of light and power switches and power wall sockets in scope of RoHS II is expected to result in limited impacts, both positive and negative. Due to the decrease of the use of hexavalent chromium and PBDE, environmental and health benefits are expected, mostly at the end-of-life. Technical costs are expected to be limited given that many manufacturers already offer RoHS compliant designs but administrative costs will represent an additional burden, albeit to a limited extent. Nevertheless, it should be stressed that this analysis is characterised by a lack of data and high uncertainties.

[40] RoHS II coming into force for this product group (2019), plus one product lifetime (20 years)

Table 12: Comparison of options

Impact indicators	Option 1 : Switches and power wall sockets not in scope of RoHS recast proposal	Option 2: Switches and power wall sockets in scope of RoHS II
Environmental impact indicators		
Energy use	=	=
Waste production / generation / recycling	=	+
International environmental impacts	=	?
Economic impact indicators		
Functioning of the internal market and competition	=	=
Competitiveness	=	=
Costs and administrative burdens	=	-
Innovation and research	=	=
Consumers and households	=	=
Social impact indicators		
Employment	=	=
Health	=	+
Social impacts in third countries	=	?

In relation to the overall policy objective of RoHS II, namely to contribute 'to the protection of human health and the environment, including the environmentally sound recovery and disposal of waste EEE'[41], the discussion above shows that including switches and power wall sockets in RoHS II does contribute to this objective:

Table 13: Policy objectives and options

Policy options in relation to overall policy objectives			
	Effectiveness	**Efficiency**	**Coherence**
Option 1: Light and power switches and power wall sockets not in scope of RoHS recast proposal	Slightly negative: Hinders the objectives	Efficiency cannot be evaluated as the option does not contribute to the overall objectives	No unintended impacts
Option 2: Light and power switches and power wall sockets in scope of RoHS II	Slightly positive: Does contribute to the effectiveness of the Directive	Limited: None of the positive impacts are significant	Unintended impacts are limited

[41] 2011/65/EU, Article 1

Annex

Table 14: Quantities of RoHS substances released to the environment in 2039 without RoHS II implementation for switches, due to end-of-life management options

Substance	Released to	Quantity (in kg)
Cadmium	Air	0
Chromium VI		0.00
Lead		0
Mercury		0
Cadmium	Water	0
Chromium VI		0.10
Lead		0
Mercury		0

Table 15: Quantities of RoHS substances released to the environment in 2039 without RoHS II implementation for sockets, due to end-of-life management options

Substance	Released to	Quantity (in kg)
Cadmium	Air	0
Chromium VI		0.08
Lead		0
Mercury		0
Cadmium	Water	0
Chromium VI		1.69
Lead		0
Mercury		0

Table 16: Characterisation factor of RoHS substances (USEtox™ method)

Substance	Type of emissions	Human toxicity midpoint, cancer effects (in CTUh/kg)	Human toxicity midpoint, non-cancer effects (in CTUh/kg)	Ecotoxicity freshwater midpoint (in CTUe/kg)
Lead	Emissions to air, unspecified	2.69E-05	9.44E-03	1.75E+02
	Emissions to water, unspecified	3.42E-07	1.20E-04	3.75E+02
Mercury	Emissions to air, unspecified	7.06E-03	8.35E-01	1.22E+04
	Emissions to water, unspecified	1.20E-04	1.42E-02	2.21E+04
Chromium VI	Emissions to air, unspecified	4.45E-03	4.16E-04	4.20E+04
	Emissions to water, unspecified	1.06E-02	2.40E-05	1.05E+05
Cadmium	Emissions to air, unspecified	2.17E-04	4.55E-02	3.94E+03
	Emissions to water, unspecified	1.59E-06	4.27E-04	9.71E+03

Table 17: Impact assessment results (USEtox™ method) for switches

Impact indicator (unit)	Avoided impacts in 2039 in EU-27, with RoHS II implementation (in impact indicator unit)	Avoided impacts in 2039 in EU-27, with RoHS II implementation (in % of annual EU-27 impacts)	USEtox™ normalisation factors (in impact indicator unit per person per year)
Human toxicity midpoint, cancer effects (in CTUh)	1.09E-03	0.000007%	3.25E-05
Human toxicity midpoint, non-cancer effects (in CTUh)	4.31E-06	0.000000001%	8.14E-04
Ecotoxicity freshwater midpoint (in CTUe)	1.07E+04	0.00000024%	3.18E+06

Table 18: Impact assessment results (USEtox™ method) for sockets

Impact indicator (unit)	Avoided impacts in 2039 in EU-27, with RoHS II implementation (in impact indicator unit)	Avoided impacts in 2039 in EU-27, with RoHS II implementation (in % of annual EU-27 impacts)	USEtox™ normalisation factors (in impact indicator unit per person per year)
Human toxicity midpoint, cancer effects (in CTUh)	1.84E-02	0.000113%	3.25E-05
Human toxicity midpoint, non-cancer effects (in CTUh)	7.31E-05	0.00000002%	8.14E-04
Ecotoxicity freshwater midpoint (in CTUe)	1.81E+05	0.000004%	3.18E+06

An EU-27 population estimate of 502m inhabitants in 2011 is used for the normalisation (source: Eurostat, in March 2012).

Pipe organs

1.1 Key issues

Pipe organs in churches were excluded from the COM recast proposal but do fall within the scope of RoHS II. In this factsheet it will be explored what the impact of this change is and whether the environmental benefits of the inclusion of pipe organs in RoHS II outweigh the cultural and economic costs.

Organ at Great St. Mary, Cambridge, UK

1.2 Background

The pipe organ is a musical instrument that produces sound when pressurised air is driven through a series of pipes. Although its origins can be traced as far back as Ancient Greece in the third century BC, pipe organs are still found today in churches, synagogues, secular town halls, concert halls and private homes where they are used for classical music performances.[1] Occasionally, pipe organs are also used by pop and rock bands. Europe remains the main centre of organ building although there are now organ builders in most other parts of the world, notably America and Japan.[2]

Whilst being a traditional craft based industry, developing over many centuries, the pipe organ has had to employ more modern technology to meet the needs of ever larger instruments required for large cathedrals or concert halls. Water and gas engines have been replaced by electric fans and the key and stop actions have often been electrified. Nowadays 99% of pipe organs built employ at least one electric blower. Some employ other electrical or electronic components, all of which are fully compliant with the RoHS legislation. The one item of the organ that has remained unchanged during this period of modernisation is the pipes. The pipes of the pipe organ are made today using techniques formulated centuries ago.[3] As these pipes contain lead, they are the part of the organ of particular interest for this assessment.

Organ pipes are made from a variety of materials and each material produces a characteristic sound. Pipes made from wood sound different from pipes made from a lead/tin alloy or pipes made from copper, brass or zinc. The vast majority of pipes are made of lead alloys because of its ideal compromise between rigidity and flexibility. Pipes need to support their own weight but also permit fine adjustments during voicing and tuning.[4] The variation of lead and tin is used to vary the timbre

[1] CORDIS (2008) *Analysing the sound of pipe organs*, accessed at: http://cordis.europa.eu/fetch?CALLER=MSS_DE_OFFR_EN&ACTION=D&DOC=365&CAT=OFFR&QUERY=0126e808375d:eed7:66629c17&RCN=4122
[2] Interview with John Mander, International Society of Organbuilders, December 2011
[3] Email from Alan Taylor, AJ & A Taylor UK Ltd, December 2011
[4] The Organ (2006) *Mixed governmental news for organs*, accessed at http://www.theorganmag.com/news/2006apr.html

of the organ sounds. The use of the lead tin alloy allows the organ builder to control the mix when casting the sheets of pipe metal. Every organ pipe is uniquely sized in diameter and length. Pipes are made from flat sheets of metal, which are cast, planed and then rolled and soldered by hand. The malleability and low melting point of tin/lead alloy enables hand soldering, easy cutting and fine adjustments in the voicing and tuning of the pipes.[5] According to pipe makers, no other material can be manufactured in the same way as the tin/lead alloy, which means that there are no substitutes to the lead in organ pipes and the product could not be modified.

There also exist electronic organs, digital organs and combination organs. These organs with major electronic functions would have already fallen in the scope of RoHS I and are therefore not further analysed in this study.

1.2.1 Legal background

Following uncertainties as to whether pipe organs would fall under RoHS I or not, the 'Technical Adaptation Committee' voted on June 26th 2006 that pipe organs were outside of the scope of the Directive.[6,7] In the Commission RoHS recast proposal of 2008, pipe organs installed in churches were then officially listed as excluded in Annex II,4.[8] As between 95% and 99% of all pipe organs are located in churches, this equates to a de facto exclusion of all pipe organs from the scope of the proposal.[9]

Due to the new and broader definition of EEE in RoHS II[10], as from July 2019, pipe organs that require electricity will fall in the scope of this Directive. Music instruments that require electricity can either be Category 4 (consumer equipment) or Category 11 (others). The RoHS II substance restrictions will apply to all components, also non-electrical ones, on the homogeneous material level.

1.2.2 Quantities and hazardous substances

There is no collection of pipe organ data at a European level and only very few Member States have a local industry representation. Available data is based on information provided by the International Society of Organbuilders (ISO). Their estimates show that there are around 200,000 pipe organs in the EU. This includes pipe organs in churches, most of which contain at least one such instrument, as well as those in colleges, schools, universities and private homes. It is estimated that between 95% and 99% of the total number of pipe organs are located in churches. Approximately 1000 to 2000 new pipe organs have been sold over the last few years at a European level.

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[5] Interview with John Mander from the International Society of Organbuilders, December 2011

[6] Technical Adaptation Committee (2006) *Unofficial note of the Technical Adaptation Committee on the WEEE and RoHS Directive*, accessed at: http://www.bis.gov.uk/files/file31677.pdf

[7] European Commission Representation in United Kingdom (2006) *Church organ-building tradition safe, says European Commissio*n, accessed at: http://ec.europa.eu/unitedkingdom/press/press_releases/2006/pr0637_en.htm

[8] COM (2008) 809 final, accessed at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2008:0809:FIN:en:PDF

[9] Interview with John Mander from the International Society of Organbuilders, December 2011

[10] Art. 3.2: 'needing [electricity] to fulfil at least one intended function'

Figure 1, below, presents the distribution of pipe organs in Europe. As can be seen, most pipe organs can be found in Germany (ca. 50,000), Great Britain (ca. 27,500) and Italy (ca.25,000).[11]

Figure 1: Pipe organs in Europe

Source: Rensch, Klaus (2011), The Organ – A Cultural Treasure, ISO Journal No.39

The part of pipe organs that is of interest for this work are the actual pipes as they contain lead. All other components either contain no RoHS substances or are already RoHS compliant. The five main organ pipe suppliers use around 28 tonnes of lead a year. It can be assumed that these five suppliers produce half of the pipes made in the EU, which suggests a total consumption of 56 tonnes per year.[12]

Pipe organs could be excluded from the scope of RoHS II through the 'large-scale fixed installation' exclusion of Article 2.4(e). No officially agreed definition of the term 'large-scale' exists at the time of writing of this report, but based on the most likely criteria presented in the RoHS 2 FAQ Final Draft of 15 May 2012, it is estimated that approximately 75% of all pipe organs could be excluded as large-scale from the scope. Please see the Annex for more information on these draft criteria. Please note, however, that until the list of criteria has been finalised, no detailed information of the possible impact can be provided.

[11] Rensch, Klaus (2011) *The Organ – A Cultural Treasure*, ISO Journal No.39
[12] Interview with John Mander, International Society of Organbuilders, December 2011

1.3 Policy objectives and options

The objective of both, the RoHS recast proposal (COM (2008) 809 final) as well as RoHS II (2011/65/EU) is to contribute 'to the protection of human health and the environment, including the environmentally sound recovery and disposal of waste EEE'[13].

The purpose of this work is to look at the impacts of pipe organs falling in scope of RoHS II compared to church pipe organs being excluded from the COM recast proposal. Policy options will then be evaluated according to their effectiveness, efficiency and coherence in reaching the above-mentioned overall objective of the RoHS Directive. The policy options analysed are the following:

OPTION 1 (baseline scenario): The COM recast proposal. Pipe organs installed in churches are excluded from the scope of the recast Directive. As between 95% and 99% of all pipe organs are located in churches, this will be treated as an exclusion of all pipe organs.

OPTION 2: RoHS II. All pipe organs, whether in churches, concert halls or any other place are included in the scope of the recast Directive.

1.4 Impacts of policy options

1.4.1 Impact indicators

The following impact indicators have been chosen as relevant in this context:

Table 1: Impact indicators for the product group pipe organs

Impact indicators		
Environmental	Economic	Social
Air quality	Functioning of the internal market and competition	Culture
Waste production / generation / recycling	Competitiveness	Employment
	Costs and administrative burdens	Health
	Innovation and research	

[13] 2011/65/EU, Article 1

The following legend will be used in summarising the impacts:

Legend	
+++	Very beneficial effect
++	Substantial beneficial effect
+	Slight beneficial effect
=	No effect
-	Negative effect
--	Substantial negative effect
---	Very negative effect
?	Unknown effect

1.4.2 Environmental impacts

As discussed above, most pipe organs are made from a tin/lead alloy for workability and sonority reasons. The proportion of tin to lead generally ranges from 35% tin/65% lead to 75% tin/25% lead. About three quarters of all lead/tin pipes consist of 65% tin/35% lead. Only a number of larger and specialised organ builders actually make their own pipes. The five main organ pipe suppliers use approximately 28 tonnes of lead a year. It can be assumed that these five suppliers produce half of the pipes made in the EU, which suggests a total lead consumption of 56 tonnes per year.[14]

The environmental impacts of lead used in organ pipes needs to be discussed looking not only at the amounts used but most importantly at the amounts actually ending up in the environment. As discussed below, neither during the making process, nor at the end-of-life should lead be emitted to the environment. However, it should be noted that the extent to which, in reality, no lead at all ends up in the environment depends on the quality of the recycling operation. It is safe to say, though, that the amounts are very limited.

1.4.2.1 Waste production / generation / recycling

Many pipe organs are between 100 and 400 years old, some as old as 500 years. It is very rare for a pipe organ to last less than 25 years. In case that an organ is beyond repair, the material used to make the pipes is not disposed of. Old pipes get either reused in their original form or the material is melted down and made into new pipes. The new organ for St. Matthew-in-the-City, Auckland, New Zealand, for example, contains a quantity of lead pipework which was originally made in 1862 and some in 1883, which has been reused in this instrument.[15]

[14] Interview with John Mander from the International Society of Organbuilders, December 2011
[15] Henry Willis and Sons Ltd (2011) *New Zealand, St. Matthew in the City, Auckland*, accessed at http://www.willis-organs.com/auckland_general.html

1.4.2.2 *Air quality*

When the lead/tin alloy is melted during the pipe making process the temperatures used are too low to emit lead into the environment. Temperatures range from 300 degree Celsius to a maximum of 350 degree Celsius whereas the critical limit lies at approximately 500 degree Celsius above which lead fumes can potentially be released.[16] Off-cuts and waste from the pipe making process are added to the melting pot, ready for the next casting session. Material not so used is sold for scrap and is refined into new material.

1.4.2.3 *Overview of environmental impacts until 2025*

Based on the above, no positive environmental impacts can be expected from pipe organs falling in the scope of RoHS II.

Table 2: Estimated environmental impacts

Estimated environmental impacts until 2025		
	2012	**2025**
Waste production / generation / recycling	=	=
Air quality	=	=

1.4.3 Economic impacts

There is no collection of pipe organ data at a European level and only very few Member States have a local industry representation. The following data is based on information provided by the International Society of Organbuilders (ISO).

Approximately 1000 to 2000 pipe organs have been sold over the last few years at a European level. The annual turnover for Germany is € 120 million and for the UK € 8 million. Extrapolated for EU wide figure, this is estimated to be around € 350-400 million. The market is being described by stakeholders as rather stable with no major changes expected for the future if pipe organs were not in scope of RoHS II. There is no average retail price for pipe organs as such, as prices vary from € 5000 to € 3 million and above. However, the average can be assumed to be somewhere around € 500,000. The International Society of Organbuilders estimates a total of approximately 200,000 pipe organs in the EU. This includes pipe organs in churches, most of which contain at least one such instrument, as well as in colleges, schools, universities and private homes.

1.4.3.1 *Functioning of the internal market and competition*

RoHS II should affect all pipe organ makers in the EU equally, which means that no competitive pressures within the Union should be expected. However, given the controversial subject matter, it is not unlikely that Member State authorities would enforce RoHS II differently, i.e. some Member

[16] Thornton, Iain; Rautiu, Radu; Brush, Susan (2001) *Lead, the facts*, IC Consultants Ltd, London, UK

States effectively banning newly built pipe organs while others turn a blind eye on the issue. In this case the internal market would be distorted.

1.4.3.2 Competitiveness

Approximately 90% of organs imported into the EU come from Switzerland. The total number remains small with an estimate of seven organs being imported per year, approximately six of which would come from Switzerland. However, EU organ makers are not expected to lose in competitiveness compared to their Swiss counterparts for two reasons:

- Swiss organ makers could no longer export pipe organs to the EU that are not RoHS compliant
- Switzerland, by and large, follows EU environmental legislations: RoHS I provisions are regulated by the Ordinance on Chemical Risk Reduction (ORRChem).[17] It can therefore be expected that this Ordinance will be revised to reflect the changes in RoHS II.

The International Society of Organbuilders estimates that approximately 5% of all new organs by value built in the EU are exported. This figure can vary considerably from year to year. Countries where these pipe organs are exported to are manifold, including, among others, Australia, Japan, Russia and the USA.

1.4.3.3 Costs and administrative burdens

Due to a lack of possible substitutes, as discussed above, pipe organ builders would have to abandon the building of new organs. In this sense, no additional administrative or technical costs and burdens would be incurred. It would, however, lead to a loss of annual European turnover of € 350-400 million from 2019.

1.4.3.4 Innovation and research

Research and development is not something that is institutionalised within the pipe organ industry and it is difficult to predict the impact of pipe organs falling in the scope of RoHS II will have. However, it could be imagined that research into alternatives of the currently predominating tin/lead alloy would be a strong focus point once the traditional alloy can no longer be used.

On the other hand, organ makers know that Member State authorities enforcing the ban of new pipe organs would be very unpopular. It has therefore been suggested that organ makers might continue their traditional craft irrespective of the ban, relying on Member State authorities not enforcing it.

[17] The Federal Authorities of the Swiss Confederation (2005) *Ordinance on chemical risk reduction*, accessed at http://www.admin.ch/ch/e/rs/c814_81.html

1.4.3.5 *Overview of economic impacts until 2025*

Based on the above, economic impacts from pipe organs falling in the scope of RoHS II are expected to be limited to the loss of annual European turnover from sales of new pipe organs. Potentially, there could be some distortion in the internal market while innovation and research could increase.

Table 3: Estimated economic impacts

Estimated economic impacts until 2025		
	2012	2025
Functioning of the internal market and competition	=	=/-
Competitiveness	=	=
Costs and administrative burdens	=	--
Innovation and research	=	=/+

1.4.4 Social impacts

1.4.4.1 *Cultural value of pipe organs*

Pipe organs have a strong cultural value in Europe and have served the Christian Church since the dawn of European civilisation. Some of the greatest composers spent much of their working life writing for and playing the organ, for example J.S. Bach. Pipe organs have as much music composed for them as all other musical instruments combined.

As discussed above, organ makers have experimented with alternatives to the tin/lead alloy without success. The impact on availability of the inclusion of pipe organs in the scope of RoHS II is therefore going to be significant: No more pipe organs of the traditional type and quality could be built. Should pipe organs disappear, this would also mean that the music composed for them could no longer be played. Culturally, this would be regarded as a significant loss and it would be likely to be a highly unpopular measure with the European (and non-European) population. The cultural impact can be expected to increase over time, as ageing pipe organs can no longer be replaced or restored.

1.4.4.2 *Employment*

Statistics regarding jobs directly and indirectly linked to the pipe organs industry are sparse. According to the International Society of Organbuilders, the total amounts to 10,000 to 11,000 people directly employed by organ builders in the EU, all of which are SMEs. Approximately one third of these employees are involved in the construction of new organs. From 2019, when pipe organs will fall in the scope of RoHS II, these jobs would be immediately lost. This loss of 3000 to 3300 jobs translates into a salary loss of € 15-16.5 million per year in Europe by 2019. Art.4.1 of RoHS II states that '[...] EEE placed on the market, including cables and spare parts for its repair, reuse, updating of its functionalities or upgrading of its capacity [...]' does not contain any of the six RoHS substances, in this particular case lead. This means that rebuilding and restoration work of pipe organs where the spare parts are the pipes containing lead also falls in the scope of the Directive. This work could hence not be carried out after July 2019. It is estimated that another 60% of jobs in the industry would be lost as a result. This would only leave organ tuners and maintainers employed, which account for approximately 10% of the current total. The accumulated job losses would translate into a salary loss of € 24-26 million from 2020 to € 59-65 million per year by 2025.[18] As all European organ builders qualify as SMEs, these would be particularly hard hit by the scope changes to RoHS II.

1.4.4.3 Health

The most direct health issue resulting from the pipe organ making process would be the effect of handling lead on the pipe maker. There is no obligation for blood testing pipe makers but where this takes place, it has not showed any abnormal results. Below, as an example, are the blood test results of a UK-based pipe maker who has been in the trade for approximately 18 years:

Table 4: Blood lead levels

Blood lead level measurement	
Pipe maker A[19]	12mg/dl
Recommended limit for:	
Women of reproductive capacity	<20mg/dl
Adults	<35mg/dl
Youths	<35mg/dl

In Austria, organ building employees had to be tested for lead on a quarterly basis in the past. This was then changed to biannual tests and has recently been abandoned altogether as in over 30 years of testing no case of reaching dangerous limits of lead in employees in the organ trade had been recorded.[20]

1.4.4.4 Overview of social impacts until 2025

The negative cultural impact of pipe organs falling in the scope of RoHS II can be expected to be significant and the employment impact negative to substantial. Both are expected to worsen over time. No health impacts are expected.

[18] Calculations are based on an average European organbuilder income adjusted for price purchasing power and inflation. Please see the Annex for more details.
[19] Please note that no name is provided for confidentiality reasons
[20] Email from Mr. Wendelin Eberle, Rieger-Orgelbau GmBH, 2012

Table 5: Estimated social impacts

Estimated social impacts until 2025		
	2012	2025
Culture	=	---
Employment	=	--
Health	=	=

1.4.5 Comparison of options

While excluding pipe organs from the scope of RoHS II is not expected to lead to any impacts, whether positive or negative, their inclusion in the scope would cause significant negative social impacts.

Table 6: Comparison of options

Impact indicators	Option 1 : Church pipe organs excluded in COM recast proposal	Option 2: All pipe organs in scope of RoHS II
Environmental impact indicators		
Air quality	=	=
Waste production / generation / recycling	=	=
Economic impact indicators		
Functioning of the internal market and competition	=	=/-
Competitiveness	=	=
Costs and administrative burdens	=	--
Innovation and research	=	=/+
Social impact indicators		
Culture	=	---
Employment	=	-
Health	=	=

In relation to the overall policy objective of RoHS II, namely to contribute 'to the protection of human health and the environment, including the environmentally sound recovery and disposal of waste EEE'[21], the discussion above shows that including pipe organs in RoHS II does not contribute to this objective:

[21] 2011/65/EU, Article 1

Table 7: Policy objectives and options

Policy options in relation to overall policy objectives			
	Effectiveness	**Efficiency**	**Coherence**
Option 1: Church pipe organs excluded in COM recast proposal	Neutral: Does not contribute to reaching the objectives but does not hinder them either	Efficiency cannot be evaluated as option does not contribute to the objectives	None or very limited unintended impacts
Option 2: All pipe organs in scope of RoHS II	Neutral: Does not contribute to reaching the objectives but does not hinder them either	Efficiency cannot be evaluated as option does not contribute to the objectives	Substantial unintended impacts, notably cultural

Based on the above it can be concluded that the inclusion of pipe organs in the scope of RoHS II offers little if no benefits paired with substantial negative cultural impacts. Excluding them from the scope, on the other hand, would not bring about negative economic, social or environmental consequences.

Annex

Table 8: Average UK organbuilder income

Average UK organbuilder income		
GBP	Conversion rate	Euros
25,900	1.18	30,562
Adjustment for UK purchasing power standard		
UK income in Euro	PPS conversion rate[22]	Adjusted UK income
30,562	0.89	27,200

Table 9: Average European organbuilder income

Average European organbuilder income based on UK						
Concentration of EU organbuilding jobs	Number of builders	Weight	GDP per capita in PPS 2010[23]	Conversion rate	EU average adjusted for pps in €	Weighted
Belgium	15	8%	119	1.19	32368.21	2582.57
France	14	7%	108	1.08	29376.19	2187.59
Germany	75	40%	118	1.18	32096.21	12804.34
Sweden	15	8%	123	1.23	33456.22	2669.38
UK	15	8%	112	1.12	30464.20	2430.65
Others	54	29%	100	1.00	27200.18	7812.82
Total	188	100%				
Average European organbuilder income						**30,487.35**

Table 10: Inflation rate adjustment

Inflation rate adjustment	
Average adjusted European organbuilder income	
2012	30487.35
2013	31097.10
2014	31719.04
2015	32353.42
2016	33000.49
2017	33660.50
2018	34333.71
2019	35020.38
2020	35720.79
2021	36435.21
2022	37163.91
2023	37907.19
2024	38665.33
2025	39438.64

[22] Based on Eurostat, *GDP per capita in PPS*, 2010, accessed at http://epp.eurostat.ec.europa.eu/tgm/table.do?tab=table&init=1&plugin=1&language=en&pcode=tec00114

[23] Eurostat, *GDP per capita in PPS*, 2010, accessed at http://epp.eurostat.ec.europa.eu/tgm/table.do?tab=table&init=1&plugin=1&language=en&pcode=tec00114

Table 11: Employment impacts

Direct costs of jobs losses			
Year	Accumulated job losses	Accumulated job losses based on 10,000 total	Accumulated job losses based on 11,000 total
2012	0	0	0
2013	0	0	0
2014	0	0	0
2015	0	0	0
2016	0	0	0
2017	0	0	0
2018	0	0	0
2019	30%	3000	3300
2020	40%	4000	4400
2021	50%	5000	5500
2022	60%	6000	6600
2023	70%	7000	7700
2024	80%	8000	8800
2025	90%	9000	9900
Total costs/yr by 2019		**15,008,735.48**	**16,509,609.03**
Total costs/yr 2020		**23,813,860.29**	**26,195,246.32**
Total costs/yr 2025		**59,157,958.50**	**65,073,754.34**

Possible criteria to determine whether an installation is 'large-scale'. Please note that this is only an indicative list.

If the installation exceeds the minimum requirements for **one** of the following criteria, it can be considered large-scale:[24]

- If, when installing or de-installing the installation, it is too large to be moved in an ISO 20 foot container because the total sum of its parts as transported is larger than 5,71m x 2,35m x 2,39m, then it can be considered large-scale.
- The maximum weight of many road trucks is 44 tonnes. Thus if, when installing or de-installing the installation, it is too heavy to be moved by a 44 tonne road truck, because the total sum of its parts as transported weighs more than the truck's load capacity, it can be considered large-scale.
- If heavy-duty cranes are needed for installation or de-installation, the installation can be considered large-scale.
- An installation that does not fit within a normal industrial environment, without the environment needing structural modification, can be considered large-scale. Examples for modifications are modified access areas, strengthened foundations etc.
- If an installation has a rated output greater than 375 kW, it can be considered large-scale.

[24] European Commission, DG ENV, *RoHS 2 FAQ, Final Draft 15 May 2012*

Electronic safes

Important notes:

In this factsheet, the product group electronic safes will always refer to such products having at least one electric or electromagnetic function.

Please note that for this product group, only a limited number of productive contacts has been established with industry or their representatives. It should be stressed that limited data led to the assessment being based on a number of assumptions.

1.1 Key issues

Electronic safes were not in scope of RoHS I or the COM recast proposal but do fall within category 11 of RoHS II. In this factsheet it will be explored what the impact of the inclusion of safes in the scope of RoHS II is and whether the benefits of this inclusion outweigh the potential costs.

Only those products will be assessed that are not large-scale fixed installation (see Annex). Equipment of this kind would be excluded from the scope by Art. 2.4(e).

1.2 Background

A safe (also called strongbox, coffer or kist) is a secure lockable box used for securing valuable objects against theft or damage. Originally, safes were secured by a mechanical key. The first electronic code lock was developed in the 1960s and 1970s. The manufacturer Elsafe[1] invented the first electronic in-room safe in 1976 in Leksvik, Norway.

Today, electronic safes comprise a wide variety of features. These include features such as the use of LED (Light-Emitting Diode) and LCD (Liquid Crystal Display) screens as a digital display used for the safe. Electric code locks use digital keypads using pin codes, magnetic card swipe systems, and fingerprint scanning identify technology (biometric system) to unlock the safe. Most of the digital locking systems on electronic safes can be powered by batteries or through an external power cord. Electronic safes are used in many different settings. The most common locations include hotel rooms, businesses, banks, homes, etc.

In terms of composition, an electronic safe in its basic form is a thick steel box, usually with a thicker steel door. Electronic safes come in a variety of different sizes; however a typical size would be approximately 200 mm (H) x 450 mm (W) x 350 mm (D)[2]. The door closes onto the box with a solid

[1] Website: www.vingcardelsafe.com

[2] Safes and Gun Safes: Online guide to safes and gun safes website: http://safesandgunsafe.com/safes/electronic-safe/

steel bolt. A digital keypad (or other electronic locking system) is required to enter the unlocking code as are a couple of LED/LCDs to display output and serve as the input/output interface. For some safes, a mechanical key is also provided for emergency access when the combination code is forgotten. Additional features provided on most electronic safes include low battery warning, freeze on repeated wrong combination code entry, and long buzz on entering the wrong combination code[3].

The lock mechanism of a safe is a very important design feature that is usually manufactured by a different company than the safe. It helps to determine the cash rating given to the safe, which provides an indication of how secure the safe is. This rating applies only if the safe has been installed correctly and according to the manufacturer's recommendations. Generally the higher the cash rating a safe has, the more secure the safe will be. Certain safes are secured by dual (2) locks, which enhances the security level and is a required security feature to achieve gradings (cash ratings). Dual lock combinations can include:

- Key + Digital: mechanical keylock and digital lock (electronic usually requiring a pin code to open).
- Digital + Biometric: digital lock (pin code) and fingerprint locking system.

Recent technological innovations for electronic safes include wireless (contactless) solutions such as the use of PDA (personal digital assistant) and cell phone devices using RFID (radio-frequency Identification).

1.2.1 Legal background

Electronic safes were not in scope of RoHS I as they did not fall in any of the product categories in Annex IA of the WEEE Directive (2002/96/EC). Due to the enlarged scope of RoHS II, all safes that requires electricity or electromagnetic fields, even if only for a minor function, will fall within category 11 (Annex I) of the Directive from July 2019. Some of the newer models of electronic safes use RFIDs, and may be interpreted as category 3 "IT and telecommunication equipment". The RoHS II substance restrictions will apply to all components, also non-electrical ones, on the homogeneous material level.

Electronic safes could be excluded from the scope of RoHS II through the 'large-scale fixed installation' exclusion of Article 2.4(e). No officially agreed definition of the term 'large-scale' exists at the time of writing of this report, but based on the most likely criteria, it is estimated that a very small percentage of all electronic safes, if any, would be excluded as large-scale from the scope. According to EN 1143-1:2012 (clause 3.1), a safe has at least one internal side of a length inferior to 1 metre, otherwise it is considered as a strong room. Therefore safes would not be considered as 'large-scale' but products such as heavy duty vault or strong rooms in banks may be. Please see the Annex for more information on the draft criteria for 'large-scale fixed installation'. Please note, however, that until the list of criteria has been finalised, no detailed information of the possible impact can be provided.

[3] Designing an electronic safe: www.eetimes.com/design/embedded/4205822/Designing-an-electronic-safe(accessed in 05/12)

1.2.2 Quantities and hazardous substances

There is no industry collection of safes data at European level, despite the existence of the European committee of safe manufacturers associations (Eurosafe[4]). Electronic safes (included in category 11) are very diverse and the size of the market for these is difficult to establish as none of the specific product types are explicitly covered by PRODCOM categories. There is a PRODCOM category for safes and strong boxes but this includes those with electrical functions as well as those with no electrical functions ("Base metal armoured or reinforced safes and strong-boxes").

The EU security sector includes a vast array of products and services, and although some security service related activities can be identified, the large majority of activities and products related to the supply of security equipment and systems cannot usually be identified from recognised industrial classifications[5]. This is the case for electronic safes.

Table 1 shows sales figures (in quantities and values) for categories containing products potentially within the scope of electronic safes or related to them, extracted from the PRODCOM database, for the EU-27 in 2010. Given the insufficient level of disaggregation of the product categories, no reliable conclusions can be drawn from these figures.

[4]Website: http://www.eurosafe-online.com/
[5]Study on the Competitiveness of the EU security industry (2009), Final Report, by Ecorys for DG ENTR: ec.europa.eu/enterprise/policies/security/files/study_on_the_competitiveness_of_the_eu_security_industry_en.pdf

Table 1: PRODCOM market figures for products related to electronic safes (EU-27, 2010)[6]

Product category	PRODCOM code	Production		Imports		Exports		EU-27 Apparent Consumption[7]	
		Quantity (in p/st)	Value (in €)	Quantity (in p/st)	Value (in €)	Quantity (in p/st)	Value (in €)	Quantity (in p/st)	Value (in €)
Base metal cash or deed boxes and the like	25992170	n.a.	90 359 000	n.a	28 139 240	n.a	9 465 300	n.a	109 032 940
Base metal armoured or reinforced doors and safe deposit lockers for strong-rooms	25992150	74 238 000	311 804 000	424 300	2 120 800	3 927 000	26 099 380	70 735 300	287 825 420
Base metal armoured or reinforced safes and strong-boxes	25992130	946 000	304 536 000	1 980 582	57 479 870	154 496	41 890 400	2 772 086	320 125 470

[6]Eurostat, extracted on 24 May 2012. Database available at: http://epp.eurostat.ec.europa.eu/portal/page/portal/prodcom/data/database
[7]Apparent Consumption = Production + Imports - Exports

According to the UN Comtrade database, Poland was ranked 5th out of the top five countries worldwide to export "Armoured/reinforced safes, strong-boxes & doors & safe deposit lockers for strong-rooms, cash/deed boxes & the like, of base metal" in 2011. In terms of imports, three EU Member States (DE, UK, and FR) are among the top worldwide importers of these products. It is important to note that similar to the PRODCOM data, this category of products includes all types of safes and not just safes with electronic locks.

Table 2: Top 5 exporters of "Armoured/reinforced safes, strong-boxes & doors & safe deposit lockers for strong-rooms, cash/deed boxes & the like, of base metal", 2011[8]

Country	Trade value
China	€2.3 billion
Italy	€43 million
Rep. of Korea	€40 million
USA	€38 million
Poland	€32 million

Table 3: Top 5 importers of "Armoured/reinforced safes, strong-boxes & doors & safe deposit lockers for strong-rooms, cash/deed boxes & the like, of base metal", 2011[8]

Country	Trade value
USA	€6.8 billion
Germany	€2.7 billion
United Kingdom	€1.2 billion
Canada	€80 million
France	€77 million

Specific information regarding electronic safes in the EU are difficult to find, however assumptions can be made based on information from around the world and on similar/related products – such as electronic locks (the main electric/electronic feature of an electronic safe). Research in India and the US indicate that with the apparent increase of crimes in the society, safety and security have become a primary concern for many. Burglars are more often equipped to destroy most of the conventional safety locker systems. The enhanced security features of the digital safe lockers have made it very difficult for thieves to operate a digital safe locker. The need for safe locker systems in homes, but also offices, shops, banks, hotels, hospitals, etc. is increasingly felt these days due to an increase in the security concerns[9]. Another reason for a heightened interest in state of the art electronic safes is, it appears, the economic crisis and a growing mistrust in banks.[10]

[8] United Nations Commodity Trade Statistics Database (accessed in 05/12): http://comtrade.un.org/db/ce/ceSnapshot.aspx?cc=830300&px=H3&y=2011&rg=2

[9] Project profile on digital safe locker (2010), MSME - Development Institute: www.dcmsme.gov.in/reports/electronic/Digitalsafelocker.pdf

[10] www.smartmoney.com/plan/banking/more-americans-keeping-valuables-in-safes-at-home-1334333683624/ and www.lemonde.fr/economie/article/2012/05/18/panique-bancaire-la-grande-ruee-vers-les-coffres-forts_1703494_3234.html#ens_id=1268560&(accessed in 05/12)

This is also the case for France where the increase in robberies in 2011 (18%) is named as an underlying reason for the increase in sales of safes. According to a recent article[11], safes produced in the EU are mainly manufactured in Italy with the rest predominantly imported from China. According to the same source, an industry stakeholder states that approximately 26 % of French households own a safe.[12] In 2011, 45 000 households in France purchased a safe. In Italy, 56 % of households own a safe compared to 36% in Germany. Sales have increased by almost 20% for several major safe manufacturers in Europe (Hartmann, Fichet-Bauche, AGCI, Bricard, Castorama and Leroy Merlin). Market estimates indicate that 2012 will continue to be a "good year" for the French safe market. However, direct feedback from stakeholders indicates that this rising market trend is not correct and that the number of sales has been decreasing since 2009. It should be noted that the above figures do not distinguish between mechanical safes (non-electronic) and electronic safes so that it is difficult to draw a reliable conclusion specific to electronic safes. Stakeholders estimate that between 15% and 30% of the currently produced safes are electronic but this estimate should be considered with caution. In the context of this study, it will be assumed that **25% of the new sales are electronic safes**.

As stated before, in 2011, 45 000 households in France (out of approximately 31 million total households in France) bought a new safe. Assuming that no more than one safe is purchased per household, figures for the rest of the EU-27 can be estimated based on extrapolation. Based on these assumptions, **approximately 317 000 new safes were purchased by households in the EU-27 in 2011** (see Table 14 in the Annex for further details on calculations). Please note that this estimate is likely to be rather high, as France is probably a country where these products are sold over the EU-27 average.

In addition to the above, many electronic safes are also expected to be purchased for professional applications, e.g. in offices, hotels, and hospitals. No direct market data on these figures could be identified. The main professional locations having safes include: hotels and hospitals, banks, SMEs, etc. The following are assumptions used to estimate the total number of annual sales of safes to professionals.

- There are approximately 20 million companies in the EU-27, almost of which being SMEs[13]. Assuming that each SME has one safe on average, 800 000 safes are being sold annually to SMEs[14]. Pharmacies and jewelleries are important examples of SMEs that require one or several safes.
- Assuming that 50% of the hotel rooms in the EU-27 have a safe, the number of safes installed in hotels represents approximately 2.6 million units[15]. Assuming a life expectancy of 25 years (see section 1.3.2.2), approximately 100 000 safes are estimated to be sold annually for installation in hotel rooms[16].

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[11] http://www.lemonde.fr/vous/article/2012/01/24/les-coffres-forts-se-vendent-comme-des-petits-pains_1633804_3238.html(accessed in 05/12)
[12] Representing 4 million units
[13] In 2005, according to M. Schmiemann for Eurostat (2008), Industry, trade and services: http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-SF-08-031/EN/KS-SF-08-031-EN.PDF
[14] Based on a lifetime of 25 years, Annual sales = Total Stock / Life Expectancy
[15] Based on the total number of hotel rooms in the EU-27 of 5.2 millions in 2010.Source: MKG Hospitality http://www.mkg-group.com/Portals/0/FILES/CP_FR/2010/MKG_CP_Bilan_2010.pdf
[16] Annual sales = Total Stock / Life Expectancy

- Concerning hospitals, there were 392.6 hospitals rooms for 100 000 inhabitants in Europe in 2006[17]. With approximately 500 million inhabitants in the EU-27 and assuming that all the rooms have a safe, the installed stock in hospital rooms account for 2 million units. This represents 80 000 annual sales.

Consequently, the total number of safes for professional applications in the EU-27 is estimated at approximately **1 million units**.

Overall, annual sales of safes in the EU-27, both for private and professional use, are therefore estimated to represent 1.3 million units. Assuming that 25% of these safes have an electric or electronic function, approximately 325 000 electronic safes are sold annually in the EU-27. Please note that this estimation contains high uncertainty and should be considered as an order of magnitude.

Regarding the uses of RoHS substances, Table 4 lists the hazardous substances and where they are expected to be present within the components of an electronic safe. No specific information was found or received from stakeholders on this subject so that the table is based past experience and assumptions.

Table 4: RoHS substances in petrol-engine powered garden equipment

Substance	Presence in electronic safes
Lead	Yes, in solder Estimation: 1 g in solder per product
Mercury	No
Cadmium	Unknown – very unlikely
Hexavalent Chromium	Yes, on screws and other metal parts for corrosion protection. Estimation: 200 µg per product
Polybrominated biphenyls (PBB)	Unlikely
Polybrominated diphenyl ethers (PBDE)	Unlikely

Source: Own estimations

As seen above, most of the hazardous substances present in electronic safes are expected to be found in the small PCBs contained in the products (lead soldering) and on metal parts (Cr VI coatings). Batteries used in electronic safes also contain hazardous substances (mercury, cadmium) but are already subject to the Battery Directive and thus not within the scope of this assessment. LCD displays are not expected to contain any RoHS substance as these will use LEDs (light emitting diodes) for illumination. Some larger safes may have internal lamps but these will be already covered by RoHS.

[17] http://www.statistiques-mondiales.com/europe_hopital.htm (accessed in 05/12)

1.2.3 Policy objectives and options

The objective of both the RoHS recast proposal (COM (2008) 809 final) as well as RoHS II (2011/65/EU) is to contribute 'to the protection of human health and the environment, including the environmentally sound recovery and disposal of waste EEE's[18].

The purpose of this work is to look at the impacts of electronic safes falling under the scope of RoHS II compared to electronic safes not being included in the COM recast proposal. Policy options will then be evaluated according to their effectiveness, efficiency and coherence in reaching the above-mentioned overall objective of the RoHS Directive. The policy options analysed are the following:

OPTION 1 (baseline scenario): The COM recast proposal. Electronic safes are not in scope of the proposed recast Directive.

OPTION 2: RoHS II. Electronic safes are included in the scope of the recast Directive.

1.3 Impacts of policy options

1.3.1 Impact indicators

The following impact indicators have been chosen as relevant for this product group (see Table 5).

Table 5: Impact indicators for the product group electronic safes

Impact indicators		
Environmental	Economic	Social
Energy use	Functioning of the internal market and competition	Employment
Waste production / generation / recycling	Competitiveness	Health
International environmental impacts	Costs and administrative burdens	Social impacts in third countries
	Innovation and research	
	Consumers and households	

[18] 2011/65/EU, Article 1

The following legend will be used in summarising the impacts:

Legend	
+++	Very beneficial effect
++	Substantial beneficial effect
+	Slight beneficial effect
=	No effect
-	Negative effect
--	Substantial negative effect
---	Very negative effect
?	Unknown effect

1.3.2 Environmental impacts

The most important stakes regarding the environmental impacts in the context of RoHS are related to the quantities of hazardous substances used in the equipment. The mere quantity of a substance is however not sufficient to estimate what will be the actual impacts of the substance on the environment and health. These indeed depend upon numerous factors such as the effective treatment of products at the end-of-life, their design for the use phase or their potential emissions during the production phase. The impact of the substances released to the environment is also determined by case-specific and complex dose-response relationships.

1.3.2.1 Energy use

Given the definition of this product group, all products are expected to consume energy during their operation. Power consumption is the second most important aspect of an electronic safe following its safety and reliability. Various designs can be implemented to save power such as the use of deep sleep if there is no input from the keypad for a specified period of time. A microcontroller that operates in a wide operating range will help to sustain long operation across battery discharges. Use of 7-segment LEDs is the norm for electronic safes because of the low power consumption of these components[19]. New batteries (3 Alkaline batteries 1.5 V LR6 (AA, AM3, E91)) will power electronic locks for approximately 8 000 openings[20] or provide a service life of approximately 3-4 years with one opening/closing cycle per working day.[21] Given the lack of specific information on the use of RoHS substances in electronic safes and the quantitative estimations made, it is assumed that the presence of these substances does not have any influence on the energy use of the devices during the use phase.

[19]Designing an electronic safe:
http://www.eetimes.com/design/embedded/4205822/Designing-an-electronic-safe(accessed in 05/12)
[20] Sargent and Greenleaf Electronic Safe Lock Guide (accessed in 05/12):
http://www.sargentandgreenleaf.com/pdf/book_elec_locks.pdf
[21]SL 523 - Operating manual by Kaba:
http://www.kaba-mauer.de/downloads/015/kaba_sl525_operating-instructions_en_01.pdf (accessed in 05/12)

The European Commission impact assessment accompanying the RoHS recast proposal[22] states that the substitution of lead solder by lead-free solder might lead to an increase in energy consumption during the production phase because of a higher melting point. The additional energy consumption will vary widely depending on the solder type, the equipment specifications and process operating parameters employed by the facility. Nevertheless, it is generally accepted that lead-free soldering requires approximately 15% more energy than tin/lead (SnPb) soldering when comparing equivalent soldering technology for the two types of alloy and the following calculations will be based on this assumption. Based on a typical solder reflow oven to make the small PCBs on which lead is found in electronic safes, the total additional energy required for lead-free solders represents 8.2 MWh per year[23]. Compared to a total EU final energy consumption of 13.6 million PWh[24], this impact of additional energy required is regarded as negligible on this environmental impact indicator. The additional energy consumption will cost approximately 766 €[25] for all units sold in the EU-27 per year, which is negligible compared to other additional costs (see section 1.3.3.3). Additional CO_2 emissions due to the change from tin/lead solder to lead-free solder represent 3.2 tonnes CO_2 eq[26]. In relation to the overall CO_2 emissions of 4 088.8 million tonnes of the EU-27 in 2008[27], this increase would also be considered negligible.

Consequently, even if lead-free solder would require more energy during the production phase, this effect is expected to be low. Thus, the inclusion of electronic safes within the scope of RoHS II should have no significant impact on this environmental indicator.

1.3.2.2 Waste production / generation / recycling

No information on the average lifespan of electronic safes was found or received. As they are usually integrated into the building, they are not expected to be disposed of like other EEE such as consumer electronics. Indeed, when a safe is installed in a certain place, it is not likely that it will be removed without any good reason (replacement due to technical failure, damage by intruders, etc.). **It is estimated that electronic safes have a lifetime between 20-30 years: 25 years will be used for the following assessment.** Parts that are more likely to require maintenance or replacement are the electronic components and the batteries. They are expected to be easily replaced without replacing the actual deposit box in case of failure. In particular, the lifetime of alkaline batteries used in electronic safes should be in the range of 3-4 years (see section 1.3.2.1).

Three end-of-life management options are available for EEE in general: recycling, incineration and disposal in landfills. Given that electronic safes are often installed and removed by professionals (especially when embedded in the floor or wall), the recovery rate of these products is expected to

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[22] European Commission (2008), SEC(2008) 2930. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=SEC:2008:2930:FIN:EN:PDF

[23] A typical solder reflow oven operates 16 hours per day, 5 days a week, 49 weeks per year and on average consumes 13.9 kWh for SnPb and 16kWh for lead-free. It is assumed that one oven can produce 300 PCBs per hour or 1 million per year (25 PCBs made in a panel every 5 minutes) as these PCBs are small. The total number of units to be made are approximately 0.325 million.

[24] 1 168.63 Mtoe, European Commission, *EU transport in figures, statistical pocketbook 2011*, accessed at http://ec.europa.eu/transport/publications/statistics/doc/2011/pocketbook2011.pdf

[25] Average EU industrial electricity price = 0.093 €/kWh in 2011 according to Eurostat.

[26] Based on 0.39 kg CO_2eq/kWh from Eurelectric

[27] 4 186.7 million tonnes. European Commission, *EU transport in figures, statistical pocketbook 2011*, accessed at http://ec.europa.eu/transport/publications/statistics/doc/2011/pocketbook2011.pdf

be quite high. No specific data was received or found for electronic safes. However, the average reuse and recycling rate of professional EEE in France was 90% in 2010, the remaining shares being 3% for incineration and 7% for disposal[28]. In absence of more specific data, this repartition will be considered as representative of the EU-27 situation, even if important discrepancies can exist regarding these rates between Member States. This estimate seems reasonable as safes are mainly composed of metal, which is highly recyclable and valuable.

Depending on the quality of the end-of-life operations, a certain share of the substances (called the leaching potential) is always lost to the environment. According to BIO (2008)[29], process control of landfills and incinerators, alongside mineralization mechanisms in landfills, are some of the options to reduce this share. But there is limited quantitative data about the fate of hazardous substances going through land filling or incineration processes, in particular their leaching potential.

Policy Option 2 (including this type of equipment in the scope of RoHS II) would progressively (over a product lifetime period, between 2019 and 2044[30]) decrease the quantities of hazardous substances from electronic safes found in the waste streams, compared to the baseline scenario. The reduction of these substances may have a beneficial effect on their end-of-life treatment. This effect is dependent on the development of the waste management sector as a whole.

Table 6 shows the estimations used to calculate the environmental impacts of RoHS hazardous substances released into the environment at the end-of-life of electronic safes. The assessment is likely to contain high uncertainties, because of the assumptions made to model the end-of-life options.

Table 6: Heavy metal emissions, by end-of-life management options

End-of-life process	Share of total end-of-life products (in %)	Emissions to air during end-of-life process	Emissions to water during end-of-life process	Source of the emissions estimates
Recycling	90%	0.001%	0.059%	COWI (2002)[31]
Incineration	3%	0.5%	2.49%	ERM (2006)[32]
Landfill	7%	-	5%	ERM (2006)

By considering the annual sales and RoHS substance quantities presented in section 1.2.2, it is estimated that 0.325 tonnes of lead from solder and 0.07 kg of hexavalent chromium would be sent annually into the end-of-life management circuit from 2044[33] if the product group was not included within the scope of RoHS II. For Option 2, it is assumed that all lead and hexavalent chromium would be removed from the products from 2019, so that none of these substances would go to the waste streams from 2044.

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[28] ADEME (2010), Équipement électriques et électroniques - Rapport annuel.
[29] BIO (2008), Study to support the impact assessment of the RoHS review – Final Report, for DG ENV.
[30] Possibly earlier if manufacturers take early measures.
[31] COWI (2002), Heavy Metals in Waste – Final Report, for European Commission DG ENV. Applicable to lead, assumed to be the same for other heavy metals
[32] ERM (2006), Battery Waste Management Life Cycle Assessment – Final Report.
[33] 25 years (the lifetime of the product) after the effective implementation of RoHS II.

Based on these assumptions, the ecotoxicity freshwater midpoint indicator was calculated[34] in order to illustrate the avoided impacts for the end-of-life, of the inclusion of electronic safes within the scope of RoHS II, in 2044. This indicator was chosen because the release of RoHS hazardous substances in the environment has an influence on its value (this is not the case for Global Warming Potential for instance).

Table 7: Avoided freshwater ecotoxicity impacts by Option 2, compared to Option 1

Year[35]	Ecotoxicity freshwater midpoint (CTUe[36])
2044	6.24E+02

This result in 2044 represents a negligible share of the overall freshwater ecotoxicity annual impact in the EU-27 (USEtox™ normalisation values). Details of the calculations are given in Annex.

In theory, end-of-life impacts also depend on the possible substitutes that would replace the six hazardous substances. A similar quantitative analysis could not be done by considering the impact of the substitution of lead solder by lead-free solder, as the most suitable substitutes are not known yet. Still, some substitutes are likely to leach hazardous substances into the environment too, even if lead is the most toxic alloying element: silver or antimony represent a potential source of toxicity in leachates when used in alloys, while bismuth, indium and copper are regarded as less dangerous[37]. Obviously, the levels of emissions depend on the specific environmental conditions the waste will be exposed to during the end-of-life management. Another source[38] builds a comparative analysis of lead-free solder, by taking into account toxicity, availability and environmental impact of extraction of substitutes to lead in solder alloys. Based on this, only tin and copper appear to have a lower overall impact than lead. These outcomes have to be considered with caution given the subjective assessment grid. Finally, a comparative life cycle assessment[39] also illustrates that depending on the environmental impact considered, either lead solder or one substitute (bismuth-tin-silver or copper-tin) can be best performing.

1.3.2.3 International environmental impacts

Concerning the production phase, many electronic safes and their components sold in the EU-27 are expected to be manufactured outside the EU-27 (e.g. in China, and Republic of Korea; see section 1.2.2 for main exporters) so that the ban of the RoHS substances might have positive effects in extra-EU countries involved in these manufacturing processes as well. The overall effect is expected to be relatively low, given the limited amount of substances in electronic safes, but it nonetheless contributes to an improvement of the supply chain in general.

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[34] According to USEtox™ methodology.
[35] RoHS II coming into force for this product group (2019), plus one product lifetime (25 years)
[36] Comparative Toxicity Unit ecotoxicity, equivalent to PAF.m3.day
[37] Edwin B. Smith III, Environmental Impacts and Toxicity of Lead Free Solders: http://leadfree.ipc.org/files/RoHS_16.pdf
[38] Anna Kua, Prof. Oladele Ogunseitanb, Prof. Jean-Daniel Saphoresc. Lead-Free Solders: Issues of Toxicity, Availability and Impacts of Extraction: http://trs-new.jpl.nasa.gov/dspace/bitstream/2014/6388/1/03-0222.pdf
[39] EPA (2005), Solders in electronics: a life-cycle assessment. Available at: http://www.epa.gov/dfe/pubs/solder/lca/lfs-lca-final.pdf

Concerning the end-of-life phase, safes being mainly composed of metal (highly recyclable and valuable, all the more given its specific properties for this application), it is estimated that a major share of the products will be driven to local recycling markets within the EU-27, and no international impact due to exportation of products at the end-of-life should occur.

1.3.2.4 Overview of environmental impacts until 2044

Based on the above, some positive environmental impacts can be expected from electronic safes falling in the scope of RoHS II, in particular during the end-of-life phase, where less hazardous substances would be released to the environment.

Table 8: Estimated environmental impacts

Estimated environmental impacts until 2044[40]		
	2012	**2044**
Energy use	=	=
Waste production / generation / recycling	=	=/+
International environmental impacts	=	=/+

1.3.3 Economic impacts

In an era marked by financial turbulence, safes have become a popular commodity, with some manufacturers, retailers and installers reporting sales increases of as much as 40% from a few years ago[41]. Furthermore, growing concerns about identity theft has made some people more eager to keep their assets in a form they can see and count, which has further increased the popularity of electronic safes in recent years[41]. This has also driven the market for further developments in innovations to improving the security and reliability of electronic locking systems.

1.3.3.1 Functioning of the internal market and competition

RoHS II should affect all manufacturers of electronic safes in the EU equally, which means that no competitive pressures within the European Union should be expected. Provided there is suitable market surveillance, no distortion of the internal market is expected.

1.3.3.2 Competitiveness

As presented in section 1.2.2, Poland is a key exporting country for "Armoured/reinforced safes, strong-boxes & doors & safe deposit lockers for strong-rooms, cash/deed boxes & the like, of base

[40] RoHS II coming into force for this product group (2019), plus one product lifetime (25 years)
[41] Web article (accessed in 05/12): www.marketwatch.com/story/more-americans-stashing-cash-in-home-safes-2012-05-03?siteid=rss&rss=1

metal". Italy is also home to several major electronic safe manufacturers. In terms of imports, three EU Member States (Germany, UK, and France) are among the top worldwide importers of these products. However, as mentioned earlier this category of products is very broad and no specific market data was identified that would enable a more accurate quantification of the EU-27 exports and imports, by country.

In theory, the implementation of RoHS II for electronics safes should have no impact on the competitiveness of EU companies on the EU market, as all products sold are subject to the same regulations. However, non RoHS-compliant manufacturers (inside or outside the EU) selling on the EU market could benefit from an implementation of RoHS II, in case that market surveillance is not properly implemented. Furthermore, additional compliance and technical costs might reduce their competitiveness for exportations in countries where such substances requirements are not compulsory. The fact that the product is RoHS substances-free is not likely to provide a marketing advantage to compliant manufacturers for this type of products, in which the functionality and reliability is of paramount importance. Depending on the possible substitutes, RoHS II implementation might also result in technical issues, such as a loss of reliability (e.g. lead-free solder vs. lead solder) but this seems very unlikely. No specific documentation was found on this topic though so that the extent of this effect is highly uncertain.

On the other hand, the same effects (described above) would apply to extra-EU manufacturers exporting electronic safes on the EU market, so that in the end, the fact that the competitiveness of a company will be impacted by RoHS II implementation or not, will depend on its different market share inside and outside the EU. The information found on the electronic safes market are not detailed enough to judge whether EU companies will suffer from a reduced competitiveness outside the EU (and an increased one inside the EU), or whether extra-EU companies will also adopt RoHS II measures to be able to continue their activities on the EU market, in which case, no effect on competitiveness would occur.

1.3.3.3 Costs and administrative burdens

No specific information was found or received from stakeholders on additional costs for the electronic safes industry. According to the 2008 Impact Assessment accompanying the Commission's recast proposal[42], there is little experience of actual compliance costs for industry. For products currently included in RoHS, estimates are it would vary from 1-4% of turnover. Other surveys give an average overall cost related to RoHS of 1.9% of turnover (past cost and one-off future costs). Assuming an average price of 115 € for a typical electronic safe (see Table 1, high uncertainty)[43] and 325 000 annual sales, the annual turnover of the whole sector is €37.4 million. Applying the 1-4% range, compliance costs would represent between k€374 and €1.5 million for all EU-27 manufacturers.

Technical costs could be due to additional research to come up with new compliant components (especially electronic locks) and to the fact that changed components would have to undergo

[42] European Commission (2008), SEC(2008) 2930. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=SEC:2008:2930:FIN:EN:PDF

[43] Purchase prices can be very variable depending on the type of safe purchased (i.e. size, robustness, reliability, etc.): from a couple dozen Euros to several thousand Euros.

extensive field testing before being implemented in products, in order to minimise the risk of durability and reliability decrease. Such costs could be reasonably supported by large manufacturers, but could be more problematic for SMEs of the sector. The additional costs are likely to be transferred all along the supply chain, e.g. from the electronic lock manufacturer to the final customer.

The replacement of lead-solder by lead-free solder would also result in additional costs due to raw material requirements. With a quantity of lead in solders of 1 g per product, and annual sales representing 325 000 products, lead solder constitutes 0.55 tonnes of tin and 0.33 tonnes of lead per year. Assuming that 100% of the lead solder is replaced by tin/silver/copper solder (more reliable than tin/copper solder), 0.3 additional tonnes of tin and 26 kg of silver would be required to replace the lead. Additional costs would therefore amount to approximately 22 000 € annually for all EU-27 manufacturers of this type of equipment[44].

Overall, with very limited data availability it is difficult to make precise estimations of additional compliance costs for the electronic safe industry due to RoHS II. Still, based on the discussion above it can be assumed that costs will be incurred albeit to a limited extent. These costs will be easier to assimilate for the large players in the market than for SMEs.

1.3.3.4 Innovation and research

The market for innovative solutions in the electronic locks sector is dynamic and growing. As stated above, there seems to be a growing demand for sophisticated electronic locks due to an apparent increase in crime[45]. Most of the research and development activities that occur in the domain of electronic safes are those that ensure more security. The following lists some of the innovations that are currently being developed in this sector:

- Biometrics: using fingerprint recognition technology. While adoption of biometric authentication is growing, biometric locks require hardwired Internet configurations (which is less secure than cable wiring for example), therefore, biometrics remain a niche market due to privacy concerns.
- Audit trails: a system that allows the user of the safe to know the exact time that a safe was opened.
- RFID technology: these systems can be integrated into a variety of items, from cards to wristbands to fobs. The technology eliminates the inconvenience of magnetic keycards that could become accidentally demagnetized.
- Anti-cloning technology: provides extra protection against keycard cloning.
- Near Field Communication (NFC) technology: allows electronic locks to communicate with compatible cell phones.

[44] Under the following assumptions: composition of tin/lead solder is 63%/37%; composition of tin/silver/copper solder is 97%/3%/0% (copper is neglected); prices of metals (LME): 1590€/tonne for lead, 16210 €/tonne for tin; 674000 €/tonne for silver; 1 g of tin/lead solder is assumed to be replaced by 1 g of tin/silver/copper solder.
[45] http://www.asmag.com/showpost/8024.aspx (accessed in 05/12)

The RoHS substances substitutions may require additional R&D effort but the extent of these efforts that will be mostly specific to the electronic safes and locks industry is not known. Indeed, concerning lead solder, suitable existing substitutes would probably be available even if testing should be carried out to ensure this. Regarding coatings, it could be that specific developments would need to be made, depending on the required properties of the safe (e.g. water, fire and corrosion resistance). The positive influence on this active industry sector is estimated as limited.

1.3.3.5 Consumers and households

An increase in both technical as well as administrative costs for manufacturers of electronic safes and electronic locks might lead to an increase in prices for consumers. Further, literature indicates that sophisticated electronic locks are sought as a cost-effective way to prevent unauthorized access due to expected increased crime rates as a result of the economic downturn. Given the motivation behind the demand for electronic safes, it is unlikely that a reasonable increase in purchase price would significantly affect the market and sales. Overall, the negative influence of electronic safes falling in scope of RoHS II is expected to be very limited.

1.3.3.6 Overview of economic impacts until 2044

Based on the discussion above, it can be said that the economic impacts, both positive and negative, from electronic safes falling in scope of RoHS II are expected to be very limited. However, the lack of data makes an accurate and reliable assessment for the chosen indicators difficult.

Table 9: Estimated economic impacts

Estimated economic impacts until 2044[46]		
	2012	**2044**
Functioning of the internal market and competition	=	=
Competitiveness	=	?
Costs and administrative burdens	=/-	-
Innovation and research	=	=/+
Consumers and households	=	=/-

[46]RoHS II coming into force for this product group (2019), plus one product lifetime (25 years)

1.3.4 Social impacts

1.3.4.1 *Employment*

Statistics regarding jobs directly and indirectly linked to the electronics safes industry have not been found and no feedback from stakeholders was received. The impact of RoHS II on these jobs is estimated to be limited given the few substances in electronics safes and the assumed presence of existing substitutes. Furthermore, the slight development of R&D to find substitutes could stimulate job creation.

1.3.4.2 *Health*

Exposure to RoHS substances during the production phase may represent a risk for the facility workers, who are a population group at greatest risk of exposure to lead (especially through air). This risk is very much dependent upon the type of exposure (time, frequency, pathway, etc.). It can be expected that EU manufacturers already respect the related legislation and implement the necessary precaution to ensure their workers' well-being. The production of the electronics containing lead solder does predominantly take place outside the EU-27. A ban of the six hazardous substances under the scope of RoHS in electronic safes would reduce health impacts in case of accidental situations. The importance of these health effects also depends on the potential effects of the substitutes to the six banned substances, if any. A quantification of these impacts could not be made given the lack of information about possible substitutes.

Impacts on the health of users are expected to be negligible. In normal operation, electronic safes represent a very low risk to the user's health, as this is taken into account in the design phase. Like in the production chain, people can be affected by accidents/maloperation though but no thorough information could be found on this particular issue.

Finally, the management at the end-of-life of the product can result in important impacts to the environment and health. These impacts are dependent upon the management options followed by products, which have already been presented (see section 1.3.2.2). Based on the same assumptions regarding the emissions to air and water of the substances during recycling, incineration and disposal (see Table 6), health impacts can be quantified via the human toxicity indicators[47]: assuming the ban of RoHS hazardous substances in electronic safes from 2044 (Option 2), a human toxicity impact of 5.27E-06 CTUh (cancer effects) and 6.74E-04 CTUh (non-cancer effects) would be avoided in 2044 (0.00000003% and 0.00000016% respectively of the overall impacts in the EU-27 annually), compared to Option 1, due to the removal of lead and chromium VI.

[47]USEtox™ method.

Table 10: Human toxicity indicators

Year[48]	Human toxicity midpoint, cancer effects (CTUh[49])	Human toxicity midpoint, non-cancer effects (CTUh)
2044	5.27E-06	6.74E-04

The monetised cost of this impact has been calculated by Defra (UK)[50] which looked at the costs in terms of health impacts of options for management of waste containing hazardous substances including lead. The study estimated health impacts from mathematical models of landfill and incineration and estimates of pollution from these disposal options. Applying these results to the heavy metal emissions per end-of-life treatment options (see Table 6), gives a monetised health benefit from not using lead of between €2 400 and €57 000[51].

1.3.4.3 Social impacts in third countries

A major concern of lead solders is the harm to health caused by unsuitable and dangerous recycling practices that are used in some developing countries. Despite legislation aimed at preventing illegal WEEE exports, some European WEEE is shipped to developing countries for recycling. Electronic safes, because they are dismantled by professionals and can be part of the construction and demolition waste, are not expected to be much exported as WEEE for recycling. Consequently, impacts outside the EU are estimated as negligible.

1.3.4.4 Overview of social impacts until 2044

Some positive social impacts can be expected from the inclusion of electronic safes in the scope of RoHS II, especially regarding health.

Table 11: Estimated social impacts

Estimated social impacts until 2044[52]		
	2012	**2044**
Employment	=	=/+
Health	=	+
Social impacts in third countries	=	=

1.3.5 Comparison of options

The inclusion of electronic safes in the scope of RoHS II is expected to result in limited impacts, both positive and negative. Due to the slight decrease of the use of the banned substances,

[48] RoHS II coming into force for this product group (2019), plus one product lifetime (25 years)
[49] Comparative Toxicity Unit human, equivalent to cases
[50] Enviros Consulting Ltd. For Defra, *Valuation of the external costs and benefits to health and environment of waste management options*, December 2004, table 3.2 and page 82)
[51] Based on a monetised impact of lead between €1.46 million/tonne and €35 million/tonne, and assuming a 0.5% leakage rate of lead at the end-of-life.
[52] RoHS II coming into force for this product group (2019), plus one product lifetime (25 years)

environmental and health benefits are expected all along the lifecycle of the products, especially at the end-of-life. On the other hand, limited negative impacts are likely to occur due to additional costs, both for manufacturers and customers. Please note that the quantitative assessment of such impacts is highly uncertain and would be very variable for each manufacturer.

Table 12: Comparison of options

Impact indicators	Option 1 : Electronic safes not in scope of COM recast proposal	Option 2: Electronic safes in scope of RoHS II
Environmental impact indicators		
Energy use	=	=
Waste production / generation / recycling	=	=/+
International environmental impacts	=	=/+
Economic impact indicators		
Functioning of the internal market and competition	=	=
Competitiveness	=	?
Costs and administrative burdens	=	-
Innovation and research	=	=/+
Consumers and households	=	=/-
Social impact indicators		
Employment	=	=/+
Health	=	+
Social impacts in third countries	=	=

In relation to the overall policy objective of RoHS II, namely to contribute 'to the protection of human health and the environment, including the environmentally sound recovery and disposal of waste EEE'[53], the discussion above shows that including electronic safes in RoHS II does contribute to this objective, even if slightly. Please note that no specific information was found or received on the uses of RoHS substances in these products and that the results of this assessment are therefore based on several assumptions and estimations.

[53] 2011/65/EU, Article 1

Table 13: Policy objectives and options

Policy options in relation to overall policy objectives			
	Effectiveness	**Efficiency**	**Coherence**
Option 1: Electronic safes not in scope of COM recast proposal	Slightly negative: Hinders the objectives to a limited extent	Efficiency cannot be evaluated as the option does not contribute to the overall objectives	No unintended impacts
Option 2: Electronic safes in scope of RoHS II	Slightly positive: Does contribute to the effectiveness of the Directive	Limited: None of the positive impacts are significant	Unintended impacts are limited

Annex

Possible criteria to determine whether an installation is 'large-scale'. Please note that this is only an indicative list.

If the installation exceeds the minimum requirements for **one** of the following criteria, it can be considered large-scale:[54]

- If, when installing or de-installing the installation, it is too large to be moved in an ISO 20 foot container because the total sum of its parts as transported is larger than 5,71m x 2,35m x 2,39m, then it can be considered large-scale.
- The maximum weight of many road trucks is 44 tonnes. Thus if, when installing or de-installing the installation, it is too heavy to be moved by a 44 tonne road truck, because the total sum of its parts as transported weighs more than the truck's load capacity, it can be considered large-scale.
- If heavy-duty cranes are needed for installation or de-installation, the installation can be considered large-scale.
- An installation that does not fit within a normal industrial environment, without the environment needing structural modification, can be considered large-scale. Examples for modifications are modified access areas, strengthened foundations etc.
- If an installation has a rated output greater than 375 kW, it can be considered large-scale.

[54] European Commission, DG ENV, *RoHS 2 FAQ, Final Draft 15 May 2012*

Table 14: Estimate on the number of households that purchased new safes in 2011*

Member State	Year of reference : 2009 unless specified	Dwelling stock (number of households)	Number of households that purchased new safes, 2011
Austria	-	3 598 000	5 179
Belgium	-	5 043 000	7 259
Bulgaria	-	n.a.	n.a.
Cyprus	2001	288 000	415
Czech Republic	2001	3 828 000	5 510
Denmark	-	2 680 000	3 857
Estonia	-	651 000	937
Finland	-	2 784 000	4 007
France	2006	31 264 000	45 000
Germany	-	39 268 000	56 521
Greece	2000	5 465 000	7 866
Hungary	-	4 303 000	6 194
Ireland	2004	1 619 000	2 330
Italy	2002	27 269 000	39 250
Latvia	2005	1 042 000	1 500
Lithuania	-	1 308 000	1 883
Luxembourg	2005	188 000	271
Malta	2005	139 000	200
Netherlands	-	7 107 000	10 229
Poland	2005	13 150 000	18 928
Portugal	2006	5 537 000	7 970
Romania	2005	8 329 000	11 988
Slovak Republic	2008	1 767 000	2 543
Slovenia	2004	798 000	1 149
Spain	-	25 129 000	36 170
Sweden	2008	4 503 000	6 481
United Kingdom	2004	23 500 000	33 825
Total – EU-27	**-**	**220 557 000**	**317 460**

Source: Housing Statistics in the European Union 2010, OTB Research Institute for the Built Environment, Delft University of Technology[55].

*Based on the assumption that all MS have a similar situation to France, where 45 000 households purchased a new safe in 2011 (representing 0.14% of total number of households in France).

[55] http://abonneren.rijksoverheid.nl/media/dirs/436/data/housing_statistics_in_the_european_union_2010.pdf

Table 15: Quantities of RoHS substances released to the environment in 2044 without RoHS II implementation, due to end-of-life management options

Substance	Released to	Quantity (in kg)
Cadmium	Air	0
Chromium VI		0.000010335
Lead		0.051675
Mercury		0
Cadmium	Water	0
Chromium VI		0.00031057
Lead		1.55285
Mercury		0

Table 16: Characterisation factor of the RoHS substances (USEtox™ method)

Substance	Type of emissions	Human toxicity midpoint, cancer effects (in CTUh/kg)	Human toxicity midpoint, non-cancer effects (in CTUh/kg)	Ecotoxicity freshwater midpoint (in CTUe/kg)
Lead	Emissions to air, unspecified	2.69E-05	9.44E-03	1.75E+02
	Emissions to water, unspecified	3.42E-07	1.20E-04	3.75E+02
Mercury	Emissions to air, unspecified	7.06E-03	8.35E-01	1.22E+04
	Emissions to water, unspecified	1.20E-04	1.42E-02	2.21E+04
Chromium VI	Emissions to air, unspecified	4.45E-03	4.16E-04	4.20E+04
	Emissions to water, unspecified	1.06E-02	2.40E-05	1.05E+05
Cadmium	Emissions to air, unspecified	2.17E-04	4.55E-02	3.94E+03
	Emissions to water, unspecified	1.59E-06	4.27E-04	9.71E+03

Table 17: Impact assessment results (USEtox™ method)

Impact indicator (unit)	Avoided impacts in 2044 in EU-27, with RoHS II implementation (in impact indicator unit)	Avoided impacts in 2044 in EU-27, with RoHS II implementation (in % of annual EU-27 impacts)	USEtox™ normalisation factors (in impact indicator unit per person per year)
Human toxicity midpoint, cancer effects (in CTUh)	5.27E-06	0.00000003%	3.25E-05
Human toxicity midpoint, non-cancer effects (in CTUh)	6.74E-04	0.00000016%	8.14E-04
Ecotoxicity freshwater midpoint (in CTUe)	6.24E+02	0.00000000004%	3.18E+06

An EU-27 population estimate of 502m inhabitants in 2011 is used for the normalisation (source: Eurostat, in March 2012).

Swimming pools

Important note: In this factsheet, the product group swimming pools will always refer to such products having at least one electric or electromagnetic function.

For this product group, it has been difficult to establish any productive contact with industry or their representatives. It should be stressed that insufficient data led to the assessment being based on a number of assumptions.

1.1 Key issues

Swimming pools were not in scope of the COM recast proposal as long as their primary function of providing a bathing area could be fulfilled without an electrical function. Because of the new definition of 'dependent' in RoHS II[1], swimming pools with any electrical function, whether primary or secondary, fall in scope of the Directive. In this factsheet, it will be explored what the impact of this change is and whether the benefits of the inclusion of swimming pools in RoHS II outweigh the potential costs.

Only those products will be assessed that are not large-scale fixed installation (see Annex). Equipment of this kind would be excluded from the scope by Art. 2.4(e).

1.2 Background

Swimming pools are water containers intended for swimming or water-based recreation activities. Many different designs are available, especially concerning their dimensions. Public pools are larger than private (domestic) pools: common lengths are 25 or 50 m.

Swimming pools can be above ground or buried in the ground, and be built with different materials (including concrete, prefabricated, polyester). To achieve the proper functioning of a swimming pool, many different electric features are necessary. These features are shown on Figure 1 thanks to their associated number in brackets:

The **heating system (1)**: The pool water requires heating during the initial heat up, and when due to the ambient temperature and relative humidity in the air surrounding the pool, the pool is losing heat as a result of evaporation, radiation, convection and/or conduction[2]. The size of the pool water heater is determined, among others, by the required pool temperature and its volume. The heating system is also dependent upon the geographical location (and associated climate) of the swimming pool, if installed outdoors. There are five commonly used systems to provide outdoor pool heating[2],

[1]Art. 3.2: 'needing [electricity] to fulfil at least one intended function'

[2] EUSA Draft paper, Heating of domestic outdoor swimming pools

which have different characteristics and installation requirements. All of them tend to require control systems:

- Gas water heaters: either direct (where the pool water flows through the boiler), or indirect (central heating boilers, which are connected to the pool water via a secondary heat exchanger);
- Oil water heaters: like gas water heaters, they are available in direct or indirect designs;
- Electrical resistance heaters
- Heat pumps: usually electrically driven. Two basic designs are available: air-to-water (where the heat content of the environmental air is utilized) is the most common; and water/soil-to-water, which requires higher investment and is more efficient (wells are bored, or coils are laid into the soil for utilizing the heat-gain from the earth)
- Solar heating: Solar collectors are connected to the pool filtration circuit such that water flowing through them is heated as a result of their ability to absorb energy from the sun.

The **circulation system (2)**: it is designed to move the water from the pool tank for passage through filtration, heating and treatment systems and returning it to the pool tank. It consists of a circulation pump and a pipework system between the pool, the pump, and the various ancillary systems[3]. A good circulation system ensures the suitable distribution of chemical treatment and heat, by keeping fine debris in suspension for the maximum period, and avoid any "dead areas" where water movement is minimal or zero. The performance of the pump has to be selected depending on the other parameters of the system (e.g. flow rate, heat losses).

The **filtration system (3)**: it removes suspended matter from the pool water. Filtration is achieved by passing the water through a suitable medium contained in a vessel[4]. There are three main types of filters for swimming pools: pre-coat filtration/Diatomaceous Earth (DE); disposable cartridge; and graded aggregate (sand or other suitable material, in conjunction with or without layered shingle, anthracite etc.). The size and performance of the filter pump should be matched to the size of the filter and the filtration rate required.

The **electrolyser/treatment system (4)**: the electrolyser is an automatic sterilisation system that produces onsite a chlorine disinfectant killing bacteria and algae. Other disinfectants are also available that do not need to be produced onsite: sodium hypochlorite, calcium hypochlorite, chlorine gas or organic chlorine products. When using UV, ozone or other treatment methods, free residual chlorine always has to be present.[5] The quantity of chlorine that is required to disinfect a swimming pool depends on the temperature and the pH value of the water. The treatment system operates only during filtration periods. It can also include a pH regulation feature. The recommended pH range in a private swimming pool is 6.8-7.6. A flocculent can also be added by the

[3]EUSA, Technical paper – Circulation systems for domestic swimming pools
[4]EUSA, Technical paper – Domestic swimming pool filtration
[5]EUSA, Technical paper – Water treatment

treatment system, to increase the size of suspension particles and improve filtration. Finally, chemicals can be used to increase water hardness.

The filtration system, the circulation system and the treatment system form an integral part of the swimming pool and are fully interdependent in their operation. Other electric functions include:

Safety systems (5): systems intended to prevent accidents/drowning, especially concerning children. They can consist of mechanical obstacles (barriers, coverage) or sound alarms. Professionals systematically offer the protection system with the swimming pool, but the consumer is free to buy it elsewhere[6]. Professionals have to supply their customers with a technical document to inform them about safety. The size of this market can strongly increase within a short period of time due to enforced regulations that can also apply to installed pools.

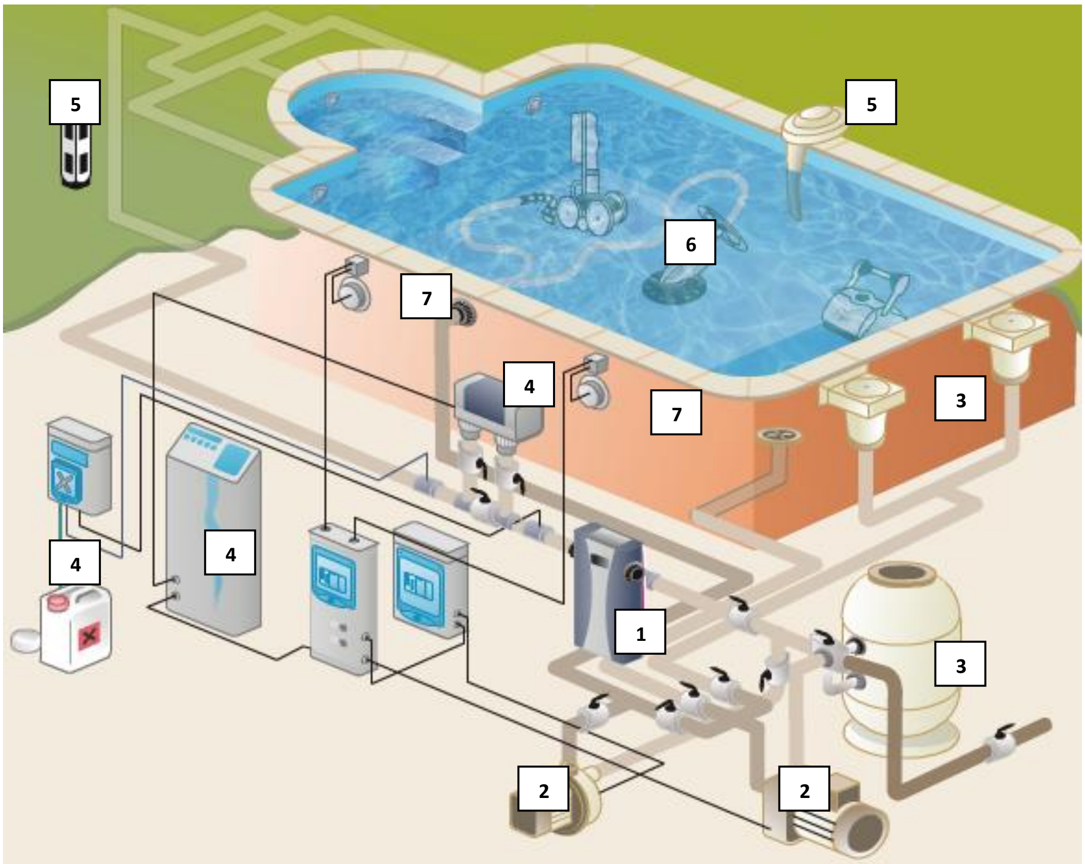
Cleaning robots (6): despite the sophisticated treatment system, there are certain manual works necessary to keep the pool water in a good condition. Brushing and vacuum cleaning can be carried out by underwater robots.

Lighting equipment (7): different lighting equipment can be installed around the perimeter of the pool or underwater. Underwater lamps are protected by shock-resistant lenses, and are available in different types (including halogen, LEDs).

Counter-current systems (8): They consist of a high volume pump providing a turbulent water flow from outlets along one side of the pool. It offers a similar sensation to swimming against the flow in a mountain stream.

[6] "The French experience in safety for private family swimming pools", Fédération des Professionels de la Piscine

Figure 1: Swimming pool and main electric features



Source: www.piscine-center.net

Table 1 below summarises the main EEE components that can be found in swimming pools and some of their characteristics. All of them have been found in RoHS compliant designs. After the circulation system, the cleaning robot, the safety system and the lighting equipment appear as the most common features. Except some specific parts that have to/can be sealed to the pool (e.g. outlets, projectors, see Figure 1), all these features seem highly modular, both during installation and maintenance/repair activities.

Table 1: EEE components found in swimming pools

EEE component	Possible sub-components	Frequency	Modular[7]	Existing RoHS compliant design
Heating systems	- LCD display - Control unit(with a PCB) - Electric cables	All systems: 36% in France[8] Heat pumps: 2.8% in Spain Solar: 3.1% in Spain[9]	Yes	Yes
Circulation system	- Pump - Pipework	Estimated at almost 100%	Yes	Yes
Electrolyser/water treatment	- Control and safety panel (switch, buttons, LCD display) - Electrolysis cell: electrodes, temperature sensor - Flow-switch	46.3% in Spain[9] 28% in France[8]	Yes	Yes
Safety systems (e.g. alarms)	Can consist of an alarm (approx. 54% in France), security barriers (29%), coverage (23%)	75% in France[6] (89.4% for inground and 28.4% for above ground) 47.5% in Spain[9]	Yes	Yes
Cleaning robot		67.2% in Spain[9] 56% in France[8]	Yes	Yes
Lighting	- Control box - Cables - Lamps - Remote control	63.1% in Spain[9]	Yes (projectors can be sealed to the pool)	Yes
Counter current systems	- Pumps - Pipework - Outlets	6.9% in Spain[9] 9% in France[8]	Yes (the outlet can be sealed to the pool)	Yes

1.2.1 Legal background

Swimming pools with electrical functions were not considered in scope of RoHS I or the COM recast proposal in most cases as they could perform their primary function of being a bathing area without any electrical function. In contrast to RoHS I and the COM recast proposal, according to Article 3.2 of RoHS II electricity is only needed for 'at least one intended function' for the equipment to be categorised as EEE. In other words, the electric function does no longer have to be primary but can also be secondary for the equipment to qualify as EEE and this is also the case for swimming pools.

[7] Is not integrated in the pool in itself, can be bought and replaced separately without change of the existing installation
[8] http://www.actu-piscine.fr/dossiers.php?Action=Article&Id=273 (accessed in 05/12)
[9] Market AAD (2009), Study base - Spanish swimming pool sector (2009).

Hence swimming pools with any electrical function are now included in Category 7 'Toys, leisure and sport equipment' of RoHS II, Annex I.

The Draft Final RoHS 2 FAQ document of 15 May 2012 details that for a product to be EEE, its electricity dependent functions must in principle be integrated. The document provides no example specifically related to swimming pools but the situation can be compared to the one provided with the example of a wardrobe with lights: "[...] even if sold as a single unit, a distinction between the piece of furniture and the electric/electronic device the piece is or can be equipped with has to be drawn. If the lighting is EEE itself and both the lighting and the wardrobe can be separated and used by the end user as fully functional separate products, it is only the electric/electronic equipment (the lighting) [that] is in the RoHS 2 scope. The furniture itself would then be outside the scope."[10] Regarding this factsheet, it will therefore need to be differentiated between fully integrated EEE components, in which case the swimming pool would be in scope as well (the RoHS II substance restrictions will apply to all components, also non-electrical ones, on the homogeneous material level), and types of modular EEE components that could be removed and used elsewhere, in which case the swimming pool would be out of scope.

Swimming pools could be excluded from the scope of RoHS II through the 'large-scale fixed installation' exclusion of Article 2.4(e). No officially agreed definition of the term 'large-scale' exists at the time of writing of this report, but based on the most likely criteria, it is estimated that a small percentage of all swimming pools could be excluded as large-scale from the scope (e.g. large unibody polyester pools). Please see the Annex for more information on these draft criteria. Please note, however, that until the list of criteria has been finalised, no detailed information of the possible impact can be provided.

1.2.2 Quantities and hazardous substances

No market data was found on swimming pool in the PRODCOM database. PRODCOM categories that include products related to swimming pools are not disaggregated enough to obtain a reliable estimation for only the products within the scope of this impact assessment.

More specific market data was therefore obtained from EUSA (European Union of Swimming Pool and Spa Associations). Table 2, Table 3, and Table 4 show the EU market in 2009, the world market in 2009, and private pool characteristics in the EU respectively.

[10] European Commission, DG ENV, *RoHS 2 FAQ, Final Draft 15 May 2012*, p.21

Table 2: EU-27 swimming pool market in 2009

Member State	Installed private pools (in thousands units)	Percentage private pools/total Europe	Installed public pools (in units)	Sales private pools in 2007 (in units)	Sales private pools in 2008 (in units)	Sales private pools in 2009 (in units)
England	213.5	4.89%	7 000	6 000	6 000	2 500
France	1 466	33.57%	24 700	96 000	61 000	59 000
Germany	862	19.74%	25 800	21 000	21 000	20 000
Hungary	68.5	1.57%	2 055	3 000	3 500	3 000
Italy	267	6.11%	14 000	21 000	24 000	22 000
Portugal	89	2.04%	2 700	5 000	5 000	4 000
Spain	1 200	27.47%	16 900	38 000	35 000	15 000
Sweden	201.5	4.61%	4 030	24 000	25 500	22 000
Total Europe[11]	**4 367.5**	**100%**	**91 185**	**214 000**	**180 000**	**147 500**

Source: EUSA estimations, Market data 2009 – Presentation by Dr. Francesco Capoccia (4-5 October 2010, Venice)

Table 3: World swimming pool market in 2009

World region	Installed private pools (in thousands units)	Percentage private pools/total world
Africa	120	0.79%
Asia	180	1.18%
Europe	4 368	28.61%
North America	9 000	58.94%
Oceania	1 000	6.55%
South America	600	3.93%
Total world	**15 268**	**100%**

Source: EUSA estimations, Market data 2009 – Presentation by Dr. Francesco Capoccia (4-5 October 2010, Venice)

[11] Corresponds to the total of the MS presented. The source does not specify whether this is an important approximation.

Table 4: Private pool characteristics in the EU

Member State	Construction		Material		
	In-ground	Above ground	Concrete	Prefabricated	Polyester
England	62%	38%	35%	50%	15%
France	64%	36%	50%	34%	16%
Germany	70%	30%	36%	50%	14%
Hungary	95%	5%	55%	40%	5%
Italy	60%	40%	60%	30%	10%
Portugal	90%	10%	n/a	n/a	n/a
Spain	70%	30%	63%	19%	18%
Sweden	70%	30%	3.5%	95%	1.5%

Source: EUSA estimations, Sector volume and market characteristics - Barcelona, 2009

France, Spain and Germany represent the three Member States with the most important number of swimming pools installed. In Germany, the annual sales volume of private swimming pools and spas represented €1.7 billion in 2010[12]. In-ground swimming pools are significantly more expensive than above ground pools, but also more common in all Member States. In France, in-ground pools represent 90% of the turnover, while above ground only represent 2% (8% is due to renovation activities)[13]. Still in France, 95% of the pools are owned by private households, and 5% by professionals (camping, hotels, etc.)[13], which shows that domestic pools represent the majority of the market.

Given the information in the background (section 1.2), most of the swimming pools should have at least one electric feature, even if only for the circulation system. In this assessment, it is considered that public swimming pools, given their larger dimensions, are large scale fixed installations (LSFI), while none of the domestic swimming pools are LSFI. Please note that until the list of criteria has been finalised (see Annex), a more precise estimation cannot be made.

Based on the above it is estimated that the annual sales of swimming pools that are not large-scale fixed installations and that have at least one electric function represent approximately 180 000 units per year[14], for a stock of 4.4 million units in the EU-27.

In France, swimming pools and spas represent 70% of the turnover in the swimming pool sector, maintenance and consumables account for 14%, shelters for 11% and refurbishment for 5%.[13] 20% of the turnover is due to exportations: the main destinations are Italy, Portugal, Spain, Belgium, Netherlands and Eastern Europe countries[15]. This information has not been available for other EU Member States.

No information regarding RoHS substances used in swimming pools has been received from stakeholders or found. As stated above, most of the electric features associated with swimming

[12] BSW (2010), Actual and potential pool owners.
[13] F.P.P. -Bilan économique du marché de la piscine -2007
[14] Average between 2007, 2008 and 2009 annual sales
[15] F.P.P. press release: http://www.propiscines.fr/pub/DPconf_2012avril.pdf

pools are available in RoHS compliant designs and these seem to be common. Concerning the pool itself, it is either built in concrete, made of prefabricated panels (steel, aluminium, polymers), or unibody (entirely prefabricated in polyester). Concerning the pool coating, several options are available. For concrete pools, these are: tiling, mosaics, plaster, paint or liner. To ensure a coating of satisfactory quality, only materials specifically designed for pools should be used, namely chlorinated rubber, emulsion and two pack epoxy resin[16]. For pools made of prefabricated panels or concrete, a PVC liner (possibly reinforced PVC) is a common option. It can be adapted to the pool dimensions and is available in different colours. Depending on its application, its thickness is variable and has a direct influence on its robustness and lifetime. The liner incorporates a fungicide and the PVC molecules should never leach to the pool water.

Table 5 lists the presence of the different hazardous substances considered by RoHS II.

Table 5: RoHS substances in swimming pools and their EEE components

Substance	Presence in swimming pools and EEE components
Lead	Possibly in PCBs of heating systems and controllers and in PVC as stabiliser
Mercury	Unlikely
Cadmium	Unlikely
Hexavalent Chromium	Possibly on fasteners (nuts and bolts)
Polybrominated biphenyls (PBB)	Unlikely
Polybrominated diphenyl ethers (PBDE)	Unlikely

Source: Own estimations

1.2.3 Policy objectives and options

The objective of both, the RoHS recast proposal (COM (2008) 809 final) as well as RoHS II (2011/65/EU) is to contribute 'to the protection of human health and the environment, including the environmentally sound recovery and disposal of waste EEE'[17].

The purpose of this work is to look at the impacts of swimming pools falling under the scope of RoHS II compared to swimming pools being excluded from the COM recast proposal. Policy options will then be evaluated according to their effectiveness, efficiency and coherence in reaching the above-mentioned overall objective of the RoHS Directive. The policy options analysed are the following:

OPTION 1 (baseline scenario): The COM recast proposal. Swimming pools are not in scope of the proposed recast Directive.

OPTION 2: RoHS II. Swimming pools are included in the scope of the recast Directive.

[16] EUSA, Technical paper – Domestic swimming pool tank installation
[17] 2011/65/EU, Article 1

1.3 Main issues regarding swimming pools

The following subsection presents the main issues that were encountered for the swimming pool impact assessment. Because of these issues, a quantitative assessment could not be carried out the way it has been done for other product groups.

1.3.1 Influence of scope interpretation

As stated in the legal background (section 1.2.1), the Draft Final RoHS 2 FAQ document of 15 May 2012 details that for a product to be EEE, its electricity dependent functions must in principle be integrated. The document provides an example of a wardrobe with lights: "[...] even if sold as a single unit, a distinction between the piece of furniture and the electric/electronic device the piece is or can be equipped with has to be drawn. If the lighting is EEE itself and both the lighting and the wardrobe can be separated and used by the end user as fully functional separate products, it is only the electric/electronic equipment (the lighting) [that] is in the RoHS 2 scope. The furniture itself would then be outside the scope."[18]

Regarding the electric features of swimming pools, the situation is not clear in regards to this wardrobe example. In particular, it is not clear what "fully functional" means: if the equipment is separated, it will not fulfil the exact same function (in the example of the wardrobe, the function of the light is to lighten the inside of the wardrobe); however, the lamp may have its 'general' functionality in the sense that it could provide light, for whatever application. In the case of swimming pools, it is unlikely that the devices will actually be used by the end user as separate products, i.e. not associated with a pool, but most will remain fully functional, even if they may be of no use if separate from the pool. They could also be used with another swimming pool or sometimes for other applications with possible adaptations of the devices. For instance:

- For the heating system: the water heaters would normally remain functional separately and could be used to heat other water circuits. This may already be the case for indirect heating systems.
- For the circulation system: the pump would remain functional separately and could be used for other pumping purposes, even if the associated pipework may require to be changed or adapted.
- For the lighting systems: even if not initially intended for such applications, some pool projectors may be installed elsewhere (e.g. a pond) without any issue. On the other hand, some of them would require an underwater operation for overheating reasons so that they would remain functional only under certain conditions.
- For the alarms: they would normally remain fully functional, even if of little use outside the pool application (e.g. floating or submerged alarms). Some of them, such as above ground alarms, may be used for other applications.
- Etc.

[18] European Commission, DG ENV, *RoHS 2 FAQ, Final Draft 15 May 2012*, p.21

Consequently, the understanding of the modularity considerations is currently not sufficient to determine when swimming pools would be considered within the scope of RoHS II, depending on their electric features. This is also complicated by the fact that the electric devices are available in many different designs, with different level of modularity. However, no such detailed market data is available to consider making a thorough assessment.

The discussion of impacts should therefore take into account several possibilities, regarding this issue:

- In the case of fully integrated EEE features, the swimming pool would be in scope as well (the RoHS II substance restrictions will apply to all components, also non-electrical ones, on the homogeneous material level);
- In case of modular EEE components, the swimming pool would be out of scope and RoHS II would only apply to the EEE components. Please note that RoHS scope considerations may be unclear for some components, which may have already been considered within the scope of RoHS I (e.g. if also sold separately).

1.3.2 Lack of data on RoHS substances

For this product group, it has been difficult to establish any productive contact with industry or their representatives. No information was received from the stakeholders.

During the literature review and web research, no information was found on possible RoHS substances in swimming pools in themselves (excluding all the electric features) but the PVC in liners and pipes may contain lead stabilisers. The liners should not contain any flame retardant as the risk of fire during the use phase of the pool is null, but these could be found in other plastic parts such as pump housings or heater enclosures.

Concerning all the electric features previously presented, all of them have been found in RoHS compliant designs (see Table 1). This is probably due to the fact that most of these products, such as pumps or lights, can be sold separately (even if they can also be sold in a kit, with the swimming pool), so that they were possibly considered within the scope of RoHS I themselves or to be used in products falling within the scope of RoHS I. No evidence was found that such accessories are still sold in non RoHS-compliant designs but it may nonetheless be the case in proportions that could not be estimated. Even if the possible applications of RoHS substances in such appliances are well-known, it was not possible to make reliable estimations concerning RoHS substances used in these features due to their diversity, and the lack of information on the share of non RoHS compliant appliances sold.

1.4 Comparison of options

Given the issues presented in section 1.3, it is impossible at this point to meaningfully assess the impacts of RoHS II implementation on swimming pools.

Most of the EEE component features of swimming pools are modular in the sense that they can be sold/replaced separately. According to the EC interpretation in the Draft Final RoHS 2 FAQ document of 15 May 2012, it is therefore likely that an important share of pools would not be in scope of RoHS II. Also, some swimming pools would be excluded because being large-scale fixed installations. Finally, for swimming pools falling within the scope of RoHS II, the overall impact should be limited given that all EEE components already exist in RoHS compliant designs (although the proportion that do not comply is unknown): health and environmental benefits as well as additional technical costs should be limited, but this is uncertain due to the lack of reliable data. An additional administrative burden and associated costs would occur but the extent of this burden is unknown as it is directly linked to the 'modularity' issue, which will determine the share of swimming pools falling into the scope of RoHS II.

Annex

Possible criteria to determine whether an installation is 'large-scale'. Please note that this is only an indicative list.

If the installation exceeds the minimum requirements for **one** of the following criteria, it can be considered large-scale:[19]

- If, when installing or de-installing the installation, it is too large to be moved in an ISO 20 foot container because the total sum of its parts as transported is larger than 5,71m x 2,35m x 2,39m, then it can be considered large-scale.
- The maximum weight of many road trucks is 44 tonnes. Thus if, when installing or de-installing the installation, it is too heavy to be moved by a 44 tonne road truck, because the total sum of its parts as transported weighs more than the truck's load capacity, it can be considered large-scale.
- If heavy-duty cranes are needed for installation or de-installation, the installation can be considered large-scale.
- An installation that does not fit within a normal industrial environment, without the environment needing structural modification, can be considered large-scale. Examples for modifications are modified access areas, strengthened foundations etc.
- If an installation has a rated output greater than 375 kW, it can be considered large-scale.

[19] European Commission, DG ENV, *RoHS 2 FAQ, Final Draft 15 May 2012*

Toys with secondary electrical functions

Important note: In this factsheet, the product group toys with secondary electrical functions will refer to those products that were not already in scope of RoHS I as their electrical function was not considered as 'primary'. This is in line with the Commission FAQ for WEEE and RoHS from 2006 although it is recognized that this is not legally binding and some Member State authorities did implemented RoHS I differently. Based on this definition, a primary electrical function in a toy is one without which the toy would be of no or little use, e.g. an electric train. On the contrary, a toy with a secondary electrical function could still be enjoyed without this function working, e.g. cuddly talking teddy bear.

1.1 Key issues

Under RoHS I Member State authorities were not in agreement on whether toys with secondary or minor electrical functions were in scope and this situation would have remained the same under the COM recast proposal. Because of the new definition of 'dependent' in RoHS II, it is now clear that toys with secondary electrical functions also fall in scope of the Directive. In this factsheet it will be explored what the impact of this change is and whether the benefits of the inclusion of toys with minor electrical functions in the scope of RoHS II outweigh the potential costs.

1.2 Background

Toys with secondary electrical functions are a diverse product group. Electrical and electronic toys in general (irrespective of whether for primary or secondary function) comprise the following:

Table 1: Electrical and electronic toys, 2003[1]

Type of toy	% of total EE toy market
Pre-school toys	28%
Boys' toys (e.g. matchbox garage)	22%
Baby/nursery toys	16%
Traditional dolls	11%
Ride-ons	6%
Car racing track sets	5%
Radio-controlled toys	4%
Stuffed toys	4%
Train sets	1%
Action figures, construction kits, creative toys, fashion dolls, games, hand-held video games, kids action games, learning aids, musical toys, novelties, outdoor toys, robots, toy tools and appliances, walkie-talkies	<1% each

Source: TIE response to stakeholder consultation, February 2012

Many of these electrical or electronic toys require electricity to perform their primary function and are therefore already in scope of RoHS I. The average electronic content of these EE toys is approximately 8%.[1]

Within Europe, the main producer countries are France, Germany, Italy and Spain.[2] In terms of sales, the most important European countries are France, Germany, Italy, Spain and the UK. In 2010, the overall retail market for traditional toys (which excludes video games) in the EU totalled €15.5 billion. The European toy market was the second largest behind the US in 2010. Total world toy sales were approximately €62billion that year with the European market constituting approximately 25% (€15.5 billion) of this. Figure 1 and Figure 2, below, present EU27 ex- and imports of traditional toys, which excludes video games. While the US is the biggest export market for European toy producers, by far the most imports of toys come from China with 86% of total imports into the EU. No data has been available on the actual overall export or import values or the import/export values for individual countries.

[1] TIE contribution to first stakeholder consultation, February 2012
[2] TIE, *Facts and Figures*, 2010

Figure 1: EU27 exports of traditional toys[2]

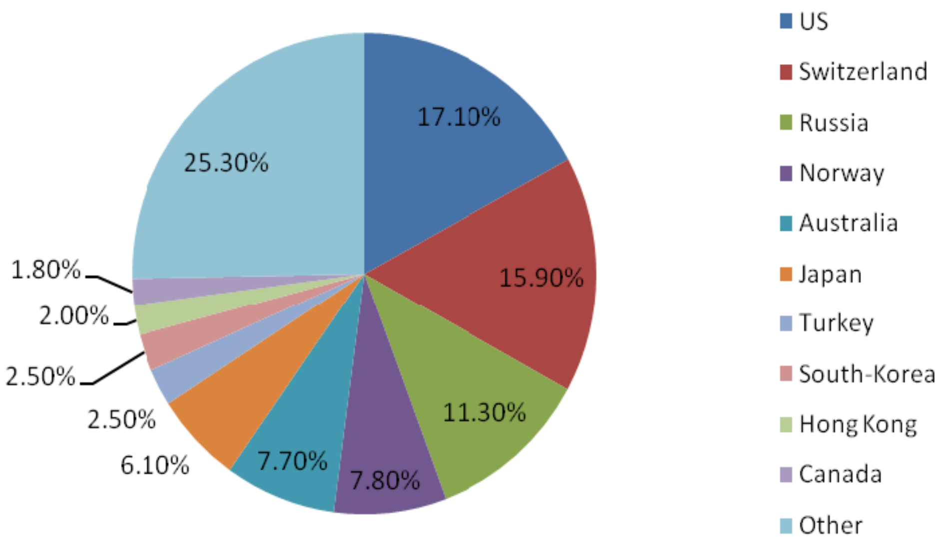
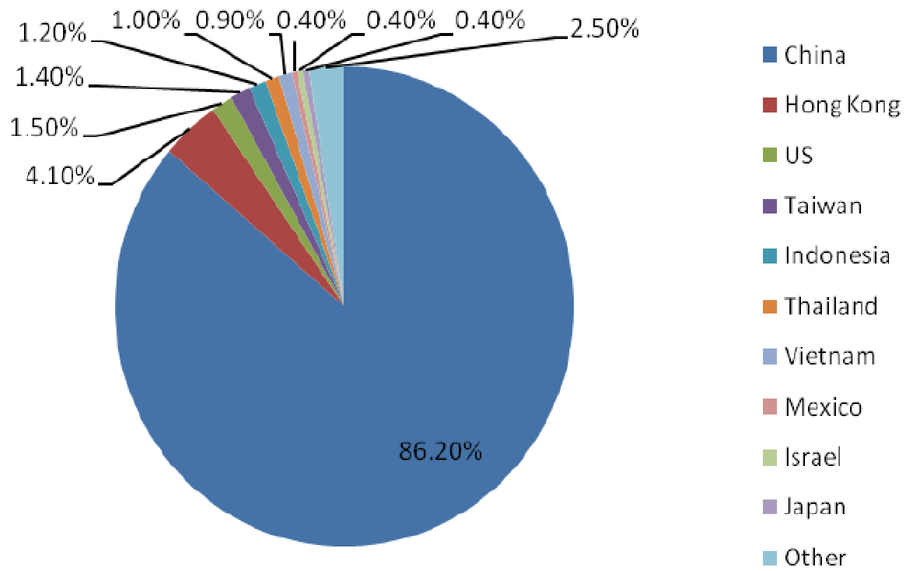


Figure 2: EU27 imports of traditional toys[2]



1.2.1 Legal background

According to the Commission FAQ document for WEEE and RoHS from 2006, under RoHS I equipment had to require electricity to fulfil its basic (primary) function in order to qualify as EEE. In this FAQ document, a teddy bear with battery is explicitly named as excluded from the scope as it can fulfil its basic (primary) function of a cuddly teddy bear even without its battery working.[3] Still, whether a function is primary or secondary is open to interpretation in many cases, which led to differences in the implementation of RoHS I regarding toys. Furthermore, some Member States argue that as toys are included in Category 7 of the WEEE Directive, Annex 1A (2002/96/EC), they

[3] European Commission, DG ENV, FAQ on RoHS and WEEE, 2006. Accessed at http://ec.europa.eu/environment/waste/pdf/faq_weee.pdf

are therefore in scope of RoHS I irrespective of whether their electric function is primary or secondary. Annex 1B of that Directive, which lists products falling in the categories of Annex 1A should not be seen as proof that only toys depending on electricity for their primary function are in scope. Belgium, Denmark, Estonia, Finland, France, Ireland, Malta, the Netherlands and Sweden are those Member States known to have considered all toys as in scope of RoHS I.

Regarding toys, the COM recast proposal remained in line with RoHS I in that its binding list of products falling in the Annex I product categories of the same proposal, stated those of WEEE Annex 1B and did not include toys with secondary electrical functions. The following were in scope of RoHS I as the electrical functions are primary:

- Electric trains or car racing sets
- Hand-held video game consoles
- Video games
- Computers for biking, diving, running, rowing, etc.
- Sports equipment with electric or electronic components
- Coin slot machines

In contrast to RoHS I and the COM recast proposal, according to Article 3.2 of RoHS II electricity is only needed for 'at least one intended function' for the equipment to be categorised as EEE. In other words, the electric function does no longer have to be primary but can also be secondary for the equipment to qualify as EEE and this is also the case for toys. Hence toys with secondary electrical functions are now included in Category 7 'Toys, leisure and sports equipment' of RoHS II, Annex I. While a number of these toys are already complying with RoHS, especially because a number of Member States already required under RoHS I, a large number of products are expected to be not yet complying.

Apart from RoHS II, toys underlie the Toy Safety Directive (2009/48/EC).

1.2.2 Quantities and hazardous substances

The overall retail market for traditional toys[4] in the EU totalled €15.5 billion in 2010.[5] There are no statistics available on the percentage of this total market which is toys with any electrical function, whether that is secondary or primary. Toy Industries of Europe estimate that toys with any electrical function account for 30% of the overall market but stress that it is difficult to judge. Nevertheless, in the absence of a more informed estimate, calculations in this assessment will be based on 30% of the overall toy market being toys with electrical or electronic functions. Regarding the percentage of toys with secondary electrical functions, there are equally no figures available. The only estimate provided comes from one large UK manufacturer who pointed out that 9% of their EE toys are affected by the RoHS scope change. This is only one estimate and although calculations in the factsheet will be based on this figure (5-10%), it should be noted that this can only provide a very rough indication of what the impacts might be. Based on the overview table of

[4] Toys excluding video games
[5] TIE, *Facts and Figures*, 2010

all EE toys in Table 1, it can be assumed that the figure is more likely to be towards the lower end of this band.

Electrical components of toys are mainly electric motors, wires, printed circuit boards, switches and in more advanced toys also different sensors. Toys with motors in many cases include some electronic parts such as parts for the remote control.[6]The average electronic content of EE toys was found to be 8%, including circuit board and wiring (1.7%) and motors and transformers (6%). Toys with only secondary electrical functions are only expected to have circuits and wiring, no motors and transformer. The 85,000 tonnes[7] of EE toys sold in the EU in 2002 represented less than 1% of total WEEE in the EU.[8]

In 2009/2010 the European RoHS Enforcement Network started a joint enforcement project on cheap toys. Participating Member States tested toys with mainly primary electrical functions but also some with secondary ones. The focus was on cheap toys under €25 as these tend to have a short life span and are very unlikely to be recycled. In total 383 toys were tested with a non-compliance rate of 25%. The main reason for non-compliance is lead in solders. When testing even cheaper toys under €2, as the Netherlands did as part of this project, the non-compliance rate increased to 75%.[9] Regarding toys with secondary electrical functions in particular, the experience showed that these are very often non-compliant because of high levels of lead in solders. There are, however, no statistics available on the exact non-compliance rates, neither on the quantities of lead.

Lead in toys is also regulated by the Toy Safety Directive (2009/48/EC), which bans the intentional use of lead in parts that are accessible to children. Nevertheless, lead can still be found in lead solder as circuit boards are internal and no accessible to children. According to the stakeholder consultation, a number of significant companies have now moved to lead-free solders but as the results of the European RoHS Enforcement Network project, discussed above, show, a significant amount of toys remain non-compliant because of the lead content in solder.[10] Based on a total of 85,000 tonnes of toys with electrical functions sold in the EU in 2002, a total of 4250 to 8500 tonnes of toys with secondary electrical functions are assumed to be sold each year in the EU. Most of the lead content in solders in these toys will be found on small printed circuit boards (PCBs). A study has shown that the lead content of PCBs varies from 0.2% to 2%, depending on the type of PCB.[11] For toys, this can be assumed to be at the lower end and 0.5% lead as a percentage of PCBs is assumed for this assessment. Where electronics is not the main function in the toy, a small PCB will typically weigh about 10 grams. Based on an assumed typical weight of 300 grams for a toy with a secondary electrical function (e.g. talking teddy bear), this would lead to a range of 0.71 tonnes to 1.42 tonnes of lead for all toys with secondary electric functions sold in the EU per year.

[6] Danish Ministry of the Environment, *Impact assessment of introduction of a general scope of the RoHS Directive – selected aspects*, 2010
[7]Excluding video games and hand-held consoles, representing less than 1% of the overall EE toy market each. No newer estimate is available from TIE.
[8]TIE contribution to first stakeholder consultation, February 2012
[9] The European RoHS Enforcement Network, *Joint Toy Project*, 2011
[10] Please note that according to industry important changes in the use of lead solder have taken place over the last years, partly due to the new Toy Safety Directive. If tested today, the number of non-compliant toys might therefore be lower.
[11]Ogunniyi, I.O. et al., Chemical composition and liberation characterization of printed circuit board comminution fines for beneficiation investigations, July 2009, Waste Management 29(7), pp. 2140-6, accessed at: http://137.215.9.22/bitstream/handle/2263/13172/Ogunniyi_Chemical(2009).pdf?sequence=1

Lead-free solders are either tin/copper (SnCu) or tin/silver/copper (SnAgCu) alloys. Both have higher melting points and SnAgCu has a significantly higher cost due to its silver content. The most likely replacement solder in toys will be cheaper Sn0.7%Cu. This solder alloy is more difficult to use and less reliable than SnAgCu but cost is most important with this type of toys.

Cadmium in plastics as well as its use in electroplating is banned under REACH and its use in batteries is regulated by the Battery Directive. RoHS II is therefore not believed to have a further impact on the use of this substance in toys with secondary electrical functions. Mercury is very unlikely to be found in toys and while Chromium VI could possibly be found in screws for corrosion protection this has not proven to be a compliance issue in the past and will be disregarded in this assessment. Like for lead, the Toy Safety Directive also bans the intentional use of cadmium, mercury and chromium VI. As PBDE is frequently used in fabrics, it could be believed that this flame retardant would be present in toys with fabrics. However, according to the TIE (Toy Industries of Europe) none of the flame retardants PBB or PBDE are used in toys. Furthermore, the joint enforcement project by the European RoHS Enforcement Network has not shown that these flame retardants are a compliance issue for toys and they will therefore be disregarded in this assessment.

Table 2: RoHS substances in toys with secondary electrical functions

Substance	Presence
Lead	Yes, in solder Estimation: 0.05 g per toy
Mercury	No
Cadmium	Potentially in plastics and electroplating – banned by REACH
Hexavalent Chromium	No
Polybrominated biphenyls (PBB)	No
Polybrominateddiphenyl ethers (PBDE)	Potentially on fabrics but no compliance issue in the past

Source: Stakeholders enquiry, own estimations

1.2.3 Policy objectives and options

The objective of both, the RoHS recast proposal (COM (2008) 809 final) as well as RoHS II (2011/65/EU) is to contribute 'to the protection of human health and the environment, including the environmentally sound recovery and disposal of waste EEE'[12].

The purpose of this work is to look at the impacts of toys with secondary electrical functions falling under the scope of RoHS II compared to an unclear situation under RoHS I and the COM recast proposal. Policy options will then be evaluated according to their effectiveness, efficiency and coherence in reaching the above-mentioned overall objective of the RoHS Directive. The policy options analysed are the following:

OPTION 1 (baseline scenario): The COM recast proposal. Toys with secondary electrical functions not in scope of the proposed recast Directive but it can be assumed that Member States would have been in disagreement on this as they were under RoHS I.

[12] 2011/65/EU, Article 1

OPTION 2: RoHS II. Toys with secondary electrical functions included in the scope of the recast Directive.

1.3 Impacts of policy options

1.3.1 Impact indicators

The following impact indicators have been chosen as relevant for this product group (see Table 3).

Table 3: Impact indicators for the product group toys

Impact indicators		
Environmental	Economic	Social
Energy use	Functioning of the internal market and competition	Employment
Waste production / generation / recycling	Competitiveness	Health
International environmental impacts	Costs and administrative burdens	Social impacts in third countries
	Innovation and research	
	Consumers and households	

The following legend will be used in summarising the impacts:

Legend	
+++	Very beneficial effect
++	Substantial beneficial effect
+	Slight beneficial effect
=	No effect
-	Negative effect
--	Substantial negative effect
---	Very negative effect
?	Unknown effect

1.3.2 Environmental impacts

The most important stakes regarding the environmental impacts in the context of RoHS are related to the quantities of hazardous substances used in the equipment. The mere quantity of a substance is however not sufficient to estimate what will be the actual impacts of the substance on the environment and health. These indeed depend upon numerous factors such as the effective treatment of products at the end-of-life, their design for the use phase or their potential emissions during the production phase. The impact of the substances released to the environment is also determined by case-specific and complex dose-response relationships.

It is therefore not straightforward to predict environmental impacts due to hazardous substances found in products. Where possible, the following subsections will make the link between the quantities of hazardous substances and their potential environmental impacts.

1.3.2.1 *Energy use*

Given the definition of this product group, all products are expected to consume energy during their operation. It can be assumed, however, that the presence of the hazardous substances considered in RoHS II does not have any direct influence on the energy use and efficiency of the devices.

The European Commission impact assessment accompanying the RoHS recast proposal[13] states that the substitution of lead solder by lead-free solder might lead to an increase in energy consumption during the production phase because of a higher melting point. The additional energy consumption will vary widely depending on the solder type, the equipment specifications and process operating parameters employed by the facility. Nevertheless, it is generally accepted that lead-free soldering requires approximately 15% more energy than tin/lead (SnPb) soldering when comparing equivalent soldering technology for the two types of alloy and the following calculations will be based on this assumption. Based on a typical solder reflow oven to make the small PCBs on which the lead is found in toys with secondary electrical functions, the total additional energy required for tin/copper (SnCu) alloys ranges from 99.17 MWh per year to 198.33 MWh per year.[14] Compared to a total EU final energy consumption of 13.6 million PWh[15] this impact of additional energy required is regarded as negligible on this environmental impact indicator.

Based on these calculations, additional CO_2 emissions due to substituting lead-free solder for lead solder amount to between 36.7 and 77.4 tonnes CO_2[16]. In relation to the overall CO_2 emissions of 4088.8 million tonnes of the EU-27 in 2008[17], this increase would be negligible.

1.3.2.2 *Waste production / generation / recycling*

There is no information available on the average lifespan of toys with secondary electrical functions but this can be assumed to be short, especially regarding cheaper imported toys that pose

[13]European Commission (2008), SEC(2008) 2930. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=SEC:2008:2930:FIN:EN:PDF

[14] A typical solder reflow oven operates 16 hours per day, 5 days a week, 49 weeks per year and on average consumes 13.9 kWh for SnPb and 16kWh for lead-free. It is assumed that one oven can produce 300 PCBs per hour or 1 million per year (25 PCBSs made in a panel every 5 minutes) as these PCBs are small. The total number of units to be made is between 14.17 and 28.33 million units (5-10% of all EE toys).

[15] 1168.63 Mtoe, European Commission, *EU transport in figures, statistical pocketbook 2011*, accessed at http://ec.europa.eu/transport/publications/statistics/doc/2011/pocketbook2011.pdf

[16] Based on 0.39 kg CO_2/kWh from Euroelectric

[17] 4186.7 million tonnes. European Commission, *EU transport in figures, statistical pocketbook 2011*, accessed at http://ec.europa.eu/transport/publications/statistics/doc/2011/pocketbook2011.pdf

substantial compliance issues. For this assessment, an average product lifespan of two years will be assumed although it should be stressed that this can vary significantly from product to product. Furthermore, toys with secondary electrical functions are very likely to be thrown into the regular household waste instead of being recycled. End-of-life management options (see Table 4) are therefore based on average EU municipal waste treatment options[18].

Depending on the quality of the end-of-life operations, a certain share of the substances (called the leaching potential) is always lost to the environment. According to BIO (2008)[19], process control of landfills and incinerators, alongside mineralization mechanisms in landfills, are some of the options to reduce this share. But there is limited quantitative data about the fate of hazardous substances going through land filling or incineration processes, in particular their leaching potential.

Policy Option 2 (including toys with secondary electric functions in the scope of RoHS II) would progressively decrease the quantity of lead found in the waste streams, compared to the baseline scenario. The reduction of these substances may have a beneficial effect on their end-of-life treatment. This effect is dependent on the development of the waste management sector as a whole. The argument that lead-free solder decreases the durability of products is of less relevance for this product group than for others, as this type of toys is already characterised by very short lifespans.

Table 4 shows the estimations used to calculate the environmental impacts of RoHS hazardous substances released into the environment at the end-of-life. The assessment is likely to contain high uncertainties, because of the assumptions made to model the end-of-life options.

Table 4: Heavy metal emissions, by end-of-life management options

End-of-life process	Share of total end-of-life products (in %)[20]	Emissions to air during end-of-life process	Emissions to water during end-of-life process	Source of the emissions estimates
Recycling	29%	0.001%	0.059%	COWI (2002)[21],
Incineration	26%	0.5%	2.49%	ERM (2006)[22]
Landfill	44%	-	5%	ERM (2006)

By considering the annual sales and lead quantities presented in section 1.2.2, it is estimated that between 0.71 and 1.42 tonnes of lead from solder would be sent annually into the end-of-life management circuit from 2021[23] if the product group was not included within the scope of RoHS II. For Option 2, it is assumed that all lead in solder would be removed from the products from 2019, so that none of these substances would go to the waste streams from 2021.

[18] With the exception of compost
[19] BIO (2008), Study to support the impact assessment of the RoHS review – Final Report, for DG ENV.
[20] Based on EU municipal waste treatment methods, http://europa.eu/rapid/pressReleasesAction.do?reference=STAT/12/48&format=HTML&aged=0&language=EN&guiLanguage=en. Please note that composted percentage is divided among other three treatment methods according to their percentage weight as this type of waste (toys with secondary electrical function) would not be composted.
[21] COWI (2002), Heavy Metals in Waste – Final Report, for European Commission DG ENV. Applicable to lead, assumed to be the same for other heavy metals
[22] ERM (2006), Battery Waste Management Life Cycle Assessment – Final Report
[23] 2 years (lifetime of the product) after the effective implementation of RoHS II

Based on these assumptions, the ecotoxicity freshwater midpoint indicator was calculated[24] in order to illustrate the avoided impacts for the end-of-life, of the inclusion of toys with secondary electrical functions within the scope of RoHS II, in 2021 and 2025.This indicator was chosen because the release of RoHS hazardous substances in the environment has an influence on its value (this is not the case for Global Warming Potential for instance).

Table 5: Avoided freshwater ecotoxicity impacts by Option 2, compared to Option 1

Year[25]	Ecotoxicity freshwater midpoint (CTUe[26])
2021	7.76E+0.3 – 1.15E+0.4

This result represents 0.00% for the minimum and maximum amount of these toys of the overall freshwater ecotoxicity annual impact in the EU-27 (USEtox™ normalisation values). Details of the calculations are given in the Annex.

In theory, end-of-life impacts also depend on the possible substitutes that would replace the six hazardous substances. A similar quantitative analysis could not be done for the impact of the substitution of lead solder by lead-free solder, as the most suitable substitutes are not known yet. Still, some substitutes are likely to leach hazardous substances into the environment too, even if lead is the most toxic alloying element: silver or antimony represent a potential source of toxicity in leachates when used in alloys, while bismuth, indium and copper are regarded as less dangerous[27]. Obviously, the levels of emissions depend on the specific environmental conditions the waste will be exposed to during the end-of-life management. Another source[28] builds a comparative analysis of lead-free solder, by taking into account toxicity, availability and environmental impact of extraction of substitutes to lead in solder alloys. Based on this, only tin and copper appear to have a lower overall impact than lead. These outcomes have to be considered with caution given the subjective assessment grid. Finally, a comparative life cycle assessment[29] also illustrates that depending on the environmental impact considered, either lead solder or one substitute (bismuth-tin-silver or copper-tin) can be best performing.

Based on the above, the inclusion of toys with secondary electrical functions in the scope of RoHS II is not expected to have an impact on this indicator.

1.3.2.3 International environmental impacts

The largest export markets for toys from the EU are the US and Switzerland, both countries with stringent environmental laws themselves, followed by a range of other developed countries. The end-of-life impact of lead in solder in toys with secondary electrical functions is therefore to be

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[24]According to USEtox™ methodology.
[25] RoHS II coming into force for this product group (2019), plus one product lifetime (2 years)
[26]Comparative Toxicity Unit ecotoxicity, equivalent to PAF.m3.day
[27]Edwin B. Smith III, Environmental Impacts and Toxicity of Lead Free Solders: http://leadfree.ipc.org/files/RoHS_16.pdf
[28]Anna Kua, Prof. OladeleOgunseitanb, Prof. Jean-Daniel Saphoresc. Lead-Free Solders: Issues of Toxicity, Availability and Impacts of Extraction: http://trs-new.jpl.nasa.gov/dspace/bitstream/2014/6388/1/03-0222.pdf
[29] EPA (2005) Solders in electronics: a life-cycle assessment. Available here: http://www.epa.gov/dfe/pubs/solder/lca/lfs-lca-final.pdf

considered similar to that within the EU. Specific calculations could not be conducted due to a lack of data on the exact quantities exported as well as the end-of-life treatment options in these countries. Overall, the impact can nevertheless be assumed to be slightly beneficial.

1.3.2.4 *Overview of environmental impacts until 2021*

Based on the above, no significant environmental impacts can be expected from toys with secondary electrical functions falling in the scope of RoHS II.

Table 6: Estimated environmental impacts

Estimated environmental impacts until 2021[30]		
	2012	2021
Energy use	=	=
Waste production / generation / recycling	=	=
International environmental impacts	=	+

1.3.3 Economic impacts

Within the EU, the main producers of toys are located in France, Germany, Italy and Spain. Even within the countries, toy production is concentrated within a few key regions, such as Franche-Comte in France or Bavaria in Germany. Approximately 80% of the overall sector is composed of SMEs. The toy business is highly seasonal with approximately 60% of purchases made during the pre-Christmas period.[31]

1.3.3.1 *Functioning of the internal market and competition*

In the past Member State authorities have not been in agreement regarding the inclusion of toys with secondary electric functions in the scope of RoHS I. Compliance checks have been carried out in a number of Member States, which means that manufacturers were in practice experiencing different compliance regimes in different Member States. In contrast, the recast Directive is very clear in its inclusion of this product group in its scope due to the definition of 'dependent' in Art. 3(2).This inclusion should have a positive impact on the internal market as all manufacturers have to comply with the same rules.

1.3.3.2 *Competitiveness*

As presented in section 1.2, key export markets for toys with secondary electrical functions produced in the EU are the USA and Switzerland with a combined share of 33% followed by a range of other developed countries. However, no data has been available on the actual overall export value or the export value to the individual countries, which makes an analysis of potential impacts

[30] RoHS II coming into force for this product group (2019), plus one product lifetime (2 years)
[31] TIE, *Facts and Figures*, 2010

on competitiveness difficult. However, as the key export markets are countries with stringent environmental legislation in place, the impact of these toys falling in the scope of RoHS II is likely to be limited. Imports would have to comply with RoHS II just as European products do, which again means no impact on competitiveness of European firms.

1.3.3.3 Costs and administrative burdens

No data on costs and administrative burdens has been received from the toy sector as part of the stakeholder consultation. Stakeholders have noted, though, that the modification from lead solder to lead-free solder was 'not easy' described the transition as an 'investment'. Toy manufacturers tend to be specialized manufacturers, which means that manufacturers of toys with secondary electrical functions will not necessarily be familiar with RoHS requirements, as it is not given that they will have already produced toys with primary electric functions that fell within the scope of RoHS I.

According to the 2008 Impact Assessment accompanying the Commission's recast proposal[32], there is little experience of actual compliance costs for industry. For products currently included in RoHS estimates are it would vary from 1-4% of turnover. Other surveys give an average overall cost related to RoHS of 1.9% of turnover (past cost and one-off future costs). Based on the 15.5 billion sales in Europe in 2010 for the total traditional toy market and the assumption that 30% of that is toys with electrical functions and only 5-10% of the latter toys with secondary electrical functions, this would give a total yearly turnover for that segment of €230-470 million. Applying the 1-4%, compliance costs would represent between €2.3 million and €18.6 million for all manufacturers of toys with secondary electric functions in the EU. It should, however, be noted that PCBs in toys with secondary electrical functions can be expected to be relatively simple designs, which means that actual transition costs should beat the low end of this range or even lower. Nevertheless, whereas such costs might be reasonably supported by large manufacturers, they could be more problematic for the many SMEs of the sector.

Technical costs will also increase due to the substitution of lead-free solder for lead solder. Based on an assumed typical weight of 300 grams for a toy with a secondary electrical function (e.g. talking teddy bear), the amount of lead would range from 0.71 tonnes to 1.42 tonnes for all toys with secondary electric functions sold in the EU per year.[33] As discussed above, in toys the tin/lead solder is most likely to be replaced by tin/copper solder. Given the cost difference between lead and tin, the total additional solder metal cost would lie between €6280 and €12560.[34] Given that this cost is calculated for the entire industry and would therefore be shared by the many manufacturers, this is not regarded as significant. EU importers of toys with secondary electrical functions will also incur compliance costs ensuring that Chinese made toys are compliant, including the audit of suppliers, selective analyses, etc. Based on previous surveys of RoHS compliance, this is likely to be approximately 0.1% of turnover[35] and will therefore have a limited impact.

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[32] European Commission (2008), SEC(2008) 2930. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=SEC:2008:2930:FIN:EN:PDF

[33] Based on assumption that toys with secondary electrical functions make 5-10% of the total European EE market

[34] Assumption that SnPb will contain 37% of lead. One tonne of lead replaced by 645 kg of tin. Value of lead not used subtracted from extra costs. Metal prices: Lead €1590/tonne; tin €16210/tonne. London Metal Exchange prices, April 2012

[35] Goodman, P., email exchange April 2012

The Danish impact assessment conducted for the introduction of a general scope of the RoHS Directive comes to the conclusion that while the costs of substitution of RoHS substances are considered to be small as RoHS compliant electric and electronic components are readily available, the administrative costs of including these products is deemed relatively high.[36] On the other hand it should be noted that the toy sector is described as one of the most dynamic business sectors in Europe with approximately 60% of toys on the market each year being newly developed products. This would mean that compliance costs should be lower than for other products.

Overall, with limited data availability it is difficult to make precise estimations of additional compliance costs for the toy industry due to RoHS II. Still, based on the discussion above it can be assumed that costs, albeit limited, will be incurred especially on the part of SMEs, which make approximately 80% of all European toy manufacturers.

1.3.3.4 Innovation and research

The toy industry dedicates an important part of its investment to market analysis, research and development (R&D) and the protection of intellectual property. As discussed above, the toy sector is described as one of the most dynamic business sectors in Europe with approximately 60% of toys on the market each year being newly developed products. Research into the use of lead-free solder in toys with secondary electrical functions would therefore just be one additional research element in this sector, but the inclusion of these toys in the scope of RoHS II is unlikely to have a significant impact. This impact would, however, be higher for the large percentage of SMEs in the sector than for larger manufacturers. Furthermore, manufacturers of toys with primary electrical functions already falling in the scope of RoHS I have the experience of the use of lead-free solder and although not one-to-one transferable to toys with secondary electrical functions, certain similarities can be assumed and additional research that is required can be expected to be limited.

1.3.3.5 Consumers and households

An increase in both technical as well as administrative costs for manufacturers of toys with secondary electrical functions might lead to an increase in prices for consumers. However, a number of manufacturers already state that their toys are RoHS-substance free while they are not sold at a premium. European toy manufacturers compete with imports, particularly from China. Unless their toys are highly specialised and not subject to this competition, it is unlikely that manufacturers will hand on potential cost increases to consumers in a significant manner. Overall, the impact on consumers and households is therefore expected to be negligible.

1.3.3.6 Overview of economic impacts until 2021

Based on the discussion above, it can be said that the only economic impacts from including toys with secondary electrical functions in RoHS II are to be expected in terms of an improvement in the functioning of the internal market and an increase in technical and administrative costs for toy manufacturers.

[36] Danish Ministry of the Environment, *Impact assessment of introduction of a general scope of the RoHS Directive – selected aspects*, 2010

Table 7: Estimated economic impacts

Estimated economic impacts until 2021[37]		
	2012	2021
Functioning of the internal market and competition	=	+
Competitiveness	=	=
Costs and administrative burdens	=/-	-
Innovation and research	=	=
Consumers and households	=	=

1.3.4 Social impacts

1.3.4.1 *Employment*

As part of the stakeholder consultation, it has not been possible to obtain estimates on the number of jobs linked to the toy industry, much less of those linked to toys with secondary electrical functions. Most EU toy manufacturers are likely to sub-contract PCB manufacturing and as most EU PCB subcontractors already make lead-free PCBs, there should be no impact on employment. This should also be the case for SMEs that comprise approximately 80% of the sector as it would be very unusual for an SME to manufacture their own PCBs.

1.3.4.2 *Health*

The overall impacts of hazardous substances on health are difficult to quantify. It needs to be differentiated between possible impacts during the production phase, the use phase and the end-of-life.

First, exposure to these substances during the production phase represents a risk for the facility workers, who are a population group at greatest risk of exposure to lead (especially through air). This risk is very much dependent upon the type of exposure (time, frequency, pathway, etc.). It can be expected that the EU manufacturers already respect the related legislation and implement the necessary precaution to ensure their workers' well-being. However, a ban of lead in toys with secondary electric functions under RoHS II could further contribute to a reduction in health impacts during the production phase, in particular in case of accidental situations. This impact also depends on possible developments in the other industrial sectors, because of the complex structure of supply chains. Finally, the importance of these health effects also depends on the potential effects of the substitute, if any. Therefore, a quantification of these impacts could not be made.

Regarding the use phase of toys, lead is regulated by Toy Safety Directive (2009/48/EC), which bans the intentional use of lead in parts that are accessible to children. RoHS II is therefore not expected to have a further impact on health related to the use phase.

[37] RoHS II coming into force for this product group (2019), plus one product lifetime (2 years)

Finally, the management during the end-of-life can result in important impacts on the environment and health. These impacts are dependent upon the management options followed by products, which have already been presented (see section 1.3.2.21.3.2.2). Based on the same assumptions regarding the emissions to air and water of the substances during recycling, incineration and landfill (see Table 4), health impacts can be quantified via the human toxicity indicators[38]: Assuming the RoHS ban of lead in toys with secondary electrical functions from 2019 (Option 2), a human toxicity impact of between 3.18E-05 and 6.36E-05 CTUh (cancer effects) and 1.11E-02 and 2.23E-02 CTUh (non-cancer effects) would be avoided in 2021. This represents between 0.0000002 and 0.0000004% of the cancer effect human toxicity impact in the EU-27 and 0.000003% and 0.0000055% for non-cancer effects.

Table 8: Human toxicity indicators

Year[39]	Human toxicity midpoint, cancer effects (CTUh[40])	Human toxicity midpoint, non-cancer effects (CTUh)
2021	3.18E-05 - 6.36E-05	1.11E-02 - 2.23E-02

The monetised cost has been calculated by Defra (UK)[41] which looked at the costs in terms of health impacts of options for management of waste containing hazardous substances including lead. The study estimated health impacts from mathematical models of landfill and incineration and estimates of pollution from these disposal options. Applying these results to the heavy metal emissions per end-of-life treatment options (see Table 4), gives a monetised health benefit from not using lead of between k€ 31 and k€ 741 for toys with secondary electrical functions being 5% of all EE toys and between k€ 62 and € 1.48 million for toys with secondary electrical functions being 10% of all EE toys.[42].

1.3.4.3 Social impacts in third countries

As discussed above, no specific data is available on the actual amounts of imports of toys with secondary electrical functions into the EU. The social impact of these toys falling in scope of RoHS II in third countries producing these toys is therefore difficult to determine. Nevertheless, a certain health impact can be expected of a ban of lead in solder, in particular in China, which is the number one exporter of toys to the EU.

As toys with secondary electrical functions are expected to be thrown into the regular bin, no impacts in third countries are assumed due to their end-of-life treatment. There may be a small benefit to workers in China who would be exposed to less lead in the production phase as health and safety at work legislation is anecdotally, believed to be less stringent in China than in the EU.

[38] USEtox™ method.
[39] RoHS II coming into force for this product group (2019), plus one product lifetime (2 years)
[40] Comparative Toxicity Unit human, equivalent to cases
[41] Enviros Consulting Ltd. For Defra, *Valuation of the external costs and benefits to health and environment of waste management options*, December 2004, table 3.2 and page 82)
[42] Based on a monetised impact of lead between €1.46 million/tonne and €35 million/tonne, and assuming a 2.99% leakage rate of lead at the end-of-life.

1.3.4.4 Overview of social impacts until 2021

Social impacts due to the inclusion of toys with secondary electrical functions in the scope of RoHS II are to be expected, albeit to a limited degree:

Table 9: Estimated social impacts

Estimated social impacts until 2021[43]		
	2012	**2021**
Employment	=	=
Health	=	+
Social impacts in third countries	=	+

1.3.5 Comparison of options

Overall, the inclusion of toys with secondary electrical functions in the scope of RoHS II is expected to have environmental, economic and social impacts, albeit all of them limited. Most importantly, the ban of the use of lead in solder is expected to lead to health improvements. An increase in costs and administrative burdens for toy manufacturers is expected but the internal market would benefit from the inclusion. Table 10 provides a comparison of the two policy options.

[43] RoHS II coming into force for this product group (2019), plus one product lifetime (2 years)

Table 10: Comparison of options

Impact indicators	Option 1 : No agreement whether toys with secondary electrical functions in scope of COM recast proposal	Option 2: Toys with secondary electrical functions in scope of RoHS II
Environmental impact indicators		
Energy use	=	=
Waste production / generation / recycling	=	=
International environmental impacts	=	+
Economic impact indicators		
Functioning of the internal market and competition	=	+
Competitiveness	=	=
Costs and administrative burdens	=/-	-
Innovation and research	=	=
Consumers and households	=	=
Social impact indicators		
Employment	=	=
Health	=	+
Social impacts in third countries	=	+

In relation to the overall policy objective of RoHS II, namely to contribute 'to the protection of human health and the environment, including the environmentally sound recovery and disposal of waste EEE'[44], the discussion above shows that including toys with secondary electrical functions contributes to this overall objective. Table 11, below, provides an overview of the policy options in relation to the overall objectives of RoHS II.

[44] 2011/65/EU, Article 1

Table 11: Policy objectives and options

Policy options in relation to overall policy objectives			
	Effectiveness	**Efficiency**	**Coherence**
Option 1: No agreement whether toys with secondary electrical functions in scope of COM recast proposal	Slightly negative: Does hinder the objectives to a limited extent	Efficiency cannot be evaluated as option does not contribute to the objectives	None or very limited unintended impacts
Option 2: Toys with secondary electrical functions in scope of RoHS II	Slightly positive: Contributes to the effectiveness of the Directive	Limited: None of the positive impacts are significant	Unintended impacts are limited

Annex

Table 12: Quantities of RoHS substances released to the environment in 2021 without RoHS II implementation, due to end-of-life management options

Substance	Released to	Quantity (in kg)
Cadmium	Air	0
Chromium VI		0
Lead		0.92
Mercury		0
Cadmium	Water	0
Chromium VI		0
Lead		20.29
Mercury		0

Table 13: Characterisation factor of the RoHS substances (USEtox™ method)

Substance	Type of emissions	Human toxicity midpoint, cancer effects (in CTUh/kg)	Human toxicity midpoint, non-cancer effects (in CTUh/kg)	Ecotoxicity freshwater midpoint (in CTUe/kg)
Lead	Emissions to air, unspecified	2.69E-05	9.44E-03	1.75E+02
	Emissions to water, unspecified	3.42E-07	1.20E-04	3.75E+02
Mercury	Emissions to air, unspecified	7.06E-03	8.35E-01	1.22E+04
	Emissions to water, unspecified	1.20E-04	1.42E-02	2.21E+04
Chromium VI	Emissions to air, unspecified	4.45E-03	4.16E-04	4.20E+04
	Emissions to water, unspecified	1.06E-02	2.40E-05	1.05E+05
Cadmium	Emissions to air, unspecified	2.17E-04	4.55E-02	3.94E+03
	Emissions to water, unspecified	1.59E-06	4.27E-04	9.71E+03

Table 14: Impact assessment results for 5% of all EE toys (USEtox™ method)

Impact indicator (unit)	Avoided impacts in 2021 in EU-27, with RoHS II implementation (in impact indicator unit)	Avoided impacts in 2021 in EU-27, with RoHS II implementation (in % of annual EU-27 impacts)	USEtox™ normalisation factors (in impact indicator unit per person per year)
Human toxicity midpoint, cancer effects (in CTUh)	3.18E-05	0.0000002%	3.25E-05
Human toxicity midpoint, non-cancer effects (in CTUh)	1.11E-02	0.000003%	8.14E-04
Ecotoxicity freshwater midpoint (in CTUe)	7.76E+03	0.00%	3.18E+06

Table 15: Impact assessment results for 10% of all EE toys (USEtox™ method)

Impact indicator (unit)	Avoided impacts in 2021 in EU-27, with RoHS II implementation (in impact indicator unit)	Avoided impacts in 2021 in EU-27, with RoHS II implementation (in % of annual EU-27 impacts)	USEtox™ normalisation factors (in impact indicator unit per person per year)
Human toxicity midpoint, cancer effects (in CTUh)	6.36E-05	0.0000004%	3.25E-05
Human toxicity midpoint, non-cancer effects (in CTUh)	2.23E-02	0.0000055%	8.14E-04
Ecotoxicity freshwater midpoint (in CTUe)	1.55E+04	0.000000001%	3.18E+06

An EU-27 population estimate of 502m inhabitants in 2011 is used for the normalisation (source: Eurostat, in March 2012).

RoHS II, Articles 2(2), 4(3) and 4(4)

1.1 Key issues

Important changes in the RoHS recast Directive are not limited to product groups. Other changes with potentially significant impacts are related to articles 2(2), 4(3) and 4(4). It should be noted that while Article 2(2) was not mentioned in the RoHS recast proposal and is therefore an effective scope change between that proposal and the final recast Directive, articles 4(3) and 4(4) were already included in the recast proposal. They are therefore not strictly speaking within the scope of this work although it is appropriate to consider how articles 4(3) and 4(4) affect product groups that are in scope of this study. The potential impacts due to these articles are discussed below due to their importance to industry and the fact that this discussion has not taken place in the previous impact assessment.[1]

1.2 Articles 2(2)/4(3)

1.2.1 Background

RoHS Recast Article 2(2) states that without prejudice to Articles 4(3) and 4(4), all newly included electrical and electronic equipment (EEE) that does not comply with RoHS may be made available until 21 July 2019. Article 4(3) states that categories 8 and 9 EEE must comply if they are placed on the EU market after the specified dates and Article 4(4) allows non-compliant spare parts to be used to repair, reuse and update products subject to the specified dates.

The implication of Article 2(2) is that all newly included EEE made available after 22 July 2019 must not contain RoHS restricted substances and this would be irrespective of when it was first placed on the EU market. Article 4(1) states that EEE includes cables and spare parts.

[1] Impact Assessment accompanying the RoHS COM recast proposal (SEC 2008 2930), available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=SEC:2008:2930:FIN:EN:PDF

Box 1: RoHS II, Art. 2(2) and 4(3)

RoHS II, Article 2(2)

"Without prejudice to Article 4(3) and 4(4)[2], Member States shall provide that EEE that was outside the scope of Directive 2002/95/EC, but which would not comply with this Directive, may nevertheless continue to be made available on the market until 22 July 2019."

RoHS II, Article 4(3)

"Paragraph 1 [see below] shall apply to medical devices and monitoring and control instruments which are placed on the market from 22 July 2014, to in vitro diagnostic medical devices which are placed on the market from 22 July 2016 and to industrial monitoring and control instruments which are placed on the market from 22 July 2017."

RoHS II, Article 4(1)

"Member States shall ensure that EEE placed on the market, including cables and spare parts for its repair, its reuse, updating of its functionalities or upgrading of its capacity, does not contain substances listed in Annex II [the six RoHS substances]."

RoHS II, Article 3(11) ***Definitions***

"'making available on the market' means any supply of an EEE for distribution, consumption or use on the Union market in the course of a commercial activity, whether in return for payment or free of charge;"

RoHS II, Article 3(12) ***Definitions***

"'placing on the market' means making available an EEE on the Union market for the first time;"

The Commission has interpreted Article 2(2) such that the implications for each newly included category will be as follows:

- Category 8: Medical devices placed on the market before 22 July 2014 (and IVD before 22 July 2016) need not be RoHS compliant but after 22 July 2019 these non-compliant products[3] cannot be sold, re-sold, leased or given away in the EU.
- Category 9: Monitoring and control instruments placed on the market before 22 July 2014 (industrial monitoring and control instruments before 22 July 2017) need not be RoHS compliant but after 22 July 2019 this equipment cannot be sold, re-sold, leased or given away in the EU if it is not RoHS compliant.
- Category 11: any Category 11 product made available (i.e. sold, leased, etc.) after 21 July 2019 must not contain RoHS substances. This means the entire supply chain of Category 11 EEE must be clear of non-compliant equipment before this deadline.

[2] See Box 2
[3] Non-compliant means that it contains one or more RoHS-restricted substances

Any remaining non-compliant equipment will become waste if it cannot be exported for sale outside of the EU.[4]

  - Category 11 products can include those affected by changes in the definition of medical devices between RoHS I and the COM recast proposal, i.e. devices that were considered as medical under RoHS I but under the COM recast proposal and RoHS II, these are defined as equipment that is in scope of the Medical Devices Directive[5]. Examples of this type of equipment may include analysers used for screening or forensic purposes[6] and interface equipment between a patient's computer and their self-testing IVD medical device[7].

- Included due to change of definition of 'dependent': The impact depends on Member States interpretation of scope of 2002/95/EC
  - Where a Member State has accepted that a product was excluded from the scope of 2002/95/EC but it is in scope of 2011/65/EU, these products made available after 21 July 2019 will need to comply.
  - Where a Member State has assumed that a product is in scope of 2002/95/EC, Article 2.2 has no impact because these products are not newly included in scope. Any non-compliant product put on the market before 1 July 2006 can be sold to a second user in the EU after 21 July 2019. As these products will be at least 13 years old, re-sale may occur but should not be common.
- Cables: those that are not already in scope will be included from 22 July 2019 so any made available after this date must comply with the substance restrictions.
- Spare parts and cables need not comply with the substance restrictions when used to repair, reuse and update products that were placed on the EU market prior to the dates specified in Article 4(4). Article 2(2) does not appear to affect this exclusion.

As part of the second stakeholder consultation of this work, stakeholders were asked for the types and numbers of products that would need to be taken off the market as a result of Article 2(2). Out of 20 respondents, three answered this question while the remainder either did not answer at all or stated that they would not be affected / were not planning to take any products off the market. Two of the three stakeholders who did say they would be affected stated that an estimate of the number of products was not possible at this stage but that the impact would potentially be significant. One stakeholder noted that 10% of stock would be a reasonable estimate of products that would need to be disposed of.

[4] Please note that for sale outside the EU the WEEE recast Directive requires certification that each item is functional, which would increase administrative cost.

[5] 93/42/EEC

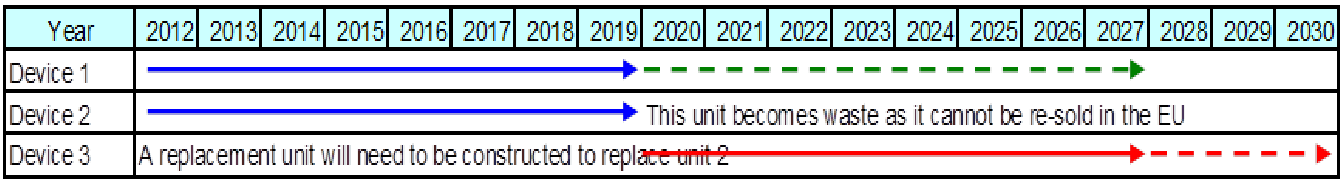
[6] May also be regarded as Category 9

[7] If considered as an accessory to the PC it would be regarded as Category 3 but if considered as an accessory to the self-test IVD, then it could be Category 11. Article 2.2 would affect these if they are not RoHS compliant and are resold after July 2019.

1.2.2 Potential costs

The impact of Article 2(2) can be illustrated by medical devices such as MRI or CT which are often refurbished and then sold to second users when they are approximately seven years old. Figure 1 below shows the impact of Article 2(2).

Figure 1: Impact of Article 2(2)



The impact would be the following, depending on whether Article 2(2) would be applied or not:

- Without Article 2(2): 'Device 1' was constructed in 2012 before RoHS compliance was required and so does not comply but as long as it was originally sold to an EU user, it could be sold any time after 7 years in 2019 to a second EU user who would use it until at least 2027.
- With Article 2(2): The first user of 'Device 2' wants to replace it after 22 July 2019. However due to Article 2(2) it cannot be refurbished for use by a second user located in the EU. As a result, unless a non-EU user can be found, this unit will become waste and will have to be replaced by new 'Device 3'. By halving the useful life of 'Device 2', there would be a resulting increase in waste generated and more raw materials and energy are consumed to construct 'Device 3'. 'Device 3' will be RoHS compliant because it will be placed on the EU market after 21 July 2014 and so this equipment can be refurbished for resale to a second EU user.

1.2.2.1 *Environmental*

The amount of waste equipment generated if used equipment cannot be re-sold to EU users would increase. The 2006 study of the possibility of including categories 8 and 9 in the scope of RoHS[8] provides tonnage data of category 8 and 9 products placed on the EU market. Regarding medical devices (Category 8), some of the types that are refurbished for reuse are:

- Radiotherapy 1460 tonnes per year
- X-ray 2360 tonnes per year
- CT 5610 tonnes per year
- Ultrasound 1290 tonnes per year
- Nuclear medicine 540 tonnes per year

This totals 11,260 tonnes per year and there will also be other types of products so the estimated total could be approximately 15,000 tonnes per year. COCIR estimate that on average, first users

[8] http://ec.europa.eu/environment/waste/weee/pdf/era_study_final_report.pdf

want to replace new equipment after seven years. Therefore 14.3% or one seventh would be discarded by the first user each year and this will become waste if resale to second users were not permitted. Therefore the total quantity of waste equals 2140 tonnes per year of additional medical equipment waste generated.[9]

One stakeholder has pointed out the large quantity of uncommon strategic materials that are in medical equipment. If refurbished equipment could not be re-used in the EU after July 2019, it will either be exported to users outside the EU or be recycled.[10] There is an incentive that the equipment reaches its end-of-life in the EU so that it is recycled in the EU. The large weight of medical equipment such as MRI, CT and X-ray systems is a disincentive to export it outside the EU for recycling. A study by one manufacturer has shown that 94% of the weight of medical equipment can be either recycled (64%) or refurbished for second users (30%) so only 6% is land-filled. Another study found that large quantities of scarce materials are used and for one EU-based manufacturer in one year, this includes: 9 tonnes of niobium titanium superconductor, 61 tonnes copper, 57 tonnes stainless steel, 254 tonnes of aluminium alloys and 41 tonnes of neodymium iron boron magnets.

Regarding Category 9, the main types of equipment that are refurbished for reuse are laboratory and test equipment. The ERA report states that up to 6000 tonnes of laboratory analysis instruments and 3000 tonnes of industrial test instruments are sold in the EU annually totalling 9000 tonnes placed on the EU market annually. If the following assumptions are made:

- The total is 10,000 tonnes per year to include other products;
- 10% of the annual consumption is discarded by the first user each year as the average time before sale by first user is 10 years;
- Resale to second users in the EU would not be permitted due to Article 2.2 so this will all become waste:

The total equals 1000 tonnes per year of additional Category 9 waste

Based on the above, the total additional category 8 and 9 waste would be 3140 tonnes per year[11].

In addition, there will also be an increased quantity of raw materials and energy consumed to produce new EEE that would have to be built instead of using the refurbished EEE that will become waste early. COCIR have calculated that using a refurbished medical device instead of building a new device will reduce production phase energy consumption by up to 73%. The quantity of materials used will be much larger than the 3140 tonnes of waste generated per year due to Article 2(2) because production of raw materials creates large quantities of waste and equipment manufacture consumes process chemicals, which also creates waste.

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[9] One seventh of 15,000 tonnes.

[10] Please note that for sale outside the EU, the WEEE recast Directive requires certification that each item is functional, which would increase the administrative costs.

[11] Medical equipment is refurbished after 7 years according to COCIR. We assumed an average of 10 years for category 9 but no published data is available. We also assumed that resale outside of the EU will not be significant whereas some sales are likely.

1.2.2.2 Economic

For RoHS II **Category 8** (Medical devices) products, the re-sale and re-leasing of many types of used medical equipment is very common in the EU and so Article 2(2) will have a significant impact. Most medical equipment such as CT, MRI, PET, ultrasound patient monitors, ventilators, blood glucose monitors, etc. put onto the EU market before 21 July 2014 will not be RoHS compliant and so it cannot be re-sold to second EU users from the 22 July 2019. This will affect EU hospitals that rely on being able to sell old equipment when they buy new. The resale value of the older equipment that will be replaced is typically ~10% of the cost of new EEE and hospitals rely on this money for their new equipment budgets. In 2010, the EU market for medical imaging equipment was €4 billion so if each new product replaced an old product that the hospital sold, this would be worth €400 million. In practice, not all new products are sold as replacements for old and some old equipment may not be sold to second users when a hospital buys a new product (e.g. they may keep it and continue to use). Also, it may be possible to sell some old equipment to users outside the EU. However, it is clear that Article 2(2) would have an impact as the market for refurbished non-RoHS compliant medical devices after July 2019 will be reduced in size. It is possible that EU hospitals will not be able to sell all of their used imaging equipment when they buy new as a result of Article 2(2) which could lose them up to €100 million but this could be more[12]. Note also that imaging equipment is only a proportion of the types of medical device that are sold to second users when new products are bought so the actual impact could be considerably larger. Clearly, the pre-2014 EEE could be sold to users outside of the EU but this is a more limited market and so hospital income from sale of old equipment would be reduced.

Many EU hospitals would also suffer financially because they would not be able to buy refurbished medical equipment from 22 July 2019 that had been first placed on the EU market pre July 2014 and was not RoHS compliant. About 17% of MRI and CT sold in the EU are refurbished products and as these sell for ~35% less than new, the hospitals who would buy refurbished after 2019 will also suffer financially. There will be (a) a loss of income from sale of their old equipment and (b) new equipment will have a ~35% higher price compared to refurbished equipment. The loss of income and higher costs are not likely to be made up by EU governments to compensate for the RoHS directive.

Some hospitals lease medical equipment and replace this with new models after approximately seven years. This will be a serious problem for companies that lease this equipment who will not be able to supply the pre-2014 non-RoHS compliant equipment to EU hospitals after 22 July 2019. This is also an issue for some hospitals that want to lease older and therefore cheaper equipment.

EU hospitals currently buy refurbished medical equipment worth €200 million[13]. If hospital funding were not limited, Article 2.2 would result in higher costs as follows:

- The inability of EU hospitals to sell used equipment could lose approximately €100 million or more.

[12] Due to the number of variables, the exact amount is uncertain.
[13] Data from COCIR

- Hospitals that have to buy new instead of refurbished equipment will have to spend an additional €70 million as new equipment prices are approximately 35% higher than refurbished14.
- In total the increased cost incurred by EU hospitals could be approximately €170 million or more.

However, EU hospital budgets are not likely to be increased to compensate for Article 2.2 and so human health will suffer as the average age of equipment will increase (see section 1.2.2.3).

There is a related impact of RoHS recast on re-sale of refurbished medical equipment that was originally sold to users outside the EU and this is described in the Annex.

Monitoring and control instruments (RoHS II, Annex II, **Category 9**) are frequently resold to second users in the EU. This is quite common when research or test laboratories close and also, many users are able to sell used equipment when it is no longer needed or when a new instrument is bought. If this were not possible, the owners of the used equipment would suffer financially and any users that would have bought used EEE would have higher costs as any non-RoHS compliant equipment would not be available from 22 July 2019. Therefore, this would result in EU industry incurring higher costs. This would affect some types of industrial test equipment, for example instruments used by the oil, gas and power sectors as this often needs to be returned to the original manufacturer for repair or calibration. One manufacturer reported that 40% of returned test equipment is subsequently supplied to different users[15] but this would not be possible after 22 July 2019 if non-RoHS compliant. This is very likely to occur as these types of industrial equipment will not be in scope until July 2017.

Some Category 9 equipment is sold via distributors and system installers and it is common for the original manufacturer to be obliged to take back any unsold or unsellable equipment. This will affect domestic and industrial monitoring and control equipment such as heating and ventilation control equipment that is not RoHS compliant but was placed on the EU market before 2014 (non-industrial) or before 2017 for exclusively industrial Category 9. Article 2(2) will prevent the sale of these from 22 July 2019. This is more likely to be an issue for industrial equipment as there is only two years between industrial monitoring and control instruments entering the scope of RoHS and 22 July 2019 and as some types of industrial products can remain on warehouse shelves for many years. Although larger numbers of domestic products are sold, these need to comply from July 2014 and most should be sold after five years and before 21 July 2019.

For **other newly included EEE**, after 22 July 2019 non-compliant equipment that had been newly included in scope due to the recast could not be sold, leased or given away and so this would either become waste or be sold to users outside of the EU. The main impact on newly included equipment other than category 8 and 9 products will probably be from unsold non-compliant stock that had been expected to be sold before 22 July 2019. This might include some cables. It is estimated to be significant only for equipment which is sold only infrequently so remains in warehouses for many years. As there is seven years until this deadline and most category 11 equipment and equipment

[14] 35% of €200 million = €70 million.
[15] Information provided by American Chamber of Commerce to the European Union, 27 June 2011

included as a result of the change of the definition of dependent will not remain in warehouses for many years, Article 2(2) should have only a limited impact on these types of new equipment.

Re-sale of used equipment of most types of newly included EEE apart from categories 8 and 9 is relatively uncommon although there are some exceptions:

- Many of these types of product have relatively short lives (e.g. toys) and so those in use today would become waste before 2019.
- Many of the types that have relatively long lifetimes such as equipment used in small and medium scale fixed installations (e.g. air conditioning, automatic doors, etc.) are rarely removed and sold to second users. It is common however that the building that this equipment is part of is sold to another owner. At the transfer of ownership of the fixed installation, non-compliant equipment may not be permitted by RoHS due to Article 2(2) because when the building is sold, the fixed installations are regarded as being part of the building and so are also sold. The implications of a change of leaseholder may also be problematic.
- There will be circumstances where resale of fairly old EEE occurs. The owners of affected types of used equipment would not be permitted to sell these after 21 July 2019 if they are not RoHS compliant and these products would include furniture with integral secondary electrical functions, gas cookers and possibly some combustion powered garden machinery. The first owners of these will be consumers as well as some businesses (e.g. hotels in the case of beds and wardrobes and restaurants in the case of gas cookers). Enforcement of this restriction on consumers who want to sell their used equipment to other consumers would not be easy and will probably be largely ineffective unless a very significant and costly effort were to be expended.

1.2.2.3 Social

As a result of the economic impacts discussed above and limited budgets, EU hospitals will be able to afford less new equipment each year from 2019 onwards and this will have a negative effect on the health of patients in EU hospitals. This will be because hospitals will not be able to buy as much new equipment each year and so the average age of medical equipment used in EU hospitals will gradually increase as old equipment replacement is delayed. It is known that the performance of old equipment for diagnosis accuracy and treatment success is inferior to newer machines although it is not possible to quantify this as there are many variables that influence medical treatment success rates. Old equipment also tends to be less reliable and so there will be delays to treatment when breakdowns occur and this can have serious implications to patients.

The National Radiotherapy Advisory Group advised the UK Government in 2007 that radiotherapy equipment should be replaced every 10 years because old equipment suffers from breakdowns due to wear causing longer recovery times, is less accurate and so causes more side-effects[16].

[16] http://www.dh.gov.uk/prod_consum_dh/groups/dh_digitalassets/@dh/@en/documents/digitalasset/dh_074576.pdf (see page 28, paragraph 74).

Equipment types such as X-ray, CT, MRI and ultrasound can be and are used in EU hospitals for much longer periods than 10 years before disposal (typical lifetimes are 20 – 30 years) but newer equipment will give superior performance so that full recovery is more likely and shorter treatment times are possible. As a result, the healthcare costs from using older equipment (excluding capital equipment costs) could be higher overall than if newer equipment were available. There will be an impact on patient's health if the average equipment age were to increase by a few years but the extent is impossible to quantify. This is because there have been improvements in diagnosis expertise, drug treatments and advances in technology so that the success rates achieved some years ago cannot be directly compared with success rates today with newer equipment. COCIR has studied the age profile of medical equipment used in EU hospitals and believes that it is already older than it should be and their report explains the implications of using older equipment[17]. Ideally, EU hospitals should buy more new equipment and so Article 2(2) would force some hospitals to buy new instead of refurbished older machines but as budgets will not increase, the end result will be that the average age will increase.

Medical equipment manufacturers themselves will be affected as their market for refurbished equipment will shrink and so there may be an impact on EU jobs. Manufacturers may, however, be able to sell more new systems so their total turnover may not be reduced significantly. A large amount of equipment (e.g. blood glucose monitors and nutrition pumps) is returned from users to manufacturers for calibration and inspection as this is required by the Medical Devices Directive (93/42/EEC). After calibration, this equipment is then supplied to customers who may not be the original owners and so any pre-July 2014 non-compliant devices would have to be exported out of the EU or they will become waste. This would inevitably increase healthcare costs.

1.2.3 Potential benefits

No potential environmental, economic or social benefits are foreseen due to the implementation of Article 2(2)/4(3).

1.2.4 Possible solution(s)

The current wording covers all EEE that was excluded from 2002/95/EC but is in scope of 2011/65/EU so that all of these made available after 22 July 2019 must comply. It seems reasonable that this obligation should not apply at least to products in categories 8 and 9 and the obligations for other newly included equipment should also be based on the same place on the market principal used for other EU CE mark directives. Options for changing Article 2.2 could be (changes underlined):

[17]http://cocir.org/uploads/documents/-609-new_members_ws_-_del._3_-_cocir_age_profile_17_june_2009.pdf

- ***Option 1: Delete Article 2.2 and amend Article 4.3***

If Article 2(2) were deleted, it will be necessary to amend Article 4.3 to:

"Paragraph 1 shall apply to medical devices and monitoring and control instruments which are placed on the market from 22 July 2014, to in vitro diagnostic medical devices which are placed on the market from 22 July 2016, to industrial monitoring and control instruments which are placed on the market from 22 July 2017 and to any other equipment that was outside the scope of Directive 2002/95/EC which is placed on the market from 22 July 2019."

- ***Option 2: Amend Article 2.2 to exclude categories 8 and 9***

"Member States shall provide that EEE that was outside the scope of Directive 2002/95/EC but which would not comply with this Directive, except for medical devices and monitoring and control instruments, may nevertheless continue to be made available on the market until 22 July 2019."

Please note that it has also been considered to reformulate Art. 2(2) by replacing 'made available on the market' with 'placed on the market'. The Commission, however, has clarified this option internally and has arrived at the conclusion that this option is not advisable for the sake of legal clarity. Most importantly, it could be argued that by replacing 'made available on the market' with 'placed on the market', any grace periods for making products available on the market until 22 July 2019, other than for market placement, would be abolished. Once non-compliant products had been placed on the market they could not subsequently be resold, refurbished or leased once in scope of RoHS II, even if that date is before 22 July 2019, e.g. 22 July 2014 for medical devices. Reformulating Article 2(2) in this way could therefore have substantial negative consequences.

Option 1 would require EEE placed on the EU market for the first time after the specified dates to comply with RoHS. Option 2 is slightly different. This treats category 8 and 9 equipment in the same way as categories 1 – 7 and 10 except that these products must comply with RoHS if placed on the EU market for the first time after the dates specified in Article 4(3). All other newly included EEE, i.e. cables, due to the change of definition of 'dependent' or products in category 11, made available from 22 July 2019 must comply with this Directive. Article 4(4)

1.3 Article 4(4)

1.3.1 Background

While Article 4(4) of RoHS II provides an exclusion for cables and spare parts for products in categories 1-7 and 10 in scope since July 2006 and categories 8 and 9 in scope from 2014, 2016 or 2017, this exclusion is legally missing for Category 11 and other products newly in scope but not mentioned in points (a)-(f) :

Box 2: RoHS II, Art. 4(4)

RoHS II, Article 4(4)

"Paragraph 1 shall not apply to cables or spare parts for the repair, the reuse, the updating of functionalities or upgrading of capacity of the following:

(a) EEE placed on the market before 1 July 2006
(b) Medical devices placed on the market before 22 July 2014
(c) In vitro diagnostic medical devices placed on the market before 22 July 2016
(d) Monitoring and control instruments placed on the market before 22 July 2014
(e) Industrial monitoring and control instruments placed on the market before 22 July 2017
(f) EEE which benefited from an exemption and which was placed on the market before that exemption expired as far as that specific exemption is concerned

RoHS II, Article 4(1)

"Member States shall ensure that EEE placed on the market, including cables and spare parts for its repair, its reuse, updating of its functionalities or upgrading of its capacity, does not contain substances listed in Annex II [the six RoHS substances]."

As part of the second stakeholder consultation of this study, stakeholders were asked about the impact of not having a spare-part exclusion for Category 11 products in Article 4(4). They were also asked for an estimate of spare parts as a percentage of the overall market volume of their product(s) as well as whether these were likely to be RoHS compliant by 22 July 2019. The following answers were received out of a total of 20:

- Nine stakeholders stated that they were either not affected or that the issue would have no or hardly any impact;
- Five stakeholders said there would be an impact as products would not be able to be repaired but this could not be quantified at this stage, neither could the amount of spare parts as part of their market volume;
- Six stakeholders did not answer the question.

The fact that none of the responding stakeholders was able to provide a quantitative estimate of the impact Article 4(4) would have on their business, shows the difficulty of this task. Even for product groups, for which the amount of repair activities in relation to the overall market value is known, it remains unclear to what extent these repair activities would be affected by RoHS II. In most cases, repair activities can still be undertaken as only those parts with RoHS II substances would be banned. An issue of concern here is that when a defective PCB needs to be replaced to repair equipment, the replacement PCB would most probably have been made at the same time as the original. It is often not possible to build a small number of RoHS compliant new PCBs many years after the original equipment ceases to be produced because some of the components used will no longer be available. If old components are retained as spares, some will not be RoHS compliant. Another issue is that the terminals of some types of components will become unsolderable after five or more years storage and could therefore not be used.

1.3.2 Potential costs

1.3.2.1 Environmental

If products are taken off the market because they cannot be repaired, this will decrease their lifetime and result in an increase in EEE waste. This would appear to stand in direct contrast to:

- The Community's waste strategy, which names waste prevention as the key factor in any waste strategy
- The sixth Community Environment Action Programme, in particular Article 8, which names the significant overall reduction in the volumes of waste as a key objective to reach the overall targets of the programme.[18]
- The objectives of the WEEE Directive, which state that the first priority is the prevention of waste electrical and electronic equipment.[19]
- Etc.

In order to ensure that an increase in waste is not the result of the RoHS Directive, it does include notions of a 'repair as produced' principle, i.e. ensuring the availability of spare parts for all products lawfully placed on the market. Less waste from these products also reduces their overall ecological impacts and conserves natural resources. Article 4(4) of RoHS II still ensures the 'repair as produced' principle for products in categories 1-7 and 10 in scope since July 2006 and in categories 8 and 9 but not for Category 11 and other newly included products. Given the vast array of products falling in this general category and the long lifetimes of many of these, e.g. 20 years for automatic doors and gates, the increase in waste due to Article 4(4) could be significant.

[18] Decision No 1600/2002/EC, accessed at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2002:242:0001:0015:EN:PDF

[19] Directive 2002/96/EC, Article 1, accessed at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:2002L0096:20080321:EN:PDF

1.3.2.2 Economic

Many of the product groups affected by the missing exclusion in Article 4(4), especially those with very long lifetimes, are likely to have important repair and resale markets. These could be severely affected by the unavailability of spare parts with potentially detrimental impacts for these industries. Furthermore, it can be assumed that most players in these markets would be SMEs. In the example for pipe organs, 60% of all related jobs are not linked to the building of new pipe organs but to the rebuilding and restoration work of existing organs. It should be noted that some repairs should be able to be carried out using RoHS-compliant spare parts but the extent to which this is possible is unknown.

Furthermore, manufacturers of affected product groups might well argue that Article 4(4) is incoherent, i.e. treating their products differently to those mentioned in points (a)-(f) without obvious reason.

1.3.2.3 Social

Potential social costs of the missing exclusion in Article 4(4) would be related to a decrease in employment opportunities linked to the economic impacts discussed above.

1.3.3 Potential benefits

1.3.3.1 Environmental

Potential environmental benefits could be envisaged due to an earlier disappearance of products containing RoHS substances from the market. However, as the most important environmental impacts of these products that is linked to RoHS substances is not expected during their use phase but at the end-of-life, shortening their use phase should have no beneficial environmental effects.

1.3.3.2 Economic

No economic benefit due to the missing exclusion in Article 4(4) is expected.

1.3.3.3 Social

The only potential benefit envisaged would be related to health, due to a potentially quicker disappearance of products containing RoHS substances. The products were, however, lawfully placed on the market and will need to be disposed of in any case at one point in time. As their health impact due to RoHS substances is not expected during their use phase but at the end-of-life, shortening their use phase should have no beneficial health effects.

1.3.4 Possible solution

Based on the above it becomes clear that while the potential environmental, economic and social costs of the missing exclusion in Article 4(4) could be significant, no particular benefits are envisaged. This analysis is characterised by a lack of data and should therefore be considered with caution. Nevertheless, if more data had been available within the very short timeframe, it would have been expected to support the points made above.

It would therefore be recommended to change Article 4(4) to introduce the 'repair as produced' principle also for those products currently excluded. The easiest option to do so would be to introduce a point (g) to include any other EEE outside the scope of Directive 2002/95/EC which is placed on the market before 22 July 2019.

Annex

Impact of recast on reuse of medical devices in the EU

The recast RoHS directive requires all medical devices that are placed on the EU market for the first time from 22 July 2014 to not contain the six restricted substances unless these are permitted by exemptions. This is not a change between the COM proposal and the recast, but medical equipment manufacturers have realised that a significant negative impact on EU healthcare would occur which was not considered by the impact assessment produced by the Commission in 2008[20] and so have asked that this impact be considered as part of this assessment.

As described above, it is fairly common in the EU for hospitals to replace old medical equipment with refurbished equipment. For example, some EU hospitals will replace CT scanners and MRI imaging typically after 15 years in use by refurbished equipment of ~7 year old which has superior performance and will be more reliable that the 15 year old equipment. Refurbished X-ray systems, ultrasound and nuclear medicine (e.g. PET) are also bought by EU hospitals. EU hospitals often do not replace old equipment with new due to limitations on the amount of money available to buy new equipment as funding from Member State governments and other healthcare providers is never sufficient for everything that medical staff would like to buy. Purchase of refurbished equipment allows hospitals to buy more types of newer equipment

The recast RoHS directive would allow a non-RoHS compliant MRI to be sold to an EU hospital in 2013 and this MRI can then be resold to another EU hospital after July 2014 (but not after 21 July 2019). An identical MRI first sold to a hospital in the USA cannot however be resold to an EU hospital after July 2014 as this MRI would be first placed on the EU market after July 2014 and so would need to be RoHS compliant.

This situation will have an impact on EU healthcare because of the following reasons:

- EU healthcare providers (Member State governments) will not increase capital budgets to hospitals due to the RoHS recast
- Refurbished equipment prices are on typically 30 - 35% lower than new systems.
- 39% of all refurbished medical equipment is sold in the EU with Germany accounting for 22% of the EU total. In Germany one of every six installed imaging equipment (CT) is a refurbished unit.
- The total difference in cost between refurbished MRI and new MRI sold in the EU annually would be from €4 to 8.5 million21.

In 2010, €200 million worth of refurbished medical equipment was sold in the EU and 30 – 50% of these were previously sold to users outside the EU. If those units originally sold outside the EU could

[20] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52008SC2930:EN:NOT

[21] Data from COCIR

not be resold to EU users, there would be a shortage of refurbished equipment to EU hospitals worth up to €100 million.

When a used medical device could not be re-used, it would become waste early and would need to be replaced by new equipment and its construction will consume more energy, more raw materials and create more waste than be generated by refurbishment.

Medical equipment manufacturers have pointed out that this issue will have a negative impact on EU hospital patients. The result of including category 8 in scope of RoHS is that there would be less refurbished equipment available after 21 July 2014 because of hospital's budgetary constraint that prevents them from buying more expensive new equipment. Many hospitals that would have bought a refurbished system will either have to wait longer to acquire one until one originally placed on the EU market becomes available or they will have to buy new instead. This could either prevent purchase of other equipment or delay purchase of equipment until sufficient funds are available for a new unit. Overall, this will result in the average age of medical equipment becoming older as equipment replacement is delayed. It is known that the performance of old equipment for diagnosis accuracy and treatment success is inferior to newer machines although it is not possible to quantify this as there are many variables that influence medical treatment. Old equipment also tends to be less reliable and so there will be delays to treatment when breakdowns occur and this can have serious implications. Medical equipment manufacturers themselves will be affected as their market for refurbished equipment will shrink with a resulting impact on EU jobs where refurbishment is carried out in the EU as many manufacturers build new equipment outside the EU. However, they should be able to sell more new systems so their total turnover may not be reduced significantly.

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