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Review of the MEErP - Methodology for Ecodesign of Energy-related Products

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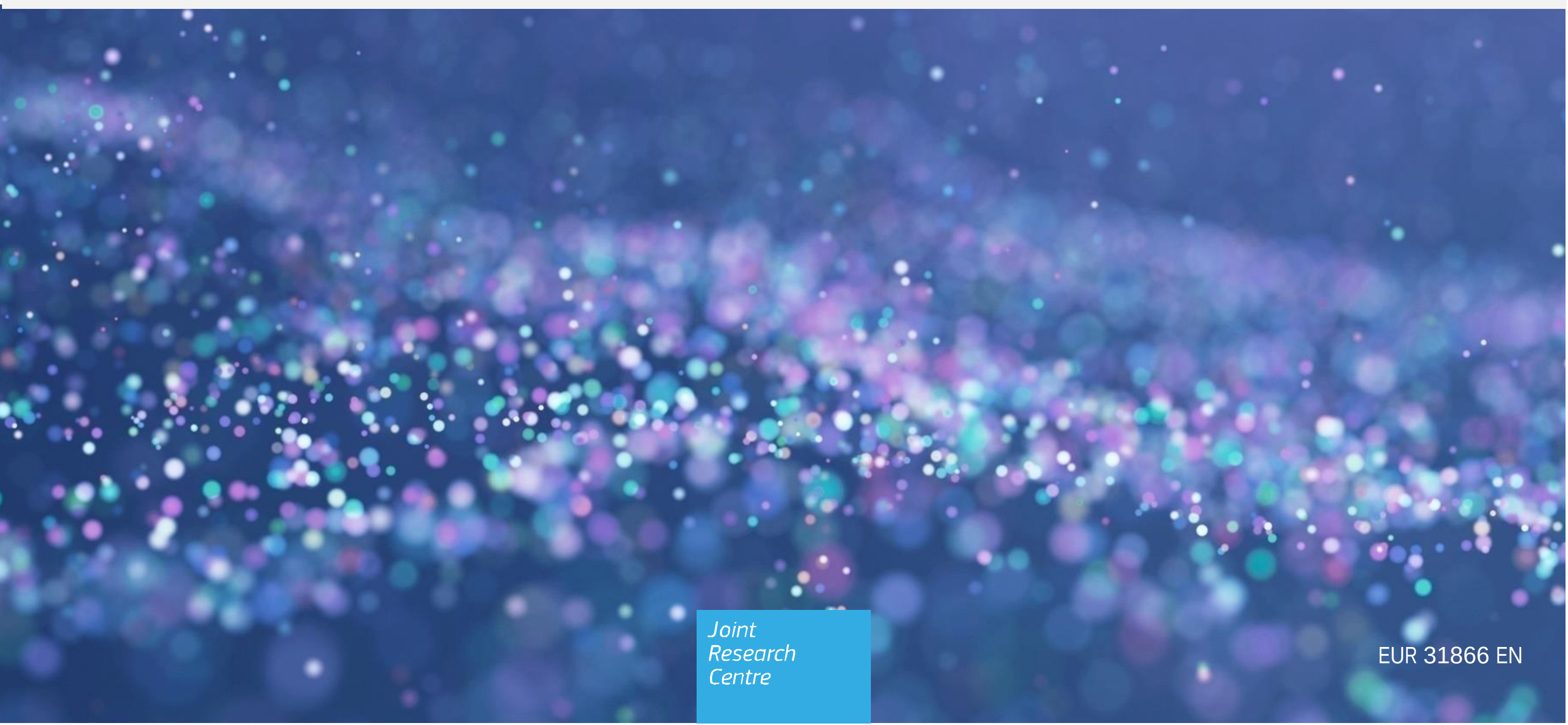
2024



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Contents

Abstract

The Methodology for Ecodesign of Energy-related Products (MEErP henceforth) consists of a techno-economic-environmental assessment of a specific product group. This assessment is the main analytical step in the potential implementation of the Ecodesign Directive for a specific product group.

Since 2013 the current MEErP methodology has been in use and considered fit for purpose. However, since 8 years have already elapsed in this very dynamic field, the need for an update is apparent.

The current report depicts the proposal for update put forth by the JRC at the request of DG GROW. Areas covered are:

1) The updating of the EcoReport Tool;
2) A more systematic inclusion of material efficiency aspects and of environmental footprint/ecological profile aspects in the design options and in the LLCC curve;
3) A more systematic inclusion of societal life cycle costs;
4) A more refined evaluation of the economic impacts in task 7 of the MEErP.

Acknowledgements

This report has been developed in the context of the Administrative Arrangement "Review of the MEErP - Methodology for Ecodesign of Energy-related Products" between DG GROW and DG Joint Research Centre. The project responsible for DG GROW was: Davide Polverini.

Authors would like to thank Serenella Sala and Andrea Amadei for the support in the inclusion of societal life cycle costs aspects in the MEErP, and Luca Zampori for support in the selection of datasets for the revised Ecoreport tool.

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Executive summary

Ecodesign and Energy Labelling legislation are key contributors in supporting the Commission's overarching priority to strengthen Europe's competitiveness and boost job creation and economic growth. Their effect can be felt in the Energy Union objectives, the transition to a Circular Economy, the internal market functioning and the environment. They also drive investment and innovation and save money for consumers.

The Methodology for Ecodesign of Energy-related Products (MEErP henceforth) consists of a techno-economic-environmental assessment of a specific product group. This assessment is the main analytical step in the potential implementation of the Ecodesign Directive on a specific product group.

Concerning the identification and the level of stringency of the (potential) Ecodesign requirements for a certain product group, the most important part of the analysis takes place within the techno-economic assessment, at the point when the life cycle cost curve is determined, and the Least Life Cycle Cost (LLCC henceforth) is defined. On the basis of the LLCC and related product environmental impact, Ecodesign requirements for a certain product can be set, aiming to gradually – and sustainably - push the market towards the LLCC. Once the requirements are defined, it is left to individual manufacturers to choose how, and with which technologies, to produce a compliant product (in line with the principle of technological neutrality). The LLCC is unique to each product category, and it provides the optimum level from a regulatory perspective because it minimises the total cost of ownership for the consumer and it pushes all manufacturers, at the same time, to make improvements to their products with existing technologies.

The MEErP is open, iterative, transparent, and utilises a tool (the EcoReport tool) that is free at the point of use, and is simple to use whilst being sufficiently complex/ complete in order to capture the main inputs and outputs at product specific level. The EcoReport is a streamlined life-cycle based tool that is openly available, with no presumption or requirement of prior purchase of a commercially-available Life Cycle Assessment package.

In 2013, the MEErP was evaluated and considered fit for purpose in the decision-making process of the Ecodesign and Energy Labelling legislative framework. A new update is now needed, in particular a) to update, when and where necessary, some of the data used in the analysis and b) to ensure that the MEErP is still fit for its purpose, in line with the policy developments of the last years. Within this framework, several areas of analysis (together with, in some cases, potential solutions/approaches) have been identified in the course of the last years, namely:

- Need for the update of the environmental impact data contained in the EcoReport tool, as well as an evaluation of the relevance of the various input categories/indicators with regard to material efficiency.
- Relevance for a more systematic inclusion of material efficiency aspects in the modelling of the MEErP. These aspects have been assessed in recent eco-design and energy labelling preparatory studies, although without having as reference a harmonised and systematic methodology. This could be attained, in particular, by systematically including two separate but equally important aspects in the construction of the LLCC curve:
    - Systematic inclusion (when relevant for the specific product group under analysis) of design options related to material efficiency aspects (such as a) increased reparability, b) increased durability, c) increased recyclability or d) aimed at promoting the reuse of secondary raw materials and/or components).
    - Systematic inclusion of lifetime in the MEErP modelling of the LLCC. In order to properly analyse and model circular economy requirements, product lifetime must be taken into account. In practical terms, following this approach would imply that an 'equivalent annual cost' (for a design option) should be calculated. With the use of the 'equivalent annual cost' it is possible to properly compare design options with different (expected) lifetimes, such as, for example, the base case (i.e. the average EU product), compared to a second product with increased durability (e.g. thanks to the higher quality of its components) and a third product with higher lifetime than the base case as a result of its improved design for reparability (see the previous point).
- Relevance of the development of the Product Environmental Footprint method (data and approach, e.g. for modelling impacts, normalising and weighting results) and related Product

Environmental Footprint Category Rules to the MEErP and the EcoReport tool for assessing life cycle impacts both for developing the base case and the design options.

- Relevance for a more systematic inclusion of design options:
    - Aimed at reducing the carbon and environmental footprint of the product.
    - (Potentially linked to the previous point) compliant with generic ecodesign requirements based on the ecological profile of the product.
- Relevance of a more systematic inclusion of societal life cycle costs (direct environmental costs, externalities and other indirect costs) in the MEErP.
- Need for a more refined method for the evaluation of the economic impacts (e.g. impacts on employment).

Introduction

The Annex to the Communication from the Commission on the Ecodesign and Energy Labelling Working Plan 2022-2024 outlines the Methodology for Ecodesign of Energy-related Products (MEErP henceforth) to be used to carry out product assessments. The MEErP consists of a set of methodological guidelines on how to perform a techno-economic-environmental assessment of a specific product group in the context of the Ecodesign legislation. This assessment is carried out by a specialized team of experts (the Study-Team henceforth) and is the main analytical step in the preparatory study that is conducted for the potential implementation of the Ecodesign legislation for a specific product group. The idea of the MEErP is not to be excessively prescriptive, thus leaving enough leeway for the Study-Team to adapt the choice of methods and procedures to the particular characteristics of the product group under study. However, the MEErP should ensure a sufficient degree of uniformity to ensure that Ecodesign remains a coherent policy across different types of product groups. In the current report, it will be stressed what are the methodological aspects that should be followed by the Study-Team and where more flexibility should be granted.

Concerning the identification and the level of stringency of the (potential) Ecodesign requirements for a certain product group, the most important part of the analysis takes place within the techno-economic assessment, at the point when the life cycle cost curve is determined, and the Least Life Cycle Cost (LLCC henceforth) is defined. On the basis of the LLCC and related product environmental impact, Ecodesign requirements for a certain product can be set, aiming to gradually – and sustainably - push the market towards the LLCC. Once the requirements are defined, it is left to individual manufacturers to choose how, and with which technologies, to produce a compliant product (in line with the principle of technological neutrality). The LLCC is unique to each product category, and it provides the optimum level from a regulatory perspective because it minimises the total cost of ownership for the consumer and it pushes all manufacturers, at the same time, to make improvements to their products with existing technologies.

The MEErP is open, iterative, transparent, and utilises a tool, the EcoReport tool[1], that is free to use, and is simple to use whilst being sufficiently complex/complete in order to capture the main inputs and outputs at product specific level. The EcoReport is a streamlined life-cycle based tool that is openly available, with no presumption or requirement of prior purchase of a commercially-available Life Cycle Assessment package.

In 2013, the MEErP was evaluated and considered fit for purpose in the decision-making process of the Ecodesign and Energy Labelling legislative framework. A new update is now needed, in particular a) to update, when and where necessary, some of the data used in the analysis and b) to ensure that the MEErP is still fit for its purpose, in line with the policy developments of the last years. Within this framework, several areas of analysis (together with, in some cases, potential solutions/approaches) have been identified in the course of the last years, namely:

- Need for the update of the environmental impact data contained in the EcoReport tool, as well as an evaluation of the relevance of the various input categories/indicators with regard to material efficiency.
- Relevance for a more systematic inclusion of material efficiency aspects in the modelling of the MEErP. These aspects have been assessed in recent eco-design and energy labelling preparatory studies, although without having as reference a harmonised and systematic methodology. This could be attained, in particular, by systematically including two separate but equally important aspects in the construction of the LLCC curve:
    - Systematic inclusion (when relevant for the specific product group under analysis) of design options related to material efficiency aspects such as: a) increased reparability, b) increased durability.
    - Systematic inclusion of product lifetime in the MEErP modelling of the LLCC. In order to properly analyse and model circular economy requirements, product lifetime must be taken into account. In practical terms, following this approach would imply that an 'equivalent annual cost' (for a design option) should be calculated. With the use of the 'equivalent annual cost' it is possible to properly compare design options with different (expected) lifetimes, such as, for example, the base case (i.e. the average EU product), compared to a second product with increased durability (e.g. thanks to the higher quality of its components)

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[1] Available at: https://single-market-economy.ec.europa.eu/industry/sustainability/sustainable-product-policy-ecodesign_en

and a third product with higher lifetime than the base case as a result of its improved design for reparability (see the previous point).

- The development of the Environmental Footprint method (data and approach, e.g. for modelling impacts, normalising and weighting results) and related Product Environmental Footprint Category Rules to the MEErP and the EcoReport tool.
- Relevance for a more systematic inclusion of design options:
    - aimed at reducing the carbon and environmental footprint of the product.
    - (potentially linked to the previous point) compliant with generic ecodesign requirements based on the ecological profile of the product.
- Relevance of a more systematic inclusion of societal life cycle costs (direct environmental costs, externalities and other indirect costs) in the MEErP.
- Need for a more refined method for the evaluation of the economic impacts (e.g. impacts on employment) in Task 7 of the MEErP.

The current report focuses thus on four main areas:

1) the updating of the EcoReport Tool;
2) a more systematic inclusion of material efficiency aspects and of environmental footprint/ecological profile aspects in the design options and in the LLCC curve;
3) a more systematic inclusion of societal life cycle costs;
4) a more refined evaluation of the economic impacts in task 7 of the MEErP.

The two tables below show which sections of the methodology (MEErP 2011) (COWI and VHK 2011a) have been updated or replaced by this revision.

The following colour codes help to identify:

- What is completely replaced by this revision (green)
- What is partially updated (blue)
- What remains unchanged (grey)

Table 1: Sections of the MEErP 2011 part1 (COWI and VHK 2011a) which are updated/replaced by the current document (2024 revision of the MEErP)

MEErP 2011 part 1: methods. Content		MEErP revision 2024 content
1. Task 1: Scope	Scope	Unchanged
2. Task 2: Markets	2.1 Introduction	Unchanged
	2.2 Sales and Trade	Unchanged
	2.3 Energy rates for private households	Unchanged
	2.4 Energy rates for industry	Unchanged
	2.5 Water rates	Unchanged

	2.6 Interest and inflation rates	Unchanged
	2.7 Tax rates	Unchanged
	2.8 Acquisition costs	Unchanged
	2.9 Summary EU averages	Unchanged
3. Task 3: Users	3.1 Extended product and systems approach	Unchanged
	3.2 Extended ErP product scope	Unchanged
	3.3 Method indirect ErP effect	Unchanged
	3.4-3.7 Examples	Unchanged
4. Task 4: Technologies	4.1 Technical product description	Unchanged
	4.2 Other subtasks	Unchanged
5. Task 5/6: Environment	5.1 Introduction	Partially updated by chapter 1 of this document): • 1.1 Impact categories • 1.2 End of Life modelling • 1.3 Datasets and further improvements
	5.2 LCI accounting rules	Completely replaced by chapter 1 of this document
	5.3 LCIA, impact indicators	Completely replaced by chapter 1 of this document[2]
	5.4 ErP Ecoreport Manual	Completely replaced by Task1 (section 1.7)
6. Task 5/6: Economics	6.1.1 Life cycle costs	Replaced by chapter 2 of this document
	6.1.2 Least Life Cycle Costs (ranking design options)	Unchanged
7. Task 7: Scenarios	7. Scenarios	Replaced by chapter 1 (task 1.f), 2 and 3 of this document

Source: JRC elaboration

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[2] The MEErP 2011 identified some environmental aspects not specifically related to LCA impact categories, such as content of Hazardous Substances and Substances of Very High Concern, and some physical impacts. These aspects were out of the scope of the current MEErP review. The analysis of these aspects would require additional investigation.

Table 2: Sections of the MEErP 2011 part2 (COWI and VHK 2011b) which are updated/replaced by the current document (2024 revision of the MEErP)

MEErP 2011 part 2: Environmental policies & data. Content		MEErP revision 2024 content
2. Resources	2.1.1 Materials (steel)	Unchanged. Not covered by this review
	2.1.2 Materials (plastics)	Unchanged. Not covered by this review
	2.1.3 Materials (aluminium)	Unchanged. Not covered by this review
	2.1.4 Materials (critical raw materials)	Completely replaced by section 1.6 of this document
	2.2 Recycling	Completely replaced by chapter 1 of this document: • 1.2 End of Life modelling • 1.4 Material efficiency
	2.3.1 Energy (Policy)	Unchanged. Not covered by this review
	2.3.2 Energy (Statistics)	Unchanged. Not covered by this review
	2.3.3 Energy (Trends)	Unchanged. Not covered by this review
	2.3.4 Energy (Consumption by application)	Unchanged. Not covered by this review
	2.3.5 Energy (Efficiency of power generation and distribution)	Partially updated by chapter 1.1
	2.3.6 Energy (Security of energy supply)	Unchanged. Not covered by this review
	2.3.7 Energy (Accounting units)	Unchanged. Not covered by this review
	2.4 Water	Unchanged. Not covered by this review
	2.5 Waste	Unchanged. Not covered by this review
3. Emissions	3. Emissions	Completely replaced by section 1.1 of this document
4. Other impacts	4.1 Noise	Unchanged. Not covered by this review
	4.2 Other health-related impacts	Unchanged. Not covered by this

		review
5. Ecoreport 2011 LCA unit indicators	5. Ecoreport 2011 LCA unit indicators	Completely replaced by chapter 1 of this document
6. Climate, Energy & Buildings	6.2 Climate	Unchanged. Not covered by this review
	6.3 Domestic water consumption	Unchanged. Not covered by this review
	6.4 Lighting	Unchanged. Not covered by this review
	6.5 Residential buildings	Unchanged. Not covered by this review
	6.6 Commercial buildings	Unchanged. Not covered by this review
	6.7 Public sector and community sector buildings	Unchanged. Not covered by this review
	6.8 Primary&secondary sector buildings	Unchanged. Not covered by this review
7. People	7.1 Introduction	Unchanged. Not covered by this review
	7.2 Occupancy rate residential buildings	Unchanged. Not covered by this review
	7.3 Occupancy rates tertiary sector buildings	Unchanged. Not covered by this review

Source: JRC elaboration

1 Updating of the Ecoreport Tool

This chapter presents the progress on Task 1 of the project "Review of the MEErP - Methodology for Ecodesign of Energy-related Products" (MEErP)"[3]. Task 1 deals with "Updating the Ecoreport Tool".

In particular, identified areas of improvement regard:

- Task 1.a: Update of underlying data sets of EcoReport tool;
- Task 1.b: introduction of new materials (in particular, those used in electronics), also considering the possibility to provide regular updates;
- Task 1.c: preparation of instructions on how to use the Ecoreport tool;
- Task 1.d: Identification, among the various input categories/indicators, of those related to the quantification of material efficiency 'features';
- Task 1.e: Identifying and proposing which of the various input categories/indicators should be part of the 'Ecological profile' of a product,
- Task 1.f: Implementing, when feasible, a finer modelling of annual sales, including the possibility to calculate or insert a dynamic stock model in the tool,
- Task 1.g: Critically revising the current approach to end-of-life,
- Task 1.h: Critically revising the current approach for Critical Raw Materials (CRMs);
- Task 1.i: Proposing a procedure for future updates (of the input categories, indicators, datasets, materials, etc..) of the Ecoreport tool;
- Task 1.j: Considering the potential use of more sophisticated IT infrastructure (web based) for the assessment of the impacts;
- Task 1.k: Considering other suggestions for review of the Ecoreport tool, as raised during the development of the project.

Since many aspects are interrelated among the sub-tasks, it is decided to combine the sub-tasks based on their content and not following the sequential order as above. The analysed sub-tasks are reported in the header of each chapter.

Proposed changes and implementations are described, including some screenshots from the new version of the tool, when available. Note that the screenshots presented in this report currently use fictitious datasets as all EF3.1 datasets are not available yet.

As general objective of this review, it was important to keep the same format of the Ecoreport tool[4] (excel file), its logic and simplified approach, whereas aiming at enhancing transparency (especially for the background data and modelling options) and consistency in the different sections of the tool.

The comparability of the results of the two versions of the Ecoreport tool (i.e. version 2013 and version 2024) cannot be achieved due to the major changes and updates applied during the revision of the methodology including underlying impact assessment methods and database.

The state of play of the Task 1 and its various subtasks is presented hereinafter.

1.1 Impact categories (subtask 1.a)

Objectives

Update of the impact categories in the Ecoreport tool.

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[3] Administrative Arrangement N ° JRC 35847-2020 // GROW SI2.831466

[4] Version 3.06 VHK for European Commission 2011, modified by IZM for European Commission 2014. Available at: https://single-market-economy.ec.europa.eu/industry/sustainability/sustainable-product-policy-ecodesign_en

Status as in the current Ecoreport tool

The results of the environmental assessment of the Ecoreport tool are currently displayed as a set of environmental inputs and outputs, as in the spreadsheet "Results". In particular, these include:

- A list of inputs as "Materials" (e.g. bulk plastics, Ferro, electronics, etc.),

- A list of inputs and outputs as "Other Resources & Waste" (e.g. Total Energy – Gross Energy Requirement (GER), water, Waste non-hazardous etc.),

- A list of "emissions to air" (grouped as e.g. Greenhouse gases, acidification emissions, etc.),

- A list of "emission to water" (heavy metals and eutrophication).

The displayed results are partially in line with usual impact assessment indicators implemented in life cycle methods and software, since the Ecoreport tool results combine inventory flows (as raw materials, water and waste) and more complex impact assessment categories (as combination of emissions multiplied by corresponding characterisation factors for the contribution to a certain impact category). This structure of environmental assessment was firstly introduced in the MEEuP in 2005, and partially revised in 2011. However, since 2011 it has been not updated, and it does not reflect the large progresses in the last decade by the scientific community to harmonize impact assessment methods for life cycle approaches. Worth of note are the developments by the UN LCA initiative[5] and by the EU Environmental Footprint method (European Commission 2013),(European Commission 2021a). Moreover, environmental impacts in the current Ecoreport tool are based on impact factors developed ad-hoc within the MEErP, and these are not in use in other common software and databases for Life Cycle Assessment (LCA). This makes particularly difficult the procedure to calculate these impacts when updating the database of the Ecoreport tool (as within the current project) and also for any new dataset introduced, for example, by consultants during preparatory studies. Moreover, except for a few examples (as Global Warming Potential - GWP, GER and water use) the impact categories in the Ecoreport tool have been not widely discussed and agreed in the LCA literature and therefore they are difficult to interpret. Based on the experience of previous preparatory studies, very few of these additional life-cycle results have actually been used to develop product requirements in the last decades.

Concerning energy aspects and primary energy consumption data, conversion factors used to estimate the primary energy conversion factor to quantify the GER are outdated (referring to data from early 2000) and background information was not detailed enough to trace back all the sources and the modelling assumptions implemented.

Only impacts for electricity have been updated in the Ecoreport tool during the 2011 review, but impacts for the majority of materials are still referring to the initial MEEuP version. This implies that the database on materials is currently outdated and not fully consistent, since impacts of materials do not reflect the new assumptions on the electricity production efficiency and changes in the energy mix (as implemented in the last decade).

Rationale and Action

Based on this analysis, it was decided to align, as far as possible, the results of the Ecoreport tool with the 16 impact categories used in the Environmental Footprint (EF) method. This choice allows to: use robust indicators aligned to prominent literature; facilitate continuous updates of characterisation factors in future (following scientific progress); grant alignment with developments in EF and other EU policies; and, overall, interpret results in an easier way. (following also relevant publications for the various categories). Moreover, this choice is relevant also for the process of updating datasets (as described in section 2.3), to achieve alignment between inventory and Impact assessment. The modelling of impact categories, is mainly focused on global effects (e.g. climate change), although some impact categories include regionalised aspects in the methods (e.g. land use and water use). In line with its previous version, the Ecoreport tool does not provide such a specific information of the impacts.

In the EF method there is the possibility to include additional technical information[6]. The EF method includes already the "Resource use, fossil" among the life cycle impact categories. This addresses the use of non-

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[5] https://www.lifecycleinitiative.org/activities/phase-i/life-cycle-impact-assessment-programme/

[6] As reported in EC Recommendation (2021), "Relevant potential environmental impacts of a product may go beyond the EF impact categories. It is important to consider and report them, whenever feasible, as additional environmental information. Similarly, relevant technical aspects and/or physical properties of the product in

renewable fossil natural resources (e.g. natural gas, coal, oil, nuclear). Because MEErP methodology and Ecoreport tool analyse energy-related products for which energy consumption plays a significant role, it is proposed to include in the revised Ecoreport tool the additional information on "Primary Energy Consumption". This inclusion was considered relevant to account for energy efficiency aspects and to reflect the increasing share of electricity produced from renewable resources. The additional information on "Primary Energy Consumption" complements the "Resource use, fossil" by considering the use of renewable resources for datasets on thermal energy and electricity from renewable sources and electricity mix.

Concerning datasets to be used in the Ecoreport tool database, it is suggested to substitute current values with most recent datasets available for the Environmental Footprint (EF) method (version EF 3.1, currently in phase of releasing/validation[7]), as detailed in section 1.3. This choice allows a full consistency with the selected life cycle impact categories as described above.

Implementation

In the new version, Ecoreport tool is currently being revised to include new impact categories and additional technical information (as in Figure 1). A specific new spreadsheet is dedicated to the impact category selection. The spreadsheet has been revised to be flexible to expand/modify this list in a simple way, in case new relevant impact categories (or new additional information) would be identified for future revisions.

Details on the new 16 impact assessment methods are provided in the Technical reports for Life Cycle Impact Assessment, as developed for the EF methods[8]. Guidance on the interpretation of these different impact categories for the user of the Ecoreport tool will be provided separately (as part of subtask 1.c).

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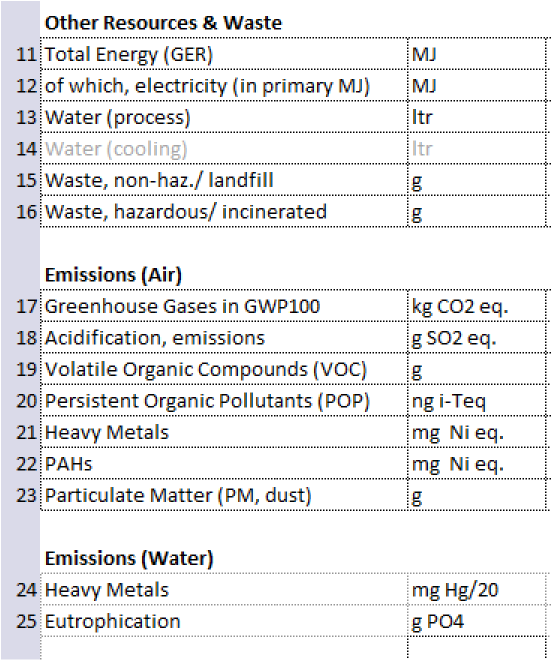
scope may need to be considered. These aspects shall be reported as additional technical information". […] "Technical parameters, such as the use of renewable versus non-renewable energy, the use of renewable versus non-renewable fuels, the use of secondary materials, the use of fresh water resources"

[7] https://eplca.jrc.ec.europa.eu/LCDN/contactListEF.xhtml

[8] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32021H2279

Figure 1: 1.a) Current impact categories in the Energy related Products (ErP) (as in the “RESULTS” spreadsheet); and 1.b) “Impact categories” spreadsheet with the new list of suggested Impact categories.

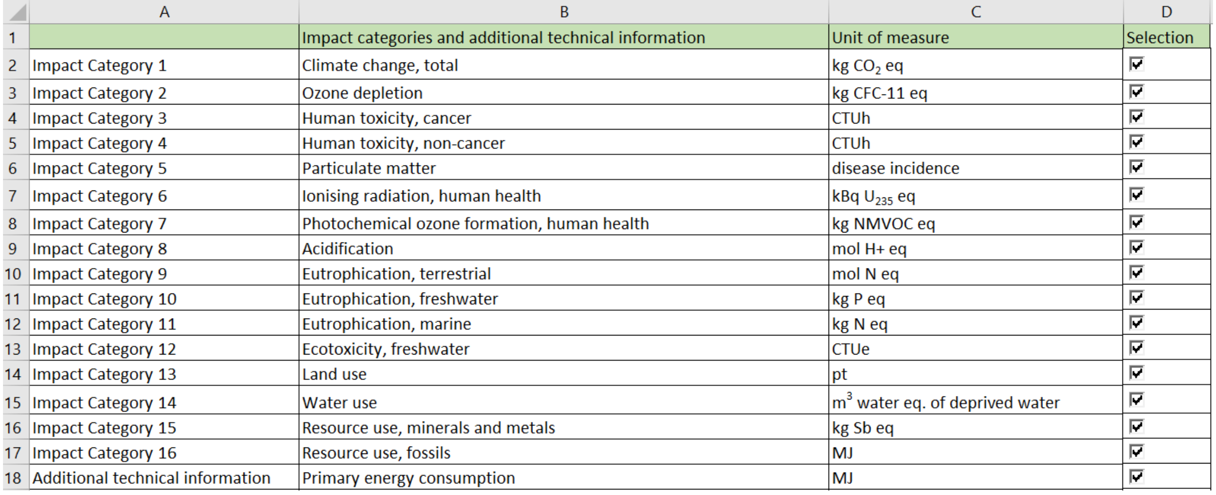
Figure 1.a: Impact categories in the Ecoreport tool (2013)



	Other Resources & Waste	
11	Total Energy (GER)	MJ
12	of which, electricity (in primary MJ)	MJ
13	Water (process)	ltr
14	Water (cooling)	ltr
15	Waste, non-haz./ landfill	g
16	Waste, hazardous/ incinerated	g
	Emissions (Air)	
17	Greenhouse Gases in GWP100	kg CO2 eq.
18	Acidification, emissions	g SO2 eq.
19	Volatile Organic Compounds (VOC)	g
20	Persistent Organic Pollutants (POP)	ng i-Teq
21	Heavy Metals	mg Ni eq.
22	PAHs	mg Ni eq.
23	Particulate Matter (PM, dust)	g
	Emissions (Water)	
24	Heavy Metals	mg Hg/20
25	Eutrophication	g PO4

Source: Ecoreport tool 2013, available at: https://single-market-economy.ec.europa.eu/industry/sustainability/sustainable-product-policy-ecodesign_en

Figure 1.b: list of new impact categories and additional information in the revised Ecoreport tool (2024)[9]



	A	B	C	D
1		Impact categories and additional technical information	Unit of measure	Selection
2	Impact Category 1	Climate change, total	kg CO$_2$ eq	☑
3	Impact Category 2	Ozone depletion	kg CFC-11 eq	☑
4	Impact Category 3	Human toxicity, cancer	CTUh	☑
5	Impact Category 4	Human toxicity, non-cancer	CTUh	☑
6	Impact Category 5	Particulate matter	disease incidence	☑
7	Impact Category 6	Ionising radiation, human health	kBq U$_{235}$ eq	☑
8	Impact Category 7	Photochemical ozone formation, human health	kg NMVOC eq	☑
9	Impact Category 8	Acidification	mol H+ eq	☑
10	Impact Category 9	Eutrophication, terrestrial	mol N eq	☑
11	Impact Category 10	Eutrophication, freshwater	kg P eq	☑
12	Impact Category 11	Eutrophication, marine	kg N eq	☑
13	Impact Category 12	Ecotoxicity, freshwater	CTUe	☑
14	Impact Category 13	Land use	pt	☑
15	Impact Category 14	Water use	m^3 water eq. of deprived water	☑
16	Impact Category 15	Resource use, minerals and metals	kg Sb eq	☑
17	Impact Category 16	Resource use, fossils	MJ	☑
18	Additional technical information	Primary energy consumption	MJ	☑

Source: JRC elaboration

The additional information concerning the “Primary Energy Consumption” is estimated as follows:

1. Primary energy factors for datasets on thermal energy and electricity from renewable sources and electricity mix are estimated according to the Energy Efficiency Directive 2018/2002.

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[9] Available at: https://single-market-economy.ec.europa.eu/industry/sustainability/sustainable-product-policy-ecodesign_en

2. For other datasets than those in bullet point “1”, the primary energy consumption would be assimilated to the **“Resource use, fossil”** consumption[10]. This information would be retrieved from the EF life cycle impact category.

Table 3 shows some examples of impact categories implemented in the Ecoreport tool, plus the additional information for the primary energy consumption.

Table 3: LCIA results of exemplary datasets of the revised Ecoreport tool. Some exemplary impact categories are highlighted in green, additional information on primary energy consumption is in yellow

	Life Cycle Impact or Information		
	EF method	EF method	Additional info
	Climate change	Resource use, fossil	Primary energy consumption
Datasets selected for the Ecoreport tool	kg CO_2 equivalent per reference unit	MJ per reference unit	MJ per reference unit
Datasets on Electricity production and thermal energy produced from renewable sources	**From EF3.1 LCIA results**	**From EF3.1 LCIA results**	**Primary Energy Factor (based on Energy Efficiency Directive) [MJ/kWh]**
Electricity mix (EF 3.1) - EU+EFTA+UK	0.42 kgCO2eq/kWh	7.29 MJ/kWh	2.1 x 3.60 = 7.56 MJ/kWh
Electricity from hydro power (EF 3.1) - EU+EFTA+UK	0.01 kgCO2eq/kWh	0.02 MJ/kWh	1 x 3.60 = 3.60 MJ/kWh
Electricity from photovoltaic (EF 3.1) - EU+EFTA+UK	0.04 kgCO2eq/kWh	0.64 MJ/kWh	1 x 3.60 = 3.60 MJ/ kWh
Electricity from wind power (EF 3.1) - EU+EFTA+UK	0.01 kgCO2eq/kWh	0.10 MJ/kWh	1 x 3.60 = 3.60 MJ/kWh
Electricity from nuclear (EF 3.1) – EU+EFTA+UK	0.006 kgCO2eq/kWh	10.09 MJ/kWh	3 x 3.60 = 10.80 MJ/kWh
Electricity from biomass (solid) (EF 3.1) - EU+EFTA+UK	0.04 kgCO2eq/kWh	0.45 MJ/kWh	1 x 3.60 = 3.60 MJ/kWh
Thermal energy from wood – (EF 3.1) - GLO	0.004 kgCO2eq/MJ	0.03 MJ/kWh	1 x 3.60 = 3.60 MJ/kWh
Thermal energy from biogas - (EF 3.1) – EU+EFTA+UK	0.03 kgCO2eq/MJ	0.11 MJ/MJ	1 x 3.60 = 3.60 MJ/kWh
Datasets on Thermal energy production from fossil fuels[11]	**From EF3.1 LCIA results**	**From EF3.1 LCIA results**	**Primary Energy consumption**
Thermal energy from natural gas (EF 3.1) – EU+EFTA+UK	0.07 kgCO2eq/MJ	1.13 MJ/MJ	1.13 MJ/MJ
Datasets on Material production and	**From EF3.1 LCIA**	**From EF3.1 LCIA**	**Primary Energy**

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[10] This applies to datasets for e.g. metals, plastics, consumables, etc. For these, it is not possible to define a primary energy factor (as done for datasets at bullet point 1), since the accounting of renewable energy in LCA datasets is generally conducted differently from the Energy Efficiency Directive 2018/2002.

[11] Few exemplary energy sources taken for illustrative purposes.

processes[12]	results	results	consumption
LLDPE granulates (EF 3.1) – EU+EFTA+UK	2.04 kgCO2/kg	73.98 MJ/kg	73.98 MJ/kg
Stainless steel hot rolled (EF 2.0)* - ROW	6.89 kgCO2/kg	75.58 MJ/kg	75.58 MJ/kg
Aluminium ingot mix (high purity) (EF 3.1) - EU+EFTA+UK	0.59 kgCO2/kg	11.64 MJ/kg	11.64 MJ/kg

Source: JRC elaboration

1.2 End of Life modelling (recycled content and recyclability at end of life) - (subtasks 1.d & 1.g)

Objectives

Revising the current approach to end-of-life in the Ecoreport tool, with the aim to achieve consistency of modelling for different materials and allowing the implementation of different assumptions about the recyclability of materials and/or use of secondary raw materials.

Status as in the current Ecoreport tool

The Ecoreport tool reports predefined End of Life (EoL) mass fraction to: re-use, recycling, recovery, incineration and landfill to calculate credits (see Figure 2). These mass fractions can be modified by the user for some materials (e.g. plastics and electronics), whereas these are fixed for metals.

Additional recyclability aspects can be taken into account by modifying recyclability assumptions (e.g. best, average worst cases) as a reduction/increased up to 10% on all impacts of the recycled mass: best/>avg/avg (base case)/<avg/worst (per materials category) with credit on recycled mass +10%/+5%/0/-5%/-10% (also for metals).

The possibility to calculate the recyclability benefit rate (RBR) was added in the latest version of the Ecoreport tool to compare different EoL scenarios. However, this RBR is currently applied to plastics only.

Moreover, the database of the Ecoreport tool is currently missing key data about recycled materials. Content of recycled materials (i.e. “recycled content”) appears to be also embodied (not fully transparently) into the Ecoreport tool datasets for certain materials (e.g. metals). Downcycling factors (to account for changes in quality of recycled materials) are also foreseen as inputs to the RBR calculation, however little detail has been provided so far for their calculation.

Overall, the current EoL modelling in the Ecoreport tool is affected by low transparency (in assumptions and datasets), and high risk of inconsistencies (e.g. about different modelling assumptions for different materials).

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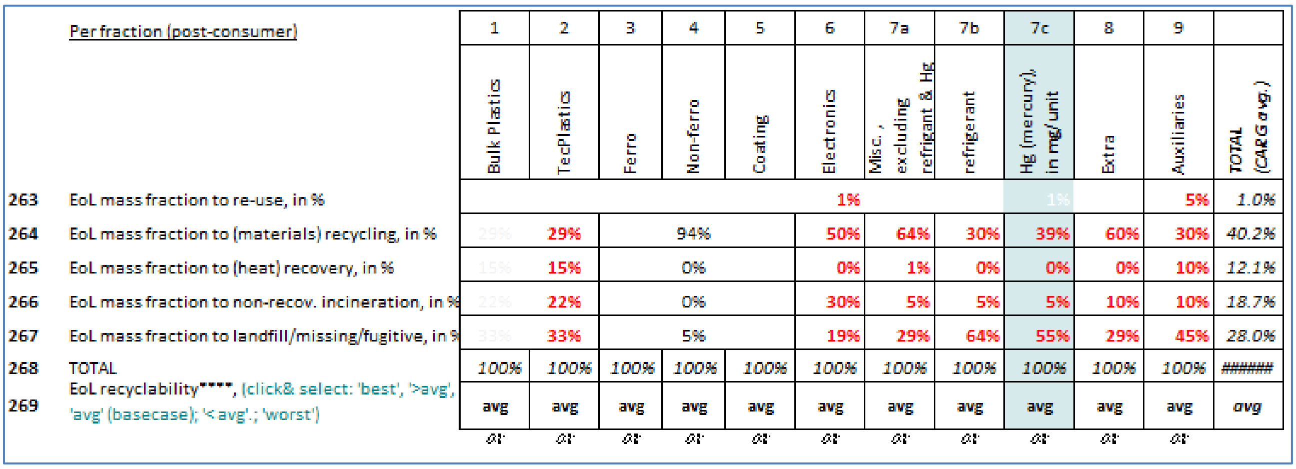
[12] Few exemplary materials taken for illustrative purposes.

Figure 2: Default assumptions in the Ecoreport tool (2013) for End of Life.



	Per fraction (post-consumer)	1	2	3	4	5	6	7a	7b	7c	8	9	
		Bulk Plastics	TecPlastics	Ferro	Non-ferro	Coating	Electronics	Misc., excluding refrigant & Hg	refrigerant	Hg (mercury), in mg/unit	Extra	Auxiliaries	TOTAL (CARG avg.)
263	EoL mass fraction to re-use, in %	1%								1%		5%	1.0%
264	EoL mass fraction to (materials) recycling, in %	29%	29%	94%			50%	64%	30%	39%	60%	30%	40.2%
265	EoL mass fraction to (heat) recovery, in %	15%	15%	0%			0%	1%	0%	0%	0%	10%	12.1%
266	EoL mass fraction to non-recov. incineration, in %	22%	22%	0%			30%	5%	5%	5%	10%	10%	18.7%
267	EoL mass fraction to landfill/missing/fugitive, in %	33%	33%	5%			19%	29%	64%	55%	29%	45%	28.0%
268	TOTAL	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	######
269	EoL recyclability****, (click& select: 'best', '>avg', 'avg' (basecase); '< avg'.; 'worst')	avg	avg	avg	avg	avg	avg	avg	avg	avg	avg	avg	avg

Source: Ecoreport tool 2013, available at: https://single-market-economy.ec.europa.eu/industry/sustainability/sustainable-product-policy-ecodesign_en

Rationale **and Action**

The EoL modelling has been updated according to the EF method by using the Circular Footprint Formula (CFF). This choice will achieve internal consistency within the Ecoreport tool (in line with updated datasets to be implemented), and potential consistency with external studies (e.g. results of EF studies developed by industries). Recyclability and recycled content will be modelled considering the CFF formula, as these parameters will be inputs for this formula.

A simplified version of the CFF is implemented in the Ecoreport tool in order to keep the EoL modelling easy and lean. Among the adopted simplifications, the contribution to the CFF related to the "energy recovery" and disposal in landfill will be not implemented in the Ecoreport tool, to simplify the modelling, and also considering their minor contribution to the life cycle impact of Energy related Products.

In this report the term "recyclability" refers to the general definition of "ability of waste product to be recycled, based on actual practises" based on the IEC/TR 62635 standard[13]. Also standard EN45555[14] states that the assessment of recyclability shall be based on the reference EoL treatment scenario which shall cover different criteria including technological representativeness such as state-of-the-art technologies[15].Whereas according to the EF method and definitions, the parameter used in the CFF is the so called "Recycling output rate R2" as defined by EC Recommendation (2021)[16]. According to the EF method, "an evaluation of the recyclability of the material shall be made before selecting the appropriate R2. The evaluation shall meet three criteria (as described by ISO 14021:2016, section 7.7.4 'Evaluation methodology'):

1. The collection, sorting and delivery systems to transfer the materials from the source to the recycling facility are conveniently available to a reasonable proportion of the purchasers, potential purchasers and users of the product;

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[13] International Electrotechnical Commission IEC/TR 62635:2012 "Guidelines for end-of-life information provided by manufacturers and recyclers and for recyclability rate calculation of electrical and electronic equipment" defines recyclability as "ability of waste product to be recycled, based on actual practises"

[14] EN 45555:2019: General methods for assessing the recyclability and recoverability of energy-related products

[15] "The reference EoL treatment scenario will include state-of-the-art technologies, meaning that the latest, most up-to-date methods for each technology are included, provided that they are already used by the industry, and economically viable in a current business setting" (EN 45555:2019)

[16] Recycling output rate – R2 is the proportion of the material in the product that will be recycled (or reused) in a subsequent system. R2 shall therefore take into account the inefficiencies in the collection and recycling (or reuse) processes. R2 shall be measured at the output of the recycling plant. For this analysis, reuse of a product as a whole is not addressed in the R2 parameter. Reuse of a product shall be considered when assessing the lifetime of the product (see Chapter 2 of this document)

2. The recycling facilities are available to accommodate the collected materials;
3. Evidence is available that the product for which recyclability is claimed is being collected and recycled.

Point 1 and 3 may be proven by recycling statistics (country specific) derived from industry associations or national bodies. Approximation to evidence at point 3 may be provided by applying for example the design for recyclability evaluation outlined in EN 13430 Material recycling (Annexes A and B) or other sector-specific recyclability guidelines if available."

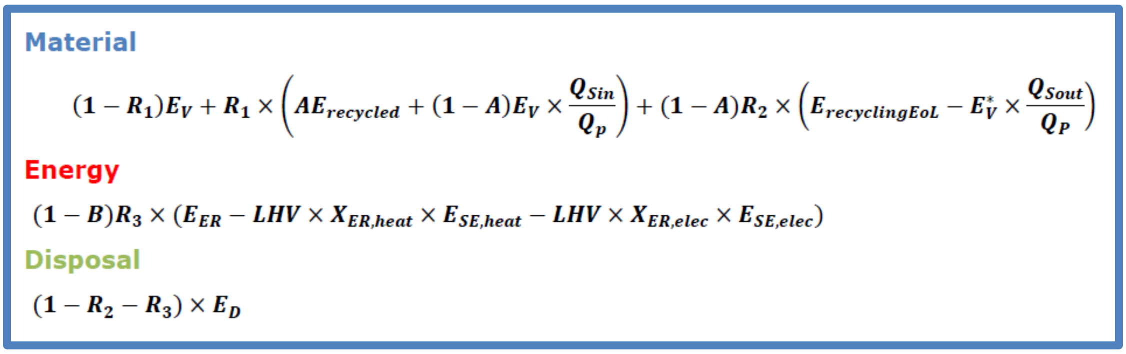
Therefore, R2 or recycling output rate is the term to use when referring to the CFF parameter.

In the proposed revision of the Ecoreport tool it is suggested to provide default values for recycled content/recycling output rate[17]. To estimate recyclability for specific products (or components) please refer to Task 2 (Dealing with material efficiency parameters).

Implementation

The CFF as developed within the EF methods is illustrated in Figure 3.

Figure 3: The Circular Footprint Formula implemented in the EF method. (European Commission 2021a)



Material

$$(1-R_1)E_V + R_1 \times \left(AE_{recycled} + (1-A)E_V \times \frac{Q_{Sin}}{Q_p}\right) + (1-A)R_2 \times \left(E_{recyclingEoL} - E_V^{*} \times \frac{Q_{Sout}}{Q_P}\right)$$

Energy

$$(1-B)R_3 \times (E_{ER} - LHV \times X_{ER,heat} \times E_{SE,heat} - LHV \times X_{ER,elec} \times E_{SE,elec})$$

Disposal

$$(1-R_2-R_3) \times E_D$$

Source: (European Commission 2021a)

The terms in use in the formula, as defined in the EF method, are:

R1 (recycled content): it is the proportion of material in the input to the production that has been recycled from a previous system

R2 (recycling output rate): it is the proportion of the material in the product that will be recycled (or reused) in a subsequent system. R2 shall therefore take into account the inefficiencies in the collection and recycling (or reuse) processes. R2 shall be measured at the output of the recycling plant.[18]

A (allocation factor) [19]: allocation factor of burdens and credits between supplier and user of recycled materials

Ev: specific emissions and resources consumed (per functional unit) arising from the acquisition and pre-processing of virgin material.

$E_{recycled}$: specific emissions and resources consumed (per functional unit) arising from the recycling process of the recycled (reused) material, including collection, sorting and transportation process

$E_{recycling\ EoL}$: specific emissions and resources consumed (per functional unit) arising from the recycling process at EoL, including collection, sorting and transportation process

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[17] Default values of recycled content R1 and recycling output rate R2 are provided by the EF method in the so called "Annex C" which is available at: http://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml

[18] For this analysis, reuse of a product as a whole is not addressed in the R2 parameter. Reuse of a product shall be considered when assessing the lifetime of the product (see Chapter 2 of this document)

[19] The "A" factor in the CFF allows to allocate impacts and/or benefits between the use of recycled materials as input (i.e. recycled content) and recycling at the end-of-life (i.e. recycling output rate).

Ev*: specific emissions and resources consumed (per functional unit) arising from the acquisition and pre-processing of virgin material assumed to be substituted by recyclable materials

Qs_{in}: quality of the ingoing secondary material, i.e. the quality of the recycled material at the point of substitution

Qs_{out}: quality of the outgoing secondary material, i.e. the quality of the recyclable material at the point of substitution

Qp: quality of the primary material, i.e. quality of the virgin material

B: allocation factor of energy recovery processes. It applies both to burdens and credits

R3: it is the proportion of the material in the product that is used for energy recovery at EoL

E_{ER}: specific emissions and resources consumed (per functional unit) arising from the energy recovery process (e.g. incineration with energy recovery, landfill with energy recovery, etc.).

$E_{SE,heat}$ and $E_{SE,elec}$: specific emissions and resources consumed (per functional unit) that would have arisen from the specific substituted energy source, heat and electricity respectively.

E_D: specific emissions and resources consumed (per functional unit) arising from disposal of waste material at the EoL of the analysed product, without energy recovery.

$X_{ER,heat}$ and $X_{ER,elec}$: the efficiency of the energy recovery process for both heat and electricity.

LHV: lower heating value of the material in the product that is used for energy recovery.

For the implementation in the Ecoreport tool, the following simplified version of the CFF (material part only) is proposed (eq. 1):

$$\boxed{(1-R_1)E_V + R_1 \times \left(AE_{recycled} + (1-A)E_V\right) + (1-A)R_2 \times \left(E_{recycled} - E_V{}^{*}\right)}$$

Equation 1

Some simplifications are introduced in the CFF to simplify the implementation of the formula in the excel file by using default values and to make data input easier for the user. The list of simplifications is as follows:

- $E_{recycling\ EoL}$: set equal to $E_{recycled}$.
- Ev*:
  - will be set by default equal to Ev.
  - For multi-material components such as electronics (e.g. populated printed wiring board) Ev* represents the impacts from acquisition and pre-processing of virgin materials which can be avoided thanks to the substitution of a fraction of recyclable materials from electronic scraps (mainly copper and precious metals as gold, palladium, platinum and silver). This fraction of copper and precious metals (material credit - k) is retrieved from the EF datasets of EoL of electronics. Ev* is calculated as the material credit of copper and precious metals multiplied by the impact values of the primary production of copper and precious metals Ev. $Ev^*_{electronics}$ is automatically calculated for dataset in the Ecoreport tool as:
  - $E^*_{v_{electronics}} = \sum_{m=Cu,Ag,Au,Pd,Pt} k_m * E_{v_m}$

  - If $E_{recycled}$ and E_v* are not available, a percentage of the Ev will replace the factor ($E_{recycled}$ – E_v*) for a simplified calculation[20].

- Qs_{in}/Qp and Qs_{out}/Qp are set equal to 1 to simplify the overall formula and inputs/checks required by the users of the tool. The available default data are still quite limited, and all generally equal (or close to 1).

As already mentioned, the contribution to the CFF related to the "energy recovery" and disposal in landfill will not be implemented in the Ecoreport tool, to keep the EoL modelling easy and lean, and also considering their minor contribution to the life cycle impact of Energy related Products. Therefore E_{ER}, $E_{SE,heat}$ and $E_{SE,elec}$ for the energy part of the CFF and E_D for the disposal part of the CFF are set equal to zero.

Datasets and default values are assigned to the various parameters (i.e. values of the recycled content R1, recycling output rate R2 and allocation factor A) for the various materials, as follows:

R1 (recycled content): default value from the EF method[21]. Possibility for the user to change according to his/her knowledge

R2 (recycling output rate): default value from EF method[22]. Possibility for the user to change according to his/her knowledge

A (allocation factor) [23]: default value provided by the Ecoreport tool and based on the EF method to allocate credit related to materials recycled[24]. The user shall enter this value only if the material is included by the user as a new material, i.e. it is not part of the Ecoreport tool database. The use of default values provided by the Ecoreport tool are highly recommended. Changes in the default values of parameter "A" should be in general be avoided since these could produce distorted results. Any modifications and actions which deviate from default settings need to be thoroughly reported in the results. The value of "A" needs to be compliant with the rules of the EF method[25]. In case no detailed information is available for the user, a default value of 0.5 shall be used.

Ev* (virgin material dataset): EF3.1 dataset automatically taken from the Ecoreport tool.

$E_{recycled}$: EF3.1 dataset of recycling processes of the recycled material.

The CFF formula is implemented in the spreadsheet "Calculations sheet" in the Ecoreport tool and split in three components to differentiate: impacts associated to primary and secondary materials input (equation 2); impacts associated to recycling processes of materials and components (equation 3) and credits obtained for avoided primary materials (equation 4).

$$(1 - R_1)E_V + R_1 \times \left(AE_{recycled} + (1 - A)E_V\right)$$

Equation 2

$$(1 - A)R_2 \times E_{recycled}$$

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[20] In such case, the credit of material recycled from the component is assumed as a share of the impacts of the component's production.

[21] Default values of R1 for CFF provided by the EF method in the so called "Annex C" which is available at: http://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml

[22] Default values of R2 provided by the EF method in the so called "Annex C" which is available at: http://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml

[23] The "A" factor in the CFF allows to allocate impacts and/or benefits between the use of recycled materials as input, i.e. recycled content (user of recycled materials) and recycling at the end-of-life, i.e. recycling output rate (supplier of recycled materials). The use of this factor allows to avoid double accounting of environmental credits due to material recycling.

[24] Default values of A for CFF provided by the EF method in the so called "Annex C" which is available at: http://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml

[25] Please refer to the section 4.4.8.2 "The A factor" of the EF method, available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32021H2279

Equation 3

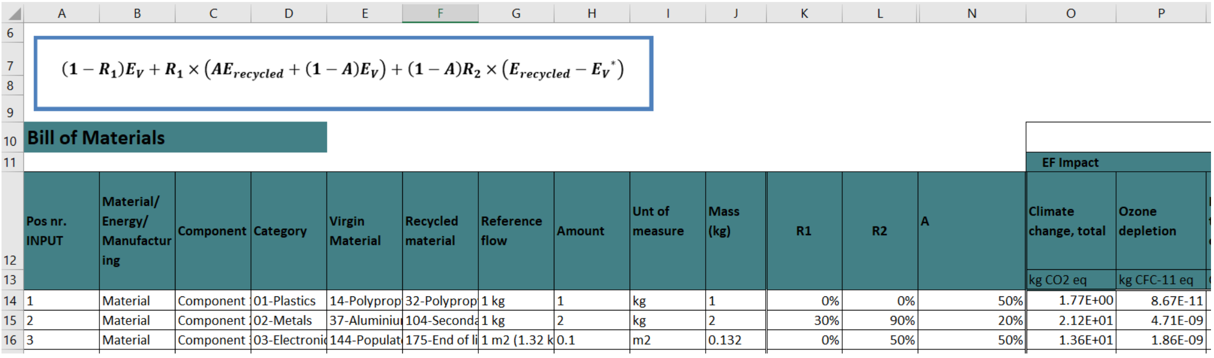
$$-(1-A)R_2 \times E_V^*$$

Equation 4

The three components are calculated separately in the Ecoreport tool and reported in the “Results” per impact categories (see Figure 11). The results calculated by 1) will represent the impacts for LC phases in which materials and components are accounted for, namely: raw materials (bill of material), manufacturing, packaging, use phase and maintenance and repair. This approach allows to show the contribution of impacts and benefits from recyclability as a separate phase (EoL) in the tool by keeping the current Ecoreport tool format.

Figure 4 is showing how the CFF is implemented in a new spreadsheet of the Ecoreport tool. Furthermore, in the spreadsheet “Inputs” it is possible for the user to adjust or change these values according to the user’s knowledge (see Figure 5). Guidance on how the user could modify parameters/assumptions for the modelling of EoL (based on better estimations for the product in study) will be provided separately (as part of subtask 1.c)[26].

Figure 4: “Calculations sheet” spreadsheet in the Ecoreport tool (2024). The CFF is implemented in this spreadsheet. Default R1, R2 and A are taken from the sheet “CFF parameters_Annex C”, while if the user inserted the values this is automatically updated and reported in columns I and J. Values shown in the table are illustrative.



$$(1-R_1)E_V + R_1 \times \left(AE_{recycled} + (1-A)E_V\right) + (1-A)R_2 \times \left(E_{recycled} - E_V^*\right)$$

Bill of Materials

Pos nr. INPUT	Material/ Energy/ Manufacturing	Component	Category	Virgin Material	Recycled material	Reference flow	Amount	Unt of measure	Mass (kg)	R1	R2	A	EF Impact Climate change, total kg CO2 eq	Ozone depletion kg CFC-11 eq
1	Material	Component	01-Plastics	14-Polyprop	32-Polyprop	1 kg	1	kg	1	0%	0%	50%	1.77E+00	8.67E-11
2	Material	Component	02-Metals	37-Aluminiu	104-Seconda	1 kg	2	kg	2	30%	90%	20%	2.12E+01	4.71E-09
3	Material	Component	03-Electroni	144-Populat	175-End of li	1 m2 (1.32 k	0.1	m2	0.132	0%	50%	50%	1.36E+01	1.86E-09

Source: JRC elaboration

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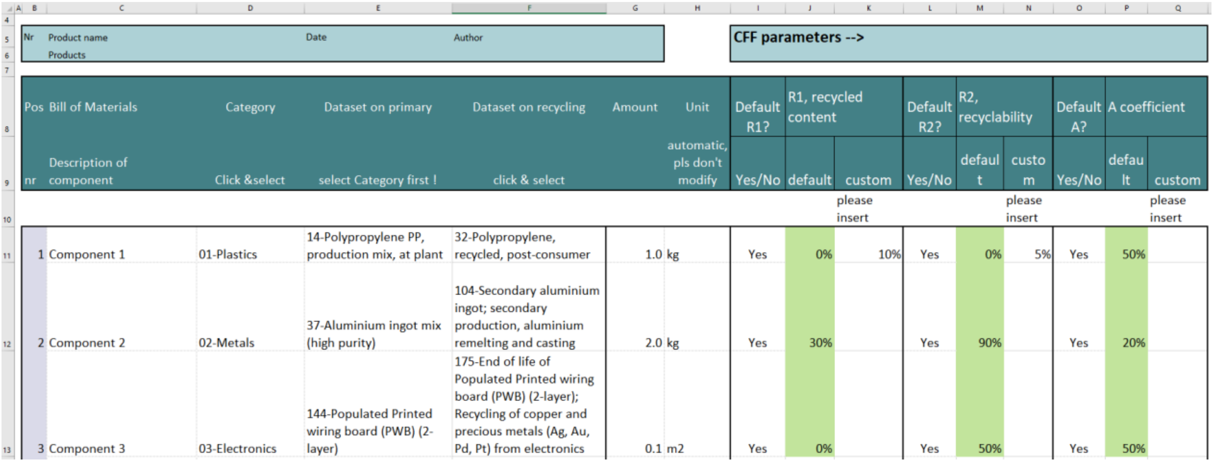
[26] Additional guidance on how potentially setting requirements on such aspects will be investigated as part of Task 2 of this project.

Figure 5: Example of introducing new inputs for the Bill of materials (“Inputs” spreadsheet in the Ecoreport tool (2024)). On the right-side there is the section for the CFF implementation. Default values are provided. User can modify the values, if relevant.



Nr Product name Date Author
Products

CFF parameters -->

Pos	Bill of Materials	Category	Dataset on primary	Dataset on recycling	Amount	Unit	Default R1?	R1, recycled content		Default R2?	R2, recyclability		Default A?	A coefficient	
nr	Description of component	Click &select	select Category first !	click & select		automatic, pls don't modify	Yes/No	default	custom	Yes/No	default	custom	Yes/No	default	custom
									please insert			please insert			please insert
1	Component 1	01-Plastics	14-Polypropylene PP, production mix, at plant	32-Polypropylene, recycled, post-consumer	1.0	kg	Yes	0%	10%	Yes	0%	5%	Yes	50%	
2	Component 2	02-Metals	37-Aluminium ingot mix (high purity)	104-Secondary aluminium ingot; secondary production, aluminium remelting and casting	2.0	kg	Yes	30%		Yes	90%		Yes	20%	
3	Component 3	03-Electronics	144-Populated Printed wiring board (PWB) (2-layer)	175-End of life of Populated Printed wiring board (PWB) (2-layer); Recycling of copper and precious metals (Ag, Au, Pd, Pt) from electronics	0.1	m2	Yes	0%		Yes	50%		Yes	50%	

Source: JRC elaboration

When a new dataset is inserted in the database by the user (description in section 1.3) the CFF parameters are set by default as R1=not available R2=not available and A=0.5. The user shall enter the values in the boxes dedicated to the CFF parameters in the “Input” spreadsheets when selecting the dataset. Detailed guidance on how to insert values for new datasets is provided as part of subtask 1.c.

1.3 Datasets and further improvements (subtask 1.a & 1.b)

Objectives

Update the underlying datasets of the Ecoreport tool and include additional datasets on new materials also considering the possibility to provide regular updates in future. Both the underlying and additional datasets should be of an appropriate degree of complexity and refinement, should be related to typical Bill of Materials of products under the scope of the EcoDesign Directive and should be representative for the "average" EU context. Information on the quality (e.g. time, technological and geographical representativeness) of the datasets should be available. Data format compatibility between the datasets and the impact categories shall be taken into account.

Further improvements need to be implemented to use the EF3.1 datasets and required parameters. It is important to increase transparency and granularity level of the assessment in order to put emphasis on life cycle stages which can be more relevant for a specific product group. The "input" spreadsheet needs to be revised.

Status as in the current Ecoreport tool

Already when the Ecoreport tool was developed, authors identified some difficulties and limitations in using life cycle inventory data for the Ecoreport tool database. In particular authors stated that "there is a wide discrepancy between emission data for one material or process between the various database sources. Several initiatives are underway to deal with this (e.g. SETAC/UNEP Life Cycle Initiative, European Platform on LCA by DG JRC-IES), but no homogenous average EU database exists. [...] Documentation regarding the origin of emission data and their validity (for which region? for which process? why are they different from the rest?) is often not clear from the tool alone and would require extensive additional research to explain the differences [...]. Public availability of data is limited" (VHK 2005). Some of these problems have been tackled by using a combination of different data from various sources, and modelled by Ecoreport tool's authors to fit for the purpose. However, the majority of datasets are now outdated (mainly referring to data from early 2000s). Moreover, few details are available on the exact source for each dataset[27] and what further elaborations were performed[28]. Those aspects (i.e. lack of detail on the data references and modelling) make it not possible to update the database following the same approach as in the original Ecoreport tool.

In addition, based on the outcomes of previous preparatory studies, the database is lacking several relevant datasets (especially those related to electronics). Finally, the current format of datasets in the Ecoreport tool is not aligned to prominent literature on inventory data for LCA (especially to what concerns the impact assessment results), which makes particularly difficult the insertion of new datasets.

In the current Ecoreport tool, the manufacturing/assembly processes are modelled based on predefined assumptions, which are not modifiable by the user and it not possible to include datasets on specific

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[27] It is generally stated that "Sources for emission data are amongst others: APME (plastics), AKZO (aramid fibres), IISI, Eurofer (St), IPAI, Aluminium Institute (Al), ETH-1996 (preliminary data on Cu pending Eurocopper input), The Nickel Institute (Ni), IPPC BREF on VOCs (Cu filaments, pre-coat, powder coat), The European Dioxin Inventory (secondary metals, solids combustion), Frauenhofer Institute and SemaTech 2002 (ICs), IPPC BREFs on Paper, Glass (misc.), NTM (transport), ANEC, Öko-institut GEMIS 4.2 (Fossil fuel heat), EPER 2001, Eurelectric (electricity), IPPC BREF on Waste Incineration (disposal), Ecolabel-studies (dishwasher detergents, paper/cardboard, CRT), USGS and US DoE EER (mining), US EPA (some Hg emissions), SAVE studies (Heating & hot water appliances), Lithuanian Cleaner Production programme (plating) and individual manufacturer's environmental reports, like AT&S (PWBs). We are especially grateful for the personal contributions/reviews by AMD (ICs), Sharp Corp. Japan (LCD Factory) and Philips (CRT). Data were checked against public VHK studies in the past (downloads from www.vhk.nl), LCI-databases such as EcoInvent in SIMAPRO 6 and a host of other literature. The largest part of the emission data refers to 2000-2005. For the electronics sector, primarily more recent (2003-2004) information was used, because of the sector-dynamics in pollution abatement" (VHK 2005). Same statement is reported in 2011 MEErP reports (https://ec.europa.eu/docsroom/documents/26526).

[28] Both MEEuP (VHK 2005) and MEErP (VHK, 2011) guidance documents provide a description of each entry line for data in the database. However, this information is no sufficient to fully reproduce and/or update the dataset as currently displayed.

manufacturing processes by the user. For example, it is not possible to link manufacturing/assembly processes to the use of additional materials[29] or energy sources.

It is not clear if/ how packaging is currently modelled in the Ecoreport tool (possibly, packaging materials can be inserted as additional input into the Bill of Material (BoM)).

Distribution is based on the volume of the package. It is not possible to distinguish different transport means and/or insert the transport distances.

The impact of Maintenance and Repair is based on the assumption that spare parts are 1% of the materials included in the Bill of Materials. The percentage is fixed and it is not possible to be adjusted to specific repair scenarios[30].

Rationale and Action

It is proposed to update the database in the Ecoreport tool by replacing all the previous datasets with EF 3.1 datasets[31] developed for the EF studies. These datasets cover virgin and recycled materials (as e.g. to be used in the CFF), manufacturing processes and thermal and energy consumption. This approach guarantees consistency and robustness across data (since all data have been developed according to same rules), and high quality and representativeness (all data are updated and representative of the recent EU context). This choice is also aligned to the strategy proposed for the update of impact assessment methods (i.e. alignment with EF impact categories). It also guarantees some interoperability with LCA software, in case additional datasets would need to be inserted.

The datasets selected for the Ecoreport tool are chosen among the most representative for the “average” EU context. In case of materials/components mainly produced in third countries, a global average is generally selected. The location for each dataset is reported in table A.1 in the Annex I of the Ecoreport manual. For example, for products produced outside the EU, additional datasets can be introduced by the user in a dedicated spreadsheet “New datasets_user”.

The proposed update of the Ecoreport tool is combined with an extension of the database to include additional datasets on plastics, metals and electronics[32].

These datasets can also be used to improve the granularity of manufacturing, packaging, transport, use and maintenance stages compared to the current Ecoreport tool. In fact, inputs for Packaging, Distribution and Maintenance&Repair can be modelled separately and consistently, and then the results are presented separately for each stage. For example, it will be possible to add energy and materials consumed during manufacturing/assembly or repair processes (inputs to be selected among data in the general database) to better model the impacts of these stages (and provided separately from impacts in the Raw materials production stage). For the Use phase the same format of the current Ecoreport tool is kept, but allowing the possibility to select data from the general database (among those as in Task 1.a and 1.b) or even additional datasets introduced by the user. The user might also introduce direct emissions occurring during the manufacturing/assembly and the use phase (if this information would be available and relevant). A dedicated line is included in the “Input” spreadsheet in case the user would need to add a new dataset in the “New dataset_user” spreadsheet for the category “Direct emission”. Additional guidance for the user of the Ecoreport tool on how to insert “direct emissions” is provided separately (as part of subtask 1.c).

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[29] Consumption of special materials during the manufacturing could be partially taken into account, by adding those materials to the “Bill of Materials” lines. However, it would be not possible to separate the contribution of these materials compared to materials in use in the product.

[30] As above for the manufacturing, it is not possible to compute for additional components necessary for the repair. These could be introduced in the initial “Bill of Materials”, but it would be not possible to differentiate them from the materials in use in the product.

[31] Datasets in use to develop EF studies, and based on the format “EF reference package 3.1” (https://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml). In the Ecoreport tool database, only a portion of the EF dataset is displayed, in particular, the series of the 16 impact category values (according to the impact categories as in the EF- see subtask 1.a in section 1.1).

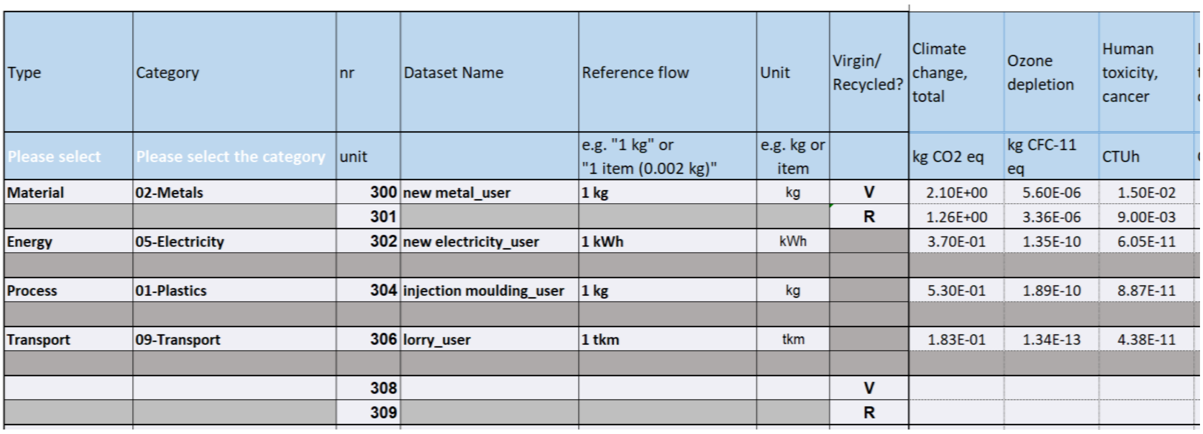
[32] The proposed extension of the database tried also to reflects some data needs, as identified in previous preparatory studies.

Implementation

A new spreadsheet in the Ecoreport tool has been developed to contain the relevant parts (mainly Life Cycle Impact Assessment results by impact category and additional technical information) of the selected EF 3.1 datasets ("Ecoreport tool_database" spreadsheet in the excel file).

The new spreadsheet "New datasets_user" (see Figure 6) has been developed for users that want to insert additional datasets, currently not included in the database. The additional datasets should meet the International reference Life Cycle Data System (ILCD) entry-level requirements[33]. These requirements were established to guarantee a minimum level of documentation, methodological consistency among datasets, and coherence in terms of format and nomenclature, and with useful information on data quality. This spreadsheet replaces the former spreadsheet "Extra materials". For each material or component, both virgin and the correspondent recycling or recycled material dataset need to be included (only if recycling is technically feasible at state of the art). The user can also include datasets on electricity, thermal energy and transport. These new datasets added by the users will be automatically stored in the "Ecoreport tool_database". The Ecoreport tool will match each dataset on virgin material/component to the correspondent datasets on recycled material/component. The mapping of datasets is reported in the Ecoreport tool within the spreadsheet "Lists" (the list of materials is also reported in Annex I).

Figure 6: "New Datasets_user" spreadsheet in the Ecoreport tool (2024). The user can include new datasets by selecting type, category, name, reference flow, unit of measure and impact assessment values of the dataset. Values shown in the table are fictitious



Type	Category	nr	Dataset Name	Reference flow	Unit	Virgin/ Recycled?	Climate change, total	Ozone depletion	Human toxicity, cancer
Please select	Please select the category	unit		e.g. "1 kg" or "1 item (0.002 kg)"	e.g. kg or item		kg CO2 eq	kg CFC-11 eq	CTUh
Material	**02-Metals**	**300**	**new metal_user**	**1 kg**	kg	**V**	2.10E+00	5.60E-06	1.50E-02
		301				**R**	1.26E+00	3.36E-06	9.00E-03
Energy	**05-Electricity**	**302**	**new electricity_user**	**1 kWh**	kWh		3.70E-01	1.35E-10	6.05E-11
Process	**01-Plastics**	**304**	**injection moulding_user**	**1 kg**	kg		5.30E-01	1.89E-10	8.87E-11
Transport	**09-Transport**	**306**	**lorry_user**	**1 tkm**	tkm		1.83E-01	1.34E-13	4.38E-11
		308				**V**			
		309				**R**			

Source: JRC elaboration

The introduction of datasets on processes and materials and energy by the user in the input spreadsheet for the different phases is implemented in the Ecoreport tool as follows:

Manufacturing/Assembly: User can insert manufacturing and assembly processes. Alternatively, it is possible to include energy, processes and materials consumption during manufacturing (e.g. materials ending in scraps; ancillary materials, etc.). The impact of these materials will be calculated according to the CFF as implemented in the Bill of Material (BoM) input table. There is also the possibility to include direct emission occurring during the manufacturing/assembly phase.

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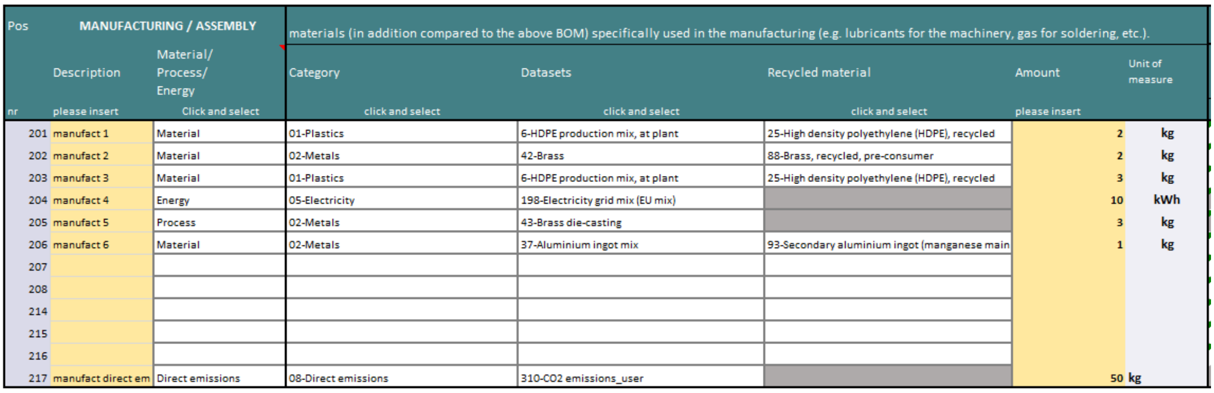
[33] International Reference Life Cycle Data System (ILCD) Data Network Compliance rules and entry-level requirements, V1.1, doi:10.2788/80302, https://eplca.jrc.ec.europa.eu/uploads/ILCD-Data-Network-Compliance-Entry-level-Version1.1-Jan2012.pdf

Figure 7: “Input” spreadsheet; Manufacturing and Assembly phase Input box as in the Ecoreport tool (2024)

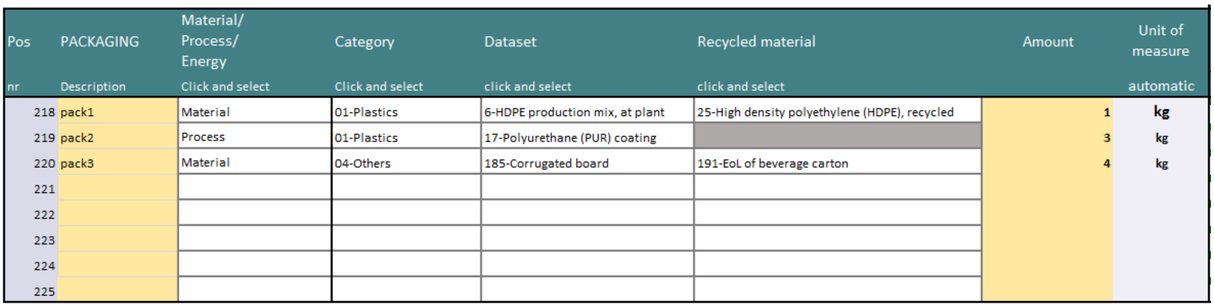


Pos	MANUFACTURING / ASSEMBLY		materials (in addition compared to the above BOM) specifically used in the manufacturing (e.g. lubricants for the machinery, gas for soldering, etc.).				
	Description	Material/ Process/ Energy	Category	Datasets	Recycled material	Amount	Unit of measure
nr	please insert	Click and select	click and select	click and select	click and select	please insert	
201	manufact 1	Material	01-Plastics	6-HDPE production mix, at plant	25-High density polyethylene (HDPE), recycled	2	kg
202	manufact 2	Material	02-Metals	42-Brass	88-Brass, recycled, pre-consumer	2	kg
203	manufact 3	Material	01-Plastics	6-HDPE production mix, at plant	25-High density polyethylene (HDPE), recycled	3	kg
204	manufact 4	Energy	05-Electricity	198-Electricity grid mix (EU mix)		10	kWh
205	manufact 5	Process	02-Metals	43-Brass die-casting		3	kg
206	manufact 6	Material	02-Metals	37-Aluminium ingot mix	93-Secondary aluminium ingot (manganese main	1	kg
207							
208							
214							
215							
216							
217	manufact direct em	Direct emissions	08-Direct emissions	310-CO2 emissions_user		50	kg

Source: JRC elaboration

Packaging: user can insert, if relevant, energy, processes and materials consumption used for packaging. The impact of these materials will be calculated taking into account also their EoL (according to the CFF as implemented for the Bill of Material (BoM) input table).

Figure 8: “Input” spreadsheet; Packaging phase input box in the Ecoreport tool (2024)

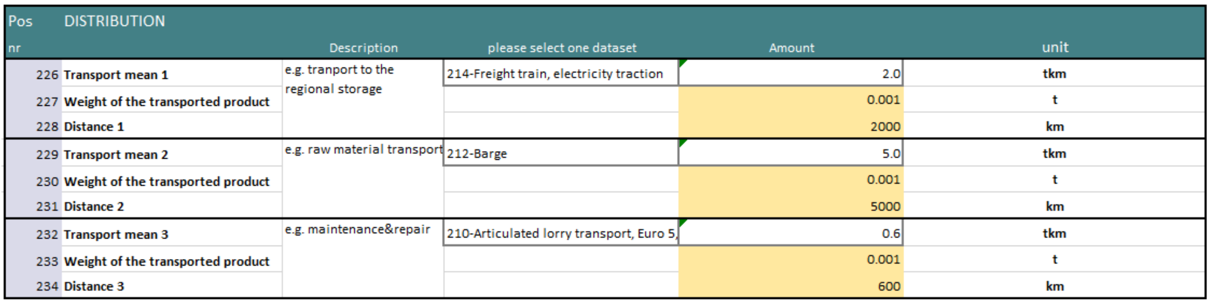


Pos	PACKAGING	Material/ Process/ Energy	Category	Dataset	Recycled material	Amount	Unit of measure
nr	Description	Click and select	Click and select	click and select	click and select		automatic
218	pack1	Material	01-Plastics	6-HDPE production mix, at plant	25-High density polyethylene (HDPE), recycled	1	kg
219	pack2	Process	01-Plastics	17-Polyurethane (PUR) coating		3	kg
220	pack3	Material	04-Others	185-Corrugated board	191-EoL of beverage carton	4	kg
221							
222							
223							
224							
225							

Source: JRC elaboration

Distribution: This input box covers all the distribution phases occurring over the life cycle. User may select a transport mean from a drop-down menu and enter the weight of the transported product and distance (yellow cells).

Figure 9: “Input” spreadsheet; Distribution phase input box (selected datasets of transport mean and figures for weight and distance are examples) in the Ecoreport tool (2024)



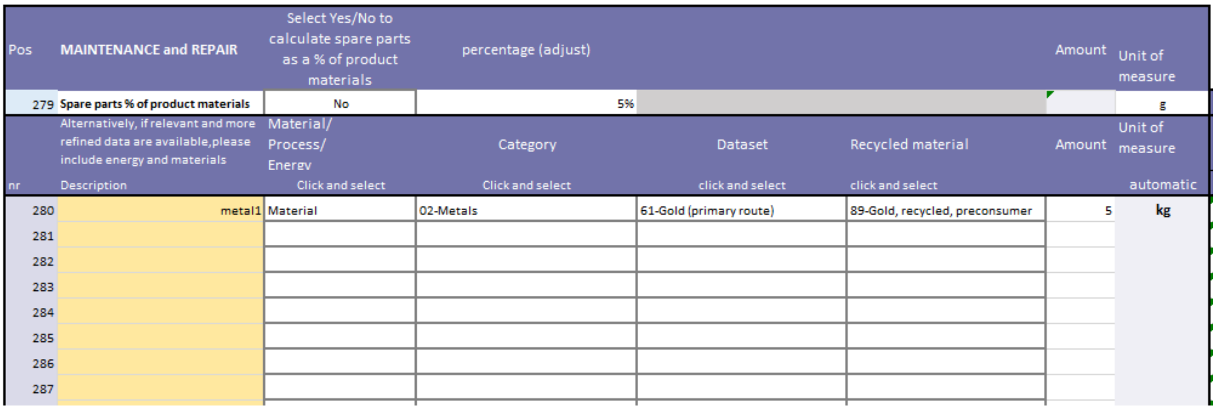
Pos	DISTRIBUTION				
nr		Description	please select one dataset	Amount	unit
226	Transport mean 1	e.g. tranport to the regional storage	214-Freight train, electricity traction	2.0	tkm
227	Weight of the transported product			0.001	t
228	Distance 1			2000	km
229	Transport mean 2	e.g. raw material transport	212-Barge	5.0	tkm
230	Weight of the transported product			0.001	t
231	Distance 2			5000	km
232	Transport mean 3	e.g. maintenance&repair	210-Articulated lorry transport, Euro 5,	0.6	tkm
233	Weight of the transported product			0.001	t
234	Distance 3			600	km

Source: JRC elaboration

Use phase: Current Ecoreport tool format is kept (with few modifications to facilitate the access to data in the database) and possibility to include other impacts caused by consumables (excluding spare parts) and direct emission occurring during the use. The impact of the consumables will be calculated considering their EoL (according to the CFF). Maintenance and repair are assessed separately (see below).

Maintenance & Repair: In the revised Ecoreport tool, the user will have the opportunity of accounting for impacts of this stage in a simplified way (e.g. as a set percentage of the impacts of the materials used in the Bill of Material (BoM), potentially adjustable compared to the fixed share as in the current Ecoreport tool version). Alternatively, if relevant and more refined data are available, the user could include details of energy, processes and materials consumed during this stage.

Figure 10: “Input” spreadsheet; Maintenance and repair input box in the Ecoreport tool (2024)

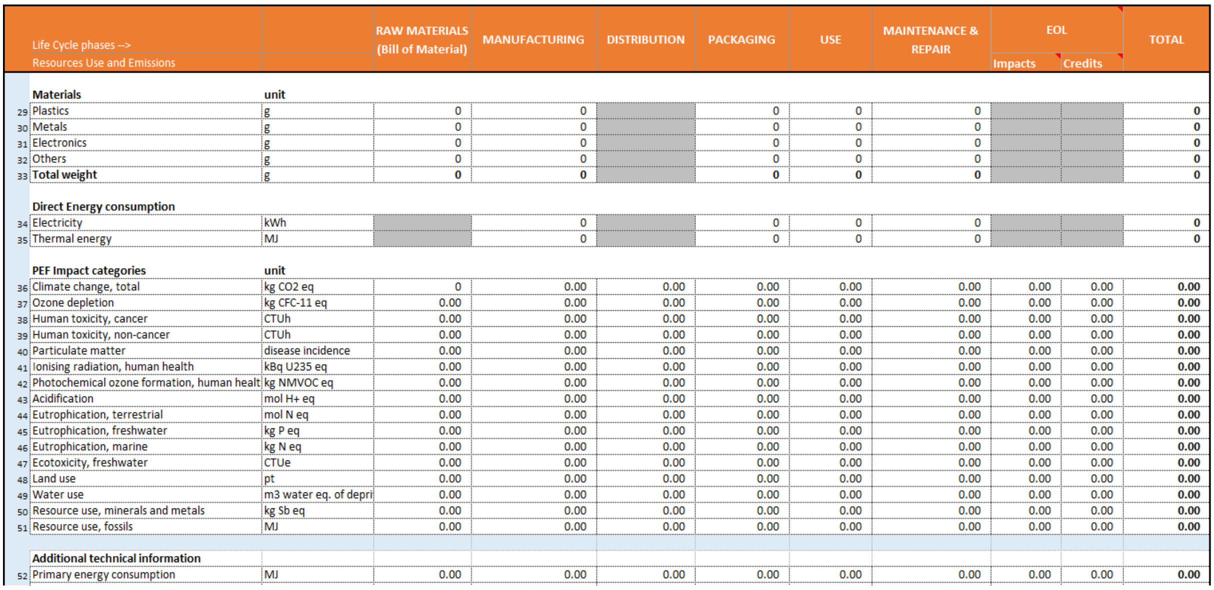


Pos	MAINTENANCE and REPAIR	Select Yes/No to calculate spare parts as a % of product materials	percentage (adjust)			Amount	Unit of measure
279	**Spare parts % of product materials**	No	5%				g
nr	Alternatively, if relevant and more refined data are available,please include energy and materials Description	Material/ Process/ Energy Click and select	Category Click and select	Dataset click and select	Recycled material click and select	Amount	Unit of measure automatic
280	metal1	Material	02-Metals	61-Gold (primary route)	89-Gold, recycled, preconsumer	5	**kg**
281							
282							
283							
284							
285							
286							
287							

Source: JRC elaboration

Results: Figure 11 presents how results for the different stages will be presented. Compared to the previous version of the tool, in addition to the material consumption, also direct energy consumption (electricity and thermal energy is reported among the results.

Figure 11: “Results” spreadsheet, Resources use and emissions are reported by phase in the Ecoreport tool (2024)



	Life Cycle phases --> Resources Use and Emissions		RAW MATERIALS (Bill of Material)	MANUFACTURING	DISTRIBUTION	PACKAGING	USE	MAINTENANCE & REPAIR	EOL		TOTAL
									Impacts	Credits	
	Materials	**unit**									
29	Plastics	g	0	0		0	0	0			**0**
30	Metals	g	0	0		0	0	0			**0**
31	Electronics	g	0	0		0	0	0			**0**
32	Others	g	0	0		0	0	0			**0**
33	**Total weight**	g	**0**	**0**		**0**	**0**	**0**			**0**
	Direct Energy consumption										
34	Electricity	kWh		0		0	0	0			**0**
35	Thermal energy	MJ		0		0	0	0			**0**
	PEF Impact categories	**unit**									
36	Climate change, total	kg CO2 eq	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
37	Ozone depletion	kg CFC-11 eq	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
38	Human toxicity, cancer	CTUh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
39	Human toxicity, non-cancer	CTUh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
40	Particulate matter	disease incidence	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
41	Ionising radiation, human health	kBq U235 eq	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
42	Photochemical ozone formation, human healt	kg NMVOC eq	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
43	Acidification	mol H+ eq	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
44	Eutrophication, terrestrial	mol N eq	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
45	Eutrophication, freshwater	kg P eq	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
46	Eutrophication, marine	kg N eq	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
47	Ecotoxicity, freshwater	CTUe	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
48	Land use	pt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
49	Water use	m3 water eq. of depri	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
50	Resource use, minerals and metals	kg Sb eq	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
51	Resource use, fossils	MJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
	Additional technical information										
52	Primary energy consumption	MJ	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**

Source: JRC elaboration

1.4 Material efficiency (subtask 1.d)

Objective

Making the EcoReport tool an effective instrument for the identification of environmental hotspots linked to material efficiency aspects.

Status as in the current Ecoreport tool

Only a partial focus was dedicated to the modelling of material efficiency aspects in the original Ecoreport tool (up to the 2011 version). For this reason, a dedicated study was conducted in 2013 to amend the methodology and the Ecoreport tool (Bio IS, 2013[34]). The study produced additional guidance on how material efficiency aspects could be modelled in the Ecoreport tool and relevant implementing measures could be derived. In this case, the Ecoreport tool was partially revised (introducing e.g. the above mentioned Recyclability benefit rate for plastics). However, tackling material efficiency aspects systematically would have required a substantial revision of the Ecoreport tool, which was not in the scope of the 2013 study.

Rationale and Action

Material efficiency aspects are modelled consistently in various parts of the revised Ecoreport tool.

Durability is modelled through expected lifetime estimation as part of Task 2. In order to do that, the modelling relies largely on the methods outlined in the EN 4555X family of standards (see chapter 2). The results will link back to the Ecoreport tool. In the proposed modelling, an initial lifetime is estimated based on the specific characteristics of the product. This would be expected until the occurrence of the first limiting event. In the terminology of standard EN 45552 this is called reliability. Then, lifetime extensions due to reparability and upgradability are estimated. Finally, all is put together and a final value for durability (or total expected lifetime) is estimated. Detailed calculations are laid out in the description of task 2 and are based on a discrete steps scoring system that allows to link design options to expected durability. The specific values for the scoring levels will be calculated using a Weibull longevity model that is described in detail in Task 2. Afterward, impacts are normalised on a per year basis using the estimated durability.

On top of its contribution to durability, reparability can be also modelled as a separate section of the Ecoreport tool (see section 2.3), allowing the user to tailor the model according to the energy and material inputs needed in this stage.

Other critical aspects of material efficiency, namely recycling output rate and recycled content are modelled as parameters of the newly introduced CFF.

Implementation

Recycled content and recycling output rate are modelled through the CFF. Default parameters are defined in the database for each material, based on average values in use in the EF (see section 1.2 for details), and displayed when materials are introduced in the Bill of Material (BoM). Still, if relevant and if more specific information is available for the product in study, the user has the possibility to modify these input values. Guidance on both how to better estimate input data for recyclability and how to potentially setting requirements on such aspects will be part of the analysis in Task2 and will be based on a discrete steps scoring system very similar to the one used to model durability.

1.5 Modelling of annual sales (subtask 1.f)

Objective

Implementation of a finer modelling of annual sales, including the possibility to calculate or insert a dynamic stock model in the tool.

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[34] https://op.europa.eu/en/publication-detail/-/publication/7c3d958d-42cc-4af7-985c-2a3347b66fa8

Status as in the current Ecoreport tool

In the current version of the EcoReport tool the sales figures are constant from year to year.

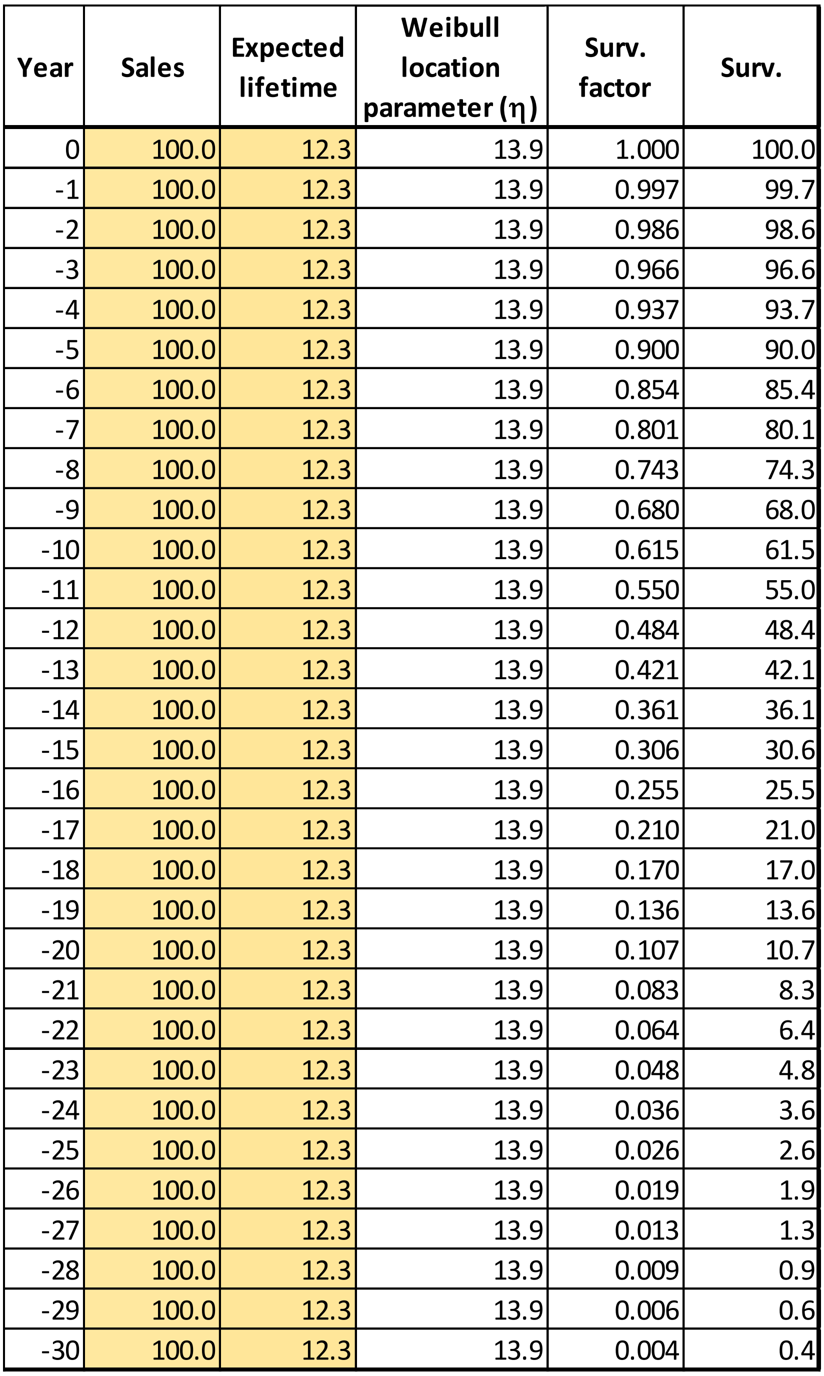
Rationale and Action

The purpose of modelling sales is twofold: 1) to estimate the economic impact of Ecodesign requirements (which, in turn, also involve that the effect that such requirements will have on sales is modelled); and 2) to estimate the total stock of the products under analysis in order to be able to estimate the overall environmental impact associated with its production and use.

Taking into account that Lifetime, sales and stock are not independent, if we model both the sales and the lifetime, the existing stock will result from calculations. It will be given by the summation of the sales of all previous years multiplied by the percentage of products surviving after time 't' has elapsed. Here we consider the year in which the product were sold as the year in which they have entered into service and, therefore, the initial point for the calculation of the expected lifetime. Please refer to Annexes III and IV for technical details on the use of a 3 parameter Weibull distribution to model the products' lifetime and the reliability function (the percentage of products surviving after time t has elapsed).

We can see below two examples of calculations using Weibull parameters typical of large household appliances (e.g., fridges, washing machines, etc.) where the stock (and also the approximated stock evolution) can be estimated given the sales and the lifetime parameters. In the first case constant sales are assumed (which, unsurprisingly, result in constant stock) and in the second case a constant yearly increase in sales of 2% is assumed (which will result, ceteris paribus, in a 2% yearly increase in stock). Please notice that while the shape parameter is constant – as it is a characteristic of the specific product group under analysis – the location parameter (determined through the expected lifetime of the device) is allowed to change in time in order to reflect technological or market/regulations changes that might occur in time.

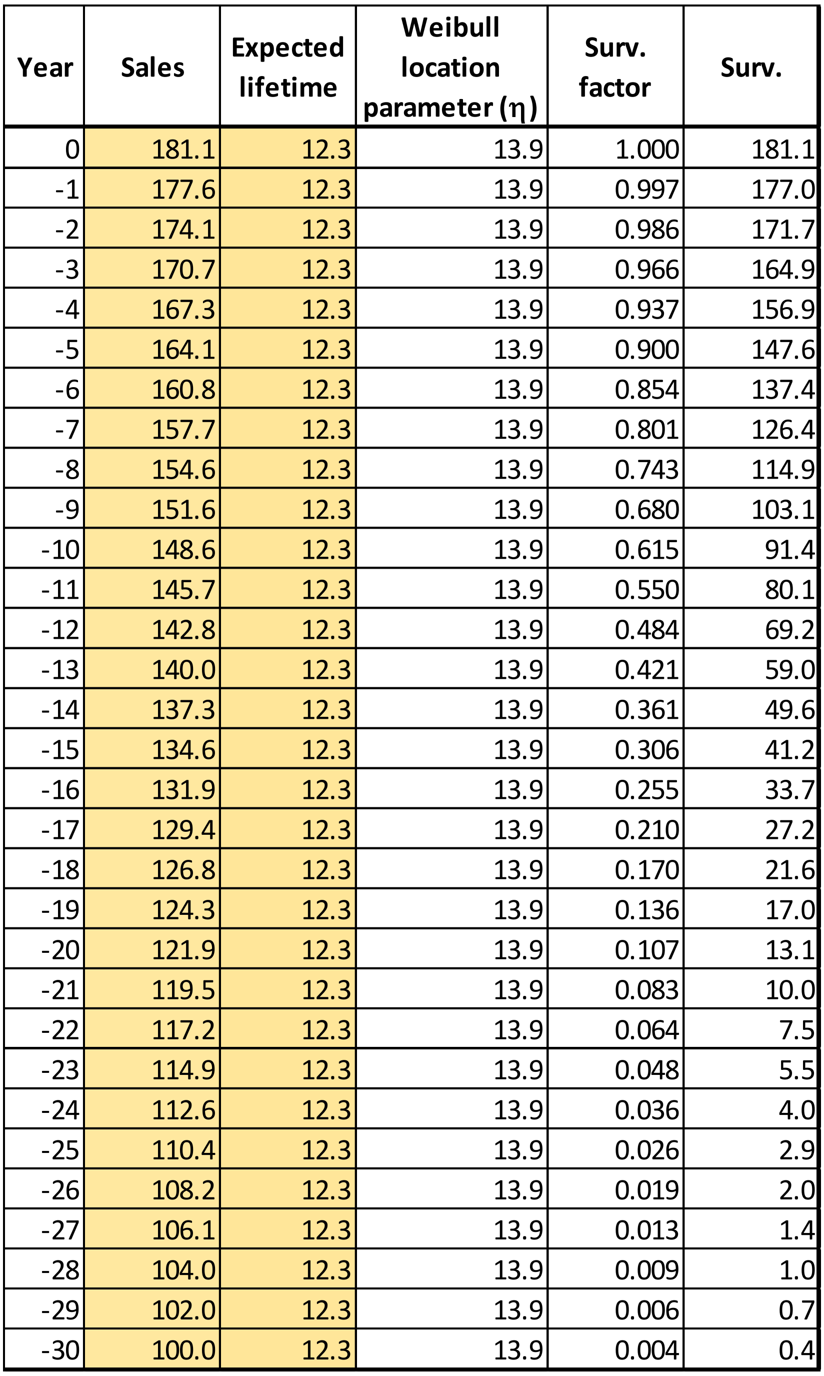
Figure 12 - Example calculation of stock and stock evolution given constant yearly sales. Ecoreport tool (2024)



Year	Sales	Expected lifetime	Weibull location parameter (η)	Surv. factor	Surv.
0	100.0	12.3	13.9	1.000	100.0
-1	100.0	12.3	13.9	0.997	99.7
-2	100.0	12.3	13.9	0.986	98.6
-3	100.0	12.3	13.9	0.966	96.6
-4	100.0	12.3	13.9	0.937	93.7
-5	100.0	12.3	13.9	0.900	90.0
-6	100.0	12.3	13.9	0.854	85.4
-7	100.0	12.3	13.9	0.801	80.1
-8	100.0	12.3	13.9	0.743	74.3
-9	100.0	12.3	13.9	0.680	68.0
-10	100.0	12.3	13.9	0.615	61.5
-11	100.0	12.3	13.9	0.550	55.0
-12	100.0	12.3	13.9	0.484	48.4
-13	100.0	12.3	13.9	0.421	42.1
-14	100.0	12.3	13.9	0.361	36.1
-15	100.0	12.3	13.9	0.306	30.6
-16	100.0	12.3	13.9	0.255	25.5
-17	100.0	12.3	13.9	0.210	21.0
-18	100.0	12.3	13.9	0.170	17.0
-19	100.0	12.3	13.9	0.136	13.6
-20	100.0	12.3	13.9	0.107	10.7
-21	100.0	12.3	13.9	0.083	8.3
-22	100.0	12.3	13.9	0.064	6.4
-23	100.0	12.3	13.9	0.048	4.8
-24	100.0	12.3	13.9	0.036	3.6
-25	100.0	12.3	13.9	0.026	2.6
-26	100.0	12.3	13.9	0.019	1.9
-27	100.0	12.3	13.9	0.013	1.3
-28	100.0	12.3	13.9	0.009	0.9
-29	100.0	12.3	13.9	0.006	0.6
-30	100.0	12.3	13.9	0.004	0.4

Source: JRC elaboration

Figure 13 - Example calculation of stock and stock evolution given constant yearly sales increase of 2%. Ecoreport tool (2024)



Year	Sales	Expected lifetime	Weibull location parameter (η)	Surv. factor	Surv.
0	181.1	12.3	13.9	1.000	181.1
-1	177.6	12.3	13.9	0.997	177.0
-2	174.1	12.3	13.9	0.986	171.7
-3	170.7	12.3	13.9	0.966	164.9
-4	167.3	12.3	13.9	0.937	156.9
-5	164.1	12.3	13.9	0.900	147.6
-6	160.8	12.3	13.9	0.854	137.4
-7	157.7	12.3	13.9	0.801	126.4
-8	154.6	12.3	13.9	0.743	114.9
-9	151.6	12.3	13.9	0.680	103.1
-10	148.6	12.3	13.9	0.615	91.4
-11	145.7	12.3	13.9	0.550	80.1
-12	142.8	12.3	13.9	0.484	69.2
-13	140.0	12.3	13.9	0.421	59.0
-14	137.3	12.3	13.9	0.361	49.6
-15	134.6	12.3	13.9	0.306	41.2
-16	131.9	12.3	13.9	0.255	33.7
-17	129.4	12.3	13.9	0.210	27.2
-18	126.8	12.3	13.9	0.170	21.6
-19	124.3	12.3	13.9	0.136	17.0
-20	121.9	12.3	13.9	0.107	13.1
-21	119.5	12.3	13.9	0.083	10.0
-22	117.2	12.3	13.9	0.064	7.5
-23	114.9	12.3	13.9	0.048	5.5
-24	112.6	12.3	13.9	0.036	4.0
-25	110.4	12.3	13.9	0.026	2.9
-26	108.2	12.3	13.9	0.019	2.0
-27	106.1	12.3	13.9	0.013	1.4
-28	104.0	12.3	13.9	0.009	1.0
-29	102.0	12.3	13.9	0.006	0.7
-30	100.0	12.3	13.9	0.004	0.4

Source: JRC elaboration

Implementation

The Study-Team should use a 3 parameter Weibull distribution for the expected lifetime calculations in order to ensure coherence amongst the modelling procedures for different product groups. The Weibull parameters to be used should be chosen by the Study-Team using the procedure that they believe to be more adequate, as there are several different methods available to do that: the most straight forward method is just to retrieve the parameters from the literature available, like, for example (Balde et al. 2015). In case the parameters are not readily available in the literature, they can be estimated either by using historical failure data (Razali, Salih, and Mahdi 2009) or by alternative methods that do not require any failure data(Cai Wen Zhang 2021).

The estimate of the yearly sales should be inserted by the Study-Team using either real data or a model (e.g., constant rate of growth), as they believe to be more adequate.

It should be noticed that with minimal and straightforward changes this model also allows for assuming an evolution model for the stock (e.g., constant stock) and using it to forecast next year sales. Again, see Annexes III and IV for technical details.

1.6 Critical Raw Materials (subtask 1.h)

Objectives

To critically revise the current approach for Critical Raw Materials (CRMs) within the MEErP.

Status as in the current Ecoreport tool

Some guidelines on how to assess the impact of CRMs have been provided by the 2011 and 2013 revisions of the MEErP (with the introduction of the Critical Raw Material Index). However, this indicator has been applied only in very few preparatory studies performed so far.

Rationale and Action

JRC analysis highlighted that the concept of CRM-equivalent was difficult to be understood and has been generally not used since it was introduced in MEErP in 2011. Moreover, the CRM-equivalent index could not be easily associated to the definition of specific Ecodesign measures (e.g. use less, report quantities, making CRMs easier to be recycled, or find a substitute).

JRC therefore suggests to replace the assessment of the CRM equivalent Index by a new 'step-by-step' approach, based on a sequential screening of CRMs contained in the product under scrutiny, and using the numerical results of the 2023 Criticality Assessment.

The main advantage of this new approach is to streamline the analysis of CRMs in the products under study while benefitting from information already available. This approach is streamlined and could be potentially updated when newer information is produced (within future 3-yearly criticality assessment reviews).

Detail on the analysis of CRMs in Ecodesign and on the novel approach proposed is detailed in (Annex II).

Implementation

Preliminary results have identified product groups for which analysis of certain CRMs could be prioritized. This analysis also concluded that a generalized and systematic procedure to automatically identify ecodesign measures looks unlikely.

Guidance on how to conduct such analysis is provided, including some suggestions of strategies (e.g. use less, report quantities, making CRMs easier to be recycled, or find a substitute) that could support the mitigation of criticality (i.e. potentially translated into future product requirements).

JRC suggests to always start from the results of the latest criticality assessment and use them for an initial screening, also taking into account specific aspects of the product group under scrutiny. A generalized and systematic procedure to automatically identify Ecodesign measures looks unlikely. A dedicated spreadsheet named "CRMs" is inserted in the Ecoreport tool.

A proposed Step-by-step approach to assess CRM is described below.

— Step 1: shortlist the CRMs that are potentially in the product group using available tables (see Annex II, e.g. table A.3 to be included in the Ecoreport tool), and any other additional information related to the product group

— Step 2: when possible, collect quantitative data on the Bill of Material (BoM) of the shortlisted CRMs;

— Step 3: look at information available in provided tables (on Substitution, RR, RIR, etc.) to define a possible strategy. Possible strategies could include:

  - Declare quantity when data is not available or of low quality, and/or

- Extend lifetime, especially in the case of low substitutability, and/or
- Improve recyclability and/or use recycled materials, especially in the case of low substitutability.

Some general rules / checklist to be considered in deriving requirements:

— If RR is low, then check if recycling technology is available or if the product group is an exception (data on recycling is always an average across all product groups)

— If RR is high, but EoL-RIR is low, demand is probably growing, so it is unlikely that recycled materials can be available in adequate quantities. So, rather than recommending higher recycled content, a more adequate measure could then be an extension of lifetime.

Detailed guidance is provided as part of subtask 1.c.

1.7 Instruction on the use of the Ecoreport tool (subtask 1.c)

Objectives

Guidance on how to use the tool (especially concerning new functionalities that have been inserted)

Status as in the current Ecoreport tool

Concerning the current Ecoreport tool, a manual illustrating the basic functionalities of the tool is available (COWI and VHK 2011a).

Rationale and Action

It is planned to develop a new detailed user manual providing guidance on how to use each section of the Ecoreport tool and addressing main novelties. This new manual will provide also a brief description of the EF impact categories implemented in the tool (for additional and more detailed information on these impact categories and other methodological aspects of the EF methods it is suggested to refer to general guidelines[35] and explanatory report (European Commission 2021b)).

Implementation

Detailed guidance on the use of the different modelling will be provided, in a separate new "Ecoreport tool manual", detailing each spreadsheet of the revised Ecoreport tool.

1.8 **'Ecological profile' of a product** (subtask 1.e)

Objectives

This subtask aimed at identifying and proposing input categories/indicators that could be part of the 'Ecological profile' of a product[36].

Status as in the current Ecoreport tool

Not implemented in the current Ecoreport tool.

Rationale and Action

According to our analysis, any of the 16 impact categories in the Ecoreport tool and other relevant information and parameters could be used as basis for generic ecodesign requirements, i.e. requirements requesting to declare the value of such indicator, if this has been identified as relevant in the life cycle of the product considered. For such requirements it is necessary to refer to ad-hoc product-specific rules. When

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[35] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32021H2279

[36] According to the Ecodesign Directive 'Ecological profile' means "a description, in accordance with the implementing measure applicable to the product, of the inputs and outputs (such as materials, emissions and waste) associated with a product throughout its life cycle which are significant from the point of view of its environmental impact and are expressed in physical quantities that can be measured"

available, Product Environmental Footprint Category Rules (PEFCRs) can represent the basis for developing such specific rules.

A potential method for imposing this type of requirements is currently being explored within the framework of the preparatory work for Ecodesign[37] and Energy Labelling[38] requirements for photovoltaic modules, inverters and systems. Inter alia, potential requirements on the carbon footprint of the manufacturing and shipment phases of photovoltaic modules are being prepared. The proposed method for the calculation of the carbon footprint builds on the product environmental footprint category rules for PV modules used in PV power systems for electricity generation (version 1.2, February 2020)[39].

Implementation

Once this preparatory work is concluded, it should be feasible to devise/start developing a more general method.

1.9 Procedure for future updates (subtask 1.i)

Objectives

This subtask describes possible strategies for the future update of the Ecoreport tool (especially to what concerns materials and energy datasets and default data used e.g. for the EoL modelling).

Status as in the current Ecoreport tool

The current Ecoreport tool is static and not flexible to accommodate future updates on new datasets or impact categories.

Rationale and Action

The Ecoreport tool database is ready to be populated by new datasets once they will be available (e.g. within the period updates of the EF database). The list of impact categories and additional technical information to include in the Ecoreport tool is easily editable for any future update of the methodology.

Implementation

The instructions on how to update the Ecoreport tool and its underlying data are included in the user manual of the revised Ecoreport tool (section 1.7 - subtask 1.c).

Moreover, consultants conducting preparatory studies might be asked to report on how the Ecoreport tool has been used in their study, including problems encountered or suggestions for the improvements. If new or updated datasets are introduced during preparatory studies, these need to be reported and considered for future updates of the Ecoreport tool database. Periodically these reports could be reviewed and considered for implementing changes in the Ecoreport tool, thus ensuring the required compatibility with IPR issues.

1.10 More sophisticated IT infrastructure (Subtask 1.j)

This task explored the possibility of moving from the current version of the Ecoreport tool to more sophisticated infrastructure (e.g. online tool). Based on the discussion with stakeholders and policy makers, it has been decided to keep the Ecoreport tool as the currently and streamlined life-cycle based approach implemented transparently in an Excel spreadsheet. More sophisticated IT infrastructure (i.e. web tools) could be developed for specific purposes (as for example, for the calculation of the ecological profile of products as in subtask 1.e).

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[37] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12819-Ecodesign-European-Commission-to-examine-need-for-new-rules-on-environmental-impact-of-photovoltaics_en

[38] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12820-Energy-labelling-European-Commission-to-examine-need-for-new-rules-on-environmental-impact-of-photovoltaics_en

[39] https://ec.europa.eu/environment/eussd/smgp/PEFCR_OEFSR_en.htm

2 More systematic inclusion of material efficiency aspects and of environmental footprint/ecological profile aspects in the design options and in the LLCC curve

This chapter presents progress on Task 2 of the project “Review of the MEErP - Methodology for Ecodesign of Energy-related Products" (MEErP)”[3]. Task 2 deals with “More systematic inclusion of material efficiency aspects and of environmental footprint/ecological profile aspects in the design options and in the LLCC curve”.

As general objective of Task 2, we aimed to keep the existing logic of the MEErP while systematically introducing material efficiency aspects in the calculations - namely of the Least Life Cycle Costs (LLCC) curve - and assuring a strong link with design options. The inclusion of environmental footprint springs out naturally from the End-of-Life (EoL) effects that are modelled through the Circular Footprint Formula (CFF), as described in Tasks 1.d and 1.g. This reflects a strong link between Tasks 1 and 2 of this project. This link will become further evident in order parts of sub-modelling of Task 2, as will be depicted throughout this chapter.

In fact, although it is true that most lifetime extending design options have no direct effect on the use-phase energy efficiency, they will certainly have an impact both on the life cycle costs from the perspective of the end user and on the environmental impacts normalised with resource to the expected lifetime which are, therefore, expressed in a ‘per year’ basis. Focussing again on energy use, the main interaction with expected lifetime regards how the built-in energy, i.e., incorporated in the product during the production phase, is diluted throughout the product’s lifetime. This aspect will be further detailed ahead in this report. There is another potential trade-off that could also play a role in the interaction between lifetime extension and use-phase energy efficiency: assuming that products are placed in the market with increasing energy efficiency as time goes by, by extending the lifetime of a product one can be forfeiting the benefits of increased energy efficiency that would be brought about by the newer, more efficient, replacement item. This effect - which can take shape either in terms of environmental impacts, or in terms of costs, or both - can be readily inserted in the proposed analysis, as it will be described further ahead in this report.

Regarding lifetime and user behaviour, it should be noticed that the overall useful lifetime of a product will depend, to a certain degree, on user behaviour. However, this aspect goes well beyond market placement. Here a cautious approach has been taken and it has been always assumed the same epistemic consumer behaviour, as determined by task 3 of the MEErP (not task 3 of the current study).

In order to take material efficiency aspects into account within MEErP, full use was made of the body of knowledge, namely nomenclature and modelling, produced by CEN-CENELEC Joint Technical Committee 10 on Energy-related products - Material Efficiency Aspects for Ecodesign (CEN-CLC/JTC 10). This technical committee developed a group of eight standards (the family of standards EN 4555X) containing generic principles to consider when addressing the material efficiency of energy-related products, such as extending product lifetime, ability to recycle materials from products at end-of-life, and use of recycled materials in products. By building on this work we are ensuring uniformity of concepts and nomenclature and avoiding duplicated work.

The development of a method to achieve the objectives of Task 2 is presented hereinafter.

2.1 Estimation of expected Lifetime (durability)

In order to properly analyse and model circular economy requirements, product expected lifetime must be taken into account. In practical terms, following this approach would imply that an 'equivalent annual cost' (for a design option) should be calculated. With the use of the 'equivalent annual cost' it is possible to properly compare design options with different expected lifetimes, such as, for example, the base case (i.e. the average EU product), compared to a second product with increased durability (e.g. thanks to the higher quality of its components) and a third product with higher expected lifetime than the base case as a result of its improved design for reparability[40].

Also, not only costs are to be calculated on a yearly basis through normalisation by the expected lifetime, but also environmental impacts should be normalised the same way. Again, only this way will it be possible to properly compare the environmental impacts of design options with different expected lifetimes, namely by taking into account the trade-off between one-off impacts (like those associated with manufacturing or EoL) and recurrent impacts resulting from the use phase. Here, once again, the previously referred trade-off between extending a product's lifetime or replacing it in order to take advantage of the potential increased energy efficiency of the more recent item, could play a role. The overall balance in terms of environmental impacts would, of course, depend on the relative magnitude of the one-off impacts and the impacts associated with energy consumption in the use-phase, as well as on the efficiency difference between the existing item and the replacement one. For instances, the effect on environmental impacts could be addressed by comparing the design option with extended lifetime (which will have a 'static' energy efficiency - i.e. not changing over time - as it models the case of a product which is durable and keeps always the same efficiency) with a value of the energy efficiency which would consist of an average between the initial energy efficiency of the product and the improved future energy efficiency (weighted average, if a different number of years is associated with different efficiencies).

The expected lifetime of a product (durability under the nomenclature of EN 45552) will be calculated based on its initial lifetime expectation (reliability under the nomenclature of EN 45552) plus the expected lifetime increase due to reparability and upgradability (equation 5).

$$Lt = Lt_0(1 + \Delta L_R)(1 + \Delta L_U)$$

Equation 5

, whereby

Lt, is the calculated expected lifetime

Lt_0 , is the initial lifetime

$\Delta L_{R,}$, is the % of lifetime increase attributed to reparability

ΔL_U, is the % of lifetime increase attributed to upgradability

Therefore, it is needed to find L_0, ΔL_R and ΔL_U in order to be able to estimate the expected lifetime (durability). In order to do that, we rely largely on the methods outlined in the EN 4555X family of standards. According to the procedures outlined there, a product will be modelled as a serial assembly (i.e., one part placed after the other, with the consequence that the failure of a single part will cause the failure of the entire assembly) of a number of priority parts for repair and upgrade, the failure of any one of which will cause the product to fail. In the context of the MEErP, these priority parts should be identified by the Study-Team.

An approach for the identification of such priority parts is provided by the JRC Report on a general method for a scoring system for repair and upgrade of products (Cordella, Alfieri, and Sanfelix 2019). Specifically, two main factors determine a part's priority: (a) its functional importance, and (b) its likelihood of failure. The standard EN45554:2020[41], provides an indicative list of sources of information, which, in the context of this methodology, the Study-Team can consult for the identification of those parts:

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[40] It is useful to note that the actual product lifetime will be dependent on user behaviour (e.g. lack of maintenance or decision of consumer to replace rather than repair regardless of conditions)

[41] CEN/CENELEC JTC10, EN 45554, 2020. General Methods for the Assessment of the Ability to Repair, Reuse and Upgrade Energy-Related Products.

- Existing regulations;
- Product manufacturers;
- Parts manufacturers;
- Repair, reuse or maintenance organisations;
- Consumer organisations;
- Scientific literature and study reports.

Once priority parts have been identified, their level of priority can be assessed by the Study-Team, and accordingly, the availability of data and scope of the study guides the Study-Team towards deciding the level of depth of the analysis, and on which priority parts the lifetime estimation should be based on (e.g. up to medium failure/medium functional relevance). Practical guidance stemming again from the aforementioned JRC report, indicates that cut-off rules could be applied to find a balance between representativeness of parts and complexity of the assessment, for example:

1. Priority parts are functionally relevant parts that are typically associated with at least 3% of the typical failure rates for that product group.
2. If failure rates are 10% or more, a high priority could be set for these parts.

Then, we follow a strategy based on a discrete step scoring system for recyclability and upgradability as depicted in a separate technical report (Cordella, Alfieri, and Sanfelix 2019). In this framework, a set of 4 discrete levels for reliability, reparability and upgradability are defined linked to design options.

2.2 Estimation of the initial Lifetime Lt_0 (reliability)

Four levels of initial lifetime (i.e., until the first limiting event takes place. This is termed reliability under the nomenclature of EN 4555X) are defined in terms of the design options and physical characteristics of the product. The Study-Team should produce a table like Table 4 below for the specific product group under analysis.

Table 4 - Levels of reliability and link to design options.

Reliability		
Level	Design options	Average expected initial lifetime
1	Design options leading to best achievable initial lifetime in the market.	Lt_{01}
2	Design options leading to a good initial lifetime in relation to the market reference.	Lt_{02}
3	Design options leading to a not-so-good initial lifetime in relation to the market reference.	Lt_{03}
4	Design options leading to worst initial lifetime in the market.	Lt_{04}

Source: JRC elaboration

The specific design options to take into account are not prescribed here, as the existing diversity among different product groups precludes such a prescriptive approach. This way, the Study-Team should have enough leeway to fully adapt the design options to be considered to the physical reality of the specific product-group under analysis.

However, just for illustration purposes, design options and characteristics taken into consideration could be, inter alia, the following:

- Results of performance tests under specific standards;
- Improved product physical structure;
- More durable components (e.g. battery if not replaceable);
- Consumables availability;
- Provision of information about use and maintenance;
- Possibility of reuse.

2.3 Estimation of the percentage of lifetime increase attributed to reparability ($\Delta L_{R,}$) and upgradability ($\Delta L_{U,}$)

This follows a strategy based on a discrete step scoring system for recyclability and upgradability as depicted in a separate technical report (Cordella, Alfieri, and Sanfelix 2019). In this framework, a set of 4 discrete levels for reliability, reparability and upgradability are defined linked to design options.

Starting with reparability, we define the 4 levels of reparability according to the following table:

Table 5 - Reparability levels based on design options.

Reparability	
Level	Design options
1	— Small disassembly depth (reduced number of steps required to disassemble) — Fasteners are reusable — Only basic tools, or no tools, needed — Repair can be performed in the use environment — Repair can be performed by a layman or generalist — Diagnosis support and interfaces are intuitive or coded with a public reference table — Spare parts and repair information are publicly available — Long-term availability of spare parts — Secure data transfer/deletion built in — Password and factory setting reset integrated in product
2	— Medium disassembly depth (significant number of steps required to disassemble) — Fasteners are supplied with the product/part

	— Specific tools needed — Repair requires workshop environment — Repair must be performed by an expert — Diagnosis support and interfaces require publicly available hardware/software — Spare parts and repair information are available to independent service providers — Mid-term availability of spare parts — Secure data transfer/deletion upon request — Password and factory setting reset with freely accessible software/hardware solutions
3	— High disassembly depth (large number of steps required to disassemble) — Fasteners are removable — Proprietary tools needed — Repair requires production-equivalent environment — Repair must be performed by the manufacturer or an authorized expert — Diagnosis support and interfaces are proprietary — Spare parts and repair information are only available to the manufacturer or authorized service providers — Short-term availability of spare parts (or no information) — Secure data transfer/deletion not available — Password and factory setting reset using services offered by the manufacturer
4	The product cannot be repaired and must be replaced in case of failure (e.g., because parts are welded, product cannot be opened, spare parts are not available, etc.).

Source: JRC elaboration

The relevance of design options presented in Table 5 to the concept of reparability is described in the JRC report on the development of a scoring system for repair and upgrade of products (Cordella, Alfieri, and Sanfelix 2019), and refer to reparability or reusability parameters identified in EN 45554:2020.

The levels defined above are indicative and the appropriateness of their use should be assessed by the Study-Team on the basis of the characteristics of the product group under study. For example, Level 1 design options may not be relevant in the case of products used in professional or industrial applications.

When assigning an overall reparability level to a product, it may happen that some characteristics belong to different levels, e.g., a product may have reusable fasteners (level 1) but proprietary diagnosis support and interfaces (level 3). In that case, a weighting method should be used to combine the different scores of the different dimensions of reparability. This would result in having different levels for different parameters and then one aggregate score for the entire product. In fact, it is likely that this is the most frequent case, and therefore should be considered the default case. The way to do that is detailed in the JRC report on the development of a scoring system for repair and upgrade of products[45].

Then, the Study-Team should identify for each of the levels the typical time necessary to carry out a repair operation and estimate the total cost of that operation, i.e., the Study-Team should fill in the shaded values in Table 6 below. Guidance on how to estimate the costs is provided further ahead in this report.

If different types of failures imply very different repair times and costs, then an average should be computed using failure frequencies as a weighting method.

Table 6 - Typical times and cost of repair operations according to the reparability level.

Reparability		
Level	Total time to carry-out a typical repair activity [h]	Total cost of the repair [€]
1	t_{R1}	C_{R1}
2	t_{R2}	C_{R2}
3	t_{R3}	C_{R3}
4	-	-

Source: JRC elaboration

An analogous procedure should be followed for upgradability, as indicated in Table 7 and Table 8 below, where the same remarks regarding weighting of the upgradability level and weighted average of the upgrade times and costs apply.

Table 7 - Upgradability levels based on design options.

Upgradability	
Level	Design options
1	— Small disassembly depth (reduced number of steps required to disassemble) — Fasteners are reusable — Only basic tools, or no tools, needed — Upgrade can be performed in the use environment — Upgrade can be performed by a layman or generalist — Spare parts and upgrade information are publicly available — Long-term availability of spare parts for upgrade — Software and firmware upgrades are publicly available
2	— Medium disassembly depth (significant number of steps required to disassemble) — Fasteners are removable — Specific tools needed — Upgrade requires workshop environment — Upgrade must be performed by an expert — Spare parts and upgrade information are available to independent service providers — Mid-term availability of spare parts for upgrade — Software and firmware upgrades are available to independent service providers
3	— High disassembly depth (large number of steps required to disassemble)

	— Fasteners are neither removable nor reusable — Proprietary tools needed — Upgrade requires production-equivalent environment — Upgrade must be performed by the manufacturer or an authorized expert — Spare parts and upgrade information are only available to the manufacturer or authorized repair service providers — Short-term availability of spare parts (or no information) — Software and firmware upgrades are only available to the manufacturer or authorized service providers
4	The product cannot be upgraded and must be replaced in case of inadequate performance or functionalities (e.g., because parts are welded, product cannot be opened, spare parts are not available, software cannot be updated).

Source: JRC elaboration

The relevance of design options presented in Table 7 to the concept of upgradability is described in the JRC report on the development of a scoring system for repair and upgrade of products[45] and refer to upgradability-related parameters identified in EN 45554:2020.

Table 8 - Typical times and cost of upgrade operations according to the upgradability level.

Upgradability		
Level	Total time to carry-out a typical upgrade activity [h]	Total cost of the upgrade [€]
1	t_{U1}	C_{U1}
2	t_{U2}	C_{U2}
3	t_{U3}	C_{U3}
4	-	-

Source: JRC elaboration

Next, we need to model how exactly the reparability/upgradability index will influence the expected future lifetime. We should keep in mind that when a product reaches a limiting state its user/owner must take a decision: either to repair/upgrade or to replace it. We have already seen that different reparability levels will mean different ease of repair, and therefore different repair costs. In our modelling we assume that this is the parameter that will tilt the balance of the decision to “repair/upgrade vs replace” and alter the expected future lifetime.

A straightforward way of performing this analysis is by calculating the average cost-per-day of the repair and comparing it with the cost-per-day of the replacement. If C_R (C_U) is the cost of the repair (upgrade) and C_{New} is the cost of replacement and L_T is the expected lifetime of the replacement (assumed to be equal to the original expected lifetime of the unit that failed) and L_E is the expected future lifetime of the repair/upgrade, then the product will be repaired if the following condition is met:

$$\frac{C_{R/U}}{L_E} < \frac{C_{New}}{L_T}$$

Equation 6

This equation can be easily manipulated in order to calculate a critical expected lifetime increase that will be used to establish a condition for the minimum expected future lifetime for repair/upgrade. This will be the minimum increment in lifetime that is required to justify the repair or upgrade operation.

$$L_E > L_{Cr} = L_T \frac{C_{R/U}}{C_{New}}$$

Equation 7

It is also worth noticing that predictable recurrent maintenance work operations should be taken into account in this analysis by, e.g., incorporating their cost in the purchasing cost. Also, if the energy efficiency in the use-phase of the replacement item is significantly different from that of the existing item, then the cost associated with energy consumption in the use-phase could also be taken into account. Including this effect on the analysis is just as straight forward as taking maintenance operations cost into account.

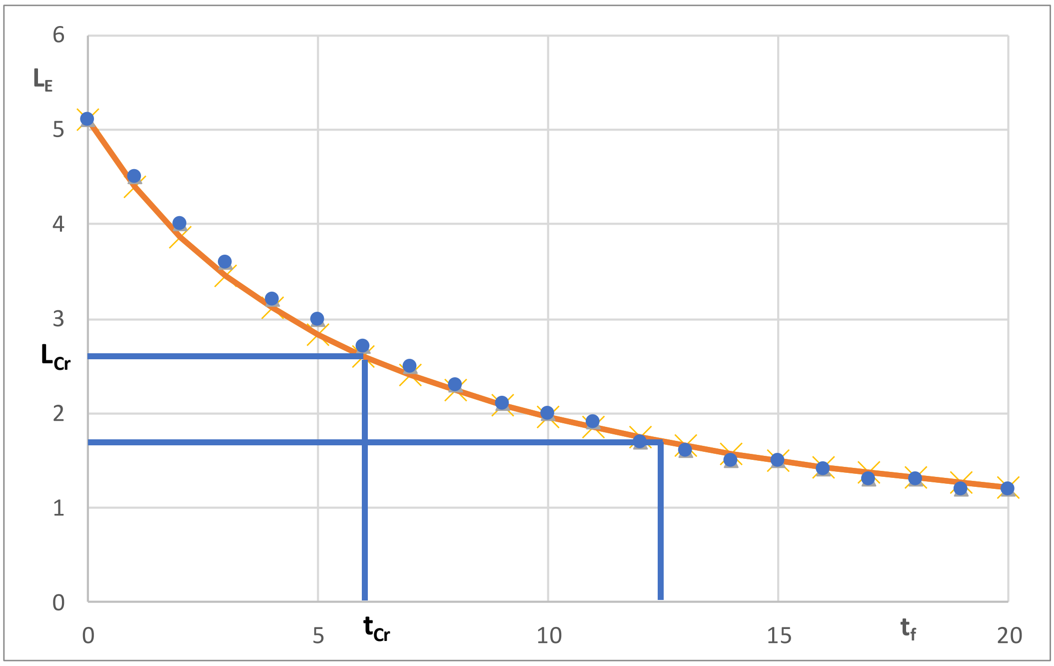
In order to make the calculations more tractable an additional simplification will be introduced: it is assumed that priority parts will be repaired or upgraded only once. Detailing, if a priority part fails for the second time, the product will be replaced even if the expected future lifetime of the repair/upgrade operation exceeds the critical lifetime.

The result of the application of this method is illustrated in Figure 14 below. The way to read this figure is as follows:

1. t_f is the time at which the limiting event happens measured in years after the device was put in place, i.e., it is the age of the product at the time of failure (either by malfunction or by inadequacy of performance or functionality);
2. L_E is the expected future lifetime of the product after the repair/upgrade operation is performed;
3. The L_E/t_f curve naturally has a downward slope, i.e., the later in the life of the product the limiting event happens the least extra time will the repair/upgrade operation provide, since all the other parts of the device are older and moving towards the end of their useful service life;
4. We have seen above that the repair/upgrade operation will only be performed if L_E exceeds some critical value, L_{Cr}, which can be calculated through Equation2. The value of L_{Cr} can be found on the vertical axis of Figure 14;
5. To the value of L_{Cr} will correspond a value of t_{Cr} in the L_E/t_f curve. This value of t_{Cr} can be found on the horizontal axis of Figure 14;
6. Final conclusion is that if the limiting event takes place before t_{Cr} then the device will be repaired or upgraded. However, if the limiting event happens after t_{Cr} then the device will be replaced.

A possible way to construct the L_E/t_f curve – based on the Weibull modelling – is presented in Annex III, but the Study-Team should have the freedom to use another method if they believe it is more adequate.

Figure 14 - Illustration of the relationship between failure time and expected future lifetime. JRC elaboration



Source: JRC elaboration

, whereby

t_{CR}, is the critical time of failure (after which replacement, rather than repair/upgrade, is assumed to take place)

t_f , is the time of the first failure

Finally, after finding out the value of the maximum failure time, t_{Cr}, (which corresponds to the minimum expected future lifetime, L_{Cr}) that will allow for repair/upgrade, a new value of expected lifetime can be calculated (again, by the Study-Team). This new value of expected lifetime allows for the estimation of the percent increased lifetime generated by the given level of reparability/upgradability. Detailed instructions on how to carry out this calculation can be found in the Annex III.

After carrying out this procedure the Study-Team should be in conditions to fil in Table 9 and Table 10 below. Again, Annex III provides detailed guidance on a possible way to carry-out these calculations.

Table 9 - Increase in lifetime according to the reparability level.

Reparability	
Level	% Increase in lifetime (ΔL_R)
1	ΔL_{R1}
2	ΔL_{R2}
3	ΔL_{R3}
4	0

Source: JRC elaboration

Table 10 - Increase in lifetime according to the upgradability level.

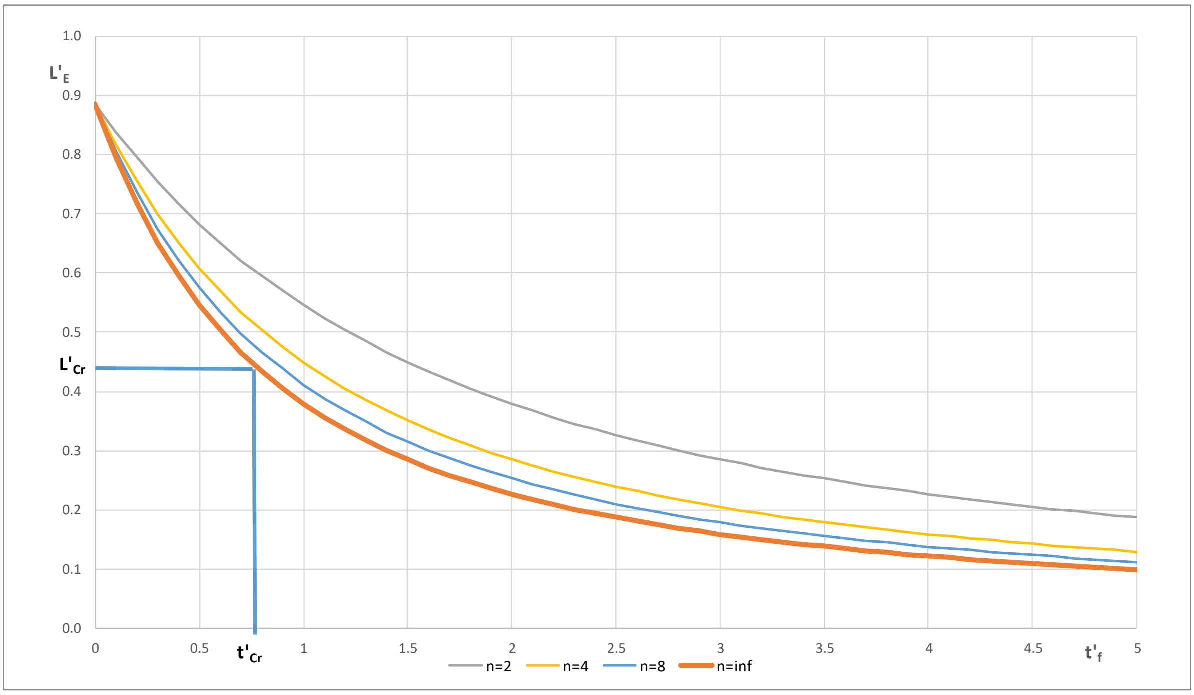
Upgradability	
Level	% Increase in lifetime (ΔL_U)
1	ΔL_{U1}
2	ΔL_{U2}
3	ΔL_{U3}
4	0%

Source: JRC elaboration

Finally, In order to make these calculations much simpler for a first analysis, a simplified method is presented here: All time related parameters are made non-dimensional by dividing by the Weibull location parameter, i.e., $L'_E=L_E/\eta$, $t'_f=t_f/\eta$, $L'_{Cr}=L_{Cr}/\eta$, $t'_{Cr}=t_{Cr}/\eta$. Then a generic shape parameter is assumed ($\beta=2$), which will provide a rather satisfactory approximation for all cases. It becomes thus possible to build Figure 15 and Figure 16, in which the L'E/t'Cr and increase in lifetime curves depend only on the number of priority parts, and use them for every case regardless of the specific distribution. The construction of these curves is explained in detail in Annex III and the curves are implemented in the Ecoreport Tool for ease of utilization.

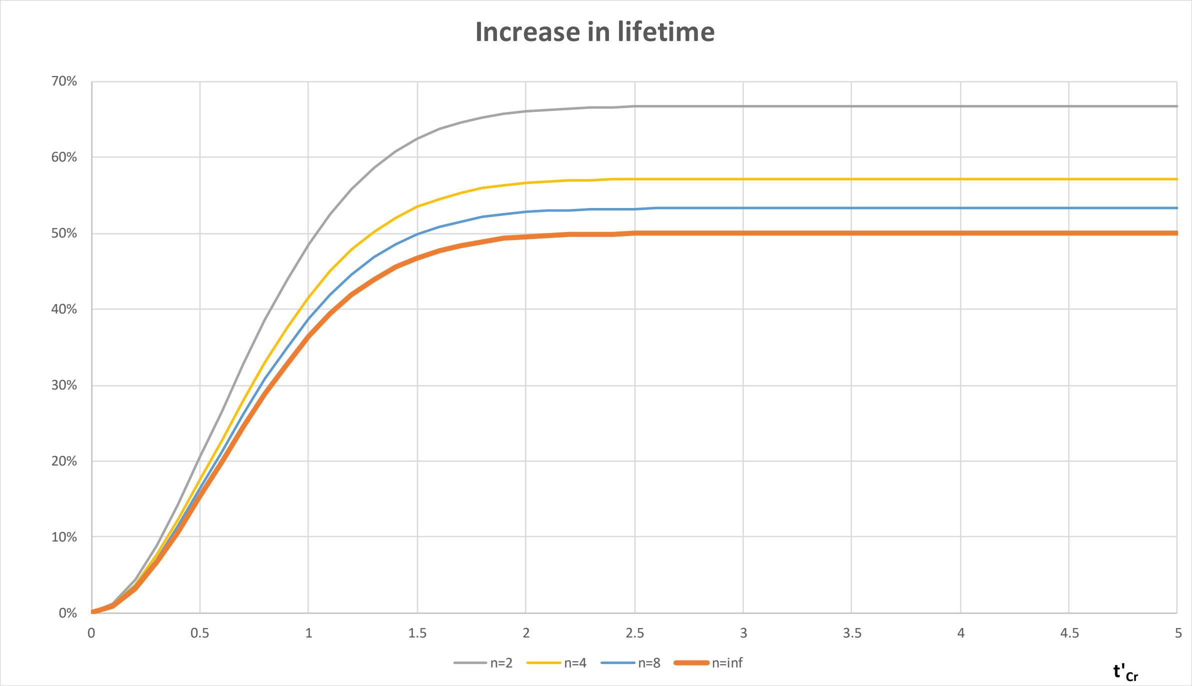
As it can be seen from Figure 15 and Figure 16, the curves converge quite quickly to the solution of 'infinite' priority parts. This means that after a not so large number of priority parts (i.e., more than 4 or 5) the curves will be very similar. Therefore, it is possible to use safely, and conservatively, the solution for a large number (i.e., 'infinite') of priority parts.

Figure 15 - Non-dimensional L'_E/t'_f curve applicable to every distribution. JRC elaboration



Source: JRC elaboration

Figure 16- Relationship between non-dimensional critical failure time and increase in lifetime for every distribution. JRC elaboration



Source: JRC elaboration

2.4 Summary of expected Lifetime calculation

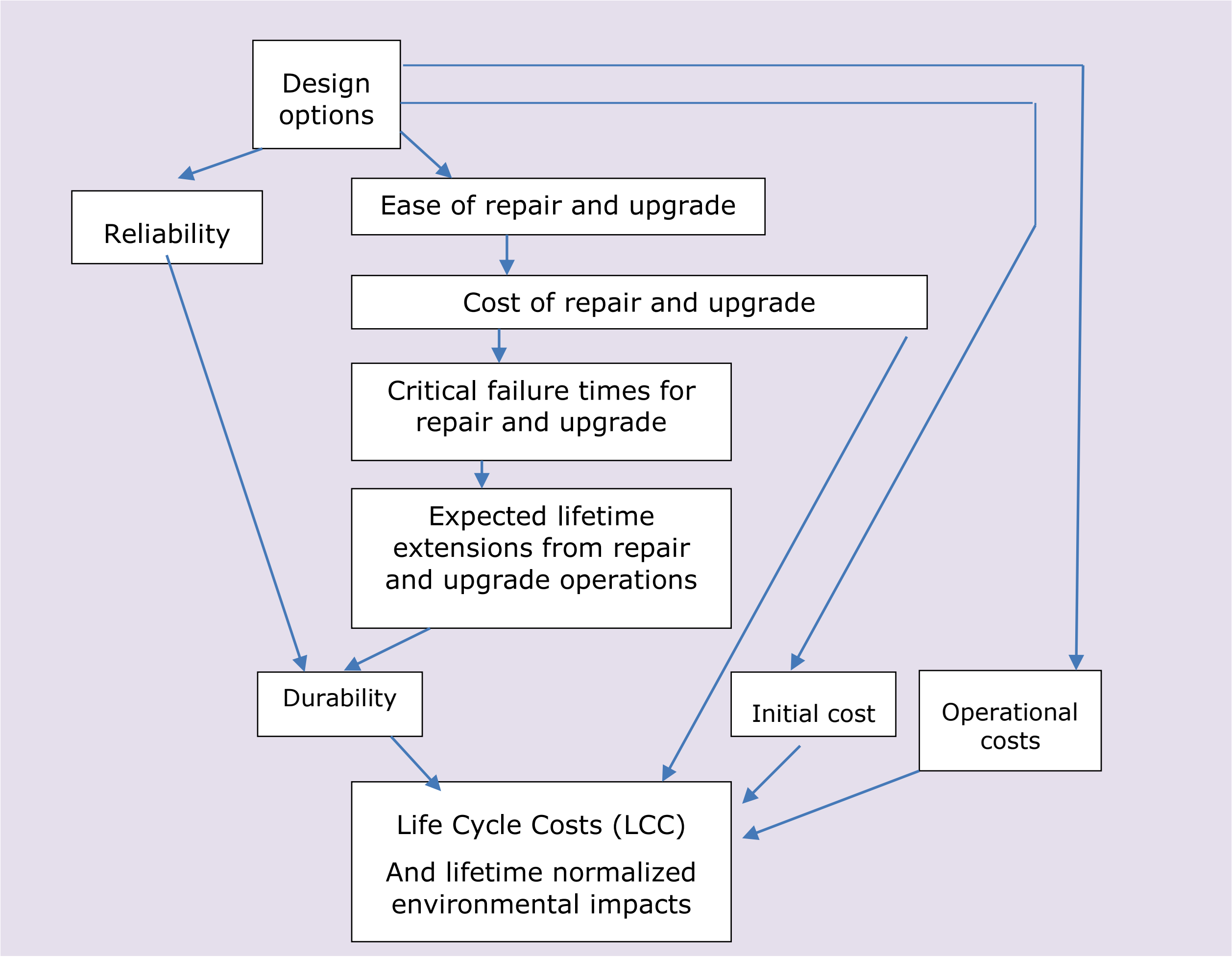
Summarizing, we can present the following sequence of steps to be followed:

1. According to standards EN 4555X, a number of priority parts for repair and upgrade are identified. For instance, according to EN45554, a priority part for repair and upgrade is determined by the likelihood of the need to replace or upgrade the part, the suitability of the part for reuse, and the functionality of the part.
2. These priority parts will be treated as a series assembly for the Weibull lifetime analysis.
3. A Weibull shape parameter is identified (by the Study-Team) for the specific product group under analysis.
4. Using the initial expected lifetime of the product (the reliability previously estimated from the scoring system), the location parameter of the Weibull distribution is calculated.
5. It is assumed that each product will at most_undergo 1 repair or upgrade operation, i.e., the second failure (either due to repair or upgrade needs) will bring about the product's end of life.
6. The product's expected future lifetime after the repair or upgrade operation is calculated (given the time when the failure happened), i.e., the L_E/t_f curve is constructed.
7. A cost analysis is performed (given the relative cost of repair or upgrade compared to the purchase price of a new item) to determine the minimum (critical) lifetime extension that is economically viable (this is a repair or upgrade vs replace decision modelling).
8. Given the critical lifetime extension calculated before, a critical time of failure will be calculated, i.e., if the product fails for the first time before this critical time, then it will be repaired or upgraded,

according to the case. If the first failure happens after this critical time, or if a second failure takes place, then the product will not be repaired or upgraded and will simply be replaced.

9. New Weibull lifetime distribution curves are calculated taking into account the described repair or upgrade scenarios. New lifetimes are calculated.

Figure 17 - Flowchart of the calculation process.



Source: JRC elaboration

2.5 Example of expected lifetime calculation: laptop computers

As an illustration of the kind of results that can be possible to obtain, we present below an example of possible values for laptop computers (values are used for purely exemplification purposes):

First, we retrieve from the literature the Weibull parameters for a standard laptop computer(Balde et al. 2015): β=1.5 and η=5.2, which corresponds to an initial lifetime of 4.7 years (which compares quite well with the values presented in the preparatory study for computers: 5 years[42]).

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[42] Documents | Preparatory study on the Review of Ecodesign Regulation 617/2013 (Lot 3) - Computers and Computer servers (computerregulationreview.eu)

We assume that this lifetime value is for a basic computer with no particular reliability concerns. Taking into account that the variation in reliability between leading brands is up to 25.6% (Dodd et al. 2015), we can conclude that the best computers in the market (reliability wise) should have an expected initial lifetime of 5.9 years. Then, expected initial lifetimes for levels 2 and 3 can be set assuming equal percent improvements between levels, as depicted in Table 11. The design options leading to this lifetime performance are those leading to an increased resistance to drop, shock and increased battery longevity. These characteristics can be assessed through standard tests like shown in Table 11 (Alfieri et al. 2021).

Table 11 - Example of a reliability scoring table filled in for laptop computers.

Reliability		
Level	Design options	Average expected initial lifetime
1	Battery lifetime according to IEC EN 61960-3:2017: 90% capacity after 500 cycles Resistant to accidental drop according to IEC 60068 2-31: freefall procedure from 76 cm Resistant to shock according to IEC 60068 2-27: 40G pulse	5.9 yrs
2	Battery lifetime according to IEC EN 61960-3:2017: 90% capacity after 500 cycles Resistant to accidental drop according to IEC 60068 2-31: freefall procedure from 76 cm	5.5 yrs
3	Battery lifetime according to IEC EN 61960-3:2017: 90% capacity after 500 cycles	5.1 yrs
4	-	4.7 yrs

Source: JRC elaboration

Regarding now reparability and upgradability, some basic data was retrieved from the Ecodesign preparatory study[43], namely: an average retail price of 1000€ for a laptop computer, an average cost of repair of 364€ (this was assumed to be the cost of repair of a level 3 laptop) and an average cost of upgrade of 190€ (this was assumed to be the cost of upgrade of a level 3 laptop). For estimating costs of repair and upgrade for levels 1 and 2, it was assumed that the level 3 cost consisted of 60% labour and 40% spare parts (exemplary value, in line with the info retrieved from the Ecodesign preparatory study for Washing Machines (Boyano et al. 2017). This is used for illustration purposes only. In the real cases this data should be specifically collected for each product group.); the average cost of labour for repair and upgrade was assumed to be 150 €/hour, again in line with the Ecodesign preparatory study for Washing Machines (Boyano et al. 2017)). Finally it was assumed that each new level of reparability/upgradability would correspond to a reduction of 25% in the labour requirements [hours] and to an accompanying reduction of 20% in the hourly rate of labour costs [€/hour], thus corresponding to an overall reduction of 40% in the labour costs [€] of the repair/upgrade operations. The cost of spare parts was assumed to remain constant. Of course, these assumptions are for illustration purposes only. In the real case, data would be collected on the prices of repair labour and on the cost of spare parts.

The resulting figures can be seen in Table 12 and Table 13 below, where Figure 15 with an 'infinite' number of priority parts was used for computing t_{Cr}.

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[43] Documents | Preparatory study on the Review of Ecodesign Regulation 617/2013 (Lot 3) - Computers and Computer servers (computerregulationreview.eu)

Table 12 - Example of a preliminary reparability scoring table filled in for laptop computers

Reparability (laptops: assumed purchase price of 1000€)				
Level	Total time to carry-out a typical repair activity [h]	Total cost of the repair [€]	L_{Cr} [yrs]	t_{Cr} [yrs]
1	0.8	220	1.03	12.2
2	1.1	274	1.29	9.3
3	1.5	364	1.71	6.4
4	-	-	-	

Source: JRC elaboration

Table 13 - Example of a preliminary upgradability scoring table filled in for laptop computers

Upgradability (laptops: assumed purchase price of 1000€)				
Level	Total time to carry-out a typical upgrade activity [h]	Total cost of the upgrade [€]	L_{Cr} [yrs]	t_{Cr} [yrs]
1	0.6	94	0.44	30.0
2	0.8	130	0.61	21.6
3	1.0	190	0.89	14.4
4	-	-	-	

Source: JRC elaboration

Finally, using Figure 16 (again, with an 'infinite' number of priority parts), the % increase in lifetime can be computed and the corresponding tables filled in, as shown in Table 14 and Table 15.

Table 14 - Example of a reparability scoring table filled in for laptop computers.

Reparability	
Level	Increase in lifetime (ΔL_R)
1	50%
2	49%
3	43%
4	0%

Source: JRC elaboration

Table 15 - Example of an upgradability scoring table filled in for laptop computers.

Upgradability	
Level	Increase in lifetime (ΔL_U)
1	50%
2	50%
3	50%
4	0%

Source: JRC elaboration

In the example above, you can see that the overall durability can float from a minimum of 4.7 years to a maximum of 13.3 years. Therefore a 183% increase in longevity (durability) is possible through an adequate choice of design options.

$$Lt_{min} = 4.7(1+0)(1+0) = 4.7\,yrs$$

Equation 8

$$Lt_{max} = 5.9(1+0.50)(1+0.50) = 13.3\,yrs$$

Equation 9

Please consider that the values 0.50 in equation 9 correspond respectively to ΔL_R (50%) and ΔL_U (50%) as reported in Table 14 and Table 15.

To finalise this example, a sensitivity analysis was performed regarding the total cost of repair and upgrade. In the case of a 10% increase in the total cost of repair, the increase in lifetimes changed from 50%, 49% and 43% to 50%, 48% and 38%, respectively. In the case of a 10% decrease in the total cost of repair, the increase in lifetimes changed from 50%, 49% and 43% to 50%, 50% and 46%, respectively. For upgradability, there was no discernible change with respect to a 10% increase or decrease in costs.

2.6 Example of expected lifetime calculation: washing machines

As another illustration of the kind of results that can be possible to obtain, we present below an example of possible values for washing machines (values are used for purely exemplification purposes):

First, we retrieve from the literature the Weibull parameters for a standard washing machine(Balde et al. 2015): β=2.2 and η=13.9, which corresponds to an initial expected lifetime of 12.3 years (which compares quite well with the values presented in the preparatory study for washing machines: 12.5 years).

We assume that this expected lifetime value is for a basic washing machine with no particular reliability concerns. Assuming a variation in reliability between leading brands similar to the computers case (25.6%), we can conclude that the best washing machines in the market (reliability wise) should have and expected initial expected lifetime of 15.5 years. Then, expected initial lifetimes for levels 2 and 3 can be set assuming equal percent improvements between levels, as depicted in Table 16. The design options leading to this expected lifetime performance are those leading to an increased resistance to environmental conditions; increased engine and control systems longevity and increased door and elastomers longevity. These characteristics can be assessed through standard tests like shown in Table 16 (Boyano et al. 2017).

Table 16 - Example of a reliability scoring table filled in for washing machines.

Reliability		
Level	Design options	Average expected initial lifetime
1	Door and elastomers - Household and similar electrical appliances - Safety - Part 2-7: Particular requirements for washing machines (IEC 60335-2-7) Engine, switches and control system - Household and similar electrical appliances - Safety - Part 1: General requirements; EN 60335-1:2012/FprAD:2014. Durability test standards and measurement methods applied in EU ecodesign and ecolabel regulations International IEC 60068-1 ed7.0 Environmental testing	15.5 yrs
2	Engine, switches and control system - Household and similar electrical appliances - Safety - Part 1: General requirements; EN 60335-1:2012/FprAD:2014. Durability test standards and measurement methods applied in EU ecodesign and ecolabel regulations International IEC 60068-1 ed7.0 Environmental testing	14.3 yrs
3	Durability test standards and measurement methods applied in EU ecodesign and ecolabel regulations International IEC 60068-1 ed7.0 Environmental testing	13.3 yrs
4	-	12.3 yrs

Source: JRC elaboration

For washing machines, the upgradability dimension is irrelevant. Regarding reparability, some basic data was retrieved from the Ecodesign preparatory study, namely: an average retail price of 450€ for a washing machine and an average cost of repair of 250€ (this was assumed to be the cost of repair of a level 3 washing machine). For estimating costs of repair and upgrade for levels 1 and 2, it was assumed that the level 3 cost consisted of 60% labour and 40% spare parts (in line with the info retrieved from the Ecodesign preparatory study for Washing Machines (Boyano et al. 2017)); the average cost of labour for repair and upgrade was assumed to be 150 €/hour, again in line with the Ecodesign preparatory study for Washing Machines (Boyano et al. 2017)). Finally it was assumed that each new level of reparability would correspond to a reduction of 25% in the labour requirements [hours] and to an accompanying reduction of 20% in the hourly rate of labour costs [€/hour], thus corresponding to an overall reduction of 40% in the labour costs [€] of the repair/upgrade operations. The cost of spare parts was assumed to remain constant. Of course, these assumptions are for illustration purposes only. In the real case, data would be collected on the prices of repair labour and on the cost of spare parts.

The resulting figures can be seen in Table 17 below, where Figure 15 with an 'infinite' number of priority parts was used for computing t_{Cr}.

Table 17 - Example of a preliminary reparability scoring table filled in for washing machines

Reparability (washing machines: assumed purchase price of 450€)				
Level	Total time to carry-out a typical repair activity [h]	Total cost of the repair [€]	L_{Cr} [yrs]	t_{Cr} [yrs]
1	0.6	158	4.31	18.5
2	0.8	196	5.36	13.4
3	1.0	250	6.83	8.7
4	-	-	-	

Source: JRC elaboration

Finally, using Figure 16 (again, with an 'infinite' number of priority parts), the % increase in lifetime can be computed and the corresponding tables filled in, as shown in Table 18.

Table 18 - Example of a reparability scoring table filled in for washing machines.

Reparability	
Level	Increase in lifetime (ΔL_R)
1	45%
2	35%
3	21%
4	0%

Source: JRC elaboration

In the example above, you can see that the overall durability can float from a minimum of 12.3 years to a maximum of 22.4 years. Therefore an 82% increase in longevity (durability) is possible through an adequate choice of design options.

$$Lt_{min} = 12.3(1 + 0) = 12.3\,yrs$$

Equation 10

$$Lt_{max} = 15.5(1 + 0.45) = 22.4\,yrs$$

Equation 11

Please consider that the value 0.45 in equation 11 corresponds to ΔL_R (45%) reported in Table 18.

To finalise this example, a sensitivity analysis was performed regarding the total cost of repair and upgrade. In the case of a 10% increase in the total cost of repair, the increase in lifetimes changed from 45%, 35% and 21% to 41%, 30% and 16%, respectively. In the case of a 10% decrease in the total cost of repair, the increase in lifetimes changed from 45%, 35% and 21% to 47%, 40% and 27%, respectively.

2.7 Estimating Costs

The estimation of repair and upgrade costs, *vis-à-vis* the purchase cost, is a critical aspect of the proposed methodology. In order to make consistent estimates of this parameter it is proposed to follow the depicted procedure:

1. Material needs are to be taken from the Ecoreport Tool (see chapter 2.4 above). Costs for these spare parts are likely to be quite homogeneous throughout the EU and can be found through a simple market research activity. This should be done during the preliminary study.
2. Labour needs (in hours) can be estimated through the work carried out in producing the tables needed for the discrete steps scoring system presented. Then these hours must be multiplied by the labour costs of the specific Member State under consideration, and these can vary widely. A method to deal with this variation is proposed in the next section.

2.8 Dealing with Costs that can vary significantly across the EU

In order to apply the methodology described in the previous section, the repair and upgrade costs must be estimated. These will depend not only on the price of replacement materials and productive factors such as the cost of electricity, but also, and maybe more importantly, on the cost of labour, which can vary quite a bit across the EU. Therefore, some kind of averaging procedure has to be developed and applied in order to get to a single estimate of repair and upgrade costs.

We propose that the same kind of modelling being used for the sales and stock model of task 1.f is used to estimate the products' stock that is in place in a representative set of member states. Then, the cost of the repair or upgrade operation should be estimated for the representative set of Member States taking into account local conditions (i.e., the local price of labour). Finally, an EU average should be calculated for the repair/upgrade operations using the member state's stock in place as a weighting factor. Alternatively, if data proves to be too hard to find, an EU average (from Eurostat or other similar source) could be used.

2.9 Dealing with other material efficiency parameters (*e.g.*, recyclability)

When including material efficiency aspects in the analysis, other parameters besides durability become important. Obvious among those are Recycled content and Recyclability. These two parameters will be modelled through the Circular Footprint Formula (CFF). This will be implemented through the Ecoreport tool as detailed in Tasks 1.d and 1.g of the project. Default parameters[44] are defined in the database for each material, based on average values in use in the EF method, and displayed when materials are introduced in the Bill of Materials (BoM). Still, if relevant and if more specific information is available for the product in study, the user has the possibility to modify these entry values (please refer to section 1.3 and to the Ecoreport tool manual).

Although the models being described here in Task 2 have a limited contribution to the estimation of recycled contents, it could be used to better estimate recyclability for specific products (or components), if it is believed that a specific value would be considerably better than default average value. The suggested way to better estimate specific values for recyclability is to use a discrete step scoring system identical in all aspects to the one used for the durability calculations.

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[44] Default values of recycling output rate R2 are provided by the EF method in the so called "Annex C" which is available at: http://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml

Thus being, a discrete steps table will be created indicating the percentage of materials which can be recovered, as shown below:

Table 19 - Discrete steps scoring system for recyclability.

Recyclability		
Level	Design options	Expected % of recyclable material
1	Design options leading to best achievable % of material recoverable for recycling in the market.	Lt_{01}
2	Design options leading to a good % of material recoverable for recycling in relation to the market reference.	Lt_{02}
3	Design options leading to a not-so-good % of material recoverable for recycling in relation to the market reference.	Lt_{03}
4	Design options leading to worst % of material recoverable for recycling in the market.	Lt_{04}

Source: JRC elaboration

The specific design options to take into account are not prescribed here, as the existing diversity among different product groups precludes such a prescriptive approach. This way, the Study-Team should have enough leeway to fully adapt the design options to be considered to the physical reality of the specific product-group under analysis.

However, just for illustration purposes, design options and characteristics taken into consideration could be, inter alia, the following:

- Improved dismantlability (*e.g.*, reduced dismantling time, provision of instructions);
- Information on material content and/or marking of parts/components;
- Restriction of materials/substances hampering recycling;
- Cost-benefit assessment of selective recycling treatments (*e.g.*, through manual or automatic separation) vs mechanical treatments (e.g. via fine shredding and sorting);
- Reduced number of different materials used within an assembly.

As before, notice that the different recyclability levels will mean different ease of recovering materials, and therefore different material recovering costs. This is the parameter that will tilt the balance on the amount of material which is economically viable to be recovered and, therefore, will in fact be recovered.

3 More systematic inclusion of societal life cycle costs

This chapter presents the progress on Task 3 of the project "Review of the MEErP - Methodology for Ecodesign of Energy-related Products" (MEErP)". Task 3 deals with "More systematic inclusion of societal life cycle costs".

It has been noted in evaluations of the Ecodesign and Energy Labelling initiatives, that the 2011 MEErP is rightly based on the life-cycle approach. But it does not adequately cater for inclusion of direct environmental costs, externalities and other indirect costs.' Actually, the current version of the MEErP allows, in theory, the inclusion of societal life cycle costs, by associating a tabular 'MEErP equivalent' price to some emissions inserted in the EcoReport tool, such as, e.g., CO_2 eq., SO_2 eq., NMVOCs and PM_{10} eq. To date, this approach has not been systematically applied in Ecodesign preparatory studies, probably because of the lack of comprehensive and reliable price factors. Therefore, in the present report we propose a set of factors that should adequately and, to the extent possible, accurately represent the societal costs, including externalities, associated with the life cycle of products. The monetary factors presented in this report relate to the Ecoreport tool impact categories and not to specific emissions, therefore making its application much simpler as the impact categories are automatically calculated by the tool. This is a significant change introduced in relation to the previous MEErP version.

As a word of caution, it should be stressed that the Ecodesign directive is very clear in the fact that Ecodesign measures are based on the Least Life Cycle Cost (LLCC) from the end-user point of view. Therefore societal life cycle costs should take no part on the calculation of the LLCC. Nevertheless, these costs do bring additional useful information. In fact, as stated before, the usefulness of this information is already acknowledged in the current version of the MEErP.

Monetary valuation is the practice of converting measures of social and biophysical impacts into monetary units. There are several approaches to calculate monetary valuation coefficients. These approaches are categorized according to their underpinning hypothesis, assumptions and monetary valuation methods. The most common monetary valuation methods are the following:

- Observed preferences - Determining willingness to pay in an existing market for a good: the marginal value of a good is identified on the basis of its market price.
- Revealed preferences - Determining willingness to pay in surrogate markets: the marginal value of a non-market good is identified on the basis of the market price of a surrogate good, i.e., a market good whose price is indirectly affected by changes in availability of the non-market good.
- Stated preferences - Determining willingness to pay in hypothetical markets or trade-off situations: the marginal value of a non-market good is identified on the basis of the preferences expressed in response to hypothetical trade-off questions.
- Budget constrain - Determining willingness to pay for an additional Quality-Adjusted Life Year in a hypothetical situation without externalities: the marginal value of a Quality-Adjusted Life Year is identified on the basis of the potential economic production per capita per year.
- Abatement cost - Determining potential cost for the marginal abatement or replacement activity: a cost estimation method where the change in availability of a non-market good is assessed in terms of the potential costs of the marginal counter-balancing change (replacement) or marginal measure that prevents the change.
- Damage cost - Determining potential cost related to the damages resulting from pollution: a cost estimation of the damage derived from an emission or from other changes in natural capital.

Monetary valuation has a great potential to be applied for the interpretation of environmental impacts derived according to the Life Cycle Assessment (LCA) methodology. This method can capture both direct environmental costs as well as externalities and other indirect costs. It is therefore potentially suggested for the modelling of the societal costs that we are looking for.

A number of monetary valuation coefficients has already been proposed in other commission initiatives[45, 46], however some of the values presented[45] refer to emissions of specific substances (e.g., SO_2) which was not possible to consider as not matching the impact categories in the ERT (e.g., acidification). For example, SO_2 emissions have an effect on several impact categories (i.e., acidification and photochemical ozone formation), and so do NH_3 emissions (acidification, terrestrial and marine eutrophication, freshwater ecotoxicity, etc.). Therefore, the monetary cost of the emission of these substances would have to be split between several different impact categories, which could be tricky to compute. Nevertheless, an effort was made to match the proposed values with existing Commission proposals. When that was not possible, we have resorted to a thorough review of existing sets of monetary valuation coefficients (focusing on LCA applications) conducted by the JRC[47] in view of identifying monetary valuation coefficients available in the literature and assess their suitability to monetize midpoint impacts calculated according to the Environmental Footprint method. It should be pointed out that when the level of uncertainty seemed too high to allow for a robust estimate, we have conservatively chosen not to propose any monetisation value at all.

Without going into further details that can be found in the original publications, we present in Table 20, the proposed preliminary set of monetary valuation coefficients.

Table 20 - Preliminary set of monetary valuation coefficients

Impact category		Unit of measure	Value	Source
1	Climate change, total	$€_{2019}$/kg CO_2 eq.	1.00×10^{-1}	DG MOVE[45]
2	Ozone depletion	$€_{2019}$/kg CFC-11 eq.	$5.55\times10^{+1}$	JRC[47]
3	Human toxicity, cancer	$€_{2019}$/CTUh	$1.66\times10^{+5}$	JRC[47] based on Trinomics report[46]
4	Human toxicity, non-cancer	$€_{2019}$/CTUh	$9.19\times10^{+5}$	JRC[47] based on Trinomics report[46]
5	Particulate matter	$€_{2019}$/disease incidence	$7.28\times10^{+5}$	DG MOVE[45]. See Annex IV for a detailed conversion calculation.
6	Ionising radiation, human health	$€_{2019}$/kBq U_{235} eq.	-	-
7	Photochemical ozone formation, human health	$€_{2019}$/kg NMVOC eq.	1.20×10^{0}	DG MOVE[45]
8	Acidification	$€_{2019}$/mol H^+ eq.	3.50×10^{-1}	JRC[47] based on Trinomics report[46]
9	Eutrophication, terrestrial	$€_{2019}$/mol N eq.	-	-
10	Eutrophication,	$€_{2019}$/kg P eq.	1.95×10^{0}	JRC[47] based on Trinomics report[46]

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[45] European Commission, Directorate-General for Mobility and Transport, Essen, H., El Beyrouty, K., Bieler, C., et al.,Handbook on the external costs of transport: version 2019, Publications Office, 2019, doi: 10.2832/51388.

[46] European Commission, Directorate-General for Energy, Smith, M., Moerenhout, J., Thuring, M., et al., External costs: energy costs, taxes and the impact of government interventions on investments: final report, Publications Office, 2020, doi:10.2833/827631.

[47] Amadei, A., De Laurentiis, V., Sala, S, Monetary valuation of environmental impacts in life cycle assessment: state of the art and challenges, European Commission, 2021, JRC125725.

	freshwater			
11	Eutrophication, marine	€$_{2019}$/kg N eq.	3.27×10^{0}	JRC[47] based on Trinomics report[46]
12	Ecotoxicity, freshwater	€$_{2019}$/CTUe	3.89×10^{-5}	JRC[47] based on Trinomics report[46]
13	Land use	€$_{2019}$/pt	1.78×10^{-4}	JRC[47] based on Trinomics report[46]
14	Water use	€$_{2019}$/m^{3} water eq. of deprived water	5.08×10^{-3}	JRC[47] based on Trinomics report[46]
15	Resource use, minerals and metals	€$_{2019}$/kg Sb eq.	-	-
16	Resource use, fossils	€$_{2019}$/MJ	-	-

Source: JRC elaboration based on (European Commission 2019),(European Commission 2020), (Amadei, De Laurentiis, and Sala 2021)

We suggest to systematically incorporate the societal life cycle costs - as given by the multiplication of the impacts taken from the ERT by the pricing factors presented here as supporting information within the economic impacts estimated in task 7 of the MEErP.

If the need to adjust the valuation coefficients for inflation, the method presented in the previously mentioned JRC report[47] could be used.

4 More refined evaluation of the economic impacts in task 7 of the MEErP

This chapter presents the progresses on Task 4 of the project ""Review of the MEErP - Methodology for Ecodesign of Energy-related Products" (MEErP)"[3]. Task 4 deals with "More refined evaluation of the economic impacts in task 7 of the MEErP".

The need for a more refined method for the evaluation of the economic impacts (e.g., impacts on employment) in Task 7 of the MEErP was identified. The current method basically makes use of the average revenue per employee, together with the expected increase in business revenues (caused, in turn, by placing on the market products features an increased price, due to their improved energy efficiency) to derive an indication on the potential of job creation linked to potential regulatory measures. The method rests on various modelling simplifications, e.g., it does not consider the reaction of labour markets to the increased turnover of manufacturers. Moreover, the evaluation of impacts from material efficiency requirements calls for a more refined method.

In this chapter we propose a more refined method for the evaluation of the impacts of Ecodesign requirements on employment, including the explicit modelling of the impact caused by changes in Lifetime of the products and redistribution effects between sectors and countries. The technical details of the modelling used in this chapter can be found in Annex V.

The use of employment factors is a widely accepted and fairly simple and robust method for estimating the direct employment effects of a given policy. Key advantages of the employment factors method are that it can be tailored to specific contexts and applied to a wide range of scenarios. The employment factor, represents the labour input required to produce one physical unit of the product under analysis. Compared to the current approach followed in the MEErP (constant revenue per employee, which could also be interpreted as the amount of labour required to generate one unit of revenue) this method is considerably more reliable because it does not take into consideration changes in pricing alone, i.e., since the units considered are physical units, pricing effects will not have a direct impact on the method. The only way that pricing can end up having an effect is by the change in demanded quantity that is induced by a pricing alteration.

Therefore, if direct labour effects are estimated using employment factors (to be retrieved from the specialized literature on a case-by-case basis by the Study-Team) and indirect labour effects are estimated by modelling the impact that pricing changes will have on the demand function, the overall model will be significantly more robust than using the revenue per employee ratio.

Also, changes induced by material efficiency requirements, *i.e.*, increased lifetime, will have to be factored in as well. It has been stated often in this report that sales, stock and longevity are not independent quantities but rather are interlinked in a way that can be captured by the dynamic sales and stock model (see Annex V).

Please notice that the previous analysis concerns only employment effects on the manufacturing sector. Effects on the service sector (repair and upgrade) will have to be modelled independently and then combined with the manufacturing sector results to find out the aggregated effect on employment.

In summary, changes in the amount of labour in the manufacturing sector are caused by:

1) A direct effect if the Ecodesign requirements change the amount of work necessary to produce one unit of the product (this will amount to a direct change in the employment factor). If present, this effect would be expected to be of a positive sign thus increasing the total labour demand associated with the product group.
2) An indirect effect caused by possible changes in the production costs of the products that were induced by the Ecodesign requirements. It is expected that firms respond to a change in production costs (including changes in the amount of labour required) adjust the pricing of their products in order to keep their profits unchanged. In turn, this change in price might induce a change in the

demand of the product. If present, this effect would be expected to be of a negative sign thus decreasing the total labour demand associated with the product group.

3) Finally, and perhaps the most relevant effect, and indirect effect caused by changes in the longevity of the products that will affect yearly sales and thus the demand for the product. This change in demand induced by longevity changes can be estimated by the dynamic sales and stock model already mentioned in this report (see Annex V for details). This effect is expected to be of a negative sign thus decreasing the total labour demand associated with the product group, *i.e.*, increased longevity is expected to result in decreased demand.

In Annex V a detailed modelling is proposed to estimate all of these effects. Then, the redistribution effects between the EU and the extra EU space can be estimated just by checking what is the fraction of the total products sold that is originated in each region and allocating the calculated changes in manufacturing labour accordingly.

Keeping in mind that the increased longevity of the products is in many cases due to an improvement in reparability and upgradability, we can conclude that the expected decrease in manufacturing labour requirement will be offset or overshadowed by an increase in labour requirements for the repair and upgrade sectors. The exact final balance is hard to be predicted in advance, but Annex V presents guidelines for the Study-Team on how to perform the detailed calculations.

The effect of increased reparability and upgradability will always be of a positive sign, *i.e.*, it will always cause an increase in labour requirements for these sectors and is of an intrinsically local nature, therefore concentrating its effects on the country where the product is being used.

The overall effect of Ecodesign on employment on a given region will then have to be estimated by the Study-Team taking into account the combined effect of the impact exerted on the manufacturing sector, the service sector (repair and upgrade) and the distribution of the country of manufacturing of the products sold. In countries where the tertiary sector outweighs the secondary sector (like in most of the EU countries), it is expected that the overall effect is positive (*i.e.*, a net increase in employment) but the detailed calculation will have to be carried out by the Study-Team on a case-by-case basis in order to confirm this intuition. Again, technical details can be found in Annex IV.

4.1 Example of employment effect calculation: laptop computers

From the Ecodesign preparatory study for computers, we can retrieve that the average manufacturing costs of a laptop computer are around 219€. If to this we add the manufacturing margin of 50% (estimated as a bit higher that the manufacturing margin for washing machines for the purposes of this example[48], which is stated in the washing machines preparatory study as 28%) we get a manufacturing exit price of 328€. Then, adding an aggregated wholesale/retail margin factor of 2.5 (taken from the washing machines preparatory study) and 22% VAT, we can retrieve the previously mentioned 1000€ average retail price.

We can estimate that 25% of the manufacturing price is related to labour and that in the manufacturing sector the rate of labour costs is much lower than the 150€/hour estimated for the repair sector. Let's assume a rate of 50€/hour. This results in a requirement of 1.1 hours of labour to manufacture a laptop computer. This would be the "employment factor", L_{M0}, in Annex IV. We also assume that this factor does not change with reparability or upgradability levels. We assume, however, that production cost increase by 2% for each reparability level, in order to take into account different materials and production methods.

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[48] During the preparatory/review study these data will have to be collected for the corresponding product by the Study-team

Finally we get from the preparatory study that the EU production of laptop computers was 6.3 million units in 2014 (we will use this value although it is clearly dated) and we can estimate the sector's elasticity of demand from the manufacturing exit price (328€) and the manufacturing production cost (219€) as detailed in Annex IV (we get $\varepsilon \approx -3$). Then using the formula below as proposed in Annex IV, we can finally get to Table 21, where the effects of increased reparability on the demand for EU manufacturing labour can be found.

$$\Delta L_M = Sl_0\left(\frac{Lt_0}{Lt_1}\left(\frac{CV_1}{CV_0}\right)^{\varepsilon} L_{M1} - L_{M0}\right)$$

Equation 12

Table 21 - Effect of reparability level on EU manufacturing labour for laptop computers.

Level	*L_{M0} [h]*	*L_{M1} [h]*	*L_{t0} /L_{t1}*	*CV_1/CV_0*	*ΔL_M [fte]*
1	*1.1*	*1.1*	*0.67*	*1.06*	*-1,694*
2	*1.1*	*1.1*	*067*	*1.04*	*-1,552*
3	*1.1*	*1.1*	*0.70*	*1.02*	*-1,305*
4	*1.1*	*1.1*	*1.00*	*1.00*	*0*

Source: JRC elaboration

In Table 21 (and in the following tables as well), the effects of reparability on labour requirements are expressed in full time equivalents (fte) for improved readability. In order to transform hours per year in to ftes a factor of 1,800 worked hours per year per employee was used.

The effects of increased reparability on the repair sector are possible to be estimate from the formula below (from Annex IV). Recalling that in this case the quantity is not the production but rather the EU sales and trade (equal to production+imports-exports) which, according to the preparatory study was 94.86 million units in 2014, we finally get Table 22 for the effects of increased reparability on the demand for EU repair labour and the respective aggregate result.

$$\Delta L_R = R_f Sl_0 \frac{Lt_0}{Lt_1}\left(\frac{CV_1}{CV_0}\right)^{\varepsilon} L_{R1}$$

Table 22 - Effect of reparability level on EU repair and aggregated labour for laptop computers.

Level	L_{R1} [h]	L_{t0} /L_{t1}	CV_1/CV_0	R_f	ΔL_R [fte]	ΔL [fte]
1	0.8	0.67	1.06	97.2%	24,191	22,505
2	1.1	0.67	1.04	90.9%	32,187	30,636
3	1.5	0.70	1.02	74.4%	38,875	37,570
4	0	1.00	1.00	0%	0	0

Source: JRC elaboration

The exact same exercise can be done for the upgradability levels as depicted below:

Table 23 - Effect of upgradability level on EU manufacturing labour for laptop computers.

Level	L_{M0} [h]	L_{M1} [h]	L_{t0} /L_{t1}	CV_1/CV_0	ΔL_M [fte]
1	1.1	1.1	0.67	1.06	-1,695
2	1.1	1.1	0.67	1.04	-1,569
3	1.1	1.1	0.67	1.02	-1,432
4	1.1	1.1	1.00	1.00	0

Source: JRC elaboration

Table 24 - Effect of upgradability level on EU upgrade and aggregated labour for laptop computers.

Level	*L_{U1} [h]*	*L_{t0} /L_{t1}*	*CV_1/CV_0*	*U_f*	*ΔL_R [fte]*	*ΔL [fte]*
1	*0.6*	*0.67*	*1.06*	*100%*	*16,590*	*14,895*
2	*0.8*	*0.67*	*1.04*	*100%*	*23,416*	*21,848*
3	*1.0*	*0.67*	*1.02*	*99%*	*32,765*	*31,333*
4	*0*	*1.00*	*1.00*	*0%*	*0*	*0*

Source: JRC elaboration

To finalise this example, a sensitivity analysis was performed regarding the total cost of repair and repair labour requirements. In the case of a 10% increase in the total cost of repair and a 5% increase in repair labour requirements, the overall labour effect changed from 22,505 ftes, 30,636 ftes and 37,570 ftes to 23,187 ftes, 30,857 ftes and 36,475 ftes, respectively. In the case of a 10% decrease in the total cost of repair and a 5% decrease in repair labour requirements, the overall labour effect changed from 22,505, 30,636 and 37,570 ftes to 21,596 ftes, 30,053 ftes and 38,217 ftes, respectively.

4.2 Example of employment effect calculation: washing machines

From the Ecodesign preparatory study for washing machines, we can retrieve that the average manufacturing costs of a washing machine are around 148€. If to this we add the manufacturing margin of 28% we get a manufacturing exit price of 189€. Then, adding an aggregated wholesale/retail margin factor of 2.5 (taken from the washing machines preparatory study) and 22% VAT, we can retrieve the previously mentioned 450€ average retail price.

We can estimate that 25% of the manufacturing price is related to labour and that in the manufacturing sector the rate of labour costs is much lower than the 150€/hour estimated for the repair sector. Let's assume a rate of 50€/hour. This results in a requirement of 0.74 hours of labour to manufacture a washing machine. This would be the "employment factor", L_{M0}, in Annex IV. We also assume that this factor does not change with reparability or upgradability levels. We assume, however, that production cost increases by 2% for each reparability level, in order to take into account different materials and production methods.

Finally we get from the preparatory study that the EU production of washing machines was 20.5 million units in 2014 (we will use this value although it is clearly dated) and we can estimate the sector's elasticity of demand from the manufacturing exit price (189€) and the manufacturing production cost (148€) as detailed in Annex IV (we get $\varepsilon \approx -4.6$). Then using the formula below as proposed in Annex IV, we can finally get to Table 25, where the effects of increased reparability on the demand for EU manufacturing labour can be found.

$$\Delta L_M = Sl_0 \left(\frac{Lt_0}{Lt_1} \left(\frac{CV_1}{CV_0} \right)^{\varepsilon} L_{M1} - L_{M0} \right)$$

Equation 13

Table 25 - Effect of reparability level on EU manufacturing labour for washing machines.

Level	L_{M0} [h]	L_{M1} [h]	L_{t0} /L_{t1}	CV_1/CV_0	ΔL_M [fte]
1	0.74	0.74	0.69	1.06	-3,967
2	0.74	0.74	0.74	1.04	-3,224
3	0.74	0.74	0.83	1.02	-2,075
4	0.74	0.74	1.00	1.00	0

Source: JRC elaboration

The effects of increased reparability on the repair sector can be estimated from the formula below (from Annex IV). Recalling that in this case the quantity is not the production but rather the EU sales and trade (equal to production+imports-exports) which, according to the preparatory study was 21.1 million units in 2014, we finally get Table 26 for the effects of increased reparability on the demand for EU repair labour and the respective aggregate result.

$$\Delta L_R = R_f Sl_0 \frac{Lt_0}{Lt_1} \left(\frac{CV_1}{CV_0} \right)^{\varepsilon} L_{R1}$$

Equation 14

Table 26 - Effect of reparability level on EU repair and aggregated labour for washing machines.

Level	L_{R1} [h]	L_{t0} /L_{t1}	CV_1/CV_0	R_f	ΔL_R [fte]	ΔL [fte]
1	0.6	0.69	1.06	84.8%	3,155	-812
2	0.8	0.74	1.04	60.3%	3,494	270
3	1.0	0.83	1.02	30.0%	2,647	572
4	0	1.00	1.00	0%	0	0

Source: JRC elaboration

To finalise this example, a sensitivity analysis was performed regarding the total cost of repair and repair labour requirements. In the case of a 10% increase in the total cost of repair and a 5% increase in repair labour requirements, the overall labour effect changed from -812 ftes, 270 ftes and 572 ftes to -847 ftes, 22 ftes and 191 ftes, respectively. In the case of a 10% decrease in the total cost of repair and a 5%

decrease in repair labour requirements, the overall labour effect changed from -812, 270 ftes and 572 ftes to -844 ftes, 467 ftes and 1,002 ftes, respectively.

5 Systematic updates

Some parameters necessary for the economic analysis are liable to change in the short term. Therefore, a method to update these parameters in a systematic way is proposed here for the parameters that have been identified as of interest.

Energy prices and prices growth rate

Eurostat provides statistics for EU household prices both for electricity[49] and natural gas[50]. These statistics are presented both for individual Member States and for the aggregate EU. Prices' time-series is presented since 2008, which allows to seamlessly extrapolate price growth rates from historical data.

Primary energy factor

The reference Primary Energy Factors (PEF) are periodically updated and published in EU law. The latest update for the EU electricity mix PEF (2.1 or 7.56 MJ/kWh) has been published in the Energy Efficiency Directive 2018/2002. Prior to that, a value of 2.5 (or 9.0 MJ/kWh) had been set by the Directive 2006/32/EC on energy end-use efficiency and energy services. Users should check for the latest update before engaging on the preparatory study.

Discount rate (d)

The European Commission periodically publishes recommendations on the social discount rate to be used when evaluating the present value of future monetary flows so that they can be compared from the point of view of society. For several years the recommendation was 4% (since the MEErP was designed), but the latest recommendation is 3%[51]. Users should check for the latest update before engaging on the preparatory study.

Inflation rate (i)

Historical values of EU inflation can be obtained from the Consumer Price Index published by Eurostat[52]. If, however, a forecast of future inflation is required, then the medium term target inflation rate set by the European Central Bank should be used. Currently, this target is set at 2%[53]. Users should check for the latest update before engaging on the preparatory study.

Escalation rate (e)

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[49] Electricity price statistics - Statistics Explained (europa.eu)

[50] Natural gas price statistics - Statistics Explained (europa.eu)

[51] European Commission, BETTER REGULATION TOOLBOX, November 2021.

[52] Consumer prices - inflation - Statistics Explained (europa.eu)

[53] The ECB's monetary policy strategy statement (europa.eu)

The escalation rate is the real (inflation-corrected) annual growth of running costs. It can be calculated directly from the extrapolated energy prices growth rate after correcting for inflation (using historical data both for prices and for inflation).

Present Worth Factor (PWF)

Calculated directly according to the following equation, where *e* is the escalation rate, *d* is the discount factor and *N* is the product's life in years:

$$PWF = \begin{cases} \left(\frac{1+e}{d-e}\right)\left[1-\left(\frac{1+e}{1+d}\right)^N\right] & e \neq d \\ N & e = d \end{cases}$$

Equation 15

NB: in the MEErP methodology report (COWI and VHK 2011a) the equation for the PWF (page 133) is not correct. The correct form of the calculation is the one presented here.

It should be noticed (as stated in the MEErP methodology report (COWI and VHK 2011a)) that as long as the discount rate and the growth ('escalation') rate are more or less balanced, the analyst can use the simplified result PWF=N that will help the ease of understanding of the analysis by policy makers.

6 Conclusions

This report presents the progresses on the project “"Review of the MEErP - Methodology for Ecodesign of Energy-related Products" (MEErP)”[3]. This project is aimed at revising the MEErP and to bridge the shortcomings that have been identified since its last revision in 2013, as described in detail in the introduction.

The main tasks of this project have been addressed individually and in-depth, with the necessary technical detail to allow an informed discussion with stakeholders on the approaches that are here proposed.

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List of abbreviations and definitions

B2B	business to business
BoM	Bill of Materials
CF	characterization factor
CFCs	Chlorofluorocarbons
CFF	Circular Footprint Formula
CRM	Critical Raw Material
DQR	Data Quality Rating
EC	European Commission
EF	Environmental Footprint
EI	Environmental Impact
EoL	End of life
FU	Functional Unit
GER	Gross Energy Requirement
GHG	Greenhouse gas
GWP	Global warming potential
ILCD	International Reference Life Cycle Data System
ILCD-EL	International Reference Life Cycle Data System – Entry Level
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organisation for Standardisation
JRC	Joint Research Centre
LC	Life Cycle
LCA	Life Cycle Assessment
LCDN	Life Cycle Data Network
LCI	Life cycle inventory
LCIA	Life cycle impact assessment
LCT	Life cycle thinking
LLCC	Least Life Cycle Cost
MEErP	Methodology for Ecodesign of Energy-related Products
MEEuP	Methodology for the Ecodesign of Energy-using Products
NACE	Nomenclature Générale des Activités Economiques dans les Communautés Européennes
OEF	Organisation Environmental Footprint
OEFSCR	Organisation Environmental Footprint Sector Rules
PEF	Product Environmental Footprint
PEFCR	Product Environmental Footprint Category Rules
PEF-RP	PEF study of the representative product
RC	Recycled Content
RF	reference flow
RIR	Recycling Input Rate

RR	Recycling Rate
RP	representative product
UNEP	United Nations Environment Programme
UUID	Universally Unique Identifier

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Annexes

Annex I - Mapping of EF 3.1 datasets on materials and components as included in the Ecoreport tool

Table 27: Mapping of virgin and recycling datasets to implement the CFF. Ecoreport tool (2024)

Virgin material	Corresponding datasets for recycling
Acrylonitrile Butadiene Styrene (ABS) emulsion polymerisation, bulk polymerisation or combined processes production mix, at plant	Recycling plastic Acrylonitrile-butadiene-styrene (ABS), waste management, technology mix
Aramid fiber low-temperature solution polymerisation of m-phenylene diamine with isophthaloyl chloride production mix, at plant petrochemical based	Recycling of post-consumer waste polypropylene (PP) collection, sorting, transport, washing, granulation, pelletization production mix, at plant 48,9% recycling rate
Epoxy plastic polymerisation of liquid epoxy resins with a latent hardener (amine) production mix, at plant petrochemical based	Not available
EPS Beads from styrene polymerization and foaming production mix, at plant 0.96- 1.04 g/cm3	Not available
Ethylene propylene dien elastomer (EPDM) copolymerization of ethylene and propylene production mix, at plant 69% ethylene, 38% propylene	Recycling of post-industrial waste EPDM rubber
HDPE granulates Polymerisation of ethylene production mix, at plant 0.91-0.96 g/cm3, 28 g/mol per repeating unit	High density polyethylene (HDPE), recycled washing, drying, shredding, pelletizing production mix, at plant Erec/ErecEoL, efficiency 98%
LDPE granulates Polymerisation of ethylene production mix, at plant 0.91-0.96 g/cm3, 28 g/mol per repeating unit	Low density polyethylene (LDPE), recycled washing, drying, shredding, pelletizing production mix, at plant Erec/ErecEoL, efficiency 90.3%
LLDPE granulates Polymerisation of ethylene production mix, at plant 0.87- 94 g/cm3, 28 g/mol per repeating unit	Mechanical recycling of polyolefins (PO) granulation, pelletization production mix, at plant 91,2% recycling rate
Nylon 6 fiber extrusion into fiber production mix, at plant 5% loss, 3,5 MJ electricity	Nylon fibre, recycled, mechanical, post-consumer washing, drying, shredding, drum rotating spinning production mix, at plant Erec/ErecEoL, efficiency 90%
Polyethylene terephthalate (PET), petrochemical based polymerisation of ethylene glycol and terephthalic acid production mix, at plant petrochemical based	Polyethylene terephthalate (PET) granulate secondary ; no metal fraction from post-consumer waste, via washing, granulation, pelletization production mix, at plant 90% recycling rate
Polyethylene terephthalate (PET), petrochemical based polymerisation of ethylene glycol and terephthalic acid production mix, at plant petrochemical based	Polyethylene terephthalate (PET), recycled, semi-mechanical, post-consumer washing, drying, shredding, pelletizing production mix, at plant Erec/ErecEoL, efficiency 80%
Polymethyl methacrylate (PMMA) granulate bulk polymerisation, from methyl methacrylate production mix, at plant 1.18 g/cm3	Recycling of post-consumer waste polypropylene (PP) collection, sorting, transport, washing, granulation, pelletization production mix, at plant 48,9% recycling rate
Polycarbonate (PC) granulate Technology mix, dipenyl carbonate route and phosgene route production mix, at plant 1.20–1.22 g/cm3	Polycarbonate (PC), recycled, post-consumer chemical recycling, depolymerisation, hydrolysis production mix, at plant Erec/ErecEoL, efficiency 80%
Polyester resin esterification and polymerization, from propylene glycol, phthalic anhydride and styrene production mix, at plant 1.22- 1.38 g/cm3	Not available
Polypropylene (PP), petrochemical based polymerisation of bio-fossil propylene production mix, at plant petrochemical based	Polypropylene, recycled, post-consumer washing, drying, shredding, pelletizing production mix, at plant Erec/ErecEoL, efficiency 90%
Polystyrene production, high impact polymerisation of styrene production mix, at plant 1.05 g/cm3	Recycling of post-consumer waste polypropylene (PP) collection, sorting, transport, washing, granulation, pelletization production mix, at plant 48,9% recycling rate
Polytetrafluoroethylene granulate (PTFE) Mix polymerisation of tetrafluorethylene production mix, at plant 2.16 g/cm3	Recycling of post-consumer waste polypropylene (PP) collection, sorting, transport, washing, granulation, pelletization production mix, at plant 48,9% recycling rate
Polyurethane flexible foam reaction of toluene diisocyanate (TDI) with long-chain polyether polyol and foaming production mix, at plant 18- 53 kg/m3	Not available
Polyurethane rigid foam from methylene diisocyanate (MDI) and polyols production mix, at plant 18- 53 kg/m3	Not available
PVC granulates, low density polymerisation of vinyl chloride production mix, at plant 62 g/mol per repeating unit	Recycling plastic (PVC), waste management, technology mix, at plant
Polyvinyl fluoride polymerisation of vinyl fluoride production mix, at plant 1.77 g/cm3	Recycling of post-consumer waste polypropylene (PP) collection, sorting, transport, washing, granulation, pelletization production mix, at plant 48,9% recycling rate
Polyvinylidenchloride granulate from vinylidene dichloride production mix, at plant 1.63 g/cm3	Recycling of post-consumer waste polypropylene (PP) collection, sorting, transport, washing, granulation, pelletization production mix, at plant 48,9% recycling rate
Polyvinylidene fluoride (PVDF) polymerisation of vinyl fluoride production mix, at plant 1.76 g/cm3	Recycling of post-consumer waste polypropylene (PP) collection, sorting, transport, washing, granulation, pelletization production mix, at plant 48,9% recycling rate
Silicone, high viscosity hydrolysis and methanolysis of dimethyldichloro silane production mix, at plant >30 000 centi Poise	Not available
Aluminium ingot (copper main solute) primary production, aluminium casting and alloying single route, at plant 2.7 g/cm3	Secondary aluminium ingot (copper main solute) secondary production, aluminium casting and alloying single route, at plant 2.7 g/cm3
Aluminium ingot (magnesium main solute) primary production, aluminium casting and alloying single route, at plant 2.7 g/cm3	Secondary aluminium ingot (magnesium main solute) secondary production, aluminium casting and alloying single route, at plant 2.7 g/cm3
Aluminium ingot (manganese main solute) primary production, aluminium casting and alloying single route, at plant 2.7 g/cm3	Secondary aluminium ingot (manganese main solute) secondary production, aluminium casting and alloying single route, at plant 2.7 g/cm3

Aluminium ingot (silicon and magnesium main solutes) primary production, aluminium casting and alloying single route, at plant 2.7 g/cm3	Secondary aluminium ingot (silicon and magnesium main solutes) secondary production, aluminium casting and alloying single route, at plant 2.7 g/cm3
Aluminium ingot (silicon main solute) primary production, aluminium casting and alloying single route, at plant 2.7 g/cm3	Secondary aluminium ingot (silicon main solute) secondary production, aluminium casting and alloying single route, at plant 2.7 g/cm3
Aluminium ingot (zinc main solute) primary production, aluminium casting and alloying single route, at plant 2.7 g/cm3	Secondary aluminium ingot (zinc main solute) secondary production, aluminium casting and alloying single route, at plant 2.7 g/cm3
Aluminium ingot mix (high purity) primary production, aluminium casting single route, at plant 2.7 g/cm3, >99% Al	Recycling of aluminium into aluminium ingot - from post-consumer collection, transport, pretreatment, remelting production mix, at plant aluminium waste, efficiency 90%
Antimony technology mix, primary production production mix, at plant 99.5% Antimony	Antimony, recycled (post consumer, from lead acid batteries)
Brass anode furnace and casting, from copper and zinc, primary production single route, at plant 8.41- 8.86 g/cm3	Brass, recycled, post-consumer die casting, from copper and zinc, primary production production mix, at plant 8.41- 8.86 g/cm3
Brass anode furnace and casting, from copper and zinc, primary production single route, at plant 8.41- 8.86 g/cm3	Brass, recycled, pre-consumer die casting, from copper and zinc, primary production production mix, at plant 8.41- 8.86 g/cm3
Coating powder, exterior production technology mix production mix, at plant 100% active substance	Not available
Cobalt hydro- and pyrometallurgical processes production mix, at plant >99% Co	Cobalt, recycled (4,77 kg Co-Sulphate heptahydrate as 1 kg Co-Metal content)
Ferrite (iron ore) iron ore mining and processing production mix, at plant 5.00 g/cm3	Not available
Ferronickel mining, ore beneficiation production mix, at plant 32 % nickel	Not available
Flat glass, uncoated cut, Pilkington process, from sand and soda ash production mix, at plant 2500 kg/m3	Recycling glass, waste management, technology mix, at plant collection, sorting, transport, recycling production mix, at plant glass waste, efficiency 95%
Gallium technology mix production mix, at plant 5.9 g/cm3	Not available
Gold (primary route) primary route, underground mining and leaching production mix, at plant 19.32 g/cm3	Gold, recycled, pre-consumer collection, transport, dismantling, shredding, separation, remelting production mix, at plant 19.32 g/cm3, recycling efficiency 98%
Platinum primary production production mix, at plant 21.45 g/cm3 , 195.08 g/mol	Platinum, recycled, post-consumer from automotive catalyst scrap
Lead (primary) primary production, mining and processing production mix, at plant 11.3 g/cm3	Secondary lead secondary production, melting of lead scrap single route, at plant 11.3 g/cm3
Manganese mining, separation, calcination, electrolysis production mix, at plant 7.21 g/cm3	Manganese, recycled (3,08 kg Mn-Sulphate as 1 kg Mn-Metal content)
Molybdenum mining & concentration flotation, roasting, reduction production mix, at plant 10.28 g/cm3	Molybdenum, recycled (pre consumer, remelting in EAF)
Nickel mining and processing production mix, at plant 8.9 g/cm3, update available	Nickel, recycled (4,48 kg Ni-Sulphate hexahydrate represent 1 kg Ni-Content)
Palladium primary production, mining and processing production mix, at plant 11.99 g/cm3	Palladium, recycled, post-consumer collection, transport, dismantling, shredding, separation, remelting production mix, at plant 11.99 g/cm3
Platinum primary production production mix, at plant 21.45 g/cm3 , 195.08 g/mol	Platinum Recycled (post-consumer mix of electronic scrap and automotive catalyst recycling)
Magnesium Pidgeon Process, primary production production mix, at plant 1.74 g/cm	Magnesium, recycled (pre consumer, remelting)
Rare earth concentrate mining, concentration, roasting, refining production mix, at plant concentrated	Not available
Silver mining, concentration, roasting, refining production mix, at plant 10.49 g/cm3	Silver, recycled technology mix production mix, at plant 10.49 g/cm3
Stainless steel cold rolled hot rolling production mix, at plant stainless steel	Secondary steel slab electric arc furnace route, from steel scrap, secondary production single route, at plant carbon steel
Stainless steel cold rolled hot rolling production mix, at plant stainless steel	Steel cast part alloyed electric arc furnace route, from steel scrap, secondary production single route, at plant carbon steel
Stainless steel hot rolled hot rolling production mix, at plant stainless steel	Secondary steel slab electric arc furnace route, from steel scrap, secondary production single route, at plant carbon steel
Stainless steel hot rolled hot rolling production mix, at plant stainless steel	Steel cast part alloyed electric arc furnace route, from steel scrap, secondary production single route, at plant carbon steel
Steel cold rolled coil blast furnace route single route, at plant carbon steel	Secondary steel slab electric arc furnace route, from steel scrap, secondary production single route, at plant carbon steel
Steel cold rolled coil blast furnace route single route, at plant carbon steel	Steel cast part alloyed electric arc furnace route, from steel scrap, secondary production single route, at plant carbon steel
Steel electrogalvanized coil steel sheet electrogalvanization single route, at plant 1.5 mm sheet thickness, 0.02 mm zinc thickness	Secondary steel slab electric arc furnace route, from steel scrap, secondary production single route, at plant carbon steel
Steel electrogalvanized coil steel sheet electrogalvanization single route, at plant 1.5 mm sheet thickness, 0.02 mm zinc thickness	Steel cast part alloyed electric arc furnace route, from steel scrap, secondary production single route, at plant carbon steel
Steel hot dip galvanised steel sheet hot dip galvanization single route, at plant 1.5 mm sheet thickness, 0.02 mm zinc thickness	Secondary steel slab electric arc furnace route, from steel scrap, secondary production single route, at plant carbon steel
Steel hot dip galvanised steel sheet hot dip galvanization single route, at plant 1.5 mm sheet thickness, 0.02 mm zinc thickness	Steel cast part alloyed electric arc furnace route, from steel scrap, secondary production single route, at plant carbon steel
Steel sheet cold rolling - thickness 2.5mm steel cold rolling process single route, at plant thickness 2.5 mm	Secondary steel slab electric arc furnace route, from steel scrap, secondary production single route, at plant carbon steel
Steel sheet cold rolling - thickness 2.5mm steel cold rolling process single route, at plant thickness 2.5 mm	Steel cast part alloyed electric arc furnace route, from steel scrap, secondary production single route, at plant carbon steel
Talcum powder grinded and purified, filler, production including underground mining and beneficiation production mix, at plant 1 to 15 microns grain size	Not available
Tin sand extraction and processing, reduction production mix, at plant 118.71 g/mol	Tin, recycled (re-refined, from electronic scrap)
Zamak zinc production, alloying single route, at plant 4% aluminium	Zamak, recycled, pre-consumer casting single route, at plant Zn Al alloy
Zamak zinc production, alloying single route, at plant 4% aluminium	Zamak, recycled, post-consumer casting single route, at plant Zn Al alloy
Zinc technology mix, primary production consumption mix, to consumer	Zinc, recycled (post consumer, refining of EAF dust)

7.14 g/cm3	
Cable, high current technology mix production mix, at plant high current, 1m, 13 g/m	End of life of cable, high current Recycling of copper and precious metals (Ag, Au, Pd, Pt) from electronics production mix, at plant recycling processes: 95- 98% efficiency, scrap incineration: 11.0 MJ/kg NCV
Cable, three-conductor cable technology mix production mix, at plant three-conductor cable, 1m, 60 g/m	End of life of cable, three-conductor cable Recycling of copper and precious metals (Ag, Au, Pd, Pt) from electronics production mix, at plant recycling processes: 95- 98% efficiency, scrap incineration: 11.0 MJ/kg NCV
Capacitor ceramic technology mix production mix, at plant capacitor, mlcc, 6 mg	End of life of capacitor ceramic Recycling of copper and precious metals (Ag, Au, Pd, Pt) from electronics production mix, at plant recycling processes: 95- 98% efficiency, scrap incineration: 11.0 MJ/kg NCV
Capacitor SMD technology mix production mix, at plant SMD capacitor, 12.5 g	End of life of Capacitor SMD Recycling of copper and precious metals (Ag, Au, Pd, Pt) from electronics production mix, at plant recycling processes: 95- 98% efficiency, scrap incineration: 11.0 MJ/kg NCV
Capacitor, electrolyte technology mix production mix, at plant electrolyte, hight <2 cm, 9.5 g	End of life of Capacitor, electrolyte Recycling of copper and precious metals (Ag, Au, Pd, Pt) from electronics production mix, at plant recycling processes: 95- 98% efficiency, scrap incineration: 11.0 MJ/kg NCV
Capacitor, Tantalum technology mix production mix, at plant tantalum capacitor, 0.5 g	End of life of Capacitor, Tantalum Recycling of copper and precious metals (Ag, Au, Pd, Pt) from electronics production mix, at plant recycling processes: 95- 98% efficiency, scrap incineration: 11.0 MJ/kg NCV
Connector for printed wiring board (PWB) technology mix production mix, at plant 1 PWB connector, 0.005kg	End of life of Connector for printed wiring board (PWB) Recycling of copper and precious metals (Ag, Au, Pd, Pt) from electronics production mix, at plant recycling processes: 95- 98% efficiency, scrap incineration: 11.0 MJ/kg NCV
Connector Peripheral Component Interconnect (PCI) bus technology mix production mix, at plant 1 PCI bus connector, 0.00255 kg	End of life of Connector Peripheral Component Interconnect (PCI) bus Recycling of copper and precious metals (Ag, Au, Pd, Pt) from electronics production mix, at plant recycling processes: 95- 98% efficiency, scrap incineration: 11.0 MJ/kg NCV
Cylindrical connector, brass body technology mix production mix, at plant brass body, 0.015 kg	End of life of Cylindrical connector, brass body Recycling of copper and precious metals (Ag, Au, Pd, Pt) from electronics production mix, at plant recycling processes: 95- 98% efficiency, scrap incineration: 11.0 MJ/kg NCV
Diode Metal electrode leadless face (mMELF) front-end and back-end processing of the wafer, including Czochralski method of silicon growing production mix, at plant 40 mg	End of life of Diode Metal electrode leadless face (mMELF) Recycling of copper and precious metals (Ag, Au, Pd, Pt) from electronics production mix, at plant recycling processes: 95- 98% efficiency, scrap incineration: 11.0 MJ/kg NCV
Flat chip resistor technology mix production mix, at plant 1 piece of resistor flat chip 1206 (9.2mg)	End of life of flat chip resistor Recycling of copper and precious metals (Ag, Au, Pd, Pt) from electronics production mix, at plant recycling processes: 95- 98% efficiency, scrap incineration: 11.0 MJ/kg NCV
Glass SMD diode front-end and back-end processing of the wafer, including Czochralski method of silicon growing production mix, at plant 130 mg	End of life of Glass SMD diode Recycling of copper and precious metals (Ag, Au, Pd, Pt) from electronics production mix, at plant recycling processes: 95- 98% efficiency, scrap incineration: 11.0 MJ/kg NCV
Hard disk drive, for desktop computer technology mix production mix, at plant 1 piece of HDD	End of life of Hard disk drive, for desktop computer Recycling of copper and precious metals (Ag, Au, Pd, Pt) from electronics production mix, at plant recycling processes: 95- 98% efficiency, scrap incineration: 11.0 MJ/kg NCV
Light Emitting Diode (LED) front-end and back-end processing of the wafer, including Czochralski method of silicon growing production mix, at plant 5 mm, 350 mg	End of life of Light Emitting Diode (LED) Recycling of copper and precious metals (Ag, Au, Pd, Pt) from electronics production mix, at plant recycling processes: 95- 98% efficiency, scrap incineration: 11.0 MJ/kg NCV
Light Emitting Diode (LED), high power front-end and back-end processing of the wafer, including Czochralski method of silicon growing production mix, at plant 5 mm, 350 mg	End of life of Light Emitting Diode (LED), high power Recycling of copper and precious metals (Ag, Au, Pd, Pt) from electronics production mix, at plant recycling processes: 95- 98% efficiency, scrap incineration: 11.0 MJ/kg NCV
Light Emitting Diode (LED), low power front-end and back-end processing of the wafer, including Czochralski method of silicon growing production mix, at plant 59 mg	End of life of Light Emitting Diode (LED), low power Recycling of copper and precious metals (Ag, Au, Pd, Pt) from electronics production mix, at plant recycling processes: 95- 98% efficiency, scrap incineration: 11.0 MJ/kg NCV
Medium power transistor semiconductor front-end and back-end processing of the wafer, including Czochralski method of silicon growing production mix, at plant 4.8 g	End of life of Medium power transistor semiconductor Recycling of copper and precious metals (Ag, Au, Pd, Pt) from electronics production mix, at plant recycling processes: 95- 98% efficiency, scrap incineration: 11.0 MJ/kg NCV
Monocrystalline silicon for photovoltaics Czochralski technique production mix, at plant 1 kg monocrystalline silicon	Not available
Plastic axial diode, Semiconductor front-end and back-end processing of the wafer, including Czochralski method of silicon growing production mix, at plant 1.12 g	End of life of Plastic axial diode, Semiconductor Recycling of copper and precious metals (Ag, Au, Pd, Pt) from electronics production mix, at plant recycling processes: 95- 98% efficiency, scrap incineration: 11.0 MJ/kg NCV
Printed wiring board (PWB) (2-layer) via the subtractive method (as opposed to additive method) production mix, at plant 2-layer, 1.32 kg	End of life of Populated Printed wiring board (PWB) (2-layer) Recycling of copper and precious metals (Ag, Au, Pd, Pt) from electronics production mix, at plant recycling processes: 95- 98% efficiency, scrap incineration: 11.0 MJ/kg NCV
Printed wiring board (PWB) (8-layer) via the subtractive method (as opposed to additive method) production mix, at plant 8-layer, 3.08 kg	End of life of Populated Printed wiring board (PWB) (8-layer) Recycling of copper and precious metals (Ag, Au, Pd, Pt) from electronics production mix, at plant recycling processes: 95- 98% efficiency, scrap incineration: 11.0 MJ/kg NCV
Power supply Unit (PSU) technology mix production mix, at plant 0.27 kg	End of life of Power supply Unit (PSU) Recycling of copper and precious metals (Ag, Au, Pd, Pt) from electronics production mix, at plant recycling processes: 95- 98% efficiency, scrap incineration: 11.0 MJ/kg NCV
SMD coil technology mix production mix, at plant 1 piece of Coil miniature wound SDR1006 (1.16g) D9.8 x 5.8	End of life of SMD coil Recycling of copper and precious metals (Ag, Au, Pd, Pt) from electronics production mix, at plant recycling processes: 95- 98% efficiency, scrap incineration: 11.0 MJ/kg NCV
Standard transformer for Printed Wiring Board (PWB) technology mix production mix, at plant 1 piece of transformer for PWB, 0.08 kg	End of life of Standard transformer for Printed Wiring Board (PWB) Recycling of copper and precious metals (Ag, Au, Pd, Pt) from electronics

	production mix, at plant recycling processes: 95- 98% efficiency, scrap incineration: 11.0 MJ/kg NCV
Switch < 1 Ampere technology mix production mix, at plant < 1 Ampere, 79 mg	End of life of Switch < 1 Ampere Recycling of copper and precious metals (Ag, Au, Pd, Pt) from electronics production mix, at plant recycling processes: 95- 98% efficiency, scrap incineration: 11.0 MJ/kg NCV
Switch > 1 Ampere technology mix production mix, at plant > 1 Ampere, 242 mg	End of life of Switch > 1 Ampere Recycling of copper and precious metals (Ag, Au, Pd, Pt) from electronics production mix, at plant recycling processes: 95- 98% efficiency, scrap incineration: 11.0 MJ/kg NCV
Switch Mode Transformer (SMT), low voltage technology mix production mix, at plant 80g of low voltage transformer	End of life of Switch Mode Transformer (SMT), low voltage Recycling of copper and precious metals (Ag, Au, Pd, Pt) from electronics production mix, at plant recycling processes: 95- 98% efficiency, scrap incineration: 11.0 MJ/kg NCV
Toner module, laser printer, black and white production of toner module, laser printer, black and white production mix, at plant 1 piece, 2.36 kg	Recycling of Toner module, laser printer, b/w
Toner module, laser printer, colour production of toner module, laser printer, colour production mix, at plant 1 piece, 2.36 kg	Recycling of Toner module, laser printer, colour
VGA plug technology mix production mix, at plant VGA steel plug, 0.0191 kg	End of life of VGA plug Recycling of copper and precious metals (Ag, Au, Pd, Pt) from electronics production mix, at plant recycling processes: 95- 98% efficiency, scrap incineration: 11.0 MJ/kg NCV
Ammonia, as 100% NH3 production technology mix production mix, at plant 100% active substance	Not available
Bitumen at refinery from crude oil production mix, at refinery 38.7 MJ/kg net calorific value	Not available
carbon dioxide, liquid production technology mix production mix, at plant 100% active substance	Not available
Concrete, production mix, at plant aggregates mixing production mix, at plant C20/25	Not available
Corrugated board, uncoated "virgin" Kraft Pulping Process, pulp pressing and drying production mix, at plant flute thickness 0.8- 2.8 mm, R1=0%	Recycling paper and cardboard, waste management, technology mix, at plant collection, sorting, transport, recycling production mix, at plant paper waste, efficiency 90,9%
Corrugated board, uncoated "virgin" Kraft Pulping Process, pulp pressing and drying production mix, at plant flute thickness 0.8- 2.8 mm, R1=0%	End of life of beverage cartons collection, transport, cleaning production mix, at plant 1kg of cardboard waste disposed
glass fiber technology mix production mix, at plant 1 kg	Not available
Kraft paper, uncoated Kraft Pulping Process, pulp pressing and drying production mix, at plant <120 g/m2	Recycling paper and cardboard, waste management, technology mix, at plant collection, sorting, transport, recycling production mix, at plant paper waste, efficiency 90,9%
Refrigerants technology mix consumption mix, at consumer Global market mix for refrigerants utilised in refrigeration and air conditioning systems.	Not available
Tap water average technology mix consumption mix, at consumer Technology mix for supply of drinking water to users	Not available
tetrafluoroethane production technology mix production mix, at plant 100% active substance	Not available
detergent dish production production mix 1 kg of detergent dish	Not available
detergents washing machine production production mix 1 kg of detergents washing machine	Not available
regeneration salt dish production production mix 1 kg of regeneration salt dish	Not available
rinsing agent dish production production mix 1 kg of rinsing agent dish	Not available
vacuum cleaner bag production 100% virgin kraft paper production mix 1 piece vacuum cleaner bag	Recycling paper and cardboard, waste management, technology mix, at plant collection, sorting, transport, recycling production mix, at plant paper waste, efficiency 90,9%
copper cathode	Secondary Copper Cathode (including scrap LCI input) copper scrap smelting and refining single route, at plant 8.92 g/cm3
Styrene-acrylonitrile resin (SAN)	Recycled Styrene-acrylonitrile resin (SAN)
Capacitor, film type technology mix production mix, at plant film type, 31.6 g	End of life of Capacitor, film type Recycling of copper and precious metals (Ag, Au, Pd, Pt) from electronics production mix, at plant recycling processes: 95- 98% efficiency, scrap incineration: 11.0 MJ/kg NCV
Controller board	Recycling of controller board
Liquid Crystal Display (LCD)	End of life of TFT LCD display panel, color Recycling of copper and precious metals (Ag, Au, Pd, Pt) from electronics production mix, at plant recycling processes: 95- 98% efficiency, scrap incineration: 11.0 MJ/kg NCV
Solder Paste (SnAg3.5Cu0.7) technology mix production mix, at plant 1 kg of solder paste	End of life of Solder paste Recycling of copper and precious metals (Ag, Au, Pd, Pt) from electronics production mix, at plant recycling processes: 95- 98% efficiency, scrap incineration: 11.0 MJ/kg NCV
electric boiler production 1 unit	Not available
gas boiler production, 10 kwh 1 unit	Not available
oil boiler production, 10 kw 1 unit	Not available
Refrigerant R290; propane	Not available
Refrigerant R404a; HFC blend	Not available
Refrigerant R407c; HFC blend	Not available
Refrigerant R410a; HFC blend	Not available
Refrigerant R600a; iso-butane	Not available
wood boiler production, 10 kw 1 unit	Not available
Magnesium Pidgeon Process, primary production production mix, at plant 1.74 g/cm	Magnesium, recycled (post consumer, from dismantled cars)
Zinc technology mix, primary production consumption mix, to consumer 7.14 g/cm3	Zinc, recycled (pre consumer, remelting)
Calcium carbonate production; technology mix; production mix, at plant; 100% active substance	Not available
calcium chloride production; technology mix; production mix, at plant; 100% active substance	Not available

Calcium hydroxide production; technology mix; production mix, at plant; 100% active substance	Not available
Chromium oxide production; technology mix; production mix, at plant; 100% active substance	Not available
Ferrochromium; primary production, ore mining and beneficiation; production mix, at plant; 60 % chrome, high carbon 6%	Not available
titanium dioxide production; technology mix; production mix, at plant; 100% active substance	Not available
Titanium; technology mix; production mix, at plant; 4.50 g/cm3, 47.87 g/mol	Not available
Silicon mix production; technology mix; production mix, at plant; 100% active substance	Not available
Pallet, wood (100x120); sawing, piling, nailing; single route, at plant; 30 kg/piece, nominal loading capacity of 1000kg	Not available
Plywood box; attaching veneer layers; production mix, at plant; 5% moisture	Not available
Strontium chromate; From sodium dichromate from acidification of sodium chromate; , at plant	Not available

Source: JRC elaboration

Annex II - Analysis of Critical Raw Materials in the MEErP

A.1 Critical discussion on past approach for CRMs in MEErP

The following paragraphs critically discuss key documents that have been dealing with CRMs in MEErP (Methodology for Ecodesign of Energy-related Products) and/or in Ecodesign Directive context since 2011.

A.1.1 MEErP 2011 - Methodology Report (Part 1 and 2)

A first attempt to deal with CRMs in the MEErP indicators was proposed in 2011[54]. The stated request of the EC to the contractors was: “for example to check possible design options that substitute or make it easier to recover CRM components.”

The authors of the report proposed to build a Critical Raw materials Index, based on their newly introduced concept of Tungsten-equivalent (or Antimony-equivalent).

The proposed approach requires as an input the content (in g per product) of all the CRMs for the EU (latest list – non stated by the authors). The Bill-of-Materials (bill-of-CRMs) would be subsequently converted into W-equivalent (or Sb-equivalent) by means of a related table with characterization factors[55].

The authors of the report concluded that: “To realize this on a structural and universal basis is not (yet) possible.” The main reason is the lack of data to build the Bill-of-Materials (content of each of the CRMs for the EU). “Therefore, the EcoReport cannot incorporate the automatic calculation of the CRM indicator, but it supports and recommends that the outcome of a ‘manual’ calculation is integrated in the tool’s outcome”.

A.1.1.1 Critical remarks:

The concept of CRM-equivalent introduced in 2011 seems not supported by a clear rationale and subsequent guidance in order to associated it to an Ecodesign goal (e.g. use less, or report quantities, etc.)[56]. As a consequence, since it was introduced there are no successful examples to show how it could be linked to the initial request of the EC (making CRMs easier to be recycled, or help finding a substitute).

It is quite known that CRMs often provides special and very specific functions in products, as well as they are typically used in tiny quantities, which are however essential (similar to ‘vitamins in human bodies’). It is therefore questioned an approach trying to fix the equivalence of one CRM to another. The reasons to support the concept of CRM equivalence are not stated in the MEErP (2011).

The characterization factors (CF) to convert the bill-of-CRMs into CRM equivalent developed in the MEErP have been calculated as in equation 2.1:

$$\mathbf{CF_i} = A_i*B_i*C_i*(1-[D_i])/[\ A_{sb}*B_{sb}*C_{sb}*(1-[D_{sb}])]$$

Equation 2.1

Where:

- CF_i= Characterisation factor of material “i”;
- A_i= EU consumption of material “i”;
- B_i = import dependency rate of material “i”;
- C_i = Substitutability of material “i”;

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[54] MEErP 2011 METHODOLOGY PART 1 FINAL. Available at: https://ec.europa.eu/docsroom/documents/26525

[55] A characterization factor for each of the CRMs for the EU was derived from some of the parameters used by the EC to calculate the supply risk (postconsumer recycling rate and substitutability), combined with other parameters (EU import dependence, current EU consumption).

[56] MEErP 2011 METHODOLOGY PART 1 FINAL : Initial request concerned to “check possible design options that substitute or make it easier to recover CRM components”.

- D_i =Recycling rate of material “i”;
- A_{sb} ; B_{sb} ; C_{sb} ; D_{sb} = same parameters as above, referred to material “antimony (Sb)”.

All these values refer to the first edition of the EU methodology for the assessment of CRMs published in 2011[57]. However, 2 out of 4 parameters were not used in the criticality calculations in 2011 (A_i= EU consumption of material and B_i = import dependency rate), whereas the latter has been used for the first time in the criticality calculations in 2017.

Moreover, in the list of CRMs for the EU, there are no materials ‘more critical’ than others. A raw materials is in fact either critical to the EU or not critical, which might even be considered in conflict with the concept of CRM equivalent.

Based on the above, the proposed methodology to calculate the CRM-equivalent appears to be a combination of parameters extracted from the EC criticality assessment, though the criteria for the selection of the relevant parameters and the way to combine them remains largely unstated.

A.1.2 MEErP 2013 - Methodology Report (Part 1)

In respect to the 2011 version, the 2013 (BIO Intelligence Service 2013b) MEErP report provided some additional guidance on how to use the CRM-equivalent. Moreover, CRM info was proposed to be added in the EcoReport tool in a separate spreadsheet, as a guide for preparatory studies.

Concerning the interpretation of the CRM indicator, the MEErP 2013 states that “the CRM indicator addresses the topic not from environmental but from scarcity perspective. The CRM indicator can help to assess whether the use of some rare earth would be better or worse than the use of e.g. platinum group metals from scarcity perspective” (BIO Intelligence Service 2013a). However, as observed by some stakeholders “CRM is a complex issue and is related mainly to economic issues - not only environmental issues. A more qualitative and in-depth approach is needed to grasp the scarcity or criticality dimension, such as the methodology currently used by the European Commission to identify CRMs. This issue should be separated from a material efficiency objective” (BIO Intelligence Service 2013b).

A.1.2.1 Critical remarks

In MEErP 2013 it is not questioned if and how the Characterization factors provide an assessment of “scarcity”, nor it is provided a practical guidance on how such results could drive some eco-design measures.

So, even in the 2013 version, it remains unclear how a CRM Index should be associated to the environmental assessment, or scarcity assessment, concerning the resource use. This is also discussed in the recent preparatory study for the Ecodesign and Energy Labelling workplan 2020-2024 (Viegand Maagøe A/S et al. 2021).

CRMs were addressed in a limited number of ecodesign preparatory studies (see complete list in Worpkplan 2020-2024 preparatory study). Below, we analyse a couple of preparatory studies that came up with tangible requirements.

A.1.3 JRC report and preparatory study on enterprise servers

A JRC report in 2015 (Talens Peiró and Ardente 2015) acknowledges that complete data on the content of CRMs in products is hard to obtain. The study investigated data from literature to estimate the average content of CRM in the servers product group and their location into components. Moreover, the study highlighted that CRMs are difficult to be recycled from waste, due to their low concentration in the waste. Some strategies (e.g. selective disassembly of certain components before the shredding) could facilitate the recovery of certain CRMs.

For such reason, the study suggested potential requirements on CRMs in enterprise servers including the provision of an exploded diagram of the product and a declaration of content of certain CRMs (especially rare earths contained in HDDs) and their location in order to facilitate recycling.

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[57] COM(2011)25 final of 2.2.2011

Such requirements were then integrated into the Ecodesign preparatory study (Berwald A. et al and Bio by Deloitte 2015),[58] and later on in the regulation 2019/424[59].

A.1.4 Preparatory Study on Ecodesign and Energy Labelling of Batteries

The CRM equivalent index was furthermore used in some preparatory studies. In particular, the recent preparatory study on Ecodesign and Energy Labelling of Batteries (2019)[60]. The study identifies two CRMs relevant for battery (i.e. cobalt and natural graphite). Although not a CRM at the time of the study, also lithium (that became critical in the 2020 list), manganese, and nickel are assessed, because considered as potentially relevant, as their "criticality threshold can be passed when the demand for the three materials increases". New characterisation factors for the lithium, manganese, and nickel (4.07, 0.02 and 0.19 kg Sb eq. / kg CRM respectively) are calculated in this preparatory study, based on the MEErP 2011 methodology (see equation 1). Reference values for this calculation are taken from the "Study on the review of the list of Critical Raw Materials Non-critical Raw Materials Factsheets"[61] (2017) and complemented by additional literature (especially concerning the recycling rates of non-CRM materials). Also previous values of CF for cobalt and natural graphite have been updated.

The study also provides the share of the CRM indicator for each material compared to the total CRM indicator for battery system. It concludes that for the CRM in EV batteries "lithium and cobalt are the biggest contributors to the CRM indicator for the EV base cases (BC1 to 5) and for the ESS base cases (BC 6 and 7) lithium and natural graphite. This is because cobalt and lithium have high CRM characterisation factors compared to the other materials. The high CF of cobalt is caused by the import dependency and for lithium because it is not being recycled".

Interestingly the study concludes with some practical recommendations for implementing measures. In particular it states that "Encouraging the emergence of a circular economy for batteries and their constituent materials in the EU can be supported introducing mandatory requirements for provision of information about recycled content for certain materials including CRM. Assessing CRM availability in stocks is an important objective of pillar 1 of the European Battery Alliance, thus, it could be important to declare their indicative quantities (or indicative range of quantities) in products put on the market"[62]. Mandatory declaration and targets for recycled content for cobalt and lithium (and also lead and nickel) are actually proposed in the draft battery regulation[63] that was derived from the preparatory study.

A.2 Proposed approach for CRMs in MEErP

A.2.1 List of concepts and principles

In order to facilitate the discussion, building on the past experience a list of relevant concepts and principles for the assessment of CRMs in products is presented as bulleted list.

In such a list, no ranking or priorities are given, as well as different perspectives are presented. The main objective is to reflect on what is available, or what has proved to be more or less feasible in the past.

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[58] The preparatory study also calculated the CRM index (in ton equivalent of Sbeq.), although these results have been not further used in the impact interpretation.

[59] Commission Regulation (EU) 2019/424 of 15 March 2019 laying down ecodesign requirements for servers and data storage products pursuant to Directive 2009/125/EC of the European Parliament and of the Council and amending Commission Regulation (EU) No 617/2013. https://op.europa.eu/s/oDsa

[60] Preparatory Study on Ecodesign and Energy Labelling of Batteries. https://ecodesignbatteries.eu/files/attachments/ED%20Battery%20study%20Task5%20draft_f.pdf

[61] https://ecodesignbatteries.eu/sites/ecodesignbatteries.eu/files/attachments/ED%20Battery%20study%20Task5_v3_20190823.pdf

[62] https://ecodesignbatteries.eu/sites/ecodesignbatteries.eu/files/attachments/ED_Battery_Task%207_V45_final_corrected.pdf

[63] https://ec.europa.eu/environment/waste/batteries/pdf/Proposal_for_a_Regulation_on_batteries_and_waste_batteries.pdf

- No clear justifications on the calculation and interpretation of a CRM Index were found in original method description (in 2011), whereas some partial and heterogeneous guidance and interpretations have been provided in the later literature we investigated. In particular, some of the parameters used to calculate the CRM index (e.g. the recycled content, recyclability, substitutability, etc.) seemed to be more relevant in the assessment than the CRM index itself. Therefore, it is suggested to discontinue the use of such index.
- CRMs provides essential functions in products, which in turn translates into valuable services to society. There are therefore no a priori reasons to introduce or suggest limitations to the use of CRMs, because less CRMs can in principle impact the product functionality.
- Applications of a general principle of resource efficiency is certainly to be incentivized, i.e. solutions that maximize the benefits to society per unit of CRM utilized. For instance, higher recyclability, higher reparability, longer service time, lower intensity of use, etc.
- Higher durability, recyclability and higher substitutability support a more secure supply and more resilient value chains and contribute to the third pillar of the Raw Materials Initiative.
- Lack of comprehensive, quantitative and qualitative information is one of the biggest problems in the context of CRMs.
- Producers that disclose information on CRMs should be incentivized (overcoming their original reluctance in disclosing detailed information on their product). Information should be provided in format and detail that do no cause data confidentiality issues.
- While a generalized and complete analysis of the bill-of-CRMs might be too difficult, and even un-necessary, a targeted reporting is likely to be a pragmatic and effective first step for CRMs in MEErP.
- A promising approach seems to be the one focusing on specific CRMs used in the product groups by shortlisting product groups based on their likelihood to contain relevant amount CRMs. This could simplify the analysis in preparatory studies, since they could be guided on focusing on a restricted number of CRMs.
- The analysis of priority product groups could also be useful to eventually develop requirements for other socio-economic aspects, for instance linked to materials responsible sourcing.
- Data collected during the EC criticality assessments (every 3 years) can help understand how and how much CRMs are used across different product groups. Such data can also help setting priorities and mitigation strategies, by e.g.: identifying which products groups use large quantities of given CRMs (prioritize); highlighting dissipative[64] uses; identifying data gaps on CRMs; better understanding the potential role of recycling and recycled content (to be potentially incentivized), also taking into account situations where substitution is particularly complicated. It therefore appears very important to exploit these synergies between various work streams on raw materials.
- The constructive dialogue with the industry can also allow building information/data on CRMs and filling data gaps.

A.2.2 Building blocks and sources of data

A novel approach for the analysis of CRMs in MEErP can build on the numerical results of the latest EC criticality assessment (with a dossier updated every 3 years). Materials in the scope of this assessment include all the CRMs for the EU. Similar information on all CRM candidates could also be made available.

The criticality assessment dossier contains relevant information for Ecodesign as:

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[64] Uses that very likely correspond to the dispersion of the materials in different compartments (e.g. air, water, soil, landfills) due to currently insurmountable technical and economic barriers to recycling.

- For all CRMs in the List for the EU[65], there is readily-available quantitative information on end-uses, in turn connected to NACE-2 sectors (publicly available) and often more disaggregated (4 or 6 digit level).
- For each end-use, the criticality dossier contains detailed information on known substitutes, which is translated into two substitution indexes[66]: $SI_{EI\ application}$ (based on cost and technical performance and functionality of the substitute materials) and $SI_{SR\ application}$ (based on three parameters related to "production and criticality aspects" of the substitute materials).
- For all CRMs, the criticality dossier contains numerical information on current recycling (in particular, about the EoL recycling input rate (EoL-RIR) and for some materials also EoL recycling rate (Eol-RR)(Talens Peiro et al. 2018)).

Building on the above information, it is possible to short-list and/or rank uses and product group with significant uses of CRMs (e.g. identifying product groups that use large quantities of a given CRM[67]).

Products that fall under this short list (see example drafted by the JRC in Table A.3) could start to focus on main CRMs that they contain (not on all CRMs, which would often create an un-necessary burden for the scrutiny).

The approach could in principle be used already during the preparatory study for new Ecodesign workplan where the consultants and the European Commission could already flag product groups where a specific focus on critical raw materials could be initiated.

The short-listing exercise should be re-run for each preparatory study, taking into account specific elements, components and/or expertise related to the product group.

The main advantage of this new approach is to streamline the analysis and avoid starting from scratch each time. The EC could prioritize product groups according to their content in CRMs, for example already when discussing the Ecodesign work plans and when launching new preparatory studies. Preparatory studies will be more focused in their analysis. Consultants that will perform preparatory studies will use general guidance on how to retrieve information about the content of CRMs relevant for the product under scrutiny and will combine such general guidance with their specific expertise (See Section 2.3). Industry players that will contribute to the preparatory studies will be requested to provide information useful for Ecodesign (e.g. steel products usually contain some amount of Fluorspar, but this would be not relevant for Ecodesign purposes). This information collected during preparatory study could be also useful to fill data gaps and contribute, on the other side, to future revision of the EU CRMs lists.

Info on current recycling could help understanding in which way recycling can contribute further to the overall objectives of eco-design and to reduce supply risk as well. Info on existing substitutes could suggest e.g. to prioritize product groups where no substitutes exist.

Some mitigation strategies could be then tackled through Ecodesign measures (e.g. increasing lifetime, improving recyclability, recycled content, reporting content, etc.), though a procedure that could be automatically applied to all cases is not applicable at the moment.

Table A.1[68] shows some of the information provided by the EC criticality assessments, and in particular, the uses of CRMs and their current recycling (End-of-Life Recycling Input rate – EoL-RIR[69]). However, not all the end-uses considered in the full criticality assessment are publicly available. Table A.1 can be considered as a starting point for steering the discussion, although this is not an exhaustive list of all potential uses of CRMs in energy related products. The full table, with all the data is provided in chapter A.3 and is made of 273 rows, corresponding to 34 CRMs and strategic raw materials and their main end-uses.

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[65] The same information is available also for non-CRMs

[66] Assessment of the Methodology for Establishing the EU List of Critical Raw Materials, Publications Office of the European Union, Luxemburg, 2017, 978-92-79-69612-1, doi:10.2760/73303, JRC106997

[67] E.g. 70% of Gallium is used in Integrated circuits (European Commission, Study on the EU's list of Critical Raw Materials – Final Report 2023).

[68] Table extracted from Study on the Critical Raw Materials for the EU 2023 – Final Report, Annex 1 Critical Raw Materials overview, doi:10.2873/725585.

[69] The EoL-RIR represents the contribution of recycling to meet the current demand for a certain material.

Table A.1 2023 List of CRMs for the EU - Study on the Critical Raw Materials for the EU 2023 – Final Report , Annex 1 Critical Raw Materials overview *(European Commission 2023)* [70].

Raw materials	*EoL-RIR*	*Selected Uses*
Aluminium/bauxite	*32%*	*Lightweight structures* *High-tech engineering*
Antimony	*28%*	*Flame retardants* *Defence applications* *Lead-acid batteries*
Arsenic	*0%*	*Semiconductors Alloys*
Baryte	*0%*	*Medical applications* *Radiation protection* *Chemical applications*
Beryllium	*0%*	*Electronic and Communications Equipment* *Automotive, aero-space and defence components*
Bismuth	*0%*	*Pharmaceutical and animal feed industries* *Medical applications* *Low-melting point alloys*
Boron/Borates	*1%*	*High performance glass* *Fertilisers* *Permanent magnets* *Solid rocket propellant*
Cobalt	*22%*	*Batteries* *Superalloys* *Catalysts* *Magnets*
Coking coal	*0%*	*Coke for steel* *Carbon fibres* *Battery electrodes*
Copper	*17%*	*Electrical infrastructure*
Feldspar	*1%*	*Glass including fibreglass* *Ceramics*
Fluorspar	*1%*	*Steel and iron making* *Refrigeration and Air-conditioning* *Aluminium making and other metallurgy*

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[70] Selection of columns. Available at: https://op.europa.eu/en/publication-detail/-/publication/57318397-fdd4-11ed-a05c-01aa75ed71a1

Raw materials	*EoL-RIR*	*Selected Uses*
Gallium	*0%*	*Semiconductors* *Photovoltaic cells*
Germanium	*2%*	*Optical fibres and Infrared optics* *Satellite solar cells* *Polymerisation catalysts*
Hafnium	*0%*	*Superalloys* *Nuclear control rods* *Refractory ceramics*
Helium	*2%*	*Controlled atmospheres* *Semiconductors* *MRI*
Lithium	*0%*	*Batteries* *Glass and ceramics* *Steel and aluminium metallurgy*
Magnesium	*13%*	*Lightweight alloys for automotive, electronics, packaging or construction* *Desulphurisation agent in steelmaking*
Manganese	*9%*	*Steel-making* *Batteries*
Natural graphite	*3%*	*Batteries* *Refractories for steelmaking*
Nickel	*16%*	*Batteries* *Steel making* *Automotive*
Niobium	*0%*	*High-strength steel and superalloys for transportation and infrastructure* *High-tech applications (capacitors, superconducting magnets, etc)*
Phosphate rock	*17%*	*Mineral fertilizer* *Phosphorous compounds*
Phosphorus	*0%*	*Chemical applications* *Defence applications*
Scandium	*0%*	*Solid Oxide Fuel Cells* *Lightweight alloys*
Silicon metal	*0%*	*Semiconductors* *Photovoltaics* *Electronic components* *Silicones*

Raw materials	*EoL-RIR*	*Selected Uses*
Strontium	*0%*	*Ceramic magnets* *Aluminium alloys* *Medical applications* *Pyrotechnics*
Tantalum	*0%*	*Capacitors for electronic devices* *Superalloys*
Titanium metal	*19%*	*Lightweight high-strength alloys for e.g. aeronautics, space and defence* *Medical applications*
Tungsten	*42%*	*Alloys e.g. for aeronautics, space, defence, electrical technology* *Mill, cutting and mining tools*
Vanadium	*1%*	*High-strength-low-alloys for e.g. aeronautics, space, nuclear reactors* *Chemical catalysts*
Platinum Group Metals	*10%*	*Chemical and automotive catalysts* *Fuel Cells* *Electronic applications*
Heavy Rare Earth Elements	*4%*	*Permanent Magnets for electric motors and electricity generators* *Lighting Phosphors* *Catalysts* *Batteries* *Glass and ceramics*
Light Rare Earth Elements	*3%*	

Source: (European Commission 2023)

A.2.3 Proposed approach for analysing CRM and identifying priorities

Building on the numerical results of the 2023 Criticality Assessment[71], general guidance on how to short-list CRMs of higher interest/priority is provided below, including suggesting strategies for mitigation of criticality (through potential Ecodesign requirements). Expertise specific to the product group is then to be combined with such general guidance in order to obtain a meaningful short list.

An ad hoc spreadsheet in the Ecoreport tool includes the data of the 2023 Criticality Assessment and is updated every three years, is made of 273 rows, corresponding to 34 CRMs and strategic raw materials and their end-uses and 15 columns, and the following columns describing:

- Name of the material
- The application where the material is used
- The average share of the material in that specific application
- The NACE 2 code of the sector corresponding to each application
- The value added of each corresponding sector expressed in million EUR

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[71] https://op.europa.eu/en/publication-detail/-/publication/57318397-fdd4-11ed-a05c-01aa75ed71a1

- The corresponding 6 digit CPA[72]
- The End-of-Life Recycling Input Rate[73] (EoL-RIR) of each material(Talens Peiro et al. 2018)
- The End-of Life Recycling Rate[74]
- Additional remarks on the CRM applications
- Column highlighting CRMs relevant for certain applications (priority uses to which focus for the further analysis in the preparatory studies), identified as explained in chapter A.3.
- Low priority materials (as used in product groups out of scope)
- Materials for which the objective of increasing recycling could be applied (preliminary)
- Materials for which the objective of declaring quantity could be applied (preliminary)
- Materials for which the objective of extending life time could be applied (preliminary)
- Substitution index ($SI_{EI\ material}$): based on cost and technical performance and functionality of the substitute materials
- Substitution index ($SI_{SR\ material}$): based on three parameters related to "production and criticality aspects" of the substitute materials:

Columns A to H contains information published in the CRM reports and disclosed to the general public. They are extracted from the excels and the factsheets used in the criticality assessment.

Column “B” reports all the main applications for CRMs as identified during the criticality assessment. It is worth to notice that such applications represents a larger set from which the “Selected uses” published in the Study on the critical raw materials for the EU 2023 (also presented in Table A.1) were extracted.

The EOL-RIR is reported in column G. Data are from the criticality assessment, and in turn from MSA studies. This is an average over all considered applications, whereas information on specific applications are generally not available. It could be relevant, within a preparatory study, to check with involved industries if these average values are representative of the studied product group.

The end-of-life-recycling-rate (EOL-RR), reported in column H refers to the current recycling of products at end of life. Data are mainly from MSA studies for the EU, or from UNEP-IRP (UNEP 2011) when EU data is not available. Even in this case, the excel spreadsheet reports average data, whose representativeness for the studied products should be checked/assessed.

Columns from “J” to “M” are intended to summarise key information and to guide the preparatory study to set LOW/HIGH priority CRM for Ecodesign purposes and including suggestions on potential mitigation strategies, i.e. Recycle More, Declare Quantity, Extend Life, etc.

For example, materials having very low values for both EOL-RIR and EOL-RR suffer probably of techno-economic barriers for their recycling. For these materials, is probably not effective nor feasible to push for improved recyclability. Attention should also be on extending products’ (or components’) lifetime. Another obvious strategy for potential ecodesign requirements could be to focus on mandatory declarations of critical raw materials (e.g. quantities of the materials contained in the products or in some specific components), in particular when data in insufficient. Such requirements could make reference to the CEN-CENELEC horizontal standard EN 45558:2019[75] that provides a general methodology for declaration of the use of critical raw materials in energy-related products in the context of the Ecodesign Directive (2009/125/EC), and that provides a means for information on the use of CRMs to be exchanged up and down the supply chain and with other relevant stakeholders.

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[72] https://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Statistical_classification_of_products_by_activity_(CPA)

[73] The end-of-life recycling input rate (EOL-RIR) is the percentage of the total material input into the production system that comes from functional recycling of post-consumer scrap (input perspective).

[74] The end-of-life recycling rate (EOL-RR) is the share of a material in waste flows that is actually recycled (output perspective).

[75] EN 45558:2019: General method to declare the use of critical raw materials in energy-related products

In addition, low substitutability (columns “N” and “O”) suggest to intensify efforts to e.g. recycle more or use more efficiently.

This information is mainly intended for an initial screening. Feasibility and potential benefits of such strategies would require as in-depth assessment as done for other material efficiency measures.

Proposed Step-by-step approach box

JRC suggests to always start from the results of the latest criticality assessment and use them for an initial screening, also taking into account specific aspects and expertise related to the product group under scrutiny. A generalized and systematic procedure to automatically identify ecodesign measures looks unlikely, as suggested by the principles discussed in this report.

With the above in mind, some recommendations are formulated:

Step 1: shortlist the CRMs that are potentially in the product group using table A.1, table A.3 (the corresponding full table), and any other additional information related to the product group;

Step 2: when possible, collect quantitative data on the Bill of Material (BoM) of the shortlisted CRMs;

Step 3: look at information available in provided tables (on Substitution, RR, RIR, etc.) to define a possible strategy. Possible strategies could include:

- Declare quantity when data is not available or of low quality, and/or
- Extend lifetime, especially in the case of low substitutability, and/or
- Improve recyclability and/or use recycled materials, especially in the case of low substitutability;

Some general rules / checklist to be considered in deriving requirements:

If RR is low, then check if recycling technology is available or if the product group is an exception (data on recycling is always an average across all product groups)

If RR is high, but EoL-RIR is low, demand is probably growing, so it is unlikely that recycled materials can be available in adequate quantities. So, rather than recommending higher recycled content, a more adequate measure could then be an extension of lifetime.

A.3 Example of how to shortlist CRMs relevant for certain applications

As a concrete example on how the available information from criticality assessments could be used in the context of eco-design, CRMs used in certain application have been prioritized based on the following criteria:

10. The initial criterion is to filter by NACE-2 sectors (Table A.2) and screen out sectors (and the corresponding applications) of low interest for MEErP (e.g. phosphates used as animal feed, or all CRMs used in *C19 - Manufacture of coke and refined petroleum products*).
11. The second criterion consists in identifying materials which are predominantly used in a single application, looking at Column D, which is particularly helpful to identify “high concentrations” of CRMs (e.g. indium in flat displays).
12. Information about recycling in columns I and J can suggest mitigation strategies, e.g. recycle more, or extend life. Therefore, attention was focused on CRMs uses for which a big gap between EoL-RIR and EoL-RR was detected.

Table A.2 NACE-2 sectors used in the criticality assessment *(European Commission 2023)*.

NACE-2 sector
B06 - Extraction of crude petroleum and natural gas
B09 - Mining support service
B09 - Mining support service activities
C10 - Manufacture of food products
C11 - Manufacture of beverages
C17 - Manufacture of paper and paper products
C19 - Manufacture of coke and refined petroleum products
C20 - Manufacture of chemicals and chemical products
C21 - Manufacture of basic pharmaceutical products and pharmaceutical preparations
C22 - Manufacture of rubber and plastic products
C23 - Manufacture of other non-metallic mineral products
C24 - Manufacture of basic metals
C25 - Manufacture of fabricated metal products, except machinery and equipment
C26 - Manufacture of computer, electronic and optical products
C27 - Manufacture of electrical equipment
C28 - Manufacture of machinery and equipment n.e.c.
C29 - Manufacture of motor vehicles, trailers and semi-trailers
C30 - Manufacture of other transport equipment
C32 - Other manufacturing

Source: (European Commission 2023)

Results of the short-listing process are shown in Table A.3, where 68 combinations of CRMs and the corresponding applications are highlighted. These represent the starting point for further investigation. Such Table A.3 could be incorporated into the EcoReport tool.

It is worth noticing that the EOL-RIR and EOL-RR values (in columns “G” and “H”) are average values across all the applications. It is envisaged that future preparatory studies could try to get more precise data for the application under scrutiny.

Table A.3: Short list of 68 combinations of CRMs and specific application derived from the proposed methodology (draft*) Ecoreport tool (2024). * all these initial recommendations (in violet columns) are to be re-checked and/or completed when running a preparatory study, taking into account specific aspects of the product group and using adequate expertise.

B	C	D	E	I	J	L	N	O	P
Material	Application	Share	NACE-2 sector	EOL-RIR	EOL-RR	High priority	RECYCLE MORE or ADD	DECLARE Q.TY	EXTEND LIFE
Aluminium/Bauxite	Construction	21%	C25 - Manufacture of fabricated metal products, except machinery and equipment	32%	69%	x	x		
Aluminium/Bauxite	Packaging	15%	C25 - Manufacture of fabricated metal products, except machinery and equipment	32%	69%	x	x		
Aluminium/Bauxite	High tech engineering	11%	C28 - Manufacture of machinery and equipment n.e.c.	32%	69%	x	x		
Aluminium/Bauxite	Consumer durables	5%	C25 - Manufacture of fabricated metal products, except machinery and equipment	32%	69%	x	x		
Antimony	Flame retardants	43%	C20 - Manufacture of chemicals and chemical products	28%	N/A	x			
Antimony	Lead-acid batteries	32%	C27 - Manufacture of electrical equipment	28%	N/A	x	x	x	x
Arsenic	Electronics	1%	C26 - Manufacture of computer, electronic and optical products	0%	<1%	x	x	x	x
Beryllium	Aerospace and Defence	17%	C30 - Manufacture of other transport equipment	0%	0%	x		x	
Beryllium	Consumer Electronics	12%	C26 - Manufacture of computer, electronic and optical products	0%	0%	x		x	
Beryllium	Telecommunication Infrastructure	11%	C26 - Manufacture of computer, electronic and optical products	0%	0%	x		x	
Boron/Borates	Magnets	0%	C25 - Manufacture of fabricated metal products, except machinery and equipment	1%	0%	x	x	x	x
Cerium	Batteries	2%	C27 - Manufacture of electrical equipment	1%	0%	x	x	x	x
Cobalt	Magnets	7%	C25 - Manufacture of fabricated metal products, except machinery and equipment	22%	32%	x	x	x	x
Cobalt	Batteries	3%	C27 - Manufacture of electrical equipment	22%	32%	x	x	x	x
Copper	Building construction, Electrical power	21%	C27 - Manufacture of electrical equipment	17%	28%	x	x		
Copper	Building construction, plumbing	10%	C28 - Manufacture of machinery and equipment n.e.c.	17%	28%	x	x		
Copper	Manufacture, Industrial, Electrical	6%	C27 - Manufacture of electrical equipment	17%	28%	x	x		
Copper	Manufacture, other, cooling	3%	C28 - Manufacture of machinery and equipment n.e.c.	17%	28%	x	x		
Copper	Infrastructure, Telecommunications	3%	C27 - Manufacture of electrical equipment	17%	28%	x	x		x
Copper	Manufacture, other, electronic	2%	C26 - Manufacture of computer, electronic and optical products	17%	28%	x	x		
Copper	Building construction, Architecture	2%	C28 - Manufacture of machinery and equipment n.e.c.	17%	28%	x	x		
Copper	Building construction, Communications	1%	C27 - Manufacture of electrical equipment	17%	28%	x	x		
Copper	Building construction,	>0%	C32 - Other manufacturing	17%	28%	x	x		

B	C	D	E	I	J	L	N	O	P
Material	Application	Share	NACE-2 sector	EOL-RIR	EOL-RR	High priority	RECYCLE MORE or ADD	DECLARE O.TY	EXTEND LIFE
	building plant								
Dysprosium	Magnets	100%	C25 - Manufacture of fabricated metal products, except machinery and equipment	1%	0%	x	x	x	x
Erbium	Lighting	26%	C27 - Manufacture of electrical equipment	1%	N/A	x		x	
Europium	Lighting	10%	C27 - Manufacture of electrical equipment	1%	N/A	x		x	
Gadolinium	Magnets	10%	C25 - Manufacture of fabricated metal products, except machinery and equipment	1%	N/A	x	x	x	x
Gadolinium	Lighting	0%	C27 - Manufacture of electrical equipment	1%	N/A	x		x	
Gadolinium	Magnetic Resonance Imaging - MRI	40%	C21 - Manufacture of basic pharmaceutical products and pharmaceutical preparations	1%	N/A	x		x	x
Gallium	Integrated circuits	70%	C26 - Manufacture of computer, electronic and optical products	0%	0%	x		x	
Gallium	Lighting	25%	C27 - Manufacture of electrical equipment	0%	0%	x		x	
Gallium	CIGS solar cells	5%	C26 - Manufacture of computer, electronic and optical products	0%	0%	x			
Germanium	Infrared optics	52%	C26 - Manufacture of computer, electronic and optical products	2%	12%	x		x	
Germanium	Optical fibers	23%	C27 - Manufacture of electrical equipment	2%	12%	x		x	
Germanium	Satellite solar cells	12%	C26 - Manufacture of computer, electronic and optical products	2%	12%	x			
Helium	Semiconductors, optic fibres	8%	C26 - Manufacture of computer, electronic and optical products	2%	0%	x			
Iridium	Electronics	26%	C26 - Manufacture of computer, electronic and optical products	12%	20-30%	x	x	x	x
Lanthanum	Batteries	3%	C27 - Manufacture of electrical equipment	1%	0%	x	x	x	x
Lithium	Batteries	12%	C27 - Manufacture of electrical equipment	0%	0%	x	x	x	x
Magnesium	Packaging	23%	C25 - Manufacture of fabricated metal products, except machinery and equipment	13%	N/A	x			
Manganese	Building and construction	43%	C25 - Manufacture of fabricated metal products, except machinery and equipment	9%	>50%	x	x		
Manganese	Domestic appliances	2%	C27 - Manufacture of electrical equipment	9%	>50%	x			
Natural Graphite	Batteries	8%	C27 - Manufacture of electrical equipment	3%	N/A	x	x	x	x
Neodymium	Magnets	80%	C25 - Manufacture of fabricated metal products, except machinery and equipment	1%	1%	x	x	x	x
Neodymium	Batteries	4%	C27 - Manufacture of electrical equipment	1%	N/A	x	x	x	x
Nickel	Building and construction	10%	C25 - Manufacture of fabricated metal products, except machinery and equipment	16%	42%	x	x		
Nickel	Electro and electronics (electronic)	6%	C26 - Manufacture of computer, electronic and optical products	16%	42%	x	x	x	x
Nickel	Electro and electronics (electrical)	6%	C27 - Manufacture of electrical equipment	16%	42%	x			
Nickel	Batteries (portable,	1%	C27 - Manufacture of electrical equipment	16%	42%	x	x	x	x

B	C	D	E	I	J	L	N	O	P
Material	Application	Share	NACE-2 sector	EOL-RIR	EOL-RR	High priority	RECYCLE MORE or ADD	DECLARE Q.TY	EXTEND LIFE
	mobility, e-bikes, industrial)								
Palladium	Electronics	4%	C26 - Manufacture of computer, electronic and optical products	12%	47%	x	x	x	x
Phosphorus	Plastics additives	21%		0%	N/A	x		x	
Phosphorus	Lithium-ion batteries	0%		0%	N/A	x	x	x	x
Platinum	Electronics	2%	C26 - Manufacture of computer, electronic and optical products	12%	60-70%	x	x	x	x
Platinum	Fuel Cells	1%	C27 - Manufacture of electrical equipment	12%	60-70%	x	x	x	x
Praseodymium	Magnets	80%	C25 - Manufacture of fabricated metal products, except machinery and equipment	1%	1%	x	x	x	x
Praseodymium	Batteries	4%	C27 - Manufacture of electrical equipment	1%	N/A	x	x	x	x
Rhodium	Electronics	0%	C26 - Manufacture of computer, electronic and optical products	12%	62%	x	x	x	x
Ruthenium	Electronics	37%	C26 - Manufacture of computer, electronic and optical products	12%	N/A	x	x	x	x
Samarium	Magnets	97%	C25 - Manufacture of fabricated metal products, except machinery and equipment	1%	N/A	x	x	x	x
Scandium	Solid Oxide Fuel Cells	100%	C27 - Manufacture of electrical equipment	0%	N/A	x	x	x	x
Silicon metal	Electronic applications	2%	C26 - Manufacture of computer, electronic and optical products	0%	0%	x	x	x	x
Strontium	Magnets	40%	C25 - Manufacture of fabricated metal products, except machinery and equipment	0%	<1%	x	x	x	x
Tantalum	Capacitors	36%	C26 - Manufacture of computer, electronic and optical products	1%	40%	x		x	
Tantalum	Sputtering targets	11%	C26 - Manufacture of computer, electronic and optical products	1%	40%	x			
Terbium	Magnets	90%	C25 - Manufacture of fabricated metal products, except machinery and equipment	1%	1%	x	x	x	x
Terbium	Lighting	10%	C27 - Manufacture of electrical equipment	1%	N/A	x	x	x	x
Titanium metal	Medical equipment	25%	C28 - Manufacture of machinery and equipment n.e.c.	1%	N/A	x			
Tungsten	Lighting and electronic uses	6%	C27 - Manufacture of electrical equipment	42%	22%	x	x		x

Source: JRC elaboration

Annex III - Technical annex: Weibull modelling of reliability, reparability, upgradability and durability

The lifetime of a product, or the component of a product, can be modelled through the 3 parameter Weibull distribution. Using this modelling we have for the probability density function of the lifetime the following expression:

$$f(t,\gamma)=\begin{cases}\frac{\beta}{\eta}\left(\frac{t-\gamma}{\eta}\right)^{\beta-1} exp\left[-\left(\frac{t-\gamma}{\eta}\right)^{\beta}\right] & t\geq\gamma\\ 0 & t<\gamma\end{cases}$$

Equation 3.1

Where n is the location parameter, β is the shape parameter and γ is the delay parameter. We have chosen to explicitly include the dependence of the delay parameter in the nomenclature for reasons that will become clear in the following analysis.

The reliability function - which can also be interpreted as the percentage of products surviving after time t has elapsed and therefore is also called the survival function - is given by:

$$R(t,\gamma)=\begin{cases}exp\left[-\left(\frac{t-\gamma}{\eta}\right)^{\beta}\right] & t\geq\gamma\\ 1 & t<\gamma\end{cases}$$

Equation 3.2

It is also possible to define the hazard function – or failure rate function, as it is also called – the following way:

$$h(t,\gamma)=\begin{cases}\frac{\beta}{\eta}\left(\frac{t-\gamma}{\eta}\right)^{\beta-1} & t\geq\gamma\\ 0 & t<\gamma\end{cases}$$

Equation 3.3

With regards to the above definitions, the following relations hold (these are valid for any lifetime modelling, not only for the Weibull distribution):

$$f(t,\gamma)=-\frac{\partial R(t,\gamma)}{\partial t}$$

Equation 3.4

$$h(t,\gamma)=\frac{f(t,\gamma)}{R(t,\gamma)}$$

Equation 3.5

It is also useful to define the expected future lifetime (also called the mean residual lifetime or mean remaining lifetime), which is the expected value of the future lifetime of an item that has survived until time t. This can be expressed by the following equation:

$$\mu(t,\gamma) = \frac{1}{R(t,\gamma)} \int_{t}^{+\infty} R(\xi,\gamma)\ d\xi$$

Equation 3.6

The above equation can also be used to compute the product's expected lifetime (Lt_γ), which is simply the value of μ(0,γ):

$$Lt_\gamma = \mu(0,\gamma) = \int_{0}^{+\infty} R(\xi,\gamma)\ d\xi$$

Equation 3.7

Again, the equations presented above for the expected future lifetime and expected lifetime are generic and apply to any distribution. For the specific case of the Weibull distribution, the lifetime and expected future lifetime are given by the following expressions:

$$Lt_\gamma = \mu(0,\gamma) = \eta\,\Gamma\left(1 + \frac{1}{\beta}\right) + \gamma$$

Equation 3.8

$$\mu(t,\gamma) = \begin{cases} \eta\ exp\left[\left(\frac{t-\gamma}{\eta}\right)^{\beta}\right] \Gamma_u \left[1 + \frac{1}{\beta}; \left(\frac{t-\gamma}{\eta}\right)^{\beta}\right] + \gamma - t & t \geq \gamma \\ \eta\,\Gamma\left(1 + \frac{1}{\beta}\right) + \gamma - t & t < \gamma \end{cases}$$

Equation 3.9

These expressions can be very easily coded in MS Excel the following way:

a) The Gamma function - $\Gamma(s)$ – is coded as GAMMA(s) in MS Excel
b) The upper incomplete Gamma function - $\Gamma_u(s,x)$ – is coded as GAMMA(s)×(1-GAMMA.DIST(x,s,1,TRUE)) in MS Excel

We also know that if a number of systems, each one of them with a given reliability and hazard function, are connected in series (i.e., the failure of one of them represents the overall failure of the entire assemble), the reliability and hazard functions of the assemble are given by:

$$R_S = \prod_{i} R_i$$

Equation 3.10

$$h_S = \sum_{i} h_i$$

Equation 3.11

$$f_S = h_S R_S$$

Equation 3.12

It should be noticed that the above equations are generic for any distribution, and not only for the Weibull.

Using this framework, it is possible to model a product as a series assembly of a number of priority parts for repair and upgrade, the failure of any one of which will cause the product to fail. In these priority parts.

Therefore, we have for the reliability and hazard function of the product:

$$R_P = \prod_{i=1}^{N} R_i = \prod_{j=1}^{N_R} R_{R,j} \times \prod_{k=1}^{N_U} R_{U,k} \qquad N = N_R + N_U$$

Equation 3.13

$$h_P = \sum_{i=1}^{N} h_i = \sum_{j=1}^{N_R} h_{R,j} + \sum_{k=1}^{N_U} h_{U,k} \qquad N = N_R + N_U$$

Equation 3.14

, we have for the reliability and hazard function of the product:

$$R_R = \prod_{j=1}^{N_R} R_{R,j} \qquad R_U = \prod_{k=1}^{N_U} R_{U,k} \qquad R_R + R_U = R_P$$

Equation 3.15

$$h_R = \sum_{j=1}^{N_R} h_{R,j} \qquad h_U = \sum_{k=1}^{N_U} h_{U,k} \qquad h_R + h_U = h_P$$

Equation 3.16

In order to model a repair/upgrade operation we assume that the component repaired/upgraded will follow a Weibull distribution with the same shape and location parameters but now with a delay parameter equal to t_F instead of zero as before. This should allow for the calculation of an expected future lifetime, if not in closed form, at least numerically. This should be done by the people conducting the preparatory study, who should have the adequate technical skills and competences to do that seamlessly.

We can, therefore, denote the original reliability function - where all the γs are equal to zero - by $R_{P0}(t)$ (being that this nomenclature implies that all γs are zero) and the reliability function after component i was repaired after failing at time t_F by $R_{Pi}(t,\gamma_i=t_F)$ (this nomenclature leaving implicit that all γs other than γ_i are zero)

Using this nomenclature, the products reliability (or initial lifetime) can be written as:

$$Lt_0 = \mu(0,\gamma) = \int_0^{+\infty} R_P(\xi,\gamma = 0)\ d\xi = \int_0^{+\infty} R_{P0}(\xi)\ d\xi$$

Equation 3.16

And the following expression will provide the expected future lifetime after component I has been repaired or upgraded at time t_F:

$$\mu_i(t_F, \gamma_i = t_F) = \frac{1}{R_{Pi}(t_F, \gamma_i = t_F)} \int_{t_F}^{+\infty} R_{Pi}(\xi, \gamma_i = t_F) \; d\xi$$

Equation 3.17

The same expressions can be written specifically for either repair or upgrade operations, which can be useful to isolate the effects of each kind of operation:

$$\mu_{Rj}\left(t_F, \gamma_{Rj} = t_F\right) = \frac{1}{R_{Rj}\left(t_F, \gamma_{Rj} = t_F\right) R_{U0}(t_F)} \int_{t_F}^{+\infty} R_{Rj}\left(\xi, \gamma_j = t_F\right) R_{U0}(\xi) \; d\xi$$

Equation 3.17

$$\mu_{Uk}(t_F, \gamma_{Uk} = t_F) = \frac{1}{R_{Uk}(t_F, \gamma_{Uk} = t_F) R_{R0}(t_F)} \int_{t_F}^{+\infty} R_{Uk}(\xi, \gamma_k = t_F) R_{R0}(\xi) \; d\xi$$

Equation 3.18

Then, the contribution of all repair related priority parts has to be integrated into a single repair expected future lifetime, and likewise for upgrade. The procedure to do that is as follows:

$$\mu_R(t_F) = \frac{1}{h_R(t_F, \gamma = 0)} \sum_{j=1}^{N_R} h_{Rj}(t_F, \gamma = 0) \; \mu_{Rj}\left(t_F, \gamma_{Rj} = t_F\right)$$

Equation 3.19

$$\mu_U(t_F) = \frac{1}{h_U(t_F, \gamma = 0)} \sum_{k=1}^{N_U} h_{Uk}(t_F, \gamma = 0) \; \mu_{Uk}(t_F, \gamma_{Uk} = t_F)$$

Equation 3.20

Aggregated reliability functions for repair and upgrade can also be calculated the following way (these will become rather useful further on):

$$R_R(t, \gamma = t_F) = \frac{R_{U0}(t)}{h_R(t, \gamma = 0)} \sum_{j=1}^{N_R} h_{Rj}(t, \gamma = 0) \; R_{Rj}\left(t, \gamma_{Rj} = t_F\right)$$

Equation 3.21

$$R_U(t, \gamma = t_F) = \frac{R_{R0}(t)}{h_U(t, \gamma = 0)} \sum_{k=1}^{N_U} h_{Uk}(t, \gamma = 0) \; R_{Uk}(t, \gamma_{Uk} = t_F)$$

Equation 3.22

If any of the priority parts of the product (including its fitness-for-purpose) fails at time t_F, the user will be faced with the decision to repair (or upgrade) or replace. This decision will be made taking into consideration the following aspects: 1) the expected time until a new failure if the product is repaired (i.e., the expected future lifetime); 2) the cost of repair (or upgrade); 3) the cost of replacement. It should be possible then to calculate, for each of the reparability levels, a minimum expected future lifetime below which the product will not be repaired.

If the parameters of the different priority parts are not known, it can be assumed a number of different parts, n, that all have the same parameters. Then, the combination in series of these parts would result in the overall Weibull distribution for the product. If we assume this model and have for the entire product the shape and location parameters β_P and n_P, then the Weibull parameters for each of the parts will be $\beta_C=\beta_P=\beta$ and $n_C=n_P\cdot n^{1/\beta}$. If we are then interested in finding the location parameters for the aggregate R and U distributions, these are given by $n_R=n_C/n_R^{1/\beta}$. and $n_U=n_C/n_U^{1/\beta}$.

These are special cases of the more generic situation where all parts have the same shape parameter (i.e., $\beta_{C,i}=\beta$; i=1..n) but different location parameters. In this case we have $\beta_P=\beta$ and n_P is given by:

$$\eta_P = \frac{1}{\left[\sum_{i=1}^{n}\left(\frac{1}{\eta_{C,i}}\right)^{\beta}\right]^{1/\beta}}$$

Equation 3.23

Notice now that the different reparability levels will mean different ease of repair, and therefore different repair costs. This is the parameter that will tilt the balance and alter the expected future lifetime.

A straightforward way of performing this analysis is by calculating the average cost-per-day of the repair and comparing it with the cost-per-day of the replacement. If C_R is the cost of the repair and C_N is the cost of replacement and L_T is the expected lifetime of the replacement (assumed to be equal to the original expected lifetime of the unit that failed) and L_E is the expected future lifetime of the repair, then the product will be repaired if the following condition is met:

$$\frac{C_R}{L_E} < \frac{C_N}{L_T}$$

Equation 3.24

This equation can be easily manipulated in order to calculate a critical lifetime that will be used to establish a condition for the minimum expected future lifetime for repair/upgrade:

$$L_E > L_{Cr} = L_T\frac{C_R}{C_N}$$

Equation 3.25

Then, after finding out the value of the maximum failure time (which corresponds to the minimum expected future lifetime) that will allow for repair/upgrade, a new value of expected lifetime can be calculated (again, numerically and by the consultants conducting the preparatory study) that would allow for the estimation of the percent increased lifetime generated by the given level of reparability/upgradability.

In order to make the calculations more tractable an additional simplification will be introduced: it is assumed that each critical component will be repaired or upgraded only once. Detailing, if a critical component fails for the second time (or the product becomes unfit for purpose after a first upgrade operation), the product will be replaced even if the expected future lifetime of the repair/upgrade operation exceeds the critical lifetime.

The new reliability function that takes into account these repair/upgrade decisions is given by the following expression (where it is implicit that the repair and upgrade operations can take place anytime between t=0 and t=t_{cr}:

$$R_R(t,\gamma = t_F) = \frac{R_{U0}(t)}{h_R(t,\gamma = 0)} \sum_{j=1}^{N_R} h_{Rj}(t,\gamma = 0)\, R_{Rj}\big(t,\gamma_{Rj} = t_F\big)$$

Equation 3.26

$$R_R(t) = \frac{1}{1 - R_P(t_{Cr};\gamma = 0)} \int_0^{t_{Cr}} f_P(t_F;\gamma = 0) R_R(t;\gamma = t_F)\, dt_F$$

Equation 3.27

And,

$$R_U(t,\gamma = t_F) = \frac{R_{R0}(t)}{h_U(t,\gamma = 0)} \sum_{k=1}^{N_U} h_{Uk}(t,\gamma = 0)\, R_{Uk}(t,\gamma_{Uk} = t_F)$$

Equation 3.28

$$R_U(t) = \frac{1}{1 - R_P(t_{Cr};\gamma = 0)} \int_0^{t_{Cr}} f_P(t_F;\gamma = 0) R_U(t;\gamma = t_F)\, dt_F$$

Equation 3.29

Again, these expressions do not have a closed form, but can be computed numerically using any of the many standard methods available for numerical integration. The authors of the preparatory studies should have the necessary technical skills and competencies to do so without any major problem.

Having computed these new reliability functions taking repair and upgrade into account, a new lifetime that incorporates repair and upgrade can be calculated and the percent increase in lifetime finally computed in order to fill in the tables of the discrete step scoring system model previously presented.

A further – and very significant - simplification can be introduced in the case previously presented where all the *n* different priority parts have the same parameters. Then, making all time related parameters non-dimensional by dividing by the Weibull location parameter, (*i.e.*, Lt'=Lt/η, t'=t/η) and assuming a generic shape parameter equal to 2 (i.e., β=2) - which will provide a rather satisfactory approximation for all cases - it becomes thus possible to write:

$$t' = \frac{t}{\eta};\quad Lt' = \frac{Lt}{\eta} \beta = 2;\quad Lt'(z) = \frac{\sqrt{\pi}}{2}\, exp[z^2]\,[1 - erf(z)];\quad z = t'(1-s);\quad s = \frac{1}{n}$$

Equation 3.30

This relationship can be approximately inverted using the following approximation:

$$\beta = 2; \quad z(Lt') \approx \left[0.74 \left(\frac{\sqrt{\pi}}{2\, Lt'} - 1\right)\right]^{0.90}$$

Equation 3.31

Or, in greater detail:

$$\beta = 2; \quad t'_{Cr}(Lt'_{CR}) \approx \frac{1}{1-s}\left[0.74 \left(\frac{\sqrt{\pi}}{2\, Lt'_{CR}} - 1\right)\right]^{0.90}$$

Equation 3.32

In terms of the lifetime increase, the following equation results for this special case:

$$\beta = 2; \quad \frac{Lt_1(t_{Cr}) - Lt_0}{Lt_0} = 2\int_0^{t'_{Cr}} exp[(t')^2(1-s)^2]\,\left[1 - erf\big(t'(1-s)\big)\right] t' exp[-(t')^2]\; dt'$$

Equation 3.33

Which can be aptly approximated as:

$$\beta = 2; \quad \frac{Lt_1(t_{Cr}) - Lt_0}{Lt_0} \approx (0.19\, s^2 + 0.24\, s + 0.50)(1 - exp[-1.30\, t'^{1.84}_{Cr}])$$

Equation 3.34

Annex IV – Monetization of societal life cycle costs for particulate mater

To enable a conversion between the values proposed in DG MOVE's report[45] and the Environmental Footprint (EF) impact categories value, we have applied the Characterization Factors (CFs) of the EF3.1 method, which can be downloaded here: https://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml

The EF3.1 method includes specific "emissions compartments" for which specific CFs are provided. This means that a single substance might have multiple CFs in a single EF impact category detailing for instance if the emissions is "to air", "to water", etc. Since multiple CFs were available, we have selected the ones related to "general" flows (listed in the EF method as "unspecified emissions"). Below are reported more details on the emissions compartments of the suggested CFs.

- In the case of the conversion factors for particulate matter, the EF method differentiates between various types of emissions (e.g., based on stack height, etc.)
    - For $PM_{2.5}$:
        - The EF suggests a CF equal to 0.000238497 [disease incidence/kg $PM_{2.5}$] for "Emission to air, unspecified". The same CF also applies to "Emissions to air, unspecified (long-term)", "Emissions to urban air close to ground", "Emission to non-urban air from high stacks". Other CFs are available for instance for "Emissions to non-urban air very high stack", "Emissions to non-urban air low stack", etc.
    - For PM_{10}:
        - The EF suggests a CF equal to 0.0000548544 [disease incidence/kg PM_{10}] for "Emission to air, unspecified". The same CF also applies to "Emissions to air, unspecified (long-term)", "Emissions to urban air close to ground". Other CFs are available for instance for "Emissions to non-urban air very high stack", "Emissions to non-urban air low stack", etc..

The conversion factors were derived based on the monetary data from DG MOVE's report and the CFs listed above. In particular, the following calculations were performed:

- Step 1: from Table 14 of the MOVE report the following monetization factors were retrieved:
    - 191.3 [EUR/kg $PM_{2.5}$] calculated as the average between the values for "transport metropole", "transport rural" and "transport city" reported in Table 14 of the MOVE report
    - 22.3 [EUR/kg PM_{10}]

- Step2: from the EF3.1 CFs list (emission to unspecified compartment), the following CFs were retrieved:
    - 0.000238497 [disease incidence/kg $PM_{2.5}$]
    - 0.0000548544 [disease incidence/kg PM_{10}]

- Step 3: two reference indicators were calculated as the ratio between the MOVE report monetization factors and the EF3.1 CFs:
    - 802246 [EUR/disease incidence] (calculated as the ratio between 191.3 [EUR/kg $PM_{2.5}$]
    - and 0.000238497 [disease incidence/kg $PM_{2.5}$])
    - 406531 [EUR/disease incidence] (calculated as the ratio between 22.3 [EUR/kg PM_{10}]
    - and 0.0000548544 [disease incidence/kg PM_{10}])

- Step 4: the weighted average between the two values of Step 3 was calculated based on the specific CFs of PM_{10} and $PM_{2.5}$. The resulting conversion factor for particulate matter is 7.28251E+05 [EUR/disease incidence]
    - *As a reference, the value suggested in the JRC report "Monetary valuation of environmental impacts in life cycle assessment: state of the art and challenges"[47] for particulate matter was equal to 7.64E+05 [EUR/disease incidence]*

Annex V - Impacts of Ecodesign requirements on employment

A dynamic model of sales and stock

The annual sales of a given product group – which is a flux under systems dynamics nomenclature - the number of existing working such products in place – which is a stock under systems dynamics nomenclature, and therefore will be called the stock of the product – and its longevity (or lifetime) are intimately related. One can develop a basic stock-flow model to express that relationship, which will become quite useful ahead.

The lifetime of a product can be modelled through the 3 parameter Weibull distribution. Using this modelling we have for the probability density function of the lifetime the following expression:

$$f(t,\gamma) = \begin{cases} \frac{\beta}{\eta}\left(\frac{t-\gamma}{\eta}\right)^{\beta-1} exp\left[-\left(\frac{t-\gamma}{\eta}\right)^{\beta}\right] & t \geq \gamma \\ 0 & t < \gamma \end{cases}$$

Equation 5.1

Where η is the location parameter, β is the shape parameter and γ is the delay parameter. It is assumed that the product starts its operation at time γ (the delay parameter) and that the shape parameter β is specific and unchangeable for each product group.

The reliability function - which can also be interpreted as the percentage of products surviving after time *t* has elapsed and therefore is also called the survival function - is given by:

$$R(t,\gamma) = \begin{cases} exp\left[-\left(\frac{t-\gamma}{\eta}\right)^{\beta}\right] & t \geq \gamma \\ 1 & t < \gamma \end{cases}$$

Equation 5.2

The above equation can also be used to compute the product's expected lifetime (*Lt*), where *Γ*() is the Gamma function:

$$Lt = \int_{0}^{+\infty} R(x,0)\ dx = \int_{0}^{+\infty} exp\left[-\left(\frac{x}{\eta}\right)^{\beta}\right] dx = \eta\,\Gamma\left(1+\frac{1}{\beta}\right)$$

Equation 5.3

This longevity models allows to calculate the "death" process for the products. The "birth" process will be the sales of new products. The equilibrium between birth and death will be expressed through the existing stock of products in place.

More specifically, the stock in place at time *t* – *St*(*t*) - will be given by the cumulative summation of the products that were sold some time ago in the past (say *x* time ago) and that have survived until time *t*. Mathematically, this is given by integrating in time the product of sales (*Sl*) by the survival function, *i.e.*:

$$St(t) = \int_{0}^{+\infty} Sl(t-x)\ R(t,t-x)\ dx$$

Equation 5.4

Replacing the expression of the survival function and allowing the average lifetime of the products to change over time by allowing the location parameter to change with time (η_x), we finally get the following equation relating sales, stock, and longevity:

$$St(t) = \int_0^{+\infty} Sl(t-x)\, exp\left[-\left(\frac{x}{\eta_x}\right)^{\beta}\right] dx$$

Equation 5.5

This sales and stock models can be used either by using sales and longevity data to estimate current stock, or to forecast future sales under given assumption for stock growth and longevity parameters.

The model presented above can be greatly simplified under the assumption of constant sales and constant longevity parameters. In this case, the model reduces to a very simple expression: the stock in place is equal to the product of the annual sales by the product's longevity.

$$St = Sl \int_0^{+\infty} exp\left[-\left(\frac{x}{\eta}\right)^{\beta}\right] dx = Sl\, \eta\, \Gamma\left(1 + \frac{1}{\beta}\right) = Sl\, Lt$$

Equation 5.6

Or, slightly inverting the order of the variables, we can say that annual sales can be estimated from dividing the stock of products by their expected longevity.

$$Sl = \frac{St}{Lt}$$

Equation 5.6

A quick reflection on pricing for an individual firm

The profit of an individual firm can be written in a simplified way as:

$$\pi = Q\ (P - CV) - CF$$

Equation 5.7

In the above equation, Q is the quantity of products sold, P is the price of the product, CV is the variable costs of producing the product (which is considered to be constant and independent of quantity for simplification)

The direct cost can be further disaggregated as labour costs (the product of the amount of labour, L, by the wage rate, w) and other direct costs (C_{oth}) associated with materials, processes, etc.

$$\pi = Q\ (P - wL - C_{oth}) - CF$$

Equation 5.8

It is assumed that firms assume a profit maximization behaviour, therefore they will set the price of their products in such a way that will maximize their profits. The quantity sold will then adjust to the price that was set. Maximizing profit under the assumption of constant costs and price will result on:

$$\frac{\partial \pi}{\partial P} = \frac{\partial Q}{\partial P}(P - CV) + Q = Q\left(\frac{\partial Q}{\partial P}\frac{P}{Q} - \frac{\partial Q}{\partial P}\frac{CV}{Q} + 1\right) = 0$$

Equation 5.9

$$1 + \varepsilon = \frac{\varepsilon\, CV}{P} \Leftrightarrow P = \frac{\varepsilon}{1 + \varepsilon} CV$$

Equation 5.10

Therefore, under the assumptions made, price will be proportional to variable costs, the proportionality constant being given by the residual demand elasticity of the firm. The relationship can also be inverted and used to estimate the demand elasticity the firm is facing, given prices and variable costs.

$$\varepsilon = -\frac{P}{P - CV}$$

Equation 5.11

As for the way that quantity will adjust to price changes, if we assume a constant elasticity model, then we have:

$$Q = AP^{\varepsilon}$$

Equation 5.12

Which means that a change of price from P_0 to P_1 will lead to a change from Q_0 to Q_1 according to the following equation:

$$Q_1 = Q_0 \left(\frac{P_1}{P_0}\right)^{\varepsilon}$$

Equation 5.13

Or, equivalently, taking into account the previously established proportionality between the price and variable costs:

$$Q_1 = Q_0 \left(\frac{CV_1}{CV_0}\right)^{\varepsilon}$$

Equation 5.14

The effect of Ecodesign requirements on Employment for manufacturing and services (repair or upgrade)

Let us assume that before Ecodesign requirements, general products required an amount of labour L_{M0} to be manufactured, an amount of variable production costs (including labour cost in the amount of wL_{M0}) of CV_0 and that these features resulted in an estimated live time of Lt_0.

Then, let us assume that under Ecodesign requirements, products require an amount of labour L_{M1} to be manufactured, an amount of variable production costs of CV_1 (including labour cost in the amount of wL_{M1}) and that these features, added to the additional requirement of L_{R1} extra amount of labour relating to repair of upgrade operations, resulted in an estimated live time of Lt_1.

Also, the fraction of the items that will be repaired once in their lifetime can be calculated directly from the critical time previously calculated, t_{Cr}, and is equal to:

$$R_f = 1 - exp\left[\left(\frac{t_{Cr}}{\eta}\right)^{\beta}\right]$$

Equation 5.15

Then, the changes in manufacturing and repair/upgrade in labour requirements due to Ecodesign requirements, considering independently the effects on total sales of the extended lifetime and of the (prospective) price change, will be equal to:

$$\Delta L_M = Sl_0 \left(\frac{Lt_0}{Lt_1} \left(\frac{CV_1}{CV_0} \right)^{\varepsilon} L_{M1} - L_{M0} \right)$$

Equation 5.16

$$\Delta L_R = R_f Sl_1 L_{R1}$$

Equation 5.17

Or, detaining a bit more for repair costs:

$$\Delta L_R = R_f Sl_0 \frac{Lt_0}{Lt_1} \left(\frac{CV_1}{CV_0} \right)^{\varepsilon} L_{R1}$$

Equation 5.18

And, obviously:

$$CV = wL + C_{oth}$$

Equation 5.14

It is expected that a decrease in the labour needs associated with manufacturing take place, while labour requirements associated with repair and upgrade increase. In order to find out what is the net effect on employment in the EU, the share of the products that are manufactured in third countries must be estimated. Then, the decrease in manufacturing employment in the EU can be estimated and compared against the increase in repair/upgrade employment, which is intrinsically of a local nature.

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