European Commission

Ecodesign preparatory study for product specific measures on scarce, environmentally relevant and critical raw materials and on recycled content

Final Study Report

Phase 2: Preparatory Study

Washing machines

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Acronyms

ABS	Acrylonitrile Butadiene Styrene
BAU	Business As Usual
BC	Base Case (used in modeling scenarios)
BFR	Brominated Flame Retardants
BoM	Bill of Materials
CBAM	Carbon Border Adjustment Mechanism
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
CF	Conversion Factor (used in environmental impact calculations)
CFC	Chlorofluorocarbons
CFF	Circular Footprint Formula
CMUR	Circular Material Use Rate
CPA	Circular Plastics Alliance
CPIV	Standing Committee of the European Glass Industries
CRM	Critical Raw Materials
DG	Directorate-General (e.g. DG GROW)
DPP	Digital Product Passport
EAF	Electric Arc Furnace
EC	European Commission
EEE	Electrical and Electronic Equipment
ELV	End-of-Life Vehicle
EN	European Norm
EPDM	Ethylene Propylene Diene Monomer
EPR	Extended Producer Responsibility
EPS	Expanded Polystyrene
ERT	EcoReportTool
ESPR	Ecodesign for Sustainable Products Regulation
EU	European Union
EURIC	European Recycling Industries Confederation
FEAD	European Waste Management Association
ERVER	European Glass Recyclers' Federation
FEVE	European Container Glass Federation

FOREWORD

This report, titled **'Preparatory Study on Washing Machines'** and focused on material aspects, has been prepared by Fraunhofer ISI. However:

- It serves to complement the on-going **Review study and support to evaluation and impact assessment for ecodesign and EU energy labelling for the product group "household washing machines and household washer-dryers"**[1] (referred to here as the "Review Study"). Consequently, certain sections (particularly in Task 1 and Task 2) are directly drawn from the Review Study, whose authors are: Antoine Durand, Tim Hettesheimer (Fraunhofer ISI), Frederick Adjei, Yifaat Baron, Katharina Hurst (Oeko-Institut), Eduard Wagner (Fraunhofer IZM), Paul Waide (Waide Strategic Efficiency Europe), Maria Papavasileiou, Mieke de Jager (ecomatters).
- Washing machines and refrigerators/freezers are large household appliances. Therefore, some sections - generic to all large household appliances - are sourced directly from or adapted from the **Preparatory Study on Refrigerators and Freezers** prepared by Leo Wierda, Greeshma Gowda (Van Holsteijn en Kemna BV, VHK) within the same project as this report.

The analysis has been conducted by Fraunhofer ISI, taking into account information gathered through desk research activities, interviews with stakeholders (including manufacturers, recyclers, and research institutes), as well as a site visit of a manufacturer.

[1] https://ecodesign-washing-machines.eu/ewm/index.php

1. MEErP Task 1, Scope

1.1. Scope

The product scope for this study is aligned with the scope proposed in the 'Review study and support to evaluation and impact assessment for Ecodesign and EU Energy Labelling for the product group "household washing machines and household washer-dryers"', which is currently on-going.

1.2. Definitions of washing machines according to Commission Regulations (EU) 2019/2023 and (EU) 2019/2014

The scope of Commission Regulation (EU) 2019/2023 laying down Ecodesign requirements for household washing machines and household washer-dryers and Commission Regulation (EU) 2019/2014 with regard to energy labelling of household washing machines and household washer-dryers apply to the placing on the market or putting into service of:

"electric mains-operated household washing machines and household washer-dryers, including built-in household washing machines and household washer-dryers and electric mains-operated household washing machines and household washer-dryers that can also be powered by batteries."

Under Article 2 (definitions) of the Regulations, the following definitions are specified and apply to washing machines and washer-dryers in scope of the Regulations:

> "(2) **'automatic washing machine'** means a washing machine where the load is fully treated by the washing machine without the need for user intervention at any point during the programme;
>
> (3) **'household washing machine'** means an automatic washing machine which cleans and rinses household laundry by using water, chemical, mechanical and thermal means, which also has a spin extraction function, and which is declared by the manufacturer in the Declaration of Conformity as complying with Directive 2014/35/EU[2] of the European Parliament and of the Council or with Directive 2014/53/EU[3] of the European Parliament and of the Council;
>
> (4) **'household washer-dryer'** means a household washing machine which, in addition to the functions of an automatic washing machine, in the same drum includes a means for drying the textiles by heating and tumbling, and which is declared by the manufacturer in the Declaration of Conformity as complying with Directive 2014/35/EU or with Directive 2014/53/EU;
>
> (5) **'built-in household washing machine'** means a household washing machine that is designed, tested and marketed exclusively:
>
> > (a) to be installed in cabinetry or encased (top and/or bottom, and sides) by panels;

[2] The Low Voltage Directive (LVD).

[3] The Radio equipment Directive (RED).

(b) to be securely fastened to the sides, top or floor of the cabinetry or panels; and

(c) to be equipped with an integral factory-finished face or to be fitted with a custom front panel;

(6) '**built-in household washer-dryer'** means a household washer-dryer that is designed, tested and marketed exclusively:

(a) to be installed in cabinetry or encased (top and/or bottom, and sides) by panels;

(b) to be securely fastened to the sides, top or floor of the cabinetry or panels; and

(c) to be equipped with an integral factory-finished face or to be fitted with a custom front panel;

(7) **'multi-drum household washing machine'** means a household washing machine equipped with more than one drum, whether in separate units or in the same casing;

(8) ***'multi-drum household washer-dryer'*** *means a household washer-dryer equipped with more than one drum, whether in separate units or in the same casing;"*

1.3. Standards

The following is a sample of standards included in the ongoing Review Study and these are applicable to washing machines being evaluated in this study.

EN 45552:2020. General method for the assessment of the durability of energy-related products.

This standard provides a comprehensive framework for assessing the durability of products, ensuring they meet the highest standards of quality and longevity. The standard establishes a general method for evaluating the durability of energy-related products. Durability not only affects the product's performance and reliability but also its environmental impact and cost-effectiveness. By adhering to the guidelines set forth in this standard, manufacturers can ensure that their products are designed to last, reducing waste and promoting sustainability.

EN 45553:2020. General method for the assessment of the ability to remanufacture energy-related products.

This standard provides a comprehensive framework for assessing the remanufacturability of energy-related products. The standard offers a structured approach to evaluate the potential for remanufacturing, ensuring that products can be reused, refurbished, and reintroduced into the market with minimal environmental impact. This not only helps in reducing waste but also in conserving resources, ultimately leading to cost savings and increased profitability.

EN 45554:2020. General methods for the assessment of the ability to repair, reuse and upgrade energy-related products.

This standard provides a comprehensive framework for assessing the ability to repair, reuse, and upgrade energy-related products. This standard is an essential tool for manufacturers, engineers, and sustainability experts who are committed to enhancing the lifecycle of their products while minimizing environmental impact. This standard outlines general methods for evaluating the repairability, reusability, and upgradability of energy-related products. It provides detailed guidelines and methodologies that help stakeholders in the energy sector to improve product design and lifecycle management.

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

This standard provides comprehensive guidelines and methodologies for evaluating the recyclability and recoverability of energy-related products, ensuring that they meet the necessary environmental standards and contribute to a circular economy. It helps to provide a structured approach to assess their potential for recycling and recovery. By following the guidelines in this standard, companies can ensure that their products are designed with end-of-life considerations in mind, promoting a more sustainable approach to product development.

EN 45556:2019. General method for assessing the proportion of reused components in energy-related products

EN 45556 provides two methodologies for assessing the proportion of reused components in energy related products, by mass and by number of components. Verification is to take the form of documented evidence from the manufacturer, supplier and/or authorised distributor. Aspects of traceability, including identification of reused components or groups or reused components must be included in the documentation. It does not oblige the collection of information for all components. However, only components verified as reused can be accounted for as reused components.

Both methods use the fraction of reused components by number or mass, against the total number of components or total mass of the product to establish a proportion of reused components. When defining product specific standards, it is foreseen that just one method will be selected.

EN 45557:2020. General method for assessing the proportion of recycled material content in energy-related products.

This standard provides a comprehensive methodology for assessing the proportion of recycled material content in energy-related products. It is an essential tool for companies aiming to enhance their environmental responsibility and transparency. The standard offers a structured approach to evaluate and report the recycled material content, thereby supporting manufacturers in their efforts to reduce the ecological footprint of their products. This standard not only aids in compliance with environmental regulations but also enhances the marketability of products by aligning them with consumer demand for sustainable solutions.

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

This standard is intended to provide a means for information on the use of CRMs to be exchanged up and down the supply chain and with other relevant stakeholders. The standard is intended for use by any public, private or social enterprises involved in the production of energy-related products (including SMEs) and other organisations in the product supply chain. It is also relevant to European market surveillance and trade authorities as well as European policy makers. This standard is horizontal in nature, and can be applied directly to any type of energy-related product. This document sets out a standardised format for reporting use of CRMs in energy-related products.

EN 45559:2019. Methods for providing information relating to material efficiency aspects of energy-related products

This standard focuses on the consistent provision of material efficiency information across the EN 4555X standard series. Like EN 45558, it is also considered directly applicable. Product specific considerations could include data sensitivity and the intended audience. It should also be taken into account if there are any specific requirements in legislation regarding the audience and the material efficiency aspects to be communicated

IEC TR 62635. Guidelines for end-of-life information provided by manufacturers and recyclers and for recyclability rate calculation of electrical and electronic equipment[4]

IEC/TR 62535 is a technical report, meaning it is not normative. Published in 2012, it provides a methodology for information exchange involving electronic and electrical equipment (EEE) manufacturers and recyclers, and for calculating the recyclability and recoverability rates.

IEC 62474:2018. Material declaration for products of and for the electrotechnical industry

The standard contains specifications on the procedure, content, and form of material declarations for products of companies of the electrotechnical industry or supplying them. Process chemicals and emissions during product use are out of scope of the standard. It provides data to manufacturers to allow them to assess products against substance restriction compliance requirements and to use it in their environmentally conscious design process (across all product life cycle phases).

EN 50614:2020. Requirements for the preparing for re-use of waste electrical and electronic equipment

This standard describes the requirements for the preparing for re-use process, regardless of size of the preparing for re-use operator and their facilities, their main focus of activity, their geographic location and the nature of the preparing for re-use organisation.

In addition, following standards were identified:

[4] IEC TR 62635 will be replaced by IEC 62635:2025 „Assessment of material recoverability rate of products", which is expected to be published by late 2025 or early 2026.

prTS 50752:20YY Design for recycling guidelines for styrenics and polyolefins products and parts in electrical and electronic equipment, with focus on ABS, PP and PS

This draft technical specification describes the best practices and technical solutions that manufacturers of electrical and electronic equipment (EEE) can adopt during the design phase, to enable consistent and effective recycling of styrenics and polyolefins plastics composing the equipment, during the Waste of Electrical and Electronic Equipment (WEEE) management.

IEC 60068-2-31:2008. Environmental testing - Part 2-31: Tests: Rough handling shocks, primarily for equipment-type specimens.

This standard establishes a test procedure for simulating the effects of rough handling shocks, primarily in equipment-type specimens, the effects of knocks, jolts and falls which may be received during repair work or rough handling in operational use. This procedure does not simulate the effects of impacts received during transportation as loosely constrained cargo and does not simulate the effects of shock applied to installed equipment.

1.4. Legislation

1.4.1. Ecodesign Directive

The 2019 Ecodesign regulation (EU) 2019/2023 for WMs[5] specifies the following resource efficiency requirements in Annex II, point 8, applicable from 1 March 2021:

(1) availability of spare parts:

(a) manufacturers, importers or authorised representatives of household washing machines and household washer-dryers shall make available to professional repairers at least the following spare parts, for a minimum period of 10 years after placing the last unit of the model on the market:

— *motor and motor brushes;*

— *transmission between motor and drum;*

— *pumps;*

— *shock absorbers and springs;*

— *washing drum, drum spider and related ball bearings (separately or bundled);*

— *heaters and heating elements, including heat pumps (separately or bundled);*

— *piping and related equipment including all hoses, valves, filters and aquastops (separately or bundled);*

— *printed circuit boards;*

— *electronic displays;*

— *pressure switches;*

[5] Commission Regulation (EU) 2019/2023 of 1 October 2019 laying down ecodesign requirements for household washing machines and household washer-dryers pursuant to Directive 2009/125/EC of the European Parliament and of the Council, amending Commission Regulation (EC) No 1275/2008 and repealing Commission Regulation (EU) No 1015/2010 Text with EEA relevance.

— thermostats and sensors;

— software and firmware including reset software;

(b) manufacturers, importers or authorised representatives of household washing machines and household washer-dryers shall make available to professional repairers and end-users at least the following spare parts: door, door hinge and seals, other seals, door locking assembly and plastic peripherals such as detergent dispensers, for a minimum period of 10 years after placing the last unit of the model on the market;

(c) manufacturers, importers or authorised representatives of household washing machines and household washer-dryers shall ensure that the spare parts mentioned in points (a) and (b) can be replaced with the use of commonly available tools and without permanent damage to the household washing machine or household washer-dryer;

(d) the list of spare parts concerned by point (a) and the procedure for ordering them shall be publicly available on the free access website of the manufacturer, importer or authorised representative, at the latest two years after the placing on the market of the first unit of a model and until the end of the period of availability of these spare parts;

(e) the list of spare parts concerned by point (b) and the procedure for ordering them and the repair instructions shall be publicly available on the free access website of the manufacturer, importer or authorised representative, when placing the first unit of a model on the market and until the end of the period of availability of these spare parts;

(2) maximum delivery time of spare parts:

during the period mentioned under (1), the manufacturer, importer or authorised representative shall ensure the delivery of the spare parts within 15 working days after having received the order;

in the case of spare parts concerned by point (1)(a), the availability of spare parts may be limited to professional repairers registered in accordance with point (3)(a) and (b);

(3) access to Repair and Maintenance Information:

after a period of two years after the placing on the market of the first unit of a model and until the end of the period mentioned under (1), the manufacturer, importer or authorised representative shall provide access to the household washing machine or household washer-dryer repair and maintenance information to professional repairers in the following conditions:

(a) the manufacturer's, importer's or authorised representative's website shall indicate the process for professional repairers to register for access to information; to accept such a request, the manufacturers, importers or authorised representatives may require the professional repairer to demonstrate that: (i) the professional repairer has the technical competence to repair household washing machines and household washer-dryers and complies with the applicable regulations for repairers of electrical equipment in the Member States where it operates. Reference to an official registration system as professional repairer, where such system exists in the Member States concerned, shall be accepted as proof of compliance with this point; (ii) the professional repairer is covered by insurance covering liabilities resulting from its activity regardless of whether this is required by the Member State;

(b) manufacturers, importers or authorised representatives shall accept or refuse the registration within 5 working days from the date of request;

(c) manufacturers, importers or authorised representatives may charge reasonable and proportionate fees for access to the repair and maintenance information or for receiving

regular updates. A fee is reasonable if it does not discourage access by failing to take into account the extent to which the professional repairer uses the information;

(d) once registered, a professional repairer shall have access, within one working day after requesting it, to the requested repair and maintenance information. The information may be provided for an equivalent model or model of the same family, if relevant;

(e) the household washing machine or household washer-dryer repair and maintenance information referred to in (a) shall include:

- *the unequivocal household washing machine or household washer-dryer identification;*
- *a disassembly map or exploded view;*
- *technical manual of instructions for repair;*
- *list of necessary repair and test equipment;*
- *component and diagnosis information (such as minimum and maximum theoretical values for measurements);*
- *wiring and connection diagrams;*
- *diagnostic fault and error codes (including manufacturer-specific codes, where applicable);*
- *instructions for installation of relevant software and firmware including reset software; and*
- *information on how to access data records of reported failure incidents stored on the household washing machine or washer-dryer (where applicable);*

<u>(4) information requirements for refrigerant gases:</u>

without prejudice to Regulation (EU) No 517/2014 of the European Parliament and of the Council (2), for household washing machines and household washer-dryers equipped with a heat pump, the chemical name of the refrigerant gas used, or equivalent reference such as a commonly used and understood symbol, label or logo, shall be displayed permanently and in a visible and readable way on the exterior of the household washing machines or household washer-dryers, for example on the back panel. More than one reference can be used for the same chemical name;

<u>(5) requirements for dismantling for material recovery and recycling while avoiding pollution:</u>

- *manufacturers, importers or authorised representatives shall ensure that household washing machines and household washer-dryers are designed in such a way that the materials and components referred to in Annex VII to Directive 2012/19/EU can be removed with the use of commonly available tools;*
- *manufacturers, importers or authorised representatives shall fulfil the obligations laid down in point 1 of Article 15 of Directive 2012/19/EU.*

Main take-aways

Based on existing regulations, it should be relatively easy to remove from the washing machines during end-of-life processing:

- motor and motor brushes;
- transmission between motor and drum;
- pumps;
- shock absorbers and springs;
- washing drum, drum spider and related ball bearings (separately or bundled);
- heaters and heating elements, including heat pumps (separately or bundled);
- piping and related equipment including all hoses, valves, filters and aquastops (separately or bundled);
- printed circuit boards (especially those > 10 cm2),
- electronic displays;
- pressure switches;
- thermostats and sensors;
- door, door hinge and seals, other seals, door locking assembly;
- plastic peripherals such as detergent dispensers

Not specifically mentioned in existing regulation are:

- parts containing Aluminium (CRM);
- parts containing Copper (CRM)

1.4.2. Energy labelling regulation on washing machines and washer dryers

The 2019 Energy Labelling regulation for WMs (EU) 2019/2014 [6] specifies the labels shown below. There are no references to CRM content, special materials or components, recycled content, recyclability, dismantlability, etc.

[6] Commission Delegated Regulation (EU) 2019/2014 of 11 March 2019 supplementing Regulation (EU) 2017/1369 of the European Parliament and of the Council with regard to energy labelling of household washing machines and household washer-dryers and repealing Commission Delegated Regulation (EU) No 1061/2010 and Commission Directive 96/60/EC Text with EEA relevance.

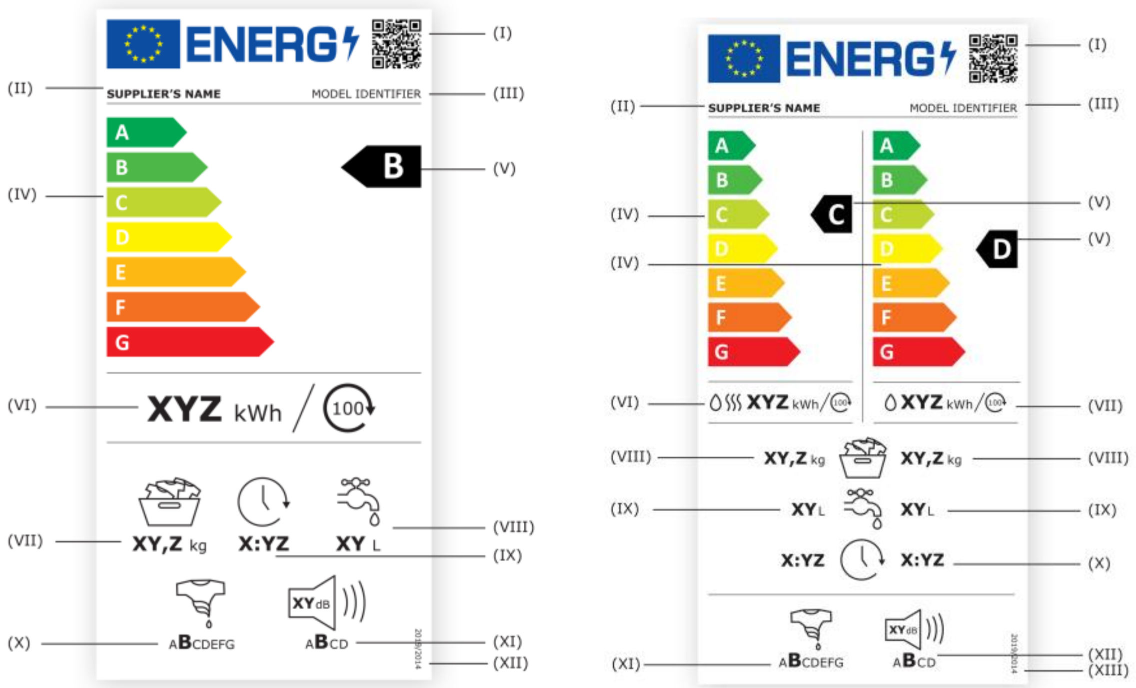

Figure 1: Energy labels for WMs (left) and WDs (right) according to (EU) 2019/2014.

The product information sheet and the technical documentation required by the 2019 Energy Labelling regulation for WMs/WDs in its Annex V and VI do not include reporting requirements on CRMs, specific materials or components, nor on end-of-life processing. The following information could be marginally relevant for this study:

- Supplier identification
- Model identification
- Type of appliance
- Overall dimensions (height, width, depth)

In the current regulation, the label does not include any information relevant for circular economy.

1.4.3. Ecodesign Directive

The Ecodesign Directive 2009/125/EC[7] is assumed to be known and not further described here, except for recalling Article 15, point 5:

5. Implementing measures shall meet all the following criteria:

(a) there shall be no significant negative impact on the functionality of the product, from the perspective of the user;

[7] DIRECTIVE 2009/125/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products (recast) (OJ L 285, 31.10.2009, p. 10), consolidated version with amendments of Directive 2012/27/EU

*(b) **health, safety and the environment shall not be adversely affected**;*

(c) there shall be no significant negative impact on consumers in particular as regards the affordability and the life cycle cost of the product;

(d) there shall be no significant negative impact on industry's competitiveness;

*(e) **in principle, the setting of an ecodesign requirement shall not have the consequence of imposing proprietary technology on manufacturers**; and*

(f) no excessive administrative burden shall be imposed on manufacturers.

The ecodesign requirements for household washing machines and household washer-dryers (see (EU) 2019/2023) have been elaborated within the framework of the Ecodesign Directive.

1.4.4. ESPR

The Ecodesign for Sustainable Products Regulation (ESPR[8]) replaces the Ecodesign Directive 2009/125/EC[9] starting from 18 July 2024, and for some products / articles from 31 December 2026, or 31 December 2030 (ESPR art.79). The (EU) 2019/2023 is currently under review, the new requirements will be elaborated within the ESPR framework.

Just like the Ecodesign Directive, the ESPR is a framework regulation under which ecodesign, performance and information requirements can be set per product group (or horizontally over various product groups) in delegated acts.

ESPR art.5.11 gives the same criteria for setting ecodesign requirements as art.15.5 of Directive 2009/125/EC (previous section), including e.g. that 'health, safety and the environment shall not be adversely affected', and that the setting of an ecodesign requirement 'shall not have the consequence of imposing proprietary technology on manufacturers'.

The ESPR refers to recycled content and critical raw materials in various points:

- ESPR Recital (6) mentions that the regulation inter alia aims '*to increase the energy and resource efficiency of products, including with regard to the **possibility of recovery of strategic and critical raw materials**, reduce their expected generation of waste and **increase the recycled content in products***'.
- ESPR Recital (24) states that performance requirements could e.g. specify *limits on […] the quantities of a given material incorporated in the product, a **requirement for minimum quantities of recycled content**, or a limit on a specific environmental impact category or on an aggregation of all relevant environmental impacts*.
- ESPR Recital (100) on specific green public procurement requirements and related award criteria gives an example that it *would be mandatory for contracting authorities and contracting entities* ***to give the recycled content of the products in question a minimum weighting between 20 % and 30 %*** or that *contracting authorities and contracting entities should* ***award at least 50 % of their annual procurement of certain products to those with more than 70 % of recyclable material.***

[8] Regulation (EU) 2024/1781 of the European Parliament and of the Council of 13 June 2024 establishing a framework for the setting of ecodesign requirements for sustainable products, amending Directive (EU) 2020/1828 and Regulation (EU) 2023/1542 and repealing Directive 2009/125/EC (Text with EEA relevance): https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L_202401781

[9] Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products (recast) (Text with EEA relevance): https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0125

- According to ESPR art.5.1, ecodesign requirements in the delegated acts shall be such as to improve e.g. *resource use and resource efficiency*, ***recycled content***, *the possibility of remanufacturing, recyclability, the possibility of the recovery of materials*.
- Among the product parameters listed in Annex I is ***the use or content of recycled materials and recovery of materials, including critical raw materials.***
- The definition of 'substances of concern' in ESPR art.2.27(d) includes ***substances that negatively affect the reuse and recycling*** *of materials in the product in which it is present*, and ESPR art.5.14 states:[10]

  For each product group concerned by ecodesign requirements, the Commission shall determine, where relevant, which substances fall under the definition in Article 2(27), point (d), taking into account, at least, whether:

  (a) based on standard technologies, the substances make the reuse, or recycling process more complicated, costly, environmentally impactful, or energy- or resource-demanding

  (b) the substances impair the technical properties or functionalities, ***the usefulness or the value of the recycled material coming from the product or products manufactured from that recycled material***

  (c) the substances negatively impact aesthetic or olfactory properties of the recycled material.
- According to ESPR art.7.2(b), information requirements shall, as appropriate, also require products to be accompanied by:

  (i) information on the performance of the product in relation to one or more of the product parameters referred to in Annex I, including a repairability score, a durability score, a carbon footprint or an environmental footprint

  (ii) information for customers and other actors on how to install, use, maintain and repair the product, in order to minimise its impact on the environment and to ensure optimum durability, on how to install third-party operating systems where relevant, as well as on collection for refurbishment or remanufacture, and on ***how to return or handle the product at end-of-life***

  (iii) ***information for treatment facilities on disassembly, reuse, refurbishment, recycling, or disposal at end-of-life***

  (iv) other information that could influence sustainable product choices for customers and the way the product is handled by parties other than the manufacturer in order to facilitate appropriate use, value-retaining operations and ***correct treatment at end-of-life****.*

The ESPR further introduces a Digital Product Passport (DPP)

- According to ESPR Recital (32), the *information requirements should include the requirement to* ***make a digital product passport available****. The digital product passport is an important tool for* ***making information available to actors along the entire value chain*** *and the availability of a digital product passport is expected to significantly enhance end-to-end traceability of a product throughout its value chain. Among other things, the digital product passport is expected to help customers make informed choices by improving their access to relevant information, allow economic*

[10] Please note that the JRC has developed a methodology for assessing the State of Compliance (SoC) in the context of the ESPR, which is not yet published.

operators, namely manufacturers, authorised representatives, importers, distributors, dealers and fulfilment service providers, and other value chain actors, such as customers, professional repairers, independent operators, refurbishers, remanufacturers, recyclers, market surveillance and customs authorities, civil society organisations, researchers, trade unions, and the Commission, or any organisation acting on their behalf, to access, introduce or update relevant data, and enable competent national authorities to perform their duties, without endangering the protection of confidential business information. To that end, it is important that the digital product passport be user-friendly, and that the data contained therein be accurate, complete and up to date. The digital product passport should, where necessary, be complemented by non-digital forms of transmitting information, such as information in the product manual or on a label. In addition, it should be possible for the digital product passport to be used for providing information concerning the relevant product group pursuant to other Union law.

- According to ESPR art.9.1: *The information requirements shall provide that* ***products can only be placed on the market or put into service if a digital product passport is available*** *in accordance with the applicable delegated acts […]. The data in the digital product passport shall be accurate, complete and up to date*.
- ESPR art.10 specifies that a DPP *shall be connected through a* ***data carrier*** *to a persistent unique product identifier, the data carrier shall be physically present on the product, its packaging or on documentation accompanying the product, as specified in the applicable delegated act.*
- Related to the DPP information and verification of compliance, ESPR recital (77) states that *the Commission should be empowered to require, where duly justified, that* ***supply chain actors provide, free of charge, information on what they supply, such as the quantity and type or chemical composition of materials used or the production process employed*** and *to* ***allow manufacturers to have access to the documents containing such information*** *or to the actual facilities of the supply chain actors so that they can access directly the necessary information if the supply chain actors do not provide the information requested within a reasonable time*.

In comments after phase 1 of the current study, stakeholders have commented that:

The phase II preparatory study should also include references and detailed examples on what type of DPP data points need to be included at what value chain stage - so that it becomes clear that all actors involved in the value chain will be required to provide mandatory disclosures, i.e. on recycled raw materials, similar to the requirements on embodied carbon, as currently implemented in the CBAM regulation.

Main take-aways

The ESPR explicitly mentions the use or content of recycled materials and recovery of materials, including critical raw materials, as a product parameter for which requirements can be set. The ESPR explicitly mentions substances that negatively affect the reuse and recycling of materials as a point to be addressed in studies. The ESPR introduces a Digital Product Passport that is intended to contain all relevant product information throughout the entire supply chain. Supply chain actors need to provide, free of charge, information on what they supply, such as the quantity and type or chemical composition of materials used or the production process employed.

1.4.5. Critical Raw Materials Act

Annex I of the Critical Raw Materials Act[11] lists the strategic raw materials, and Annex II the critical raw materials. The list is presented in Table 1.

Aluminium and Copper are strategic and critical raw materials that are used in WMs.

Coking coal is used in the production of steel and thus also (indirectly) relevant for WMs.

Other CRMs can occur in WMs as alloying elements in metal parts, in electronic parts, in magnets or in batteries. See section 4.1.6 for WM components potentially using CRMs.

[11] Regulation (EU) 2024/1252 of the European Parliament and of the Council of 11 April 2024 establishing a framework for ensuring a secure and sustainable supply of critical raw materials and amending Regulations (EU) No 168/2013, (EU) 2018/858, (EU) 2018/1724 and (EU) 2019/1020 (Text with EEA relevance), https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L_202401252

Table 1: List of strategic and critical raw materials (source: Critical Raw Materials Act, annex I and II)

Raw material / element	critical	strategic
Antimony	x	
Arsenic	x	
Bauxite/alumina/aluminium	x	x
Baryte	x	
Beryllium	x	
Bismuth	x	x
Boron	x	x (metallurgy grade)
Cobalt	x	x
Coking coal	x	
Copper	x	x
Feldspar	x	
Fluorspar	x	
Gallium	x	x
Germanium	x	x
Hafnium	x	
Helium	x	
Heavy rare earth elements [12]	x	
Light rare earth elements [13]	x	
Rare earth elements for permanent magnets (Nd, Pr, Tb, Dy, Gd, Sm, and Ce)		x
Lithium	x	x (battery grade)
Magnesium	x	x (metal)
Manganese	x	x (battery grade)
Graphite	x	x (battery grade)
Nickel – battery grade	x	x
Niobium	x	
Phosphate rock	x	
Phosphorus	x	
Platinum group metals [14]	x	x
Scandium	x	
Silicon metal	x	x
Strontium	x	
Tantalum	x	
Titanium metal	x	x
Tungsten	x	x
Vanadium	x	

Among the provisions of the CRM Act most relevant for the current study [15]:

- **Article 26, National measures on circularity**

  1. Each Member State shall, […], adopt […] measures designed to:

[12] The CRM Act does not further define this, but heavy rare earth elements should include Y (Yttrium), Gd (Gadolinium), Tb (Terbium), Dy (Dysprosium), Ho (Holmium), Er (Erbium), Tm (Thulium), Yb (Ytterbium), and Lu (Lutetium)

[13] The CRM Act does not further define this, but light rare earth elements should include La (Lanthanum), Ce (Cerium), Pr (Praseodymium), Nd (Neodymium), Pm (Promethium), Sm (Samarium) and Eu (Europium).

[14] The CRM Act does not further define this, but platinum group metals (PGM) should include: Pd (Palladium), Pt (Platinum), Rh (Rhodium), Ru (Ruthenium), Ir (Iridium) and Os (Osmium).

[15] The following are extracts or summaries of the legal text. See the act itself for the precise text.

(c) increase the collection, sorting and processing of waste with relevant critical raw materials recovery potential [16], including metal scraps, and ensure their introduction into the appropriate recycling system, with a view to maximising the availability and quality of recyclable material as an input to critical raw material recycling facilities.

(d) increase the use of secondary critical raw materials, including through measures such as taking recycled content into account in award criteria related to public procurement or financial incentives for the use of secondary critical raw materials.

(e) increase the technological maturity of recycling technologies for critical raw materials and promote circular design, materials efficiency and substitution of critical raw materials in products and applications, at least by including support actions to that effect under national research and innovation programmes.

5. Member States shall identify separately, and report, the quantities of components containing relevant amounts of critical raw materials removed from waste electrical and electronic equipment and the quantities of critical raw materials recovered from such equipment.

- **Article 28, Recyclability of permanent magnets**

Automatic washing machines and tumble driers are explicitly in the scope of Article 28 of the CRM Act. From November 2028, Article 28 requires a labelling indicating whether those products incorporate one or more permanent magnets, and if so, whether those permanent magnets belong to any of the following types:

(i) neodymium-iron-boron;

(ii) samarium-cobalt;

(iii) aluminium-nickel-cobalt;

(iv) ferrite.

In future, there will also be a data carrier providing access to information on the weight, location and chemical composition of all individual permanent magnets included in the product, and on the presence and type of magnet coatings, glues and any additives used, and to information enabling access and safe removal of all permanent magnets incorporated in the product, at least including the sequence of all removal steps, tools or technologies required for the access and removal of the permanent magnet.

For products where permanent magnets are exclusively contained in one or more electric motors, the information may be replaced by information on the location of those electric motors, and on the access and removal of the electric motors, at least including the sequence of all removal steps, tools or technologies required.

The natural or legal person placing a product on the market shall ensure that the information is complete, up-to-date, and accurate and remains available for a period at least equal to the product's typical lifetime plus 10 years, including after an insolvency, a liquidation or a cessation of activity in the Union.

For products for which a product passport is required pursuant to another Union legal act [17], the information shall be included in that product passport.

[16] The Commission has to define by May 2025 which products, components and waste streams shall at least be considered as having a relevant critical raw materials recovery potential.

[17] See section 7.1.13.1 on the Digital Product Passport

- **Article 29, Recycled content of permanent magnets**
    1. By 24 May 2027 […] any natural or legal person that places on the market products […] which incorporate one or more permanent magnets […], and for which the total weight of all such permanent magnets exceeds 0,2 kg shall make publicly available on a free-access website the share of neodymium, dysprosium, praseodymium, terbium, boron, samarium, nickel and cobalt recovered from post-consumer waste present in the permanent magnets incorporated in the product.
    2. By 24 May 2026, the Commission shall establish rules for the calculation and verification of these shares.
    3. […] By 31 December 2031, the Commission shall lay down minimum shares for neodymium, dysprosium, praseodymium, terbium, boron, samarium, nickel and cobalt recovered from post-consumer waste that must be present in the permanent magnet incorporated in the products […].
    4. Where requirements relating to the recycled content of permanent magnets are established in Union harmonisation legislation for any of the products […], those requirements shall apply to the products concerned in place of this Article.

Main take-aways

Aluminium and Copper are strategic and critical raw materials that are used in WMs.

Coking coal is used in the production of steel and thus also (indirectly) relevant for WMs.

Stainless steel might contain manganese, cobalt and nickel. However, regarding nickel, the CRM Act include only “nickel (battery grade)” as CRM.

Other CRMs can occur in WMs as alloying elements in metal parts, in electronic parts, in magnets or potentially in batteries.

The CRM Act already has provisions for permanent magnets used in products. By May 2026, the Commission shall establish rules for the calculation and verification of the shares of post-consumer recycled CRMs used in permanent magnets. By December 2031, the Commission shall lay down minimum shares for selected CRMs recovered from post-consumer waste that must be present in permanent magnets.

1.4.6. WEEE directive

The WEEE Directive 2012/19/EU[18] lays down measures to protect the environment and human health by preventing or reducing the adverse impacts of the generation and management of waste from electrical and electronic equipment (WEEE) and by reducing overall impacts of resource use and improving the efficiency of such use in accordance with Articles 1 and 4 of Directive 2008/98/EC (this is the ‘general’ waste directive[19]).

[18] Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE) (recast) Text with EEA relevance, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012L0019

[19] Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives (Text with EEA relevance), https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008L0098

Among the provisions of the WEEE Directive most relevant for the current study [20]:

- **Article 4 Product design**

  Member States shall, […], encourage cooperation between producers and recyclers and measures to promote the design and production of EEE, notably in view of facilitating re-use, dismantling and recovery of WEEE, its components and materials. In this context, Member States shall take appropriate measures so that the ecodesign requirements facilitating re-use and treatment of WEEE established in the framework of Directive 2009/125/EC are applied and producers do not prevent, through specific design features or manufacturing processes, WEEE from being re-used […].

- **Article 5 Separate collection**

  1. Member States shall adopt appropriate measures to minimise the disposal of WEEE in the form of unsorted municipal waste, to ensure the correct treatment of all collected WEEE and to achieve a high level of separate collection of WEEE, notably, and as a matter of priority, for temperature exchange equipment containing ozone-depleting substances and fluorinated greenhouse gases, fluorescent lamps containing mercury, photovoltaic panels and small equipment […] [21].
  2. For WEEE from private households, Member States shall ensure that:

     (a) systems are set up allowing final holders and distributors to return such waste at least free of charge. […]

     (b) when supplying a new product, distributors are responsible for ensuring that such waste can be returned to the distributor at least free of charge on a one-to-one basis as long as the equipment is of equivalent type and has fulfilled the same functions as the supplied equipment […].

     (d) […] producers are allowed to set up and to operate individual and/or collective take-back systems for WEEE from private households provided that these are in line with the objectives of this Directive;

- **Article 7 Collection rate**

  From 2019, the minimum collection rate to be achieved annually shall be 65 % of the average weight of EEE placed on the market in the three preceding years in the Member State concerned, or alternatively 85 % of WEEE generated on the territory of that Member State.

- **Article 11 Recovery targets**

[20] The following are extracts or summaries of the legal text. See the act itself for the precise text.

[21] Definitions from Directive 2008/98/EC, article 3: 'municipal waste' means: (a) mixed waste and separately collected waste from households, including paper and cardboard, glass, metals, plastics, bio-waste, wood, textiles, packaging, waste electrical and electronic equipment, waste batteries and accumulators, and bulky waste, including mattresses and furniture; (b) mixed waste and separately collected waste from other sources, where such waste is similar in nature and composition to waste from households;

'collection' means the gathering of waste, including the preliminary sorting and preliminary storage of waste for the purposes of transport to a waste treatment facility

'separate collection' means the collection where a waste stream is kept separately by type and nature so as to facilitate a specific treatment;

1. Regarding all WEEE separately collected in accordance with Article 5 (see above) and sent for treatment […], Member States shall ensure that producers meet the minimum targets set out in Annex V (see below).
2. The achievement of the targets shall be calculated, for each category, by dividing the weight of the WEEE that enters the recovery or recycling/preparing for re-use facility, after proper treatment [22] […] with regard to recovery or recycling, by the weight of all separately collected WEEE for each category, expressed as a percentage.

- **ANNEX III and IV, Categories of WEEE**

  All electrical and electronic appliances concerned are assigned to different categories in Annex III, including the category "Large equipment (any external dimension more than 50 cm)". According to Annex IV, this category includes washing machines and clothes dryers. These are therefore within the scope of the directive.

  In case that some laundry appliances should fall below these dimensions, it is assumed that they are covered by the category “Small equipment (no external dimension more than 50 cm)”, including “Household appliances” and therefore would be still in the scope of the directive. However, such laundry appliances currently have no market relevance in the EU.

- **Annex V Minimum recovery targets**

  From 15 August 2018, minimum targets applicable to WMs and WDs (category 1[23]) [24]:

  — 85 % shall be recovered [25], and

  — 80 % shall be prepared for re-use and recycled [26];

- **ANNEX VII, Selective treatment for materials and components of WEEE**

  1. As a minimum the following substances, mixtures and components have to be removed from any separately collected WEEE:

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[22] Proper treatment, other than preparing for re-use, and recovery or recycling operations shall, as a minimum, include the removal of all fluids and a selective treatment in accordance with Annex VII.

[23] See Annex I of the regulation

[24] The 85% and 80% are shares from the separately collected WEEE (see article 7), not from all the WEEE produced.

[25] Definitions from Directive 2008/98/EC, article 3:

‘recovery’ means any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy. Annex II sets out a non-exhaustive list of recovery operations.

‘material recovery’ means any recovery operation, other than energy recovery and the reprocessing into materials that are to be used as fuels or other means to generate energy. It includes, inter alia, preparing for re-use, recycling and backfilling.

[26] Definitions from Directive 2008/98/EC, article 3:

‘preparing for re-use’ means checking, cleaning or repairing recovery operations, by which products or components of products that have become waste are prepared so that they can be re-used without any other pre-processing.

‘recycling’ means any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations.

‘backfilling’ means any recovery operation where suitable non-hazardous waste is used for purposes of reclamation in excavated areas or for engineering purposes in landscaping. Waste used for backfilling must substitute non-waste materials, be suitable for the aforementioned purposes, and be limited to the amount strictly necessary to achieve those purposes.

— polychlorinated biphenyls (PCB) containing capacitors […] [27],

— mercury containing components, such as switches or backlighting lamps,

— batteries,

— printed circuit boards of mobile phones generally, and of other devices if the surface of the printed circuit board is greater than 10 square centimetres,

— toner cartridges, liquid and paste, as well as colour toner,

— plastic containing brominated flame retardants,

— asbestos waste and components which contain asbestos,

— cathode ray tubes,

— chlorofluorocarbons (CFC), hydrochlorofluorocarbons (HCFC) or hydrofluorocarbons (HFC), hydrocarbons (HC),

— gas discharge lamps,

— liquid crystal displays (together with their casing where appropriate) of a surface greater than 100 square centimetres and all those back-lighted with gas discharge lamps,

— external electric cables,

— components containing refractory ceramic fibres […],

— components containing radioactive substances […],

— electrolyte capacitors containing substances of concern (height > 25 mm, diameter > 25 mm or proportionately similar volume).

These substances, mixtures and components shall be disposed of or recovered in compliance with Directive 2008/98/EC.

2. The following components of WEEE that is separately collected have to be treated as indicated:

— cathode ray tubes: the fluorescent coating has to be removed,

— equipment containing gases that are ozone depleting or have a global warming potential (GWP) above 15, such as those contained in foams and refrigeration circuits: the gases must be properly extracted and properly treated. Ozone-depleting gases must be treated in accordance with Regulation (EC) No 1005/2009,[28]

— gas discharge lamps: the mercury shall be removed.

3. Taking into account environmental considerations and the desirability of preparation for re-use and recycling, points 1 and 2 shall be applied in such a way that environmentally-sound preparation for re-use and recycling of components or whole appliances is not hindered.

Main take-aways

[27] Polychlorinated biphenyls (PCBs) were banned in Europe in 1987. Accordingly, by now, very few washing machines should arrive to recyclers with PCB containing capacitors. This was confirmed during an interview with Electrocycling, one of the largest WEEE recyclers in the EU.

[28] Some washer-dryer models have heat pump technology

The minimum collection rate (for all WEEE together) is 65 % of the average weight of EEE placed on the market in the three preceding years (in the Member State).

For category 1 WEEE (including WMs and WDs), 85% shall be recovered, and 80% prepared for re-use and recycled. The percentage is calculated, dividing the weight of the WEEE that enters the recovery or recycling/preparing for re-use facility, after proper treatment, by the weight of all separately collected WEEE for the category.

Components to be removed from separately collected WEEE potentially relevant for WMs and WDs include:

- mercury containing switches or lamps
- batteries
- printed circuit boards > 10 cm2
- plastic containing brominated flame retardants
- chlorofluorocarbons (CFC), hydrochlorofluorocarbons (HCFC) or hydrofluorocarbons (HFC), hydrocarbons (HC)
- liquid crystal displays (with casing where appropriate) of a surface > 100 cm2
- external electric cables
- equipment containing gases that are ozone depleting or have a global warming potential (GWP) above 15, such as those contained in foams or heat pumps
- PCB containing capacitors (no longer relevant for new washing machines and washer-dryers)

1.4.7. Packaging regulations

The current study does not regard packaging materials for washing machines, but the recent packaging and packaging waste regulation (PPWR)[29] addresses recycled content in plastics, so it can be interesting as a reference.

PPWR article 7 specifies the minimum recycled content in plastic packaging:

1. By 1 January 2030 […], any plastic part of packaging placed on the market shall contain the following minimum percentage of recycled content recovered from post-consumer plastic waste, per packaging type and format […], calculated as an average per manufacturing plant and year:

(a) 30 % for contact-sensitive packaging made from polyethylene terephthalate (PET) as the major component, except single-use plastic beverage bottles

(b) 10 % for contact-sensitive[30] packaging made from plastic materials other than PET, except single-use plastic beverage bottles

[29] Regulation (EU) 2025/40 of the European Parliament and of the Council of 19 December 2024 on packaging and packaging waste, amending Regulation (EU) 2019/1020 and Directive (EU) 2019/904, and repealing Directive 94/62/EC (Text with EEA relevance), https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L_202500040

[30] Contact-sensitive packaging refers to plastic packaging of products covered by Regulation (EC) No 1831/2003 of the European Parliament and of the Council of 22 September 2003 on additives for use in animal nutrition (OJ L 268, 18.10.2003, p. 29), Regulation(EC) No 1935/2004 of the European Parliament and of the Council of 27 October 2004 on materials and articles intended to come into contact with food (OJ L 338 13.11.2004, p. 4), Regulation (EC) No 767/2009 of the European Parliament and of the Council of 13 July 2009 on the placing on the market and use of feed, amending European Parliament and Council Regulation (EC) No 1831/2003 and repealing Council Directive 79/373/EEC, Commission Directive 80/511/EEC, Council Directives 82/471/EEC, 83/228/EEC, 93/74/EEC, 93/113/EC and 96/25/EC and Commission Decision 2004/217/EC (OJ L 229, 1.9.2009, p. 1), Regulation (EC) No 1223/2009 of the European Parliament and of the Council of 30 November 2009 on cosmetic

(c) 30 % for single-use plastic beverage bottles

(d) 35 % for plastic packaging other than those referred to in points (a), (b) and (c) of this paragraph.

2. By 1 January 2040, […]:

(a) 50 % for contact-sensitive packaging made from PET as the major component, except single-use plastic beverage bottles

(b) 25 % for contact-sensitive packaging made from plastic materials other than PET, except single-use plastic beverage bottles

(c) 65 % for single-use plastic beverage bottles

(d) 65 % for plastic packaging other than those referred to in points (a), (b) and (c) of this paragraph.

PPWR art.7.3 further specifies that the recycled content shall be recovered from post-consumer plastic waste that has been collected in the Union and recycled in an installation located within the Union according to the Union rules or collected and recycled in third countries under equivalent rules [31].

Compliance with the requirements shall be demonstrated by manufacturers or importers in the technical information (art.7.6). However, many details are still to be defined:

- 31 December 2026: Commission shall adopt implementing acts establishing the methodology for the calculation and verification of the percentage of recycled content, as well as the format for the technical documentation (art.7.8).
- 31 December 2026: Commission shall adopt delegated acts to supplement the Regulation with sustainability criteria for plastic recycling technologies (art.7.9).
- 31 December 2026: Commission shall adopt delegated acts establishing the methodology for assessing, verifying and certifying, including through third-party audit, the equivalence of the rules applied in cases where the recycled content recovered from post-consumer plastic waste is recycled or collected in a third country (art.7.10).
- 1 January 2028: Commission shall assess the need for derogations from the minimum percentages of recycled content laid down in paragraph 1, points (b) and (d), or the revision of the list of exceptions for specific plastic packaging (art.7.12).
- Where the lack of availability or excessive prices of specific recycled plastics makes compliance with the minimum percentages of recycled content excessively difficult, the

products (OJ L 342, 22.12.2009, p. 59), Regulation (EU) 2017/745, Regulation (EU) 2017/746, Regulation (EU) 2019/4 of the European Parliament and of the Council of 11 December 2018 on the manufacture, placing on the market and use of medicated feed, amending Regulation (EC) No 183/2005 of the European Parliament and of the Council and repealing Council Directive 90/167/EEC (OJ L 4, 7.1.2019, p. 1), Regulation (EU) 2019/6, Directive 2001/83/EC and Directive 2008/68/EC.

[31] PPWR art.7.3: For the purposes of this Article, recycled content shall be recovered from post-consumer plastic waste that:

(a) has been collected within the Union pursuant to this Regulation or the national rules transposing Directives 2008/98/EC and (EU) 2019/904, as relevant, or that has been collected in a third country in accordance with standards for separate collection to promote high-quality recycling equivalent to those referred to in this Regulation and Directives 2008/98/EC and (EU) 2019/904, as relevant; and

(b) where applicable, has been recycled in an installation located within the Union to which Directive 2010/75/EU of the European Parliament and of the Council applies, or that has been recycled in an installation located in a third country to which rules concerning the prevention and reduction of emissions into air, water and land associated to the recycling operations apply, and those rules are equivalent to those concerning emissions limits and environmental performance levels established in accordance with Directive 2010/75/EU that are applicable to an installation located in the Union carrying out the same activity; that condition shall apply only in the case where those limits and levels would be applicable to an installation located in the Union and carrying out the same activity as an analogous installation located in the third country.

Commission shall be empowered to adopt a delegated act to amend those paragraphs by adjusting the minimum percentages accordingly (art.7.13).

As regards labelling and marking:

- The Commission commits to assess the feasibility of Union-wide labelling that facilitates the correct separation of packaging waste at source (recital (5)).
- Labelling of packaging in an easily understandable way to inform consumers about the recyclability of packaging and where packaging waste should be discarded to facilitate recycling (recital (7)).
- The labelling of recycled content in packaging should not be mandatory, as that information is not critical to ensure the proper end-of-life treatment of packaging. However, manufacturers will be required to meet recycled content targets and they might wish to display that information on their packaging to inform consumers of recycled content in the packaging. To ensure that such information is communicated in a harmonised manner across the Union, a label to indicate the recycled content should be harmonised (recital (67)).
- The previous point applies similarly to labelling for biobased plastic content (recital (68))

For products that have a digital product passport (section 1.4.4), the recycled content information and its demonstration shall be provided in that DPP.

As mentioned in the Review Study, several delegated acts will further specify details, e.g. on concrete design for recycling criteria or on how to perform recyclability assessment. APPLiA points out that, in addition to the EU regulation, some countries (Spain, Italy, and France) also have their own national regulations on packaging which affect appliances like washing machines and washer-dryers. The Regulation (EU) 2025/40 on Packaging and Packaging Waste allows this under certain conditions (Article 4 (3), Article 29(15), Article 51 (2c)). APPLiA also points out that the Commission has initiated infringement procedures against both France and Spain in November 2024 as their national requirements might have the potential to impede the harmonization and effectiveness of the single market. It is therefore currently unclear whether these national requirements will continue to exist in the future.

Main take-aways

The PPWR requires minimum 35% post-consumer recycled contents for non-food-contact plastics others than PET in 2030, increasing to 65% in 2040

The recycled contents shall be recovered from post-consumer plastic waste that has been collected in the Union and recycled in an installation located within the Union according to the Union rules, or collected and recycled in third countries under equivalent rules.

Compliance with the recycled content requirements shall be demonstrated by manufacturers or importers in the technical information, but many details on this are still to be defined.

2. MEErP Task 2, Markets

This section offers a very brief look at the market data estimates for washing machines, based on the current figures of the on-going Review Study.

2.1. Sales and Stock

Table 2 presents the estimated sales of washing machines and washer-dryers in five-year increments from 2010 through 2050 in the baseline scenario. Between 2025 and 2050, overall sales are projected to remain almost constant.

Table 2: Sales of appliances by Base Case, (BAU[32], thousands of units) (according to the Review Study 2025)

Type	2010	2015	2020	2025	2030	2035	2040	2045	2050
BC1 Washing machine 8 kg	10,868	10,451	10,726	9,496	9,496	9,496	9,496	9,496	9,496
BC2 Washing machine 10 kg	55	550	1,192	1,945	1,945	1,945	1,945	1,945	1,945
BC2 Washer-dryer 9 kg	519	532	546	549	552	555	557	560	563
TOTAL	**11,442**	**11,533**	**12,464**	**11,990**	**11,993**	**11,996**	**11,998**	**12,001**	**12,004**

Table 3 presents the estimated installed stock of appliances in five-year increments between 2010 and 2050. These data are presented in thousands of units.

Table 3: Stock of appliances by Base Case, (BAU, thousands of units) (according to the Review Study 2025)

Type	2010	2015	2020	2025	2030	2035	2040	2045	2050
BC1 Washing machine 8 kg	151,312	158,016	159,039	157,039	151,426	145,573	144,769	144,769	144,769
BC2 Washing machine 10 kg	760	4,482	8,818	13,833	21,798	26,996	26,847	26,847	26,847
BC2 Washer-dryer 9 kg	6,246	6,591	6,877	7,037	7,128	7,168	7,204	7,240	7,276
TOTAL	**158,318**	**169,089**	**174,734**	**177,909**	**180,352**	**179,737**	**178,820**	**178,856**	**178,892**

2.1.1. End-of-Life (EoL)

2.1.2. Introduction

At end-of-life, washing machines and washer dryers (WM/WD) become part of the waste from electrical and electronic equipment (WEEE). From 2019, the WEEE directive (section 1.4.6)

[32] Business-as-Usual : baseline scenario

requires a minimum annual collection rate of 65 % of the average weight of EEE placed on the market in the three preceding years (in the Member State concerned), or alternatively 85 % of WEEE generated (on the territory of that Member State). To be noted that:

- The WEEE requirement generically refers to 'collection' and not specifically to 'separate collection'. This is relevant because some statistics distinguish between 'separate collection' and 'complementary collection'. In addition, at least for plastics, the recycling rate is larger for separately collected WEEE.
- There are two alternative references for the collection rate: 'average EEE placed on the market in the three preceding years' and 'WEEE generated in a year'. In the available statistical data, both are being used (and easily confused).

During the transitional period until August 2018, washing machines and washer dryers were part of the WEEE category 'large household appliances' [33]. After that period, WM/WD products are part of WEEE category 4, 'Large equipment (any external dimension more than 50 cm)' [34]. In the statistical data, it is not always clear in which category WM/WD products have been counted, raising some doubts.

The available statistical data on end-of-life processing refer to all WEEE together, to all home appliances together, or at best to the categories 'large household appliances' or 'large equipment (any external dimension more than 50 cm)'. There is little or no EoL processing information specific for washing machines and washer dryers.

The information presented below is a study team elaboration of data from APPLiA statistical reports [35] and Eurostat data [36]. It is relevant e.g. for the determination of values for the factor R2 (recycling output rate) of the EcoReportTool (see section 5.5), and for estimating the maximum recycled plastic content that can be realistically required for WM (section 7.1.2).

2.1.3. Collection and recovery for all WEEE

Considering all types of WEEE together, APPLiA and Eurostat data for collected, recovered and recycled WEEE mass are the same (Figure 2, bottom curves). However, the mass of EEE placed on the market differs (Figure 2, top curves) and consequently, the collection rates also differ. Eurostat data show a collection rate of approximately 40% over the period 2009-2019 (Figure 3), decreasing in recent years due to the strong increase in the amount of EEE placed on the market (Figure 2). APPLiA data show an increase from around 30% in 2012 to 45% in 2020 (Figure 3), with differences between the two curves depending on the reference used (EEE placed on market or WEEE generated). The interpretation is that these data refer only to separately collected WEEE [37].

Recovery rates (around 90%) and recycling rates (80-85%) are the same for APPLiA and Eurostat.

[33] WEEE directive, Annex I and II

[34] WEEE directive, Annex III and IV.

[35] The Home Appliance Industry in Europe 2022-2023, APPLiA statistical report, and https://www.statreport2021applia-europe.eu

[36] Eurostat online datasets env_waselee and env_waseleeos, accessed January 2025.

[37] For comparison: the WEEE directive requires a minimum collection rate of 65% for all WEEE together (computed as collected WEEE vs. EEE placed on the market (3-years average)), or 85% if the generated WEEE is used as reference.

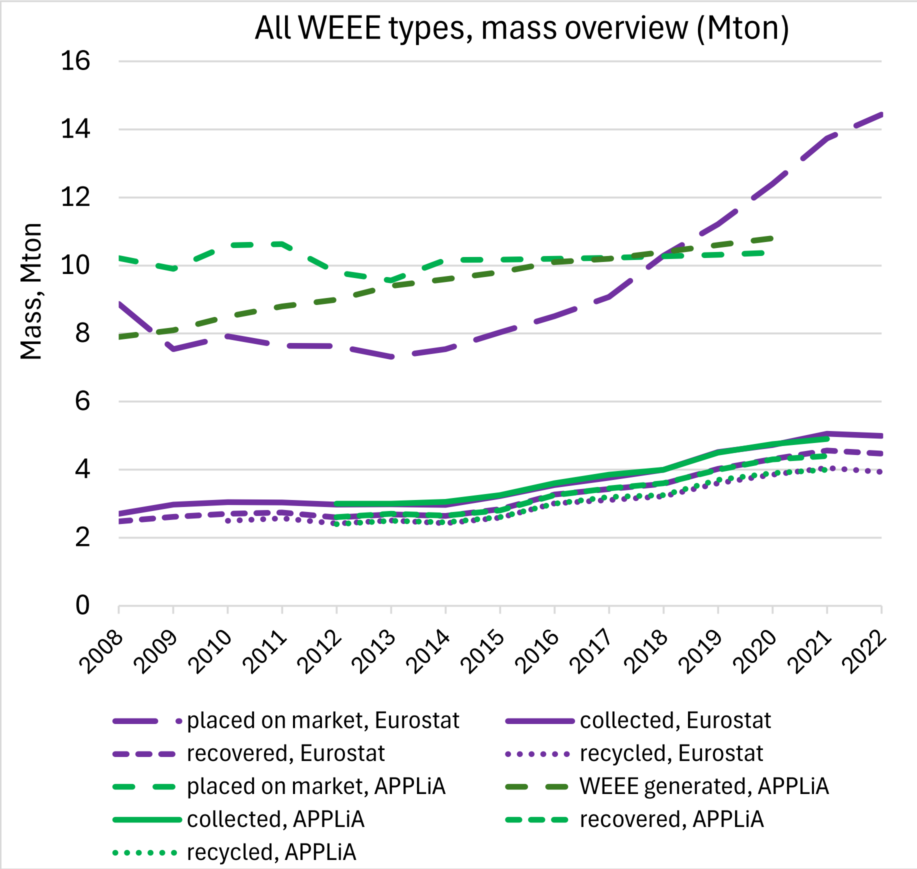

Figure 2: Mass of EEE (in Mton) placed on the market in the period 2008 – 2022, and mass of WEEE generated, collected, recovered and recycled (Source: VHK elaboration of APPLiA and Eurostat data).

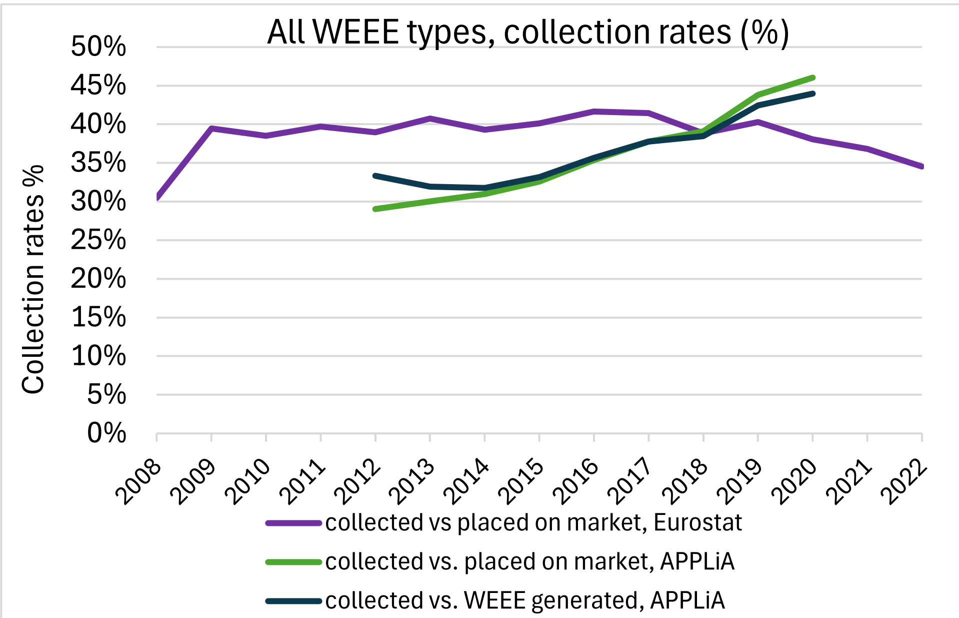

Figure 3: Collection rates for all WEEE together. The interpretation is that these data refer only to separately collected WEEE (Source: VHK elaboration of APPLiA and Eurostat data).

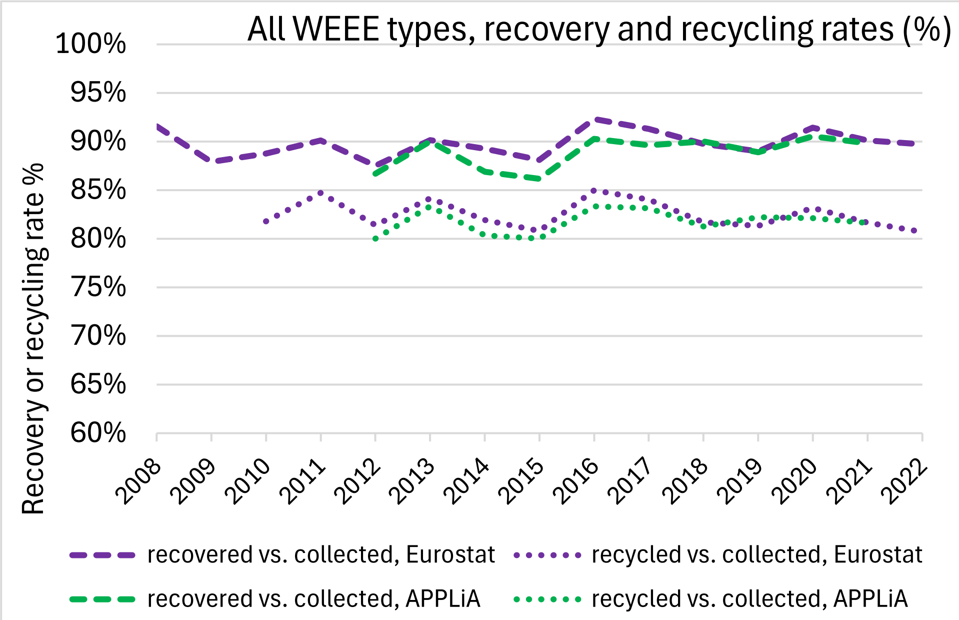

Figure 4: Recovery and recycling rates for all WEEE together (Source: VHK elaboration of APPLiA and Eurostat data).

2.1.4. Collection for all home appliances

The green stacked areas in Figure 5 indicate the separately collected mass of WEEE from home appliances (other WEEE is not included here) [38]. This is only WEEE collected through dedicated schemes, e.g. by organizations or companies working for the home appliance manufacturers in the context of extended producer responsibility (EPR). The grey stacked areas indicate the complementary mass, collected outside the EPR schemes. For reference, the blue solid curve in the graph gives the WEEE generated from home appliances, and the red curve the mass of home appliances placed on the market.

Figure 6 shows the corresponding separate and total collection rates, compared to home appliances placed on the market (red curves [39]) and compared to WEEE generated from home appliances (blue curves [40]). The collection rates increased between 2012 and 2017, but they are more stable over the period 2017-2020. In 2020, of the 5.4 Mton WEEE generated from home appliances, 74% was collected, of which 54% separately. Using as reference the average mass of home appliances placed on the market (6.4 Mton), the collection rates are lower: 62% collected, of which 46% separately.

As shown in Table 4, collection rates are lower for small home appliances, which more often end up in the waste bin.

[38] APPLiA data from https://www.statreport2021applia-europe.eu/slide/weee-flows-in-the-sector , with further elaboration by VHK.

[39] Average of preceding three years

[40] In the year of the collection

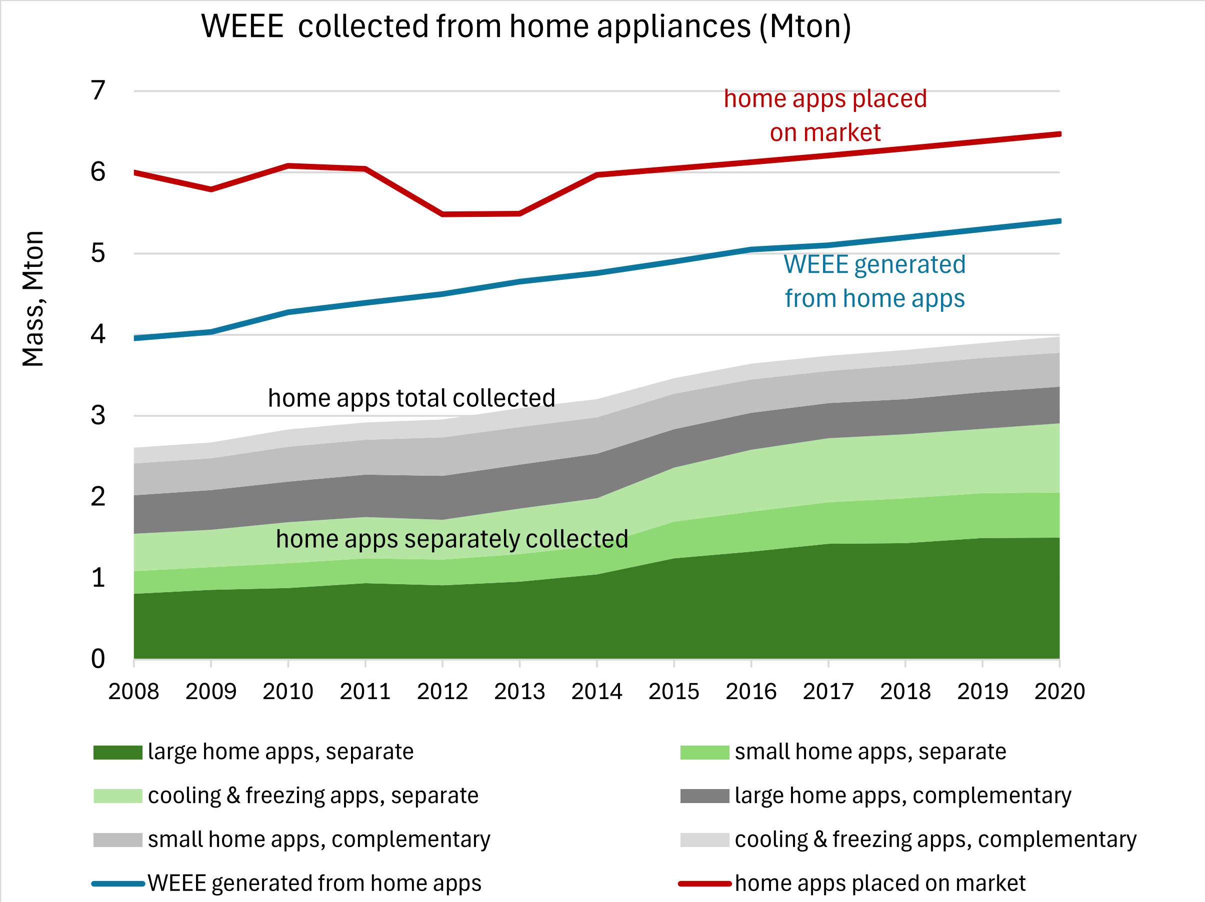

Figure 5: Mass of WEEE separately (green) or complementary (grey) collected from home appliances (in Mton) in the period 2008 – 2020, according to APPLiA data, subdivided in large home appliances, small home appliances, and cooling & freezing products. The mass of WEEE generated from home appliances (blue curve) and the mass of home appliances placed on the market (red curve) are indicated for reference. (Source: VHK elaboration of APPLiA data).

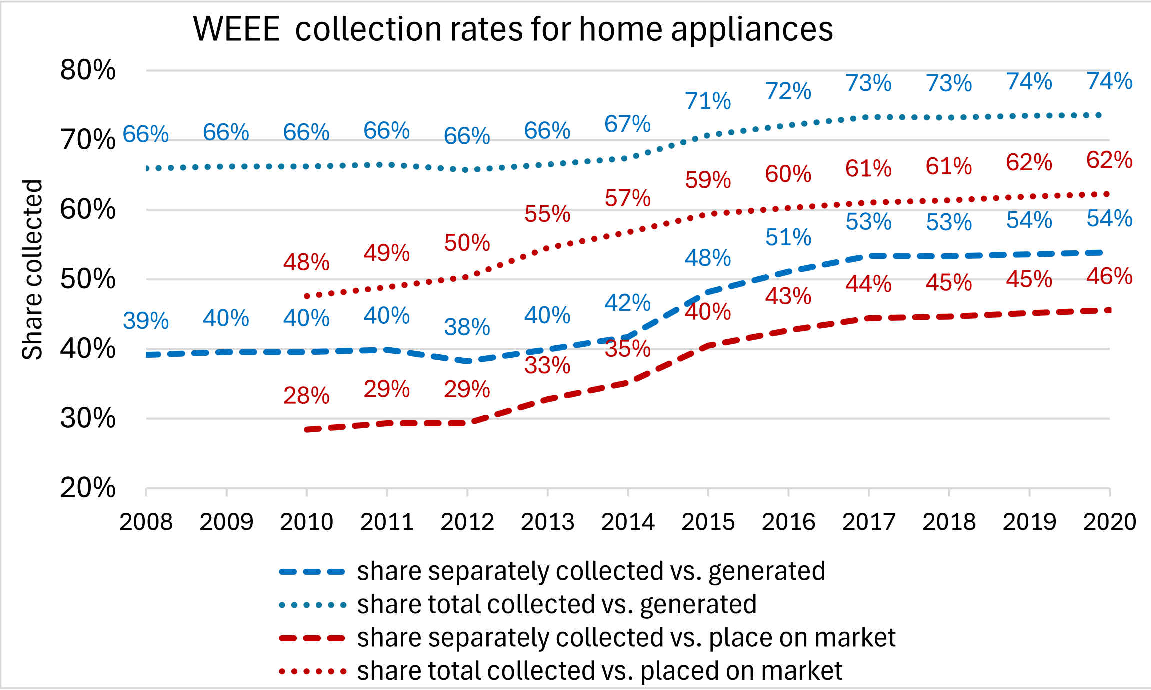

Figure 6: Separate and total collection rates for WEEE from home appliances, vs. WEEE generated (blue curves) and vs. home appliances placed on the market (red curves) (Source: VHK elaboration of APPLiA data).

Table 4: WEEE from home appliances in year 2020, generated, separate collection, complementary collection, waste bin and gap (unknown) (source: APPLiA, elaboration by VHK)

Year 2020	Large home appliances		Small home appliances		Cooling & freezing equipment		All home appliances	
	Mton	%	Mton		Mton	%	Mton	%
WEEE generated	**2.5**		**1.50**		**1.40**		**5.40**	
Collected, separately	1.50	60%	0.56	37%	0.85	61%	2.91	54%
Collected, complementary	0.45	18%	0.42	28%	0.20	14%	1.07	20%
Waste bin	0.05	2%	0.26	17%	0.01	1%	0.32	6%
Gap, unknown	0.50	20%	0.27	18%	0.34	24%	1.11	20%

2.1.5. Collection for large home appliances

Specifically for large home appliances, Figure 7 shows the EoL destinations, split in separate collection, complementary collection, waste bin and unknown (gap) [41]. In addition to the separate, dedicated, large-scale collection (e.g. EPR schemes), there is a complementary collection e.g. from home appliances ending up in metal scrap, or collected directly by recycling industries or by local small-scale collectors. The stacked green areas together (from APPLiA data) are the total collected WEEE mass from large home appliances. The top of the stack (including also the red and grey areas) is the WEEE generated from large home appliances according to APPLiA. For comparison, the purple dashed curve indicates the collected mass from Eurostat for the same category of products [42] and the purple solid curve Eurostat's large home appliances mass placed on the market.

Figure 8 shows the corresponding collection rates. Green curves come from APPLiA data, purple curves from Eurostat. According to APPLiA data, 78% of WEEE generated from large

[41] APPLiA data from https://www.statreport2021applia-europe.eu/slide/weee-flows-in-the-sector , with further elaboration by VHK.

[42] Eurostat online dataset env_waselee , with further elaboration by VHK.

home appliances was collected in 2020, of which 60% through separate collection schemes (see also Table 4).

Eurostat collection rates (versus EEE placed on the market) are lower: 48% for large home appliances in 2018, and 42% for temperature exchange equipment over the period 2019-2022 [43]. Although Eurostat's collected mass is close to the sum of APPLiA's separately and complementary collected masses (Figure 7), the interpretation is that Eurostat's mass refers to separately collected only. The difference in collection rates seems to be mainly due to the reference used (high mass placed on the market for Eurostat compared to much lower mass of WEEE generated for APPLiA).

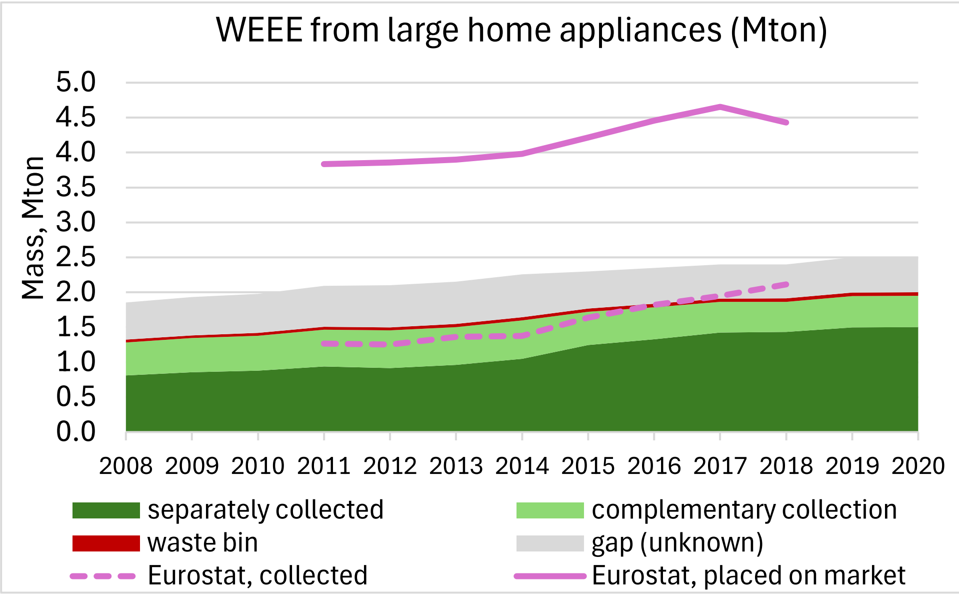

Figure 7: Destinations for the WEEE from large home appliances: separate collection, complementary collection, waste bin, and unknown (gap). The stacked areas are from APPLiA data. The dashed purple curve is the total collection from Eurostat, and the solid purple curve the EEE placed on the market from Eurostat. (Source: VHK elaboration of APPLiA and Eurostat data).

[43] Temperature exchange equipment includes, apart from refrigerators and freezers, also air conditioners and heat pumps, for which sales have recently strongly increased while units reaching EoL are comparatively low. This drives down Eurostat's overall collection rate for this category (which refers to mass placed on the market).

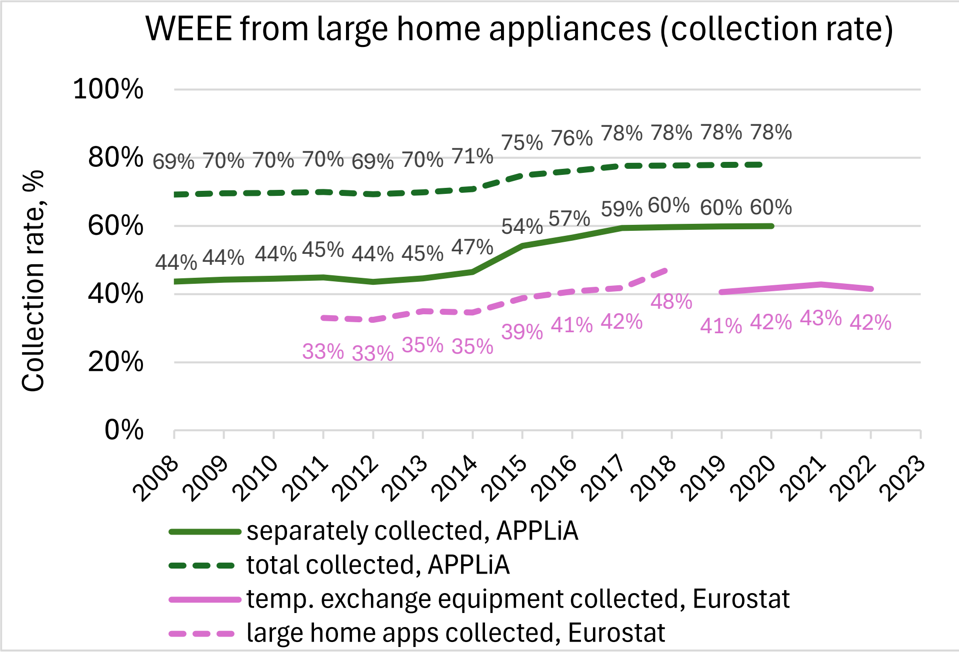

Figure 8: Collection rates for WEEE from large home appliances, for separate collection (from APPLiA), separate + complementary collection (from APPLiA), collection for large home appliances (from Eurostat, until 2018) and collection of temperature exchange equipment (from Eurostat, from 2019) (Source: VHK elaboration of APPLiA and Eurostat data).

2.1.6. Collection and recovery per type of material

Table 5 shows WEEE data per material type for all home appliances together in year 2018, derived from APPLiA data [44]. The totals are consistent with other presented data, and the overall 73% collection rate (vs. WEEE generated) and 93% recovery rate (vs. collected) seem reasonable. However, the subdivision over the material types presents inconsistencies: for steel, copper and concrete the amount recovered is higher than the amount collected [45]. Hence, caution is required when using the data in this table.

Nevertheless, the recovery rates for metals are generally high, while those for plastics (34% vs. generated) and glass (29% vs. generated) are significantly lower.

[44] https://www.statreport2021applia-europe.eu/slide/materials-recovered-from-weee-collected-by-the-industry
https://www.statreport2021applia-europe.eu/slide/materials-recovered
https://www.statreport2021applia-europe.eu/slide/circularity-of-the-sector
The Home Appliance Industry in Europe 2022-2023, APPLiA, p.32 Materials recovered from waste

[45] One of the reasons can be that for generated and collected the breakdown over the material types assumes that the composition is the same as for placed on the market, which is not necessarily true. In addition, the presence or not of stainless steel in the figures for steel might not be consistent.

Table 5: WEEE collection and recovery from all home appliances in year 2018, per material type, placed on market, generated, separate collection, complementary collection, material recovery, energy recovery (source: APPLiA, elaboration by VHK)

All home appliances, Year 2018, Masses in Mton	Placed on market	WEEE generated	total collected	Collected vs generated	Recovered from separate collection	Recovered from complementary collection	Total recovered	Recovered vs. placed on market	Recovered vs generated	Recovered vs. collected
Aluminium	0.17	0.14	0.10		0.064	0.03	0.094	55%	67%	91%
Concrete	0.39	0.32	0.24		0.290		0.290	74%	90%	123%
Copper	0.15	0.12	0.09		0.064	0.03	0.094	63%	76%	103%
Glass	0.23	0.19	0.14		0.055		0.055	24%	29%	39%
Plastics	2.04	1.69	1.24		0.388	0.19	0.578	28%	34%	47%
Steel	2.75	2.27	1.67		1.691	0.56	2.251	82%	99%	135%
Other	0.56	0.46	0.34		0.061	0.12	0.181	32%	39%	53%
Sum materials	**6.29**	**5.20**	**3.81**	**73%**	**2.61**	**0.94**	**3.54**	**56%**	**68%**	**93%**
Energy recovery					0.12	0.035	0.155	2%	3%	4%
Sum recovery					**2.73**	**0.98**	**3.70**	**59%**	**71%**	**97%**

2.1.7. Collection and recycling of plastics from home appliances

Table 6 shows further details on plastic WEEE from all home appliances, probably for year 2018, based on APPLiA data [46].

Of the 2 Mton home appliances placed on the market, 49% is separately collected, but only 18% becomes plastic recyclate: 8.7% PP, 5.3% PE, 3.4% (HI)PS and 0.5% ABS. The rest still goes to incineration (25%) or landfill (6%).

Note that only PP, PE, (HI)PS and ABS are mentioned as plastics being recycled.

9% of the plastic ends up in the waste bin (mainly from small home appliances) and most of this is incinerated.

Overall, 18% is recycled, 32% is incinerated, 8% goes to landfill, and for 42% the destination is unknown.

For comparison, PlasticsEurope [47] for post-consumer plastics from EEE in 2018 reports that 18% was recycled, 52% was incinerated and 20% went to landfill. In 2022 this becomes 20% recycled, 50% incinerated and 30% landfill. In the 20% recycled, approximately 13% was post-consumer mechanically recycled, 6% pre-consumer mechanically recycled, 1% bio-based and 0.1-0.2% chemically recycled. Hence, chemical recycling is still a small fraction.

The same sources state that in 2022 EEE products consumed 3.1 Mt of plastics, of which 3.2% (0.1 Mt) came from post-consumer recycled plastic.

PlasticsEurope further reports that from the 16.4 Mton post-consumer separately collected plastics 49.4% was recycled in 2022, while from the 15.9 Mton mixed waste collection only

[46] The Home Appliance Industry in Europe 2022-2023, APPLiA, p.27 Plastic flows from home appliances
The Home Appliance Industry in Europe 2022-2023, APPLiA, p.28 Routes of recycled plastics from WEEE
https://www.statreport2021applia-europe.eu/slide/plastic-generated-vs-collected

[47] https://plasticseurope.org/wp-content/uploads/2024/11/PE_TheFacts_24_digital-1pager.pdf
https://plasticseurope.org/knowledge-hub/the-circular-economy-for-plastics-a-european-analysis-2024/

3.8% was recycled (but this is not specific for EEE, including e.g. also packaging and construction waste).

Table 6: WEEE plastics collection, recovery and recycling from all home appliances (source: APPLiA, elaboration by VHK)

All home appliances, Year 2018 (?), Masses in Mton	Plastic WEEE placed on market (or generated?) [48]	Collection [49 50]	Collection share	EoL destination	EoL destination share	Type of recyclate	Type of recyclates, share
Small home apps.	1.04	0.39	38%				
Large home apps.	0.55	0.32	58%				
Cooling & Freezing	0.46	0.28	61%				
All home apps.	**2.06**	**0.99**	49%				
Separate collection		1.01	49%				
Incineration / co-processing				0.51	25%		
Landfill				0.13	6%		
Plastic recyclates				0.37	18%		
Polypropylene (PP)						0.18	8.7%
Polyethylene (PE)						*0.11*	*5.3%*
(High impact) polystyrene (HI)PS						*0.07*	*3.4%*
Acrylonitrile butadiene styrene (ABS)						0.01	0.5%
Waste bin		0.19	9%				
Incineration / co-processing				0.15	7%		
Landfill				0.04	2%		
Complementary collection		0.27	13%				
Unknown destination				0.27	13%		
undocumented		0.59	29%				
Unknown destination				0.59	29%		

2.1.8. Hoarding trends in Europe

The growing accumulation of unused electrical and electronic equipment (EEE) in households is an emerging challenge with significant environmental and economic consequences. A data collection initiative led by the WEEE Forum across several European countries and Lebanon, highlights the scale of the issue. In 2022, this study surveyed 8,775 households to examine the extent of hoarding EEE and WEEE. Addressing this issue could drastically improve reuse and recycling, and contribute to a more sustainable economy[51].

[48] In APPLiA statistics it is presented as WEEE generated, but comparing with Table 5, it is more likely that it refers to the amount placed on the market.

[49] The amounts on the first four rows are for separate collection. The difference between 0.99 and 1.01 is due to rounding.

[50] The total collection is 1.01 Mton (separate) + 0.27 Mton (complementary) =1.28 Mton. This is close to the 1.24 Mton total plastics collected in Table 5

[51] Hoarding of Electrical and Electronic Equipment (EEE) and Waste Electrical and Electronic Equipment (WEEE): A Hidden Challenge, Nov. 21, 2024, FutuRaM, https://futuram.eu/hoarding-of-weee/

The findings reveal that the average EU household owns 74 electrical items, representing approximately 90 million tons (Mt) of equipment across Europe. Out of these, 61 items are actively in use, while four items per household are hoarded but broken. This amounts to 3 Mt of appliances that could be repaired or handed over to WEEE collection schemes. In addition to this, nine working items, for a total of 7 Mt, are not being used, yet they have the potential to reduce the need for new electrical goods and minimize future WEEE generation if they were brought back into circulation.

Small electronic devices, such as laptops and kitchen equipment, are the most commonly hoarded items. Although small, these devices represent a large portion of hoarded WEEE by quantity. In contrast, larger items like washing machines and refrigerators, while less frequently hoarded, make up a significant portion of the total mass of WEEE when discarded.

Interestingly, the motivation for keeping unused EEE varies. The main reason cited by 46% of survey respondents was the belief that the item might be useful again in the future. Other common reasons included plans to sell or give away the item (15%), sentimental attachment (13%), and the perception that the item may increase in value (9%). A small portion of respondents (7%) admitted that they simply did not know how to dispose of these items properly.

2.2. Market for recycled materials

This chapter collects information that was gathered during the mini-preparatory study on the recycling market, and more specifically on the recycling of washing machines. For further information see also the general, horizontal part of the study report on recycled content and CRMs.

2.2.1. General information

Washing machine recycling.

Washing machines are recycled with other large household appliances and usually in large shredders also used for vehicles (more info in 4.2).

End-of-waste declaration.

There are rules on how waste can be stored, transported, processed, etc. There have been problems with transport of recycled materials because officially they still had the status of waste. One washing machine manufacturer actively working on the topic of recycled plastic reported this issue, particularly regarding transport between two Member States. At a certain moment, there must be an ‘end-of-waste’ declaration to change the status of the recycled material, but it is currently (January 2025) not clear who can or has to issue such a declaration.

Organizations.

Various recycling market organizations are active in Europe (list is not exhaustive):

EuRIC (https://euric.org/) is the leading voice of the European recycling industries and strives to realise its vision by:

- Advocating for conditions that enable recycling and waste management sectors to be competitive, grow and re-invest.
- Connecting the European recycling industries and other circular economy stakeholders.

- Acting as a trusted partner between the European recycling value chain and policymakers.
- Advancing the socio-economic, climate and environmental benefits of recycling.
- Providing specific and cross-sectoral expertise on a broad range of materials including Metals (ferrous and non-ferrous), Plastics, Paper, Textiles, Tyres, End-of-life vehicles (ELVs), E-waste including batteries, Construction & Demolition waste [52]

FEAD (European Waste Management Association) (https://fead.be/) is a Brussels based association promoting the circular economy by representing Europe's private resource and waste management industry. Its vision for 2030 is:

- Shifting Europe's overall material use towards recycled materials through industrial excellence in waste management.
- To supply the European economy with secondary raw materials and energy, while managing waste in a safe and environmentally responsible way.
- To support the European Union's ambition to double its Circular Material Use Rate (CMUR) in this decade.

FEAD aims to:

<u>Boost recycling</u>

- Introduce mandatory recycled content requirements, to build on proposals for PET bottles, to create strong European markets for recycled materials
- Improve the recyclability of products through eco-design and reduce of substances of concern, and where needed, to contribute to efficient EPR schemes
- Ensure the implementation of existing recycling targets at national level
- Use eco-labelling to empower consumer decision making
- Leverage public sector buying power through obligatory green public procurement
- Accelerate programs designed to strengthen regulatory enforcement to help all EU Member States reach their recycling targets

<u>Foster resource efficiency</u>

- Recycle as much as possible, yet recognize that not all waste can be recycled either technically or economically at this moment in time
- Recover energy and construction materials from non-recyclable and non-compostable waste in waste-to-energy facilities

<u>Encourage private sector investment in the circular economy</u>

- Enforce Single Market rules on state aid
- Open up household waste markets to competition and give private entities a level playing field
- Abolish the principle of unanimity in the process of negotiations related to VAT harmonization in the European Union

[52] EuRIC has branches for:

- Ferrous metals recycling (EFR, European Ferrous Recovery & Recycling Branch, including end-of-life vehicles recycling)
- Non-ferrous metals recycling (EuroMetrec, European Non-Ferrous Recovery & Recycling Branch, including E-waste recycling)
- Plastics (EPRB, European Plastics Recycling Branch)
- Paper (ERPA, European Recovered Paper Branch)
- Tyres (EuRIC MTR, Mechanical Tyre Recycling Branch)
- Textiles (EuRIC Textiles, Textiles Re-use & Recycling Branch)
- Construction and Demolition (ECDB, EuRIC Construction and Demolition Branch)

PRE, Plastic Recyclers Europe (https://www.plasticsrecyclers.eu/) is the voice of the European plastics recyclers, representing 850 recycling facilities, 13.2 Mtons installed capacity, €9.1 billion turnover and 30 thousand employees. PRE stands for:

- Advancing circularity of plastics through increased quality plastics recycling & use of recycled materials in high-end products
- Improving recyclability of plastic products
- Harmonizing of the recycling standards & practices across Europe
- Genuine transition towards the circular economy

ERP, European recycling platform (https://erp-recycling.org/**)**: Created by producers for producers, the ERP informs consumers about, and services both private companies and public authorities with optimal solutions for recycling waste from electronic and electrical equipment (EEE), batteries, packaging and, most recently, textiles. ERP makes it easy for its members (companies that place new products on the market) to meet compliance and reporting requirements at the best possible price and with the least possible admin.

CPA, Circular Plastics Alliance

(https://single-market-economy.ec.europa.eu/industry/industrial-alliances/circular-plastics-alliance_en)

The Circular Plastics Alliance aims to boost the EU market for recycled plastics. The alliance covers the full plastics value chains and includes over 330 organisations representing industry, academia and public authorities. New stakeholders can join the alliance by signing its declaration. The signatories "take action to boost the EU market for recycled plastics up to 10 million tonnes by 2025". The Circular Plastics Alliance is an initiative under the European Strategy for Plastics (2018), in particular under Annex III related to voluntary pledges by industry.

The deliverables of the CPA include:

- Design for recycling work plan [53]: 26 products targeted, but most are in agriculture, packaging and construction, for use of recycled LDPE, HDPE, PP, EPS, PET, PS and PVC. Under Electrical and Electronic Equipment, small household appliances, large household appliances and cooling and freezing appliances are targeted for use of recycled ABS, PS and PP.
- CPA Roadmap to 10 Mt – Untapped Potential Report [54]. Achieving the European Commission’s 2018 target of 10 million tonnes of recycled plastics used in the EU by 2025 requires producing an additional 3.4 million tonnes of recycled plastics in Europe by 2025 (compared to 2020). Therefore, sorting capacities should increase by at least 4.2 million tonnes by 2025 and recycling capacities by at least 3.8 million tonnes. This corresponds to estimated investment needs between € 7.6 billion and € 9.1 billion.
- A European monitoring system. The CPA established a monitoring system to track progress towards 10 million tonnes of recycled plastics produced and used in Europe by 2025. This is the first-ever EU-wide monitoring system on recycled plastics. As per the CPA declaration, this system is transparent and trusted, with auditing and

[53] Circular Plastics Alliance, DESIGN FOR RECYCLING WORK PLAN, Updated final draft – Version Sept. 2021, https://ec.europa.eu/docsroom/documents/47334

[54] Circular Plastics Alliance – Roadmap to 10 Mt recycled content by 2025, September 2021, https://ec.europa.eu/docsroom/documents/46956

traceability of both the system and data. The CPA has approved two platforms for collecting data in compliance with the CPA monitoring rules and methodology

- MORE, managed by EuPC, collecting data only on the use of recycled plastics
- RecoTrace managed by PolyREC, collecting data on both the production and use of recycled plastics

I4R platform (https://i4r-platform.eu/): provides treatment and recycling facilities and preparation for re-use operators with access to WEEE recycling information in line with the requirements of Directive 2012/19/EU.

Article 15 of the Directive 2012/19/EU (WEEE Directive) requires producers to provide information free of charge about preparation for re-use and treatment for each type of EEE placed on the market. This provision with slightly different wording already existed at the time of the first WEEE Directive (old Art. 11). Since 2005, manufacturers have been collecting the information according to a harmonized reporting format for each product and uploaded it on their website.

To better respond to recyclers' needs, APPLiA and DIGITALEUROPE have created this single central online platform – the Information for Recyclers Platform (I4R) – where recyclers can access recycling information at product category level. The WEEE Forum, an international association of producer responsibility organisations and a centre of competence, will host and maintain the platform. To meet the requirements of Directive 2012/19/EU, the recycling information will be linked to the presence and location of materials and components in electronic waste that require separate treatment.

The European Power Tool Association (EPTA) has recently joined the I4R platform and contributed with a new product category on Power tools and four new product fiches.

A grand total of 47 product fiches in six product categories are currently at the user's disposal.

Research projects.

Various research projects on recycling have been performed or are ongoing in Europe (list is not exhaustive):

PRecycling (https://www.precycling-project.eu/) aims to produce high-quality recyclates from plastics waste streams by developing an easy-to-use methodology for sorting, sampling, tracing, recycling techniques, and analysis procedures of both plastic waste streams (PWS) and recyclates, and to assess the environmental and financial viability of them in selected waste management processes for plastics waste and secondary raw materials, in order to change the current paradigm of low cost non-environmentally friendly actions such as landfilling [55].

PRecycling aims at achieving specific technological/strategic goals:

- Development and demonstration of standard, robust and easy-to-use sampling and analysis procedures to ensure consistent recyclate quality and safe products.
- Development of methodologies to determine the degree of degradation of recycled materials and to foresee their end-of-life.

[55] This project has received funding from the European Union's Horizon Europe research and innovation program under grant agreement No 101058670.

- Development of methods for traceability of recyclates to allow the identification of the origin of recycled materials via digital information management, throughout marking technologies and blockchain approaches.
- Development of methods for detection and separation of legacy additives in the plastics waste streams to ensure safe recycling of plastics containing such additives.

Plast2bcleaned (https://plast2bcleaned.eu/): In 2021, 10 million tons of Waste Electrical and Electronic Equipment (WEEE) were generated in Europe containing 25 wt. % of plastics. Due to the growing number of electronics sold and decreasing product life spans, this waste stream is predicted to continue to grow in the following years. WEEE plastics often contain undesired additives that hamper recycling in Europe. WEEE plastics containing brominated flame retardants (BFR) as additives are currently incinerated or landfilled. Hence for WEEE plastics, a closed-loop solution is needed. PLAST2bCLEANED's aim was to develop a human and environmentally safe recycling process for WEEE plastics in a technically feasible and economically viable manner. Three material loops were intended to be closed: (1) polymer; (2), bromine fraction; and (3) antimony trioxide fraction [56].

INCREACE project (https://increace-project.eu/):

INCREACE aims at increasing the uptake of recycled plastics in various products through innovative and interdisciplinary solutions. This goes along the plastics recycling value chain embedded in a systemic framework with a focus on Electrical and Electronic Equipment (EEE). By using (in principle) recycled plastics from Electrical and Electronic Waste (WEEE), the INCREACE project will tackle areas where the use of recycled plastics is marginal today.

INCREACE is a project funded by the European Health and Digital Executive Agency (HADEA) of the European Commission under the Horzion Cluster 4 program.

The project partners will develop new data-driven sorting solutions to prevent potentially hazardous substances entering the recycled plastics system and combine complementary recycling technologies (mechanical, chemical and solvent based) to increase the overall recycling yield. Traceability is essential; therefore, the project will rely on an innovative blockchain approach. The overall concept will be applied to and validated by specific business cases. INCREACE will also analyse implications of systematic changes in the plastic industry from different perspectives.

The business cases include food contact applications and high-tech plastic components in EEE.

In INCREACE, PHILIPS and PEZY collaborated to develop a tool for designers to calculate the recyclability rate of a product and point you to design improvements. It enables designers to develop recyclable designs only using product data available to the designers (for electronic small household devices). We call the tool RAT (recyclability assessment tool).

PRIMUS (https://www.primus-project.eu): researching new polymer recycling technologies that allow to produce new technically and safety compliant recycled materials that can be used for manufacturing high value products. Relevant for washing machines: the feasibility of gaskets with recycled EPDM was demonstrated, further information in section 4.3.6.

[56] https://plast2bcleaned.eu/wp-content/uploads/2024/07/Project-Sumary_Plast2_V4_compressed.pdf

ABSolEU project (https://absoleu.univ-cotedazur.eu/): The ABSolEU project is an initiative funded under the EU's Horizon Europe Program. It is simultaneously a multilateral collaboration that aims to pave the way to circularity for the ubiquitous plastic ABS, found in durable products from toys and other consumer goods to automotive components, and therefore revolutionize the current state of the art of ABS recycling in Europe and beyond.

FutuRaM project (https://futuram.eu/about/): FutuRaM will develop the Secondary Raw Materials knowledge base on the availability and recoverability of secondary raw materials (2RMs) within the European Union (EU), with a special focus on critical raw materials (CRMs). The project research will enable fact-based decision making for the recovery and use of 2RMs within and outside the EU, and disseminate the data generated via an accessible knowledge base developed in the project. The project runs from June 2022 to May 2026.

PolyCE project (https://www.polyce-project.eu/): PolyCE stands for Post-Consumer High-tech Recycled Polymers for a Circular Economy. It was a European Commission funded project consisting of a consortium of 20 expert organisations, the project had taken on the challenge of addressing this problem during the next four years.

Through significantly reducing the use of virgin plastics and enhancing the use of recycled plastics in new electronics applications, PolyCE aimed at:

- Demonstrating the feasibility of a circular model for the plastics supply and value chain.
- Developing a grading system for recycled plastics, which will ultimately serve to provide guidelines for designing new electronic products.
- Involving green public procurement initiatives and consumer awareness raising campaigns across the EU (with a focus on Germany, Poland, Italy and France).
- Establishing a feedback loop from research activities that provides policy input regarding technical feasibilities and conflicts from a technical perspective.

Among others, the PolyCE project published a useful guideline entitled 'Design for and From Recycling: Practical Guidelines for Designers'[57], Within the project, Whirlpool demonstrated the effective re-use of closed loop recycled plastics (PCR) from WEEE waste streams, by manufacturing a (PCR)PP washer tub filled with CaC3.

2.2.2. Market for recycled metals

Steel

Based on EURIC's metal recycling fact sheet [58]:

- European steel scrap recycling collects and re-processes more than the demand for steel scrap in the EU. In 2018, the domestic supply of the EU-28 exceeded 112 million tonnes. This is consistently apparent year after year, showing that there is no scrap shortage in the EU.
- The largest importer of steel scrap from the EU-28 is Turkey, whose imports represent more than 50% of EU-28 steel scrap exports (11.09 million tonnes in 2018). The

[57] PolyCE-E-book-Circular-Design-Guidelines-2.pdf

[58] https://circulareconomy.europa.eu/platform/sites/default/files/euric_metal_recycling_factsheet.pdf The publication is from 2020, but reported data are older.

Turkish steel industry relies vastly on the EAF steel production route using steel scrap as main infeed [59].

- In 2018, European scrap recyclers exported more than 21,400 thousand tonnes and imported 2,850 thousand tonnes.
- The proportion of steel scrap used in relation to crude steel production in the EU is 56%. Steel scrap use (consumption) for steelmaking was 93.8 million tonnes in the EU in 2018.
- Over 90% of EoL stainless steel is currently collected and recycled into new products.
- 16% of steel in the EU is used for domestic appliances. For the remaining 84% of steel, the share of recycled content is much lower.

For comparison, the average washing machine contains 28.2 kg of ferrous metals. Multiplying this by the 12.5 million appliances[60] sold, gives 352 thousand tonnes of generated ferrous waste from WMs/WDs. Assuming a 78% collection rate of EoL for large appliances (section 2.1.5) this means 275 thousand tons of ferrous scrap. Ferrous scrap from WMs/WDs is 0.29% of the total 93.8 million tonnes used in the EU in 2018.

Aluminium

Based on EURIC's metal recycling fact sheet [58]:

- 4.9 million tonnes of aluminium were recycled in the EU in 2017.
- In the coming decades, demand for aluminium is expected to increase by a further 50% by 2050, reaching over 9 million tonnes of scrap demand in the EU.
- Secondary aluminium production represents globally twice the production of primary aluminium. As a result, aluminium scrap from recycling is a valued commodity, traded worldwide, and the major source of total aluminium production.
- Of the total amount of aluminium scrap generated in the EU at EoL (i.e., 4,338 thousand tonnes of aluminium), about 2,986 thousand tonnes of aluminium were collected and recycled, resulting in an EoL recycling rate of 69%.
- 6% of aluminium in the EU is used for consumer durables.

For comparison, the average washing machine contains 2.58 kg of aluminium. Multiplying this by the 12.5 million appliances[61] sold, gives 32.2 thousand tonnes of generated aluminium waste from WMs/WDs. Assuming a 78% collection rate of EoL for large appliances (section 2.1.5) this means 25.11 thousand tons of aluminium scrap. Aluminium scrap from WMs/WDs is 0.51% of the total 4.9 million tonnes used in the EU in 2018.

Copper

Based on EURIC's metal recycling fact sheet [58]:

- 44% of EU copper demand comes from recycled sources.

[59] An electric arc furnace (EAF) can handle 60-70% of metal scrap. Such furnaces are mainly found in Turkey and India. Blast furnaces in the EU can handle only up to 10% of metal scrap.

[60] Considering washing machines and washer dryers

[61] Considering washing machines and washer dryers

- 70% of copper in EoL products is recycled.
- 90% of copper in civil infrastructure is recycled.
- The modest natural deposits of copper within the EU (48,000 thousand tonnes) drive a strong reliance on recycling, otherwise imports of primary and secondary forms to meet the domestic demand would increase.
- Despite the amount of secondary copper sent to domestic processing is supplemented by imports of copper waste and scrap, in absolute terms, the EU-28 is a net-exporter of secondary copper forms.
- The EU exported 986,000 tonnes of copper scrap with a value of €1.91 billion to third countries in 2016.
- Of the total amount of copper scrap generated at EoL (i.e., 2,625 thousand tonnes of copper), about 1,603 thousand tonnes of copper (61%) were collected and recycled within the EU.
- 25% of copper in the EU is used for 'other equipment' (different from transport, construction, industrial and infrastructure)

For comparison, the average washing machine contains 1.73 kg of copper. Multiplying this by the 12.5 million appliances[62] sold, gives 21.6 thousand tonnes of generated copper waste from WMs/WDs. Assuming a 78% collection rate of EoL for large appliances (section 2.1.5) this means 16.2 thousand tons of copper scrap. Copper scrap from WMs/WDs is 1.1% of the total 1.6 million tonnes collected and recycled in the EU.

In a meeting with the study team, a specialist EU copper recycler [63] explained that copper is a market, where demand is higher than supply. The main issue would be to increase end-of-life collection rates and adequately regulate exports of copper scrap and recycled copper, so that the supply of recycled material can be increased.

No focus on recycled metal content

During the stakeholder meeting following phase 1 of the present study, there seemed to be agreement that setting minimum recycled content requirements on metals is not useful. The recycling chain for metals is well established and there is a well-established market (see prices for recycled metals in Table 7).

Table 7: Virgin and recycled material prices (based on data from the German Mineral Resources Agency (DERA[64]))

Material	Price (US$ / kg)		Dataset
	April 2025	Average 2020-2024	
Aluminium	2,38	2,31	LME, high grade primary
Aluminium (recycled)	1,60	1,33	New aluminium alloy scrap (Angel)
Aluminium (recycled)	1,25	0,96	Cast aluminium scrap (Aster)
Copper	9,19	8,38	LME, grade A

[62] Considering washing machines and washer dryers

[63] https://www.montanwerke-brixlegg.com/

[64] https://www.deutsche-rohstoffagentur.de/DERA/DE/Produkte/Rohstoffpreise/Preismonitor/preismonitor_node.html

Copper (recycled)		7,82	7,18	Chopped copper wire scrap (kasus)
Copper (recycled)		7,54	6,80	Chopped copper wire scrap (katze)
Copper (recycled)		5,52	5,13	Brass scrap (magda), rolled brass scrap 63
Copper (recycled)		6,67	5,85	Gunmetal scrap (radar), gunmetal scrap I
Iron ore		0,10	0,12	Iron ore (any origin) fines, spot price, c.f.r. China, 62% FE
Steel (recycled)		0,28	0,30	Steel scrap (grade E1), old steel scrap
Steel (recycled)		0,33	0,34	Steel scrap (grade E2/E8), new steel scrap
Steel (recycled)		0,33	0,33	Steel scrap (grade E3) Heavy steel scrap
Steel (recycled)		0,33	0,34	Steel scrap (grade E4), shredded steel scrap
Steel (recycled)		0,27	0,26	Steel scrap (grade E5), steel chips
Steel (recycled)		0,85	1,17	Steel scrap (V2A), chromium-nickel alloyed exw Germany
Steel (recycled)		1,97	1,96	Steel scrap (V4A), chromium-nickel alloyed exw Germany
Rare earth elements (REE)	Neodymium (Nd)	-	102,28	Neodymium (metal), min. 99%, fob China
	Dysprosium (Dy)	-	420,25	Dysprosium (metal), min. 99%, fob China
	Samarium (Sm)[65]	-	13,09	Samarium (metal), min. 99 % fob China
	Praseodymium (Pr) (for reference)	-	115,57	Praseodymium (metal), min. 99%, fob China
	Terbium (Tb) (for reference)	-	1.554,59	Terbium (metal), min. 99%, fob China
	REE (recycled)	61,17	-	Praseodymium-neodymium from NdFeB magnetic scrap, PrNd = 50%
Gold (for reference)		103.461,09 *3.217,64 US$/troz*	62.384,89 *1.940,17 US$/troz*	99,5% fine, London, afternoon
Cobalt (for reference)		33,08	41,25	LME, min. 99,8%
Lithium (for reference)		9,77	-	Lithiumcarbonate, battery quality, Li2Co3 = 99,5%
Nickel (for reference)		15,20	19,27	Primary, min. 99,8%

Due to the fixed availability of waste metal supply (as it depends on the volume of old cars and appliances, etc., that are scrapped), introducing minimum ecodesign requirements for recycled metals in home appliances might lead to a shift of supply of metals with recycled content between sectors that use steel, such as e.g. the construction industry. Hence, such requirements do not assist the recycling industry, resolve waste stream problems, or reduce environmental impacts. Consequently, setting minimum recycled content requirements on metals used in washing machines/washer dryers has not been a study focus. For further information see also the general, horizontal part of the study report on recycled content and CRMs.

[65] Used in samarium-cobalt magnets, but very low market share (Baghel et al. (2025), https://doi.org/10.1038/s41598-025-94667-x; Lucas et al. (2005), ISBN: 978-0-444-62735-3)

In its comments after the September 2024 stakeholder meeting, APPLiA emphasised that metals used in washing machines/washer dryers such as copper, aluminium and ferrous materials already contain a significant amount of recycled material compared to plastics. In general, metals demonstrate good recycling rates. The reason for this is that there is a market for recycled metals, and these can readily be used to produce new metal raw material. However, appliance manufacturers do not have control over the amount of recycled metals in the supply of metal they receive. Overall, metals are not disposed of in landfill or incinerated and become a lost resource. Metals are recovered and reused [66]. The view was confirmed during interviews with the manufacturers and a recycler.

2.2.3. Market for recycled plastics

In 2023, 54 Mt of plastics were produced in Europe, of which 79.4% was fossil-based, 1.4% bio-based or bio-attributed, and 19.2% from recycling. The latter included 13.2% mechanically recycled post-consumer, 5.8% mechanically recycled pre-consumer, and 0.2% chemically recycled [67]. The EU plastics production decreased from 62.3 Mt in 2018 to 54 Mt in 2023. Post-consumer mechanically recycled plastic increased from 4.9 Mton in 2018 to 7.1 Mt in 2023, with a peak of 7.7 Mton in 2022. Pre-consumer mechanically recycled plastic decreased from 3.8 Mton in 2018 to 3.1 Mton in 2023.

In 2022 [68]:

- 58.8 Mt plastic produced in Europe
- 54.1 Mt plastic converted to products and parts (-4.7 Mt import/export balance)
- 53.3 Mt plastic products and parts consumption by users (-0.8 Mt imp/exp balance)
- 32.3 Mt plastic waste collected and sorted in 2022 (60% of consumed). Approximately half from separate waste collection (with high recycling rate) and half from mixed waste collection (with low recycling rate) (Table 8).

  Collection increased from 24.4 Mt in 2018 to 32.3 Mt in 2022. Recycling and energy recovery shares increased since 2018 while the landfilling share decreased.

Table 8: Plastic collection and recycling shares

	Total collection 2018	Total collection 2022	Separate collection 2022	Mixed collection 2022
Collection	24.4 Mt	32.3 Mt	16.4 Mt	15.9 Mt
Recycling	14.0%	27.0%	49.4%	3.8%
Energy recovery	30.3%	49.5%	39.6%	59.7%
Landfill	55.7%	23.5%	11.0%	36.5%

- Of the 53.3 Mt consumed plastics, 4.0 Mt (7.5%) was contained in electrical and electronic equipment, of which:
  - 3.1 Mt was converted into products and parts in Europe
  - 0.9 Mt is import/export balance

[66] APPLiA input to priority products under ED study on ReCo and CRM, 2024-09-13, Refrigerators, Q2: For which components/materials is recycled content being used; how much? (Plastics, copper, aluminium, ferrous metals, electronics)

[67] Source: https://plasticseurope.org/wp-content/uploads/2024/11/PE_TheFacts_24_digital-1pager.pdf

[68] Source : https://plasticseurope.org/knowledge-hub/the-circular-economy-for-plastics-a-european-analysis-2024/

  - 2.0 Mt was collected and sorted post-consumer, of which
    - 20% to recycling
    - 50% to energy recovery
    - 30% to landfill
  - 0.1 Mt was the input of post-consumer recycled plastics into EEE products. This is 3.2% of the total 3.1 Mt plastics conversion for EEE, and 1.5% of the total PCR plastics used in the EU (6.8 Mt).
  - 0.1 Mt was the input of pre-consumer recycled plastics into EEE products.

- Of the 54.1 Mt converted plastics in 2022, 43.7 Mt was fossil-based, of which [69]:
  - 8.6 Mt was PP (15.9%)
  - 0.8 Mt was ABS (or SAN) (1.5%)

- In 2023, the total installed recycling capacity in the EU27+3 was 13.2 Mt [70]. This gradually increased from 6.6 Mt in 2018. Of the 2023 capacity, 13% is for PP, 9% for PVC and 2% for PS and EPS.

The main differences between both kind of recyclates is provided in Chapter 2 (§2.2.1, Table 5). Post-consumer plastic waste is by far the most important stream (representing 88% of plastics waste according to PlasticsEurope, 2021b). Since one of the main goal of setting targets is to deviate post-consumer plastic waste from landfill/incineration to recycling, targeting in priority post-CR sources appears as a priority.

Currently, PP and ABS and rubber (EPDM) seem to be the main types of plastics recycled from washing machines and washer-dryers (see also section 5.2).

For additional information, see also JRC's modelling of plastic flows [71]

For further details on collection and recycling rates for home appliances, see section 2.1.1.

For price information on virgin plastics compared to those for recycled plastics, see the general, horizontal part of the study report on recycled content and CRMs.

In comments following phase 1 of the study [72], APPLiA observed that:

- Compared to metals, for recycled plastics it is much more difficult to obtain a stable supply of sufficient quality and quantity.

[69] Only plastic types most relevant for washing machines and washer-dryers are shown here. Unfortunately, the source does not report recycled plastics by type

[70] Plastics-Recycling-Industry-Figures_2023.pdf, Publications - Plastics Recyclers Europe

[71] Amadei, A. and Ardente, F., Modelling plastic flows in the European Union value chain, EUR 31242 EN, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-57510-8, doi:10.2760/66163, JRC130613. JRC Publications Repository - Modelling plastic flows in the European Union value chain

[72] APPLiA input to priority products under ED study on Recycled Content and CRM, 2024-09-13, Refrigerators, Q2: For which components/materials is recycled content being used; how much? (Plastics, copper, aluminium, ferrous metals, electronics). To some extent, this also applies to washing machines.

- The ability of the manufacturers to use recycled plastic material and its competitive advantage is further affected by its price fluctuations, where recycled plastics compete with the price of virgin plastic, which tends to follow the price of oil.
- Post-industrial content should also be taken into account, as plastics cannot be infinitely recycled as well as plastics with legacy substances, which cannot be recycled and are currently incinerated instead.
- Recyclability and Recycled Content: APPLiA stressed during also that a long-term master plan is needed before setting minimum requirements that could disrupt the market.

However, manufacturers have various experiences:

- One manufacturer incorporates some PCR-plastic components in washing machines, as well as in other household appliances. The manufacturer emphasized that the packaging industry, due to new packaging regulations, and the automotive industry have a high demand for recycled plastic materials, making sourcing for the electrical and electronic equipment (EEE) sector very challenging.
- Another manufacturer makes a relative extensive use of plastics:
    - PP: Up to around 30% recycled PP (by weight) in a lot of parts but sourced from PIR.
    - ABS: recycled ABS is already reality in few appliances (e.g. dishwashers) and is going to be introduced for washing machine, up to 100% possible, sourced from PCR (from the automotive sector).
    - Currently, around 15% of the plastic in a washing machine is not virgin.
- A third manufacturer:
    - Uses some recycled PP to manufacture washing tubs. Supply of rPP is not always guaranteed, therefore, the moulding tool has also to be able to manufacture all part with virgin PP.
    - Currently, most of the recycled plastic used in a washing machine is PCR sourced.
- A fourth manufacturer:
    - Stressed that recyclate streams derived from packaging are mechanically and chemically too unstable for use in household appliances, also they are usually too contaminated for use in household appliances.
    - Projects demonstrated that properties of regranulates coming from recycling single-variety streams in the manufacturers' appliances are similar to those of virgin material.
    - Emphasizes the necessity of case studies to further explore technical and economic challenges of recycling and recycled plastic
- BEKO uses recycled PET in washing tubs (patented Leopet technology)[73]. Here, 1/3 of the glass fibres can be replaced by recycled PET.

[73] Recycled Pet Tub : https://www.bekocorporate.com/en/technology/r-d/recycled-pet-tub/

Plastic recyclers are having difficult times. This is due to cheap virgin plastic (there is an overproduction in Korea and Japan that comes to EU) and due to a drop in demand (automotive, appliances). Setting Ecodesign requirements on recycled content is necessary but will not resolve these problems (also because of a time-delay in the impacts). More protective measures need to be urgently taken.

One stakeholder pointed out the limited availability of high-quality material may create competition across industries.

2.2.4. Market for recycled glass

Glass consumption per application

The consumption of glass in the European Union varied from 36.3 to 39.3 Mton over the period 2019-2022 [74] [75]. Of this [76]:

- 60% is container glass (or hollow glass, e.g. bottles and jars, packaging)
- 30% is flat glass (e.g. for windows, PV panels)
- 10% is domestic glass (e.g. tableware, drinking glasses), speciality glass (including also products like handmade glass jewellery or optical glasses [77]), or used for glass fibres (reinforcement, insulation, data transmission).

According to Glass for Europe [78] [79]:

- 10 million tons of flat glass are produced every year in the EU,
- The largest flat glass market is the building industry, which accounts for 80% of the output.
- About 15% is processed into glazing for the automotive and transport industry.
- The 5% remaining is shared between glass for many different applications such as solar applications, appliances (for example fridges or ovens), electronics, furniture, etc.

For comparison, the average washing machine contains 2.2 kg of glass (see also section 5). Multiplying this the 12.5 million appliances[80] sold, gives 27.5 thousand tonnes of glass waste from WMs/WDs. Assuming a 78% collection rate of EoL for large appliances (section 2.1.5) this means 21.5 thousand tons of glass cullet. Glass cullet from WMs/WDs would correspond to 0.25% of the total glass consumption in the EU (near 40 Mton).

[74] https://www.statista.com/statistics/1402078/consumption-of-glass-in-the-european-union/#:~:text=The%20apparent%20consumption%20of%20glass,million%20metric%20tons%20in%202022.

[75] Glass Alliance Europe states that 40 million tons of glass are produced annually in Europe. https://glassallianceeurope.eu/the-world-of-glass/

[76] https://single-market-economy.ec.europa.eu/sectors/raw-materials/related-industries/non-metallic-products-and-industries/glass_en

[77] https://climate.ec.europa.eu/system/files/2016-11/bm_study-glass_en.pdf

[78] https://glassforeurope.com/the-sector/key-data/

[79] https://glassforeurope.com/food-contact-materials/

[80] Considering washing machines and washer dryers

As regards quality issues, a 2016 study [81] remarks that:

- Even if cullet is available, the glass industry is reliant on its suppliers to meet basic quality specifications to be able to make saleable glass. Unfortunately, the collection and reprocessing infrastructure is not always able to do this. This is a particular problem when post-consumer glass is collected mixed with other recyclates (paper, plastic, metals, glass ceramics, ceramics) or when glass of different colours are collected mixed together. Material and colour separation at the source is therefore crucial.
- The quality requirements of the product must not be undermined. The specific quality requirements of several products limit the ability of the industry to use even high-quality post-consumer cullet. In some special cases, the technique for producing the glass is even such that no solid raw materials can be used. The possibilities of post-consumer cullet recycling in flaconnage, tableware, flat glass and special glass production are very limited for evident quality reasons. For these sub-sectors, only internal cullet is recycled or, in the case of flat glass, perfectly treated post-consumer cullet.

Glass Magazine [82] further clarifies that:

- Within the flat glass industry, there are three origins of cullet: internal cullet (offcuts in the plant itself); pre-consumer cullet (offcuts in the downstream fabrication process); and end-of-life post-consumer cullet (glass from an old car windshield or an old window that has been dismantled). The vast majority of cullet used in flat glass is internal, coming from offcuts in the plant itself. In Europe, 75 to 80 percent of cullet is internal; 20 to 25 percent is pre-consumer; just 0 to 5 percent comes from end-of-life cullet [83].
- In Europe, on average, float plants are running with approximately 26 percent of recycled cullet [84]. This is an average. There are float plants in Europe running with 40 or 50 percent of cullet in a batch. Though that also means there are others that are much lower.
- Almost all types of fabricated glass can be recycled, even coated, laminated or insulating glass. However, if additional processing is necessary, this may affect economics, and in some cases it may limit the markets. Ceramic band, found mainly in automotive applications, can be present at a limited percentage in cullet and will burn off in the float oven. Insulation units must be disassembled prior to re-use. The spacers must be removed prior to recycling. However, the sealants (silicone/ polyisobutylene/ polysulfide) will burn off in a float oven so long as it meets certain threshold limits. Coated glasses can be used, but some coatings may affect the final colour of the glass. For laminated glass, the glass cullet itself can be re-used, but the PVB [85] itself can be more difficult to recycle as after crushing laminated glass, 4 percent

[81] https://climate.ec.europa.eu/system/files/2016-11/bm_study-glass_en.pdf

[82] https://www.glassmagazine.com/article/flat-glass-recycling

[83] Most of the consulted sources consider only pre-consumer and post-consumer cullet for glass recycling rates or recycled glass content. Internal cullet is not considered. However, this may not be done consistently in all sources. The often-cited 26% recycled cullet seems to exclude internal cullet, but in majority it is pre-consumer cullet.

[84] AGC Glass Europe states an average cullet ratio of 30% in their raw materials, and the aim to increase this to 50% by 2030. https://www.agc-glass.eu/en/sustainability/decarbonisation/recycling?language=de

[85] PVB Laminated Glass has a thin layer of polyvinyl butyral (PVB) film at its heart. The PVB film is made from a thermoplastic material that is sandwiched between two layers of glass. When the glass and PVB film are laminated together, they form a strong and durable bond that helps to ensure the integrity of the glass over time. This bond is created by heating the glass and PVB film to a high temperature, which softens the PVB, allowing it to flow and spread evenly over the surface of the glass. The heated glass and PVB film are then placed under pressure, which helps to ensure that the bond is as strong as possible. One of the key benefits of PVB Laminated Glass is its increased safety, holding the glass together in the event of breakage.

of the glass fragments remain on the PVB. Introducing glass fragments to a PVB extruder would damage the equipment.

- Metal contaminants in the cullet should be avoided. Aluminium can create infusible particles on the glass ribbon, making it unfit for sale and non-recyclable in flat glass furnaces. Stainless steel contains nickel that can create 'spontaneous' glass breakage in tempered glass; tungsten can lead to deposits that make the glass not sellable. And lead can lead to deposits that can attack the glass.
- Borosilicate glass and ceramic glasses, such as those used for fire-rated architectural applications, appliances or fireplace products can have recycling problems. Other "doubtful products" include digitally printed glass, smart glass and electronic mirrors.

AGC Glass Europe [86] (and other Glass organizations) aim at flat-to-flat closed loop recycling, avoiding other forms of recycling (to other glass sectors) or downcycling. This requires an increased quantity of cullet returning to the flat glass industry. Today the clean cullet that can be used in float glass furnaces represents only 8.5 per cent of all the glazing waste collected because we need to ensure that the cullet is not contaminated, that means not mixed with other contaminant materials.

Glass recycling from washing machines

In APPLiA statistics (section 2.1.6, Table 5), the recovery rate of glass from home appliances is relatively low: 29% of the generated glass waste, or 39% of the collected waste. However, two WM manufacturers [87] [88] stressed that glass in washing machines is used only for the door and is tempered glass, because of the mechanical and thermal requirements. Tempered glass can only be recycled in the same tempered glass, which makes the recycling almost impossible.

Reference organizations:

CPIV, the Standing Committee of the European Glass Industries.

FEVE, the European Container Glass Federation

GLASS FOR EUROPE, the European Flat Glass Federation

APFE, the European Continuous Filament Glass Fibres Association

ESGA, the European Special Glass Association

EDG, the European Domestic Glass Association

FERVER (European Glass Recyclers' Federation)

2.2.5. Market for recycled concrete

The typical weight composition of concrete includes about 10% to 15% cement, 15% to 20% water, and 65% to 80% aggregates, in addition to any admixtures. In 2022, the EU produced around 176 million tons of cement, the demand for concrete is primarily driven by the

[86] https://www.agc-glass.eu/en/sustainability/decarbonisation/recycling?language=de

[87] Personal communication of Electrolux to the study team

[88] Personal communication of BSH to the study team

construction and infrastructure sectors.[89] According to the JRC[90], moderate incorporation rates of recycled aggregates are technically viable, but they are frequently downcycled and rarely utilized in concrete.

The average washing machine contains 21.4 kg of concrete (see also section 5.2). Multiplying this the 12.5 million appliances[91] sold, gives 276.5 thousand tonnes of concrete waste from WMs/WDs. Assuming a 78% collection rate of EoL for large appliances (section 2.1.5) this means 208.6 thousand tons of concrete waste. Concrete from WMs/WDs would correspond to less than 0.01% of the total concrete demand in the EU.[92]

Reference organization:

CEMBUREAU, the European Cement Association

2.2.6. Market for recycled electronics

See the general, horizontal part of the study report on recycled contents and CRMs.

2.2.7. Market for recycled CRMs

See the general, horizontal part of the study report on recycled contents and CRMs.

[89] CEMBUREAU (European Cement Association): Key fact & figures publication-June 2024

[90] Nuno Pacheco, J., de Brito, J. and Lamperti Tornaghi, M., *Use of recycled aggregates in concrete – Opportunities for upscaling in Europe*, Publications Office of the European Union, 2023, **https://data.europa.eu/doi/10.2760/144802**

[91] Considering washing machines and washer dryers

[92] Based on the previously presented figures, the estimate concrete demand is calculated as follows : 176 Mt / 12.5% = 1,408 Mt.

3. MEErP Task 3, Product usage

Product usage aspects are less relevant for the current study on recycled contents and CRMs: see the latest study report on Task 3 of the on-going Review Study[93].

[93] Available under https://ecodesign-washing-machines.eu/ewm/documents/

4. MEErP Task 4, Technologies

4.1. Washing machine technologies

4.1.1. Overview of the main components of washing machine

The main components of a washing machine can be grouped as follows:[94]

- Housing
    - Housing
    - Frame
    - Top panel
    - Front and back panels
    - Further panel

  Most of these parts are in steel or in ABS
- Oscillating system
    - Weight: used to be in cast iron, which was easy to recycle.[95] But – for cost reasons - most of the washing machines have now weights in concrete
    - Pulley[96]
    - Belt drive (in elastomer)[97]
    - Wash drum (inner drum): perforated drum in stainless steel
    - Washer tub (outer drum): used to be in stainless steel, which was easy to recycle.[98] But – for cost reasons - most of the washing machines have now washer tub in PP reinforced with glass fibres (typically 10%-30%) or calcium carbonate ($CaCO_3$)
    - Heating element
    - Shock absorbers
    - Boot gasket (in elastomer)
- Dispenser/tray/hose
    - Dispenser
    - Hose
    - Drain

[94] Detailed exploded views can typically be found online in the spare parts section of most manufacturers' websites. E.g. https://www.bosch-home.co.uk/sparepartslist/WGB244AW0/11#/Togglebox=tb0301/ or https://shop.electrolux.de/search?q=%3Arelevance%3Apnc%3A91461073300%3Aprice%3A%25E2%2582%25AC200%2B-%2B%25E2%2582%25AC500&text=

[95] Miele is one of the manufacturers still using cast iron (the foundry is located directly on the premises of the washing machine production site).

[96] Direct drive washing machine construction does not include pulleys: the motor shaft is directly mounted to the drum shaft.

[97] Direct drive washing machine construction does not include belts: the motor shaft is directly mounted to the drum shaft.

[98] Miele is one of the manufacturers still using cast iron

    - Drain gutter

  Most of these parts are in PP, hoses may be in PVC

- Door
    - Window: in tempered glass
    - Frame window: usually in ABS
- Control system
- Motor and pumps
    - Motor
    - Drain and circulation pump
- Cables: high share of copper

For the purposes of the work being conducted in this study, apart from product re-design to incorporate recycled content or to improve recyclability, development of more efficient washing machine and improvements in washing quality or durability are outside of scope.

The on-going Review Study on washing machines provide updates on technological innovation in their analysis, and this is therefore not included in this report. Only relevant material aspects are presented and discussed in this mini study.

4.1.2. Dispenser, trays and hoses

Most on these parts are manufactured in PP, as lightweight, resistant to moisture and detergent chemicals, and durable enough.

The visible parts are usually in ABS, even if some manufacturers use also PP.

4.1.3. Plastic panels

Some large plastic panels are manufactured using recycled material:

According to the 2017 preparatory study on washing machine[99]:

- *"Indesit has produced a plastic back panel for two of its washing machine models using 100 percent recycled content with similar characteristics to the previous part that was made from virgin material. The access panel is made by using recovered fridge waste, which is then shredded and made into a high grade polymer pellet. The plate was developed in a pilot project first, and is now being integrated into the back of the premium Hotpoint Aquarius and Ultima Washing Machines. According to WRAP ([n.d.]a), Indesit has achieved the same production cost for the recycled plates by achieving the same cycle time in the moulding process. This is combined with a 5 percent saving on raw material costs."*
- *"Sharp and Kansai Recycling Systems Co. Ltd. jointly developed a closed-loop plastic material recycling technology that repeatedly recovers plastic from used consumer electronics and reuses it in parts of new consumer electronics for the Japanese market. This technology has been in practical use since 2001. By combining of a high-efficiency metal removal line, high-purity PP (polypropylene) separation and recovery*

[99] Villanueva, A., Hook, I., Alborzi, F., Cordella, M., Graulich, K. et al., Ecodesign and energy label for household washing machines and washer dryers – Preparatory study - final report, Publications Office, 2017, https://data.europa.eu/doi/10.2760/029939

technology, and other property improvement/quality control technologies, Sharp has been able to recover recyclable plastic, as well as to find applications for its use, such as in the exterior panels of home appliances and as flame-retardant materials. Because recycled plastic can be reused numerous times, the practice has been adopted for use inter alia in washing machines (base frame and washing tub), and other similar home appliances sold within Japan which are subject to the Home Appliance Recycling Law (Sharp 2012)."

- *"Also manufacturer feedback confirms that from a technical point of view, the use of recycled materials does not fulfil their technical requirements (mechanical stability, aging requirements, chemical requirements/REACH/RoHS, detergents resistance, colour, etc.), especially for functional components as the required quality levels cannot be reached. Some less critical components could eventually contain a certain level of recyclates. The share of implementing them in production depends on the quality level of recyclates fulfilling minimum quality levels, as well as the availability in sufficient quantities and at a competitive price in comparison with virgin materials."*

During an interview, a manufacturer mentioned that the back panel and the base of its washing machines are produced with recycled plastic.

4.1.4. Oscillating system

The inner drum of a washing machine is made of stainless steel, and the outer drum (washing tub) used to be as well. While some manufacturers still manufacture tubs in stainless steel, nowadays PP is the main material. The PP properties make it an ideal choice for producing the drums of washing machines, as PP can withstand the mechanical stresses of washing cycles, resist damage from detergents, and remain lightweight, contributing to the overall efficiency of the appliance and contribute to reduce the costs.

To increase the mechanical resistance of the tub, glass fibres (typically 20%-40%) or calcium carbonate (CaCO3) are added as filler. The filler content depends on the spinning speed of the washing machine: the higher the spinning speed, the higher the filler content. Many manufacturers use some recycled materials to produce washing tubs:

- Whirlpool could demonstrate within the PolyCE project the feasibility of producing washing tubs made of recycled (PCR) PP.[100] The PolyCE project aimed to effectively reuse closed-loop recycled plastics (PCR) from WEEE waste streams while ensuring that the parts meet established quality and performance standards. The project also demonstrated that no significant difference was found between a cluster where the plastics of an entire machine were collected and a second cluster where only washer tubs were collected.
- One manufacturer mentioned that some models have washing tub contents some (PCR)PP.
- Beko replaces 1/3 of the glass fibres by (PCR)PET.[101]

However, there are some limitations:

- Supply chain and price of (PCR)PP

[100] https://www.polyce-project.eu/wp-content/uploads/2021/04/PolyCE-E-book-Circular-Design-Guidelines-2.pdf

[101] See Leopet: https://www.bekocorporate.com/en/technology/r-d/recycled-pet-tub/

- Different moulding tools and manufacturing process (injection/cooling time). To decrease the risk, some manufacturers invest in tools, that can produce washing tubs with (PCR)PP or – in case of supply shortage – with virgin PP as well.

The manufacturers mentioned that the amount of filler depends on mechanical stress. This suggests that the trend toward larger washing machines (with higher nominal capacity and drum diameter) and higher spinning speeds (1,400 rpm or even more) lead to an increase in the filler content, making the recycling of PP-reinforced washer tubs more challenging.

4.1.5. Wood top

As reported in the 2017 preparatory study on washing machine, wood can be found in the top panels of washing machines. While one manufacturer confirmed that wood-based materials (MDF[102] or similar) are still used, it is unclear how representative this material is for the entire market.

Furthermore, a review of the front panel in the 'spare parts' section for different manufacturers suggests that the use of wood in top panels is limited. Consequently, wood has not been further investigated in detail the study and is even not considered in the updated BoM.

Remark:

Following the fourth stakeholder meeting, APPLiA highlighted that wood tops are a standard technology in Europe and emphasized that these panels can be clearly distinguished from plastic or metal panels.[103]

4.1.6. CRMs in washing machines

4.1.7. From Phase 1

CRMs are those listed in Annex I and II of the Critical Raw Materials Act [104], see also Table 1 and the phase 1 report of the current study [105].

Compared to other product groups, washing machines did not score high (17th place) on the CRM ranking derived in phase 1. Consequently, CRMs for washing machines were not a study focus.

Table 9 shows the CRM quantities used in washing machines (WM), as preliminarily derived in phase 1 of the current study, see following notes.

- The table uses a decimal point, and a comma as thousands separator. Values with decimal point are in blue font.
- The phase 1 analysis also includes some materials that were studied in CRM context but that did not end up on the final list of Critical or Strategic Raw Materials. These data are in grey.
- Column (0): mass in the average WM, in grams per unit

[102] Medium-Density Fibreboard.

[103] The BOM was based on the one of the ongoing review study. Nevertheless, the Policy Options mentioned in sections 6.3.4 and 7.1.17 took into consideration wood panels.

[104] REGULATION (EU) 2024/1252 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 April 2024 establishing a framework for ensuring a secure and sustainable supply of critical raw materials and amending Regulations (EU) No 168/2013, (EU) 2018/858, (EU) 2018/1724 and (EU) 2019/1020, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ:L_202401252

[105] Ecodesign preparatory study for product specific measures on scarce, environmentally relevant and critical raw materials and on recycled content, Interim Study Report, Phase 1: Prioritization of materials and product, e.g. Table 21, https://www.ecodesignmaterials.eu/documents

- Column (1): mass in WMs sold in EU27 in 2020 (12 mln), in metric tons (thousands of kilos)
- Column (2): supply risk factor, used as weighting factor in column (4)
- Column (3): primary material production in tons, used as weighting factor in column (4)
- Column (4): CRM weighted score: EU27 sales mass (1) multiplied by supply risk factor (2) and divided by primary production (3).
- Column (5): ranking of CRM materials used in washing machines based on the weighted CRM score.
- Column Metal alloy: CRM mass derives from metal masses on the Bill-of-Materials (major alloying elements)
- Column Display: CRM mass derives from breakdown of display / screen mass (none for WMs)
- Column PCB / Elec: CRM mass derives from breakdown of Electronics mass on the Bill-of-Materials, using literature breakdown for low-grade PCBs.
- Column Glass: CRM mass derives from breakdown of Glass mass on the Bill-of-Materials.
- Column Critical RM: materials listed in Annex II of the CRM Act as Critical
- Column Strategic RM: materials listed in Annex I of the CRM Act as Strategic.

Table 9: *CRMs in washing machines, see notes below table. Source: current study, phase 1 report*

material	(0) Mass per unit RF (g)	(1) Mass in RF sold in 2020 (ton)	(2) Supply Risk Factor (SR)	(3) Primary production (ton)	(4) CRM weighted score, (1)*(2) / (3)	(5) Rank among CRMs in WMs	Metal Alloy	Display	PCB / Elec	Glass	Critical RM	Strategic RM
Silicon metal (Si)	18	222	1.40	3.0E+06	1.0E-04	8	x				x	x
Palladium (Pd)	0.005	0.056	1.50	2.2E+02	3.8E-04	5			x		x	x
Aluminium (Al)	2,368	29,520	1.20	6.3E+07	5.6E-04	4	x		x		x	x
Copper (Cu)	1,786	22,260	0.10	2.1E+07	1.1E-04	7	x		x		x	x
Iron (Fe)	23,714	295,583	0.50	1.5E+09	9.9E-05	9	x		x			
Tin (Sn)	2	25	0.90	2.9E+05	7.8E-05	10			x			
Bismuth (Bi)	0.030	0.371	1.90	9.1E+03	7.7E-05	11			x		x	x
Nickel (Ni)	1,444	17,996	0.50	2.7E+06	3.3E-03	1	x		x		x	x
Chromium (Cr)	3,249	40,490	0.70	1.6E+07	1.8E-03	3	x		x			
Antimony (Sb)	0.225	2.804	1.80	1.3E+05	3.9E-05	13			x		x	
Manganese (Mn)	9	111	1.20	2.1E+07	6.4E-06	16	x				x	x
Zinc (Zn)	119	1,487	0.20	1.3E+07	2.3E-05	14	x		x			
Gold (Au)	0.012	0.148	0.40	3.3E+03	1.8E-05	15			x			
Silver (Ag)	0.011	0.140	0.80	2.8E+04	4.0E-06	17			x			
Cobalt (Co)	0.005	0.056	2.80	1.3E+05	1.2E-06	18			x		x	x
Strontium (Sr)	0.006	0.074	2.60	1.6E+05	1.2E-06	19			x		x	
Beryllium	0.000	0.003	1.80	6.0E+03	8.4E-07	20			x		x	
Lead (Pb)	0.450	5.609	0.10	5.0E+06	1.1E-07	21			x			
Baryte	0.016	0.196	1.30	8.8E+06	2.9E-08	22			x		x	
Natural graphite	93	1,158	1.80	1.1E+06	1.9E-03	23						
Platinum Group metals (PGM)	0.005	0.056	2.70	4.6E+02	3.3E-04	23						

Based on work done by VHK in Phase 1 for all products and in Phase 2 for fridges, the study team identified the following components in washing machines that potentially contain scarce, environmentally relevant and critical raw materials:

- Motor, VSDs (Copper, Aluminium, Ferrite permanent magnets)
- Motor for dosing system and some sensors (Nd)
- Capacitors (Tantalum)
- LED light sources (Gallium, Indium, rare earths (e.g. Yttrium, Europium) used as phosphors in some white LEDs).
- Batteries (Lithium-ion)
- Magnets (mostly ferrite)
- Displays (LED matrix, OLED, Indium-Tin-Oxide)
- Temperature/humidity sensors (Cu, Al, Ni, Mn, Co)
- Control electronics boards and components (Cu, Au, Pd, Pt, Ag, Si, Ga, As, In)
- Power supplies (Cu, Al, rare earths)
- Electric connectors, switches and wiring/cabling (Cu)
- Parts in Aluminium or aluminium alloy (Al itself, alloying elements)
- Parts in Copper or copper alloy (Cu itself, alloying elements)
- Parts in steel (alloying elements, coatings; use of coking coal)
- Plastic parts (fillers, additives, pigments, flame retardants)
- Coatings (large variety of possibilities [106])
- Drums (stainless steel: Cr, No, Mn)
- Housing (galvanized steel: Zn)

For electric motors with permanent magnets, article 28 of the CRM Act (see section 1.4.5) already requires a labelling indicating whether those products incorporate one or more permanent magnets, and if so, whether those permanent magnets belong to any of the following types:

(i) neodymium-iron-boron
(ii) samarium-cobalt
(iii) aluminium-nickel-cobalt
(iv) ferrite

In future, there will also be a data carrier providing access to information on the weight, location and chemical composition of all individual permanent magnets included in the product, and on the presence and type of magnet coatings, glues and any additives used, and to information enabling access and safe removal of all permanent magnets incorporated in the product, at least including the sequence of all removal steps, tools or technologies required for the access and removal of the permanent magnet.

4.1.7.1. Permanent magnets in washing machines

- Motors and pumps

For energy efficiency reasons, motors are permanent magnet motors. While some manufacturers used rare earth magnets in the past for the drum motor, ferrite magnets are currently the standard. In washing machines, rare earth PM seems to be only used in very small quantities for specific applications/features, such as the detergent pump in dosing systems, which are not present in all models.

- Further components

PM might be used in few further components, like door lock.[107]

[106] https://www.plastmagazine.it/masterbatch-coloranti-classificazione-e-applicazioni/

[107] Washer dryers may also content PM in the heat pump (if available)

In total, a typical washing machine contains approximately 200 grams of ferrite magnets.

Regarding rare-earth based PM:

Not all washing machines utilize rare earth-based permanent magnets. In some models, rare earth-based permanent magnets may be present (averaging far below 100 grams in total) spread across a few components, which are not present in all models. Assuming that NdFeB[108] is used for the rare earth permanent magnets, this implies that there is significantly less than 30 grams of Nd per washing machine, and often much less for many models, if any. At least one manufacturer declared to use exclusively ferrite-based PM, even for its high-end models. Altogether, 10 gr. of NdFeB magnet (3 gr. of Nd) per washing machine might be a realistic figure for an average washing machine on the EU market.

Accordingly, in the practice, washing machines are unlikely to be affected by Article 29 points 1 and 2 of the CRM Act.

4.2. EoL process of washing machines

4.2.1. Preparatory study 2017

The previous preparatory study[109] provided the following detailed description of the EoL of a typical washing machine:

> *Different materials are recycled into raw materials and used to make new products. Some of the equipment is not collected separately, but as part of waste fractions where WEEE waste is mixed with other waste. Some of this is sorted and then becomes available for further processing and recycling. The rest ends up in the waste incinerators or at a landfill.*
>
> *The devices collected within the formal WEEE-System in the EU undergo recycling treatments, which can be classified into the following steps:*
>
> - *Preparation for reuse;*
> - *Pre-processing / dismantling (including depollution, and material resource recovery);*
> - *End-processing and final disposal.*
>
> ***Preparation for reuse,*** *i.e. checking, cleaning or repairing, by which products or components of products that have become waste are prepared so that they can be re-used without any other pre-processing. This is mostly conducted with devices deemed suitable in terms of age, product model, appearance and spare part availability.*
>
> ***Pre-processing: 1. depollution****: The majority of end-of-life washing machines are passed-on to the pre processing stage, which may start with a a depollution step, which requires a selective treatment during which certain substances, mixtures and components are removed from the WEEE stream. In other cases, the first step is shredding, followed by sorting, and final depollution.*

108 *NdFeB alloy is typically composed of 30% of neodymium (Nd), 1% of boron (B) 1% of dysprosium (Dy) and 1% of niobium (Nb), less than 1% of aluminium (Al) and the rest is iron (66%)*

109 Villanueva, A., Hook, I., Alborzi, F., Cordella, M., Graulich, K. et al., *Ecodesign and energy label for household washing machines and washer dryers – Preparatory study - final report*, Publications Office, 2017, https://data.europa.eu/doi/10.2760/029939

If depollution is the first step, it is important that parts to be removed are identifiable and accessible. In this step, the following components are removed from the devices for separate treatment:

- *Power-cables,*
- *Large accessible printed circuit boards > 10 cm². According to (Ardente & Talens Peirò 2015), printed circuit boards can be removed preventively, by specific dismantling, hand-picking or mechanical sorting after preliminary and fine shredding.*
- *Capacitors with a height >25mm and a diameter >25mm might contain substances of concern. In particular old capacitors might contain polychlorinated biphenyls (PCB). Capacitors, generally included in printed circuit boards, are generally manually separated after the removal of the printed circuit boards.*
- *Some modern devices might contain LCD displays > 100cm2, which have to be removed for separate treatment to comply with the WEEE Directive. (Ardente & Mathieux 2012) state that new washing machines introduced in the market embody some LCD screens. All the recyclers interviewed within the study of (Ardente & Mathieux 2012) agreed that LCDs in WMs ideally have to be preventively extracted, because potentially contaminating other fractions (for example PCBs without LCD) causing a potential downcycling of recyclable resources.*
- *Devices containing volatile hydrofluorocarbons (HFC) or hydrocarbons (HC) – which might be the case for modern devices with integrated heat pumps – have to undergo degassing to prevent emissions to the atmosphere. Devices containing volatile hydrocarbons need to be handled specifically (also during collection, transport and storage) as uncontrolled leakages might cause fires and explosions (CENELEC 2012), and have to be treated in a similar way to refrigerators.*

<u>Pre-processing: 2.Material recovery</u>*: In the subsequent pre-processing, appliances are treated to reclaim and concentrate the various materials such as steel, aluminium and plastics. This is either done by manual disassembly, or by mechanical means (shredding and automated sorting). Pre-processing (manual and mechanical) typically yields the following output fractions:*

- *Steel*
- *Stainless-steel*
- *Aluminium*
- *Copper (insulated or liberated)*
- *Plastics (including thermoplastics, thermosets and rubber)*
- *Glass*
- *Concrete (from balance-weight of washing machines)*

Some of the above listed fractions undergo further treatment and/or sorting (examples: liberation of insulated copper-cables, sorting of aluminium in different grades, further sorting of plastics according to colour and polymer-types). Depending on the technology sequence of the recycler, depollution may proceed or take place after material sorting.

In most treatment plants in Europe (likely >95%, although no clear statistics are available), most treatment is purely mechanical, with limited manual treatment intervention. The sequence described above is reversed: the first treatment stage is *shredding, followed by mechanical separation, and only in specific cases there would be manual separation of certain components. One of the consequences of this is that the separated fractions have a lower purity (and therefore market value) than the fractions obtained with manual separation. Normally, large-volume treatment plans are essentially mechanical. The few plants in Europe base their treatment in manual separation operate relatively low flows of appliances.*

End-processing: *The outputs are generally fed into end-processing units, which can be described as follows:*

- *Steel and stainless-steel is fed into secondary steel plants;*
- *Aluminium is fed into secondary aluminium smelters;*
- *Copper is fed into copper-refineries;*
- *Printed circuit boards are fed into integrated smelters to recover copper, precious metals and other metals as by-products (e.g. lead, tin, indium); however, according to stakeholder feedback, PCBs of domestic appliances are not comparable to those of ICT, as they have a lower content of copper and other precious metals;*
- *Plastics are either recycled (material recovery of thermoplastics) or incinerated (energy recovery);*
- *Glass is fed into glass recycling, when feasible, or otherwise landfilled;*
- *Concrete is disposed together with inert construction/demolition waste. According to feedback of one stakeholder via questionnaire, the concrete might create dust formations if not extracted before the shredding process, however this rarely occurs and can easily be prevented.*

According to feedback from stakeholders, in general washing machines have a high metal content, with some plastic and concrete where this is present. Metals and some plastics have good recycling values."

4.2.2. Update 2025

A large EEE recycler[110] was interviewed to provide an update regarding the EoL practices for washing machines. The findings are largely in line with the last section but offer the following additional insights:

- **Preparation for reuse:** This is possible only at facilities that receive the appliances directly from dealers without damaging due to stocking/handling/transport. Appliances having been dropped at municipal waste collection centres are typically too damaged to reuse purposes.
- **Pre-processing 1 (depollution):**
  - Capacitor with PCB-containing should be removed, but in practice, this is not relevant anymore as this concerned only very old machines. Batteries have also to be removed, but this is not relevant for washing machines.

  Note: WEEE does not specify that PWB > 10 dm² have to be removed before the shredding, there it happens in step 3 as the valuable metals (in step 4).

[110] Electrocycling (www.electrocycling.de)

    - Check for components containing impurities. Wood (in the top panel of some machines) and glass (of the window) are usually not good in the recycling process. They are usually separated:
        - either manually: but expensive (and therefore not applied often done this way).
        - or during the handling at the facility: as the container is dumped in the yard, then roughly sorted by excavator, or with the scrap grab

    It can be assumed that there is no dismantling, as this is not economically feasible
- **Pre-processing 2 (material recovery):**
    - Shredder: in the same shredder where vehicles are shredded (for cost reasons)
    - Material Separation – Advanced sorting techniques (such as magnetic separation and density-based sorting) separate metals, plastics, and other materials.

The recycler indicated that the recycling process is unlikely to undergo significant changes in the future, despite ongoing developments in Artificial Intelligence. Typically, recycling occurs without dismantling, as appliances are directly shredded.

Regarding material recovery:

- Metals already have a high recovery rate, supported by a well-established and efficient market.
- Plastics can achieve a high recovery rate, although impurities - such as glue and adhesive tape - remain a challenge.
- Rare earth elements in washing machines are present in very small quantities. As the price of neodymium (Nd) remains low, it makes currently the recovery of permanent magnets (PM) from washing machines economically not viable.[111]

4.3. Plastic recycling technologies

4.3.1. Recycling of polypropylene (PP)

In 2018, 6600 kton of rigid PP were used in EU28+2. Of this, 37% went to packaging, 20% to automotive applications, 20% to household products, 7% to building and construction, 4% to EEE, and 11% to other applications [112].

Bottle caps (circa 0.7 Mt): 55% of plastics caps and closures are made from HDPE, while 45% are made from PP. HDPE is more commonly used for standard plastic caps, whereas customized and hinged caps are more commonly made from PP due to its high stress tolerance.

Other packaging, including boxes and crates (at least 0.66 Mt HDPE, 0.27 Mt PP): Since both polymers are strong and lightweight, they are used to manufacture boxes and crates, pallets, drums/kegs and bulk containers for transporting goods.

[111] See also section 4.6

[112] https://www.plasticsrecyclers.eu/wp-content/uploads/2022/10/hdpe-pp-market-in-europe.pdf

A primary use of PP is food packaging: 55% of PP rigid packaging (1 Mt) is food contact, equivalent to around 10% of total PP demand.

Recycling of PP

In 2018, the EU28+2 had the processing capacity to recycle 1.7 Mt of rigid HDPE and PP, of which 1.2 Mt was for post-consumer material [113] [114]. Combined rHDPE and rPP production in the EU28+2 in 2018 was estimated at 0.8 Mt from post-consumer material, with this figure rising to 1.2 Mt when pre-consumer recyclate is included. EU28+2 recycling capacity has increased recently and is expected to continue to grow with additional investment [112].

The 1.2 Mt capacity for post-consumer rigid polyolefins is estimated to produce in the region of 0.8 Mt of rHDPE and rPP, based on assumed utilization at 86% and an average yield assumption of 80%. Typical output yields from recyclers vary depending on the material:

- Household packaging is diverse and has high levels of moisture, organic and non-target material. Yields are between 70% and 90% depending on the quality of the input material and the standard of sorting at sorting plants for household recycling.
- Conversely, yields from bulk containers and other rigid applications, where levels of non-target material and organic contamination is lower, tend to be 90% or higher.

The largest end markets for rPP are for injection moulding in the automotive industry, and in packaging and construction. In packaging applications, rPP can be used in non-food film packaging applications, and injection-moulded reusable transport packaging products such as crates and boxes.

A proportion of PP and HDPE packaging is recycled into mixed polyolefin recyclate, often in compound form for use in injection-moulded applications (i.e. buckets, flowerpots). Additives are used to enhance structural characteristics for specific product categories.

Plastics Recyclers Europe [112] report 67 kton of rPP used in EEE in 2018, on a total PP consumption of 285 kton for EEE. This would imply an rPP usage rate of 23%.

PP in washing machines

PP represents 63% of the plastics mass and 11% of the overall washing machine mass. Polypropylene (PP) is mainly used for the washer tub.[115]

PP is recyclable if it is unfilled or with maximum 10% chalk, talcum, or fibre glass filler. As washer tubs have between 10% and 30% of filler (see 4.1.4), it is assumed that PP based washer tubs are not recyclable. [116]

HDPE may end up as an impurity in the PP and then also ends up in the recycled PP [117].

[113] Since the reprocessing steps for HDPE & PP rigid applications are the same, the same capacity can process both HDPE & PP (in batches), and the total capacity is tracked together.

[114] In 2023 this increased to 3.4 Mt for PP alone in the EU27+3. Source: Plastics Recycling Industry 2023, https://www.plasticsrecyclers.eu/publications/

[115] Based on the BOM considered in this study, see Table 12 and Table 14

[116] One manufacturer mentioned that PP with 40% talcum (PP-T40) can be easily recycled,

[117] Study team (mini study on refrigerators) visit to CoolRec facilities and CoolRec answers of 14/3/2025.

4.3.2. Recycling of acrylonitrile butadiene styrene (ABS)

ABS plastic consists of three main components [118]:

- Acrylonitrile: An organic compound with the chemical formula C3H3N, it provides the rigidity and mechanical strength of ABS plastic.
- Butadiene: An organic compound with the chemical formula C4H6, it provides elasticity and impact resistance.
- Styrene: Having the chemical formula C8H8, this is an organic compound that provides the gloss and thermal stability of ABS plastic.

In addition, depending on the final product, manufacturers may add additives such as flame retardants, antistatic agents, colorants or anti-corrosion agents. Other additives can include:

- Processing-aid additive is added to the polymer to lower the friction between plastics and machines during production. It helps enhance the melting, processability, and handling of high molecular weight plastics without any technical effect on products. Polymer processing aids have a wide range of applications, including blown film, extrusion, and injection moulding. Thanks to processing-aid additives, thermoplastic resins can be extruded more effectively. They can add aesthetic qualities by reducing flow traces and die lines, resulting in glossy, transparent products.
- Smelly plastics (especially recycled plastics) can affect their application and competition. Therefore, eliminating bad odours is essential to enhance plastics' effectiveness and value in industrial production.

  Odour-removing additive is a saviour that works as an odour-neutralizer. It does not replace the original smell in products with fragrances or perfume. Instead, it will prevent the absorption of unwanted odours and irritating chemicals. Odour control additive is utilized widely in rubber plastic products or items made of regrind material such as home appliances, toys, or textile packaging.
- Moisture exists in everything, and polymer material is no exception. Especially in technical resins, moisture may cause fisheye and surface defects on final products. Desiccant additive is added to the formula to absorb moisture in the plastic materials, thereby limiting common errors in processing (bubbles, fisheyes, ...) and improving the quality of the end-product [119].

ABS is a thermoplastic polymer, which means it can be melted and reshaped multiple times without losing its properties, which depend on the constituent proportion of the monomers. [120].

The advantages of ABS plastic are its relatively low melting point and glass transition temperature, making ABS easy to melt down and use in injection moulding. Products and components made from ABS offer high impact and heat resistance as well as strong tensile

[118] https://europlas.com.vn/en-US/blog-1/recycled-abs-plastic-recycling-code-process-advantages-and-disadvantages

[119] Desiccant masterbatches can contain Calcium Oxide (CaO), which is a strong water absorber. In polymer processing, Calcium Oxide disperses, eliminates moisture, and prevents phenomena such as fisheye. It also solves moisture problems in extrusion (blow film, film casting, blow moulding, etc.) and injection moulding. Especially for recycled plastic, it helps remove moisture and cuts out the oxidizing effect that occurs during the recycling of the polymer.

[120] https://www.plasticexpert.co.uk/plastic-recycling/abs-plastic-recycling/#:~:text=Yes%2C%20ABS%20plastic%20(Acrylonitrile%20Butadiene,times%20without%20losing%20its%20properties.

strength. Other benefits include dimensional stability, chemical resistance, low production costs and ease of machinability [121]. This makes it versatile for a great number of applications.

ABS if often used for telephone handsets, rigid luggage, domestic appliance housings (food mixers, vacuum cleaners), electroplated parts, radiator grills, handles, computer housings, keyboards, displays, automotive applications, healthcare, reels, construction, 3D printing elements [122], electrical frames [123]. ABS is used in products that do not get hot, because of its low melting point. Industrially it is used where there is a need for a relatively cheap product which can withstand bumps and knocks, so it is often found in housings. Probably one of the most widely known and recognisable products made from ABS is Lego [124].

Recycling of ABS

ABS plastics are recyclable – this includes sheets, shower trays, car parts, skeletal waste and ABS pipe. Recycled ABS is becoming increasingly popular as raw ABS can be expensive to use in manufacturing. Recyclers ask to keep acrylic-capped ABS and ABS with Fire Retardant (FR) separate in the waste supply. Some recyclers can supply the recycled ABS plastic segregated according to material origin [122].

According to Europlas [118], compared with other recycled plastics such as PP, PVC, LDPE or HDPE, ABS recycled plastic is superior in low cost, suitable for industry.

Advantages:

- Equivalent physical properties: Even after being crushed and recycled many times, recycled ABS plastic retains the same physical properties as new ABS plastic.[125]

Disadvantages

- Unequal quality: Depending on each factory, the screening and production process of recycled ABS plastic will be different, so the uniformity and overall quality of the output cannot be guaranteed.
- Difficult to control purity: During the screening process, it may not be possible to remove all impurities, thereby affecting the quality of the output product.
- Not easy to maintain: Recycled ABS plastic is easily damaged under the influence of sunlight, requiring manufacturers to invest in the preservation period.

ELIX [126]

Since 2020, ELIX Polymers works in partnership with Repsol (Spain) and AnQore (Netherlands) to produce feedstock materials to help produce 100 percent recycled-content

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[121] https://www.sulapac.com/blog/replacing-abs-plastic-sustainably/#:~:text=%E2%80%93%20ABS%20has%20a%20complex%20composition,cost%20to%20the%20whole%20process.

[122] https://www.vandenrecycling.com/en/what-we-do/buy-and-sell-plastic/abs/#:~:text=Is%20ABS%20recyclable%3F,expensive%20to%20use%20in%20manufacturing.

[123] Material recycling of acrylonitrile butadiene styrene (ABS) from wiring devices using mechanical recycling, Esra ÇETİN, Oytun Tuğçe TÜRKAN, Sustainable Chemistry for the Environment, Volume 6, June 2024, 100095

https://www.sciencedirect.com/science/article/pii/S2949839224000385#:~:text=In%20order%20to%20recycle%20ABS,by%20incorporation%20of%20triggerable%20additives.

[124] https://www.agsplasticgranulation.co.uk/services/abs-plastic-recycling/#:~:text=Like%20most%20polymers%2C%20ABS%20is%20totally%20recyclable.

[125] This is valid, especially for PP

[126] https://www.recyclingtoday.com/news/elix-repsol-anqore-plastic-abs-chemical-recycling-europe/

ABS plastic. Styrene and butadiene are produced from chemically recycled postconsumer scrap and in some cases from bio-circular raw materials from used cooking oil.

LIFE ABSolutely Circular project (2020-2024) [127]

Indaver (Belgium), a leader in sustainable waste management, and INEOS Styrolution (Germany), global leader in styrenics, have teamed up as technology partners in a project funded by the EU LIFE programme. The project, called LIFE ABSolutely Circular aims at demonstrating the environmental and economic benefits of using advanced recycling technologies to close the loop of plastic recycling.

An initial key objective of the project is to demonstrate for the first time the production of ABS based on recycled feedstock taking advantage of advanced recycling technologies. The project is also planned to demonstrate scaling of the solution from lab scale to demo plant and ultimately to commercialisation.

In November 2024, the first Plastics2Chemicals facility at Indaver's Antwerp site was almost ready for operation.

ABSOlEU project (June 2022 – May 2026) [128] [129]

Acrylonitrile butadiene styrene (ABS) is a useful impact-resistant engineering thermoplastic material. It is used in all sorts of durable products, from consumer goods to automotive parts. At least 85 % of end-of-life ABS is incinerated or dumped in landfills due to the presence of additives and fillers that prevent its proper recycling. The EU-funded ABSolEU project will pave the way for its circularity. It will develop technology for the physical recycling of waste ABS [130], providing a clean and safe recyclate that is free of additives and contaminants and ready to be reintroduced into the value chain. ABSolEU will also develop new analytical methods for safety assessment and quality assurance.

ABSolEU aims to pave the way to circularity for the ubiquitous plastic ABS, found in durable products from toys and other consumer goods to automotive components. Despite the potential of this material, at least 85% of end-of-life ABS ends up in landfills or incineration due to the presence of additives and fillers that hamper its proper recycling. ABSolEU will develop and mature to TRL 6 a technology for the physical recycling of waste ABS, providing a clean and safe recyclate that is free of additives and contaminants and ready to be reintroduced into the value chain for value-added, high-performance products.

In parallel, ABSolEU will develop new analytical methods for safety and quality assurance; these will allow project partners to establish a thorough understanding of the composition of ABS waste streams, including the presence of additives and the degree of degradation, as well as monitor these throughout recycling and compounding processes.

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[127] https://absolutely-circular.com/#:~:text=The%20project%2C%20called%20LIFE%20ABSolutely%20Circular%20aims%20at,technologies%20to%20close%20the%20loop%20of%20plastic%20recycling.

[128] Innovative physical recycling technology for ABS waste. HORIZON.2.4 - Digital, Industry and Space Main Programme, HORIZON.2.4.4 - Advanced Materials, Grant agreement ID: 101058636, DOI 10.3030/101058636, https://cordis.europa.eu/project/id/101058636

[129] ABSolEU project https://absoleu.univ-cotedazur.eu/

[130] Dissolution, or purification, processes stand apart from other molecular recycling methods because they do not break the plastic polymer bonds. Because it is non-chemical, this process is often referred to as "physical recycling." Purification uses solvents to extract colours and additives from single-polymer feedstock or mixed plastics, resulting in virgin-like polymers. These processes maintain the integrity of the material, ensuring a plastic-to-plastic outcome. Additionally, purification is part of molecular recycling technologies, but this specific method does not break the polymeric structure.

https://www.plasticsengineering.org/2024/09/solvent-recycling-006376/#!

In addition, ABSolEU aims to provide the scaffolding to support adoption of physical recycling for ABS and support the uptake of ABS recyclates by industry and consumers. This is achieved through circular value chain labs and explorative citizen labs, investigation of new traceability systems for ABS materials and products, and standardisation of processes for recycling, analysis and traceability.

ABSolEU's research outputs are communicated, disseminated and synthesised into best practices, methodologies, and policy recommendations for ABS recycling to contribute to a resource efficient industry. The project is implemented by a strong consortium that spans the entire ABS value chain. It is led by UCA and involves 10 additional partners: 3 global brand owners, 2 RTOs, an ABS-producing company, a recycler, a traceability solutions company, a standardisation institute and a company specialised in stakeholder engagement. With ABSolEU, the consortium is seeking to lay the first bricks of a sustainable future for ABS plastics.

Study on recycling of coated ABS [131]

Coating plastic components is a widely preferred method to improve their surface properties, but it poses a challenge for reusing or recycling. Foreign substances and all kinds of impurities reduce the performance of the recycled material. Recovery of high-value material can be increased by removing coatings. Coat stripping is not a new process in engineering and plays a significant role in the maintenance and restoration of materials throughout their lifecycle. The authors of the article studied the feasibility of recycling coated ABS materials for use in electrical frame production, aiming to bridge the gap in current recycling practices [131].

One way of achieving debonding is by incorporation of triggerable additives. These additives need to be added to the primer layer, which is in contact with the substrate (ABS), to be able to remove as much coating material as possible.

This study investigated the use of recycled ABS (rABS) material in the remanufacturing of electrical frames. The main purpose of the study was to examine whether the proportional addition of recycled ABS material would change the mechanical properties. It was observed that adding rABS material did not adversely affect the mechanical properties (impact strength, tensile strength) of the ABS polymer and that it passed all the tests required for production.

This fact reinforces the suitability of the upcycling strategy incorporating impact strength additive to the recyclate compounds and allows to increase the percentage of recyclate rABS above 30% in further developments. Only the tensile modulus property shows more variability and more noticeable decrease down to 15–20% for the rABS recyclates compared to the reference ABS raw grade.

Plast2bcleaned H2020 Project

The PLAST2bCLEANED[132] project successfully demonstrated that recycled ABS from the TRL5 facility could be re-compounded and blended with 30% recycled ABS and 70% virgin ABS to create washing machine door frames, which complied with regulatory limits and met industry standards. Mechanical tests confirmed that the recycled ABS frame performed

[131] Material recycling of acrylonitrile butadiene styrene (ABS) from wiring devices using mechanical recycling, Esra ÇETİN, Oytun Tuğçe TÜRKAN, Sustainable Chemistry for the Environment, Volume 6, June 2024, 100095

https://www.sciencedirect.com/science/article/pii/S2949839224000385#:~:text=In%20order%20to%20recycle%20ABS,by%20incorporation%20of%20triggerable%20additives.

[132] https://plast2bcleaned.eu/wp-content/uploads/2024/07/Project-Sumary_Plast2_V4_compressed.pdf

similarly to virgin material, with the only limitation being its grayish color, though coating adhesion tests proved satisfactory.

ABS – PS separation

Generally, different polymers are separated based on their density, on waterbeds. However, the separation of ABS from PS requires electrostatic sorting, i.e. high voltage charging and separation using electromagnets [133].

ABS in washing machines

ABS represents 12% of the plastics mass and 2% of the overall washing machine mass. ABS is used in most of the visible plastic parts.[134]

ABS from washing machines is being recycled, but most recycled ABS comes from small domestic appliances and ICT products [135]. As far as known, no recycled ABS is used currently in washing machines. However, one manufacturer has reported using (PCR)ABS in other appliances, such as dishwashers, and plans to use at large scale (PCR)ABS for the production of washing machines soon.

4.3.3. Recycling of polyvinyl chloride (PVC)

Polyvinyl chloride (PVC) is a type of plastic commonly used in construction, packaging, and other consumer products, as it's one of the most cost-effective plastics available. Some of its key properties are its durability, resistance to chemicals, heat, water and moisture, low thermal conductivity and electrical insulation. PVC also doesn't rust, degrade easily, or rot, which makes it ideal for applications like pipes, window and door frames, and siding in the construction industry. PVC is available in rigid (RPVC) and flexible (FPVC) forms [136].

The production of PVC is resource-intensive and environmentally damaging, as it relies on chlorine and ethylene, derived from salt and petroleum, respectively. The process releases toxic chemicals like dioxins, harming the environment and human health. These dioxins can persist in the environment for years, contaminating air, water, and soil.

Oil makes up 43% of the raw material required to make PVC.

Looking at waste, 82% of global PVC waste goes to landfill, 15% is incinerated. Only 3% is recycled. The majority of PVC waste comes from the construction industry, which is logical, as 70% of PVC is used in the construction sector.

PVC in washing machines

In the on-going Review Study, no PVC was reported in the BoM. However, power cables and electric wiring in the WMs/WDs may contain PVC sheathing. PVC can be also utilized for piping purposes.

[133] Study team (mini study on refrigerators) visit to CoolRec facilities.

[134] Based on the BOM considered in this study, see Table 12 and Table 14

[135] E.g. Coolstar ABS uses recycled plastics from small domestic appliances and ICT products (76% recycling rate; >98% purity granulates). Basic grade ABS-E Plus for injection moulding applications. Modified grade ABS-E Master for higher impact strength (Charpy impact strength tested), suitable for thin wall sheet extrusion and for injection moulding.

[136] https://www.front-materials.com/news/can-pvc-be-recycled/#:~:text=The%20short%20answer%20is%20yes%2C%20PVC%20recycling%20is%20possible.

4.3.4. Recycling of polycarbonate (PC)

Polycarbonate is used in a variety of application areas, including [137]:

- Automotive industry: headlight lenses, instrument panels, and exterior trims.
- Electronics industry: computer and phone cases, LCD screens, and printer components.
- Medical industry: IV components, syringes, and surgical instruments.
- Construction industry: roofing sheets, windowpanes, and skylights.
- Eyewear: eyeglasses and sunglasses due to PC's high impact resistance and clarity.
- Water bottles: reusable water bottles due to PC's durability and resistance to shattering.
- Toys: toys and children's products due to PC's safety and strength.

PC in washing machines

In the on-going Review Study, no PC was reported in the BoM. However, PC may be used for some user-interface components. Based on the situation regarding PC in refrigerators, it is assumed that PC from washing machines is not being recycled and that no recycled PC is currently used in washing machines.

Recycling of Polycarbonate

Polycarbonate is a recyclable plastic but is not as widely recycled as other plastics due to its relatively low demand in the recycling market. Polycarbonate products can be recycled into various products, including automotive parts, construction materials, and electronic components [137].

4.3.5. Recycling of polyamides (PA, nylon)

Recycling polyamide (PA) can be difficult due to its complex molecular structure, which makes it difficult to break down and process. However, PA can be recycled mechanically and chemically. The recycling of polyamide is becoming increasingly important as the demand for sustainable materials grows [138].

Mechanical recycling involves shredding the PA/Nylon waste and melting it to create new products. The process involves the following steps [138]:

- Sorting: PA/Nylon waste is sorted based on type and colour.
- Shredding: The sorted PA/Nylon waste is shredded into small pieces.
- Melting: The shredded waste is then melted and extruded into pellets.
- Manufacturing: The pellets are then used to create new products.

Mechanical recycling of PA/Nylon has several advantages, including:

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[137] https://www.recycledplastic.com/pc-polycarbonate/

[138] https://www.recycledplastic.com/pa-polyamide-nylon/#:~:text=The%20recycling%20of%20polyamide%20is,including%20mechanical%20and%20chemical%20recycling.

- Reduced Energy Consumption: The recycling process requires less energy than virgin PA/Nylon production.
- Reduced Landfill Waste: Mechanical recycling reduces the amount of PA/Nylon waste in landfills.
- Cost-Effective: Using recycled PA/Nylon can reduce production costs, making it an attractive alternative to virgin PA/Nylon.

Mechanical recycling of PA/Nylon also has some disadvantages, including:

- Reduced Quality: The quality of recycled PA/Nylon is lower than that of virgin PA/Nylon due to degradation during the recycling process.
- Limited Recycling Options: PA/Nylon cannot be recycled indefinitely, and the quality of the recycled material decreases with each cycle.

Chemical recycling involves breaking down the PA/Nylon waste into its constituent components to create new polymer products. The process involves the following steps [138]:

- Depolymerisation: The PA/Nylon waste is broken down into its constituent monomers using heat and chemicals.
- Purification: The monomers are purified to remove any impurities.
- Polymerisation: The purified monomers are then polymerised to create new PA/Nylon.

Chemical recycling of PA/Nylon has several advantages, including:

- High-Quality Material: The recycled material produced through chemical recycling is of high quality and can be used to produce new products.
- Reduced Environmental Impact: Chemical recycling reduces the environmental impact of PA/Nylon production by reducing greenhouse gas emissions and waste.

Chemical recycling of PA/Nylon also has some disadvantages, including:

- High Cost: Chemical recycling is currently more expensive than mechanical recycling and producing virgin PA/Nylon.
- Technical Challenges: The depolymerisation process can be technically challenging and may require additional research and development.

PA in washing machines

PA represents 3% of the plastics mass and less than 1% of the overall washing machine mass.[139]

Based on the situation regarding PA in refrigerators, it is assumed that PA from washing machines is not being recycled and that no recycled PA is currently used in washing machines.

4.3.6. Recycling of (synthetic) rubber

Washing machine door gaskets are made entirely of rubber, with most consisting of ethylene propylene diene monomer (EPDM) rubber. EPDM offers exceptional resistance to water and heat, maintaining its sealing properties even at temperatures up to 150°C. No manufacturer mentioned the recyclability of gasket. However, within the PRIMUS website (https://www.primus-project.eu), gaskets with recycled material were manufactured.[140] and the

[139] Based on the BOM considered in this study, see Table 12 and Table 14

[140] https://www.primus-project.eu/wp-content/uploads/2025/03/202503124_Best-Practice-Book-.pdf

feasibility of gaskets with 10% of recycled EPDM could be demonstrated.[141] In the Re-use project[142], Fraunhofer ICT demonstrated that rubber from washing machine gaskets can be recycled, with up to 25% of the rubber mixture replaced by devulcanized material.

4.4. Glass recycling technologies

Washing machines contain tempered glass, which is used in the door. Key aspects regarding the tempered glass recycling process:

a) Challenges in Recycling

1. **High Melting Point**: Tempered glass does not melt like regular glass and has a significantly higher melting point (above 760°C). If not reheated evenly, it shatters into small fragments. Specialized equipment and a gradual heating process are necessary to relieve internal stresses before liquefaction.
2. **Irreversible Structure**: Once broken, tempered glass cannot be remoulded.
3. **Difficult Handling & Sorting**: The glass breaks into small, pebble-like pieces, making sorting challenging. Additionally, the risk of contamination is high.
4. **Limited Market for Alternative Uses**: There are restricted applications for recycled tempered glass, limiting economic feasibility.

b) Recycling Process

1. **Glass Separation and Extraction**: Washing machines are usually not dismantled to separate glass components. However, the door/glass is typically removed before the machine is shredded (see 4.1.7.1).
2. **Sorting**: The recovered glass is categorized into tempered glass, laminated glass from doors, and other decorative glass panels.
3. **Cleaning**: Residual food particles, adhesives, coatings, and contaminants are removed.
4. **Shredding & Crushing**:
    - Tempered glass does not melt conventionally but is designed to break into small fragments. The glass is crushed into cullet (small pieces) for further processing.
    - **Thermal Treatment**: High-temperature kilns (above 600°C) are used to reverse the tempering process.
    - **Chemical Treatment**:
        - **Acid Treatment**: Strong acids like hydrofluoric or sulfuric acid remove coatings and films.
        - **Alkali Treatment**: Sodium hydroxide or potassium hydroxide weakens the molecular bonds, bringing the glass closer to annealed glass behaviour.

[141] The production of gaskets with 20% recycled material was experimented but deemed unsatisfactory due to visible signs of prevulcanization on the surface

[142] Rubber Recycling of Washing Machine Gaskets: https://www.ict.fraunhofer.de/content/dam/ict/en/documents/technical_contributions/pe/Fraunhofer%20ICT%20Plastics%20Insights_2023_09_.pdf

    - **Ion Exchange Process**: Experimental methods use reverse ion exchange to alter stress balance, allowing remelting and reshaping.

5. **Processing and Repurposing**: Recycled tempered glass is repurposed into various materials, including:
    - Fiberglass insulation
    - Glass tiles and countertops
    - Abrasive materials for sandblasting
    - Artificial sand for industrial applications
    - Water filtration media
    - Reflective road paint and micro glass beads for highway markings
    - Solar panel glass, glass bottles, and packaging
    - Construction materials such as road base and concrete aggregate

Stakeholders consulted for the study emphasized that only a closed-loop recycling process for glass with identical characteristics would be feasible. This is in practice hardly possible, accordingly, recycled tempered glass cannot be used to produce the window of a new washing machine.

4.5. Metal recycling technologies

See the general, horizontal part of the study report on recycled content and CRMs.

4.6. CRM recycling technologies

See the general, horizontal part of the study report on recycled content and CRMs.

5. MEErP Task 5, Environment and Economics

5.1. Base Cases

This mini study considers the same baseline cases (BCs) as the Review Study:

- BC 1 washing machine (8 kg nominal capacity)
- BC 2 washing machine (10 kg nominal capacity)
- BC 3 washer-dryer (9 kg nominal capacity)

Table 10 presents the main characteristics of the three BCs.

Table 10: Base case characteristics (from the on-going review study)

	BC1	BC2	BC3
Type	Washing machine	Washing machine	Washer-dryer
Nominal rated capacity (kg)	8	10	9 (wash cycle) 6 (complete cycle)
Energy efficiency class	A	A	Wash cycle A, complete cycle D
Washing efficiency index	1.0314	1.033	1.031
Spin speed (full load) rpm	1400	1400	1400
Noise washing/spinning (dB(A))	53/72.2	53/71.6	53/71.6
Lifetime (years)	12.5	12.5	12.5
Annual electricity consumption (kWh/unit/a)[143]	135.2	143.6	636.9
Annual water consumption (m^3/unit/a)[144]	11.4	12.2	13,2
Annual deter consumption (kg/unit/a)[145]	8.9	8.9	10.7
Sales EU27 2025 (thousand units)	9,496	1.944	549
Share in EU27 sales 2025	79%	16%	5%
Stock EU27 2025 (thousand units)	141,823	29,048	6,877

5.2. Bill-of-Materials (BoM)

According to the Review Study, the aggregated Bill of Materials is as follows:

[143] weighted value, taking into account the use of eco and non-eco programs as well as the performance of the programs

[144] weighted value, taking into account the use of eco and non-eco programs as well as the performance of the programs

[145] weighted value, taking into account the use of eco and non-eco programs as well as the performance of the programs

Table 11: Currently available aggregated BoMs, from the on-going Review Study

Component / material	BC1	BC2	BC3
ABS Plastics	1.51	1.65	1.63
Aluminium	2.41	3.04	5.07
Cables	0.58	0.66	0.59
Concrete	21.40	22.00	14.00
Copper	1.14	1.18	1.35
Elastomer	2.64	2.67	2.76
Ferrite magnet	0.04	0.07	0.07
Heatsink (Aluminium)	0.16	0.16	0.13
PA (polyamide)	0.40	0.60	0.40
Other technical and non-technical plastics	0.85	0.90	0.85
PP (polypropylene)	7.09	9.11	8.13
Glass fibre	1.67	2.12	2.10
Powder paint	0.60	0.60	0.60
Printed wire boards	0.77	0.92	0.86
Glass	2.20	2.20	2.20
Silicone	0.03	0.03	0.03
Stainless steel	4.11	4.69	4.30
Steel	24.09	28.06	27.44
Sum	71.71	80.66	72.49

As shown in Table 11, the BOMs of the base cases are similar, with total weights ranging from 71.1 kg to 80.7 kg and comparable materials. This is also the case for the washer-dryer, as it has no heat pump. In addition, BC1 accounts for 79% of EU-sales (Table 10).

Consequently, Task 5 and Task 6 will focus on BC1 (8 kg washing machine).

5.3. Bill-of-Materials, comparison Review Study – APPLiA

Table 12 shows the difference in BoM shares (without packaging) between the on-going Review Study and the latest APPLiA annual statistic report.[146]

Table 12: BoMs, from the on-going Review Study and from APPLiA

	BC1 kg	BC1 share %	APPLiA share %
ABS	1.51	2.1%	3.1%
Aluminium	2.58	3.6%	3.5%
Concrete	21.40	29.9%	26.6%
Copper	1.73	2.4%	0.8%
PWB	0.77	1.1%	0.5%
Steel	24.09	33.7%	30.6%
Glass	2.20	3.1%	3.5%
PC/ABS Alloy	-	-	0.1%
PA	0.40	0.6%	0.4%
POM	-	-	0.2%
PP	7.94	11.1%	13.2%
PS	-	-	0.1%
PVC	-	-	0.6%

[146] APPLiA has published on 22nd May 2025 the 9th annual Statistical Report on the European home appliance industry: http://statreport2024.applia-europe.eu/

Stainless steel	4.11	5.7%	9.4%
Other plastics	-	-	1.2%
Other	4.98	7.0%	6.1%
Other includes:			
Elastomer	2.64	3.7%	n.a.
Ferrite	0.04	0.1%	n.a.
Coating	0.60	0.8%	n.a.
Glass fiber	1.67	2.3%	n.a.
Silicone	0.03	0.0%	n.a.

There are differences in both material composition and distribution. APPLiA includes a few plastic types—PC/ABS, POM, PS, PVC, and other plastics—that are not present in the BC1 BoM, though their overall share remains limited at 2.2%. Additionally, APPLiA reports 6.15% of “other” materials, while the BC1 BoM lists five materials not included in the APPLiA BoM, together accounting for 7.0% of the BC1 BoM.

5.4. Bill-of-Materials for base case 1 (8 kg washing machine)

Based on:

- Analysis of exploded views and spare parts of various models,
- Material characteristics and their potential applications in washing machine component manufacturing,
- Information gathered during a two-day visit organized by APPLiA at Miele factories[147],
- Relevant BOM data provided by some manufacturers.

the BOM of BC1 was disaggregated and assigned to the main component groups of a washing machine as shown in Table 13, in order to have a better insight later (in Task 6) on how and where to apply which Design Options. This disaggregation was presented and shortly discussed with the interviewees consulted during this study.[148]

[147] on 18 and 19 March 2025 in Bielefeld and Gütersloh (household laundry care factory), with Miele, APPLiA, DG ENV, Oeko Institut and Fraunhofer ISI. See: https://www.linkedin.com/posts/applia-europe_our-team-just-wrapped-up-an-insightful-visit-activity-7308143533389996033-tjB-?utm_source=share&utm_medium=member_desktop&rcm=ACoAAAcNHAYBNqBG3vQxkqp3X8mFWyRwUZpQpFk. It was a unique occasion to gain in-depth insight into the manufacturing and testing of washing machines, as well as the recycling of plastics used in household appliances.

[148] 3 manufacturers in addition to Miele

Table 13: Detailed BOM of Base Case 1 (washing machine 8 kg)

Material	Cables	Control system	Dispenser/ tray/hose	Door	Oscillating system	Housing	Motor & Pumps	All
ABS	0.00	0.00	0.59	0.93	0.00	0.00	0.00	1.51
Aluminium	0.00	0.00	0.00	0.00	1.49	0.00	1.09	2.58
Coating	0.00	0.00	0.00	0.00	0.00	0.60	0.00	0.60
Concrete	0.00	0.00	0.00	0.00	21.40	0.00	0.00	21.40
Copper	0.86	0.00	0.00	0.00	0.00	0.00	0.86	1.73
Elastomer	0.00	0.00	0.00	0.00	2.64	0.00	0.00	2.64
Ferrite	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04
Glass	0.00	0.00	0.00	2.20	0.00	0.00	0.00	2.20
Glass fibre	0.00	0.00	0.00	0.00	1.67	0.00	0.00	1.67
PA	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.40
PP	0.00	0.00	2.09	0.57	4.90	0.00	0.38	7.94
PWB	0.00	0.77	0.00	0.00	0.00	0.00	0.00	0.77
Silicone	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.03
Stainless steel	0.00	0.00	0.00	0.00	3.58	0.00	0.53	4.11
Steel	0.00	0.00	0.16	0.16	5.04	17.19	1.55	24.09
All	0.86	0.77	2.84	3.86	40.74	17.78	4.85	71.71

The study team uses the new EcoReportTool (ERT) [149] released in March 2025 and the current Methodology for the ecodesign of energy-related products (MEErP) [150]. For most material types the new ERT offers a virgin material (V) and a recycled material (R), each with their own dataset of unit environmental impacts. Table 14 indicates the chosen ERT datasets for the virgin and recycled materials for the BoM of the base case 1, see notes following the table. For the factors R1 (recycled content), R2 (recycling output rate) and A (allocation factor), see section 5.5.

Table 14: Bill of Materials for base case 1 (8 kg washing machine) and corresponding entries in the EcoReportTool

Component	Mass kg	Material category	Virgin material dataset	Recycled material dataset	R1 (BaU)	R2	A
Dispenser/tray/hose - ABS	0.587	01-Plastics	1- *Acrylonitrile Butadiene Styrene (ABS) emulsion polymerisation, bulk polymerisation or combined processes	36- Recycling plastic Acrylonitrile-butadiene-styrene (ABS), waste management, technology mix	0%	49%	50%
Door - ABS	0.926						

[149] Ecoreport tool_v1.7.2.xlsx, see: https://circabc.europa.eu/ui/group/418195ae-4919-45fa-a959-3b695c9aab28/library/3fb62627-0843-44df-b038-444cd1ac79b4?p=1&n=10&sort=modified_ASC

[150] MEErP:European Commission, Joint Research Centre, Eynard, U., Ardente, F., Gama Caldas, M., Spiliotopoulos, C. and Mathieux, F., Ecoreport tool - Manual, Publications Office of the European Union, Luxembourg, 2024, https://data.europa.eu/doi/10.2760/473257, JRC133597.

			production mix, at plant				
Total - ABS	**1.513**						
Oscillating system - Elastomer	**2.643**	01-Plastics	6-Ethylene propylene dien elastomer (EPDM) copolymerization of ethylene and propylene production mix, at plant 69% ethylene, 38% propylene	39- *Recycling of post-industrial waste EPDM rubber	0%	0%	50%
Motor&Pumps - PA	**0.400**	01-Plastics	11-Nylon 6 fiber extrusion into fiber production mix, at plant 5% loss, 3,5 MJ electricity	31-Nylon fibre, recycled, mechanical, post-consumer washing, drying, shredding, drum rotating spinning production mix, at plant Erec/ErecEoL, efficiency 90%	0%	0%	50%
Dispenser/tray/hose - PP	2.095	01-Plastics	16-Polypropylene (PP), petrochemical based polymerisation of bio-fossil propylene production mix, at plant petrochemical based	35-Polypropylene, recycled, post-consumer washing, drying, shredding, pelletizing production mix, at plant Erec/ErecEoL, efficiency 90%	0%	49%	50%
Door - PP	0.571						
Oscillating system - PP	4.897[151]						
Motor&Pumps - PP	0.379						
Total - PP	**7.942**						
Oscillating system - Silicone	**0.031**	01-Plastics	26-Silicone, high viscosity hydrolysis and methanolysis of dimethyldichloro silane	not available	0%	0%	50%

[151] Here, for this component, R2 = 0% as it is reinforced with glass fibre

			production mix, at plant >30 000 centi Poise				
Total plastics	**12.529**	**17.5%**					
Oscillating system - Stainless steel	3.578	02-Metals	85-Stainless steel cold rolled hot rolling production mix, at plant stainless steel	128-Steel cast part alloyed electric arc furnace route, from steel scrap, secondary production single route, at plant carbon steel	30%	76%	20%
Motor&Pumps - Stainless steel	0.534						
Total - Stainless steel	**4.112**						
Dispenser/tray/hose - Steel	0.155	02-Metals	87-*Steel cold rolled coil blast furnace route single route, at plant carbon steel	128-Steel cast part alloyed electric arc furnace route, from steel scrap, secondary production single route, at plant carbon steel	30%	76%	20%
Door - Steel	0.160						
Oscillating system - Steel	5.036						
Housing - Steel	17.185						
Motor&Pumps - Steel	1.555						
Total - Steel	**24.091**						
Housing - Coating	**0.596**	02-Metals	59-Coating powder, exterior production technology mix production mix, at plant 100% active substance	not available	0%	0%	20%
Motor&Pumps - Ferrite	**0.037**	02-Metals	68-Ferrite (iron ore) iron ore mining and processing production mix, at plant 5.00 g/cm3	not available	0%	0%	20%
Total Ferrous	**28.836**	**40.2%**					

Oscillating system - Aluminium	1.488	02-Metals	52-Aluminium ingot mix (high purity) primary production, aluminium casting single route, at plant 2.7 g/cm3, >99% Al	123-Recycling of aluminium into aluminium ingot - from post-consumer collection, transport, pretreatment, remelting production mix, at plant aluminium waste, efficiency 90%	30%	76%	20%
Motor&Pumps - Aluminium	1.087						
Total - Aluminium	**2.575**						
Cables - Copper	0.863	02-Metals	61-Copper Concentrate (Mining, mix technologies); copper ore mining and processing; single route, at plant; Copper - gold - silver - concentrate (28% Cu; 22.3 Au gpt; 37.3 Ag gpt)	124-Recycling of copper from clean scrap; collection, transport, pretreatment; production mix, at plant; copper content in input scrap 90%, copper losses 1%	37%	74%	20%
Motor&Pumps - Copper	0.863						
Total - Copper	**1.725**						
Total non-ferrous	**4.300**	**6.0%**					
Door - Glass	**2.204**	02-Metals	72-Flat glass, uncoated cut, Pilkington process, from sand and soda ash production mix, at plant 2500 kg/m3	116-Recycling glass, waste management, technology mix, at plant collection, sorting, transport, recycling production mix, at plant glass waste, efficiency 95%	0%	0%	20%
Oscillating system - Glass fibre	**1.670**	04-Others	222-glass fiber technology mix production mix, at plant 1 kg	not available	0%	0%	50%

Total Glass	**2.204**	**3.1%**					
- PWB	**0.768**	03-Electronics	164-Printed wiring board (PWB) (2-layer) via the subtractive method (as opposed to additive method) production mix, at plant 2-layer, 1.32 kg	195-*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	0%	0%	50%
Total Electric	**0.768**	**1.1%**					
Oscillating system - Concrete	**21.400**	04-Others	216-Concrete, production mix, at plant aggregates mixing production mix, at plant C20/25	not available	0%	0%	50%
Total Other	**23.070**	**32.2%**					
Cables	**0.863**	**1.2%**					
Control system	**0.768**	**1.1%**					
Dispenser/tray/hose	**2.837**	**4.0%**					
Door	**3.861**	**5.4%**					
Oscillating system	**40.742**	**56.8%**					
Housing	**17.781**	**24.8%**					
Motor&Pumps	**4.855**	**6.8%**					
Total Mass	**71.707**						

Notes on Table 14:

1- The BoM is based on the of the on-going Review Study. The table anyway indicates the main washing machine components in which each material type is being used.

2- In the “oscillating system”: the inner drum is in stainless steel (3.58 kg). The outer drum (washer tub) is mainly of PP (3.90 kg) reinforced with glass fibre (1.67 kg), the 5.57 kg heaving, of which 70% is PP with 30%reinforced with glass fibre.

3- EPDM (Terpolymer Ethylene-Propylene-Diene) is mainly used for the door gasket and for the drive belt.

4- There is no specific dataset for NdFeB magnets in the ERT. In addition, the indicated 100 gr of NdFeB magnet (see 4.1.7.1) is a “worst case” figure for washing machines, which is not reflection the BAU scenario in the Base Case. Therefore, no NdFeB is considered in the LCA analysis.

5- Five materials (concrete, ferrite magnet, glass fibre, powder paint and silicone) have been considered but have no data for on recycling.

6- Recycled plastics dataset are for “recycled, post-consumer”.

Important remark and limitations of the analysis in this study

The datasets used for the plastics considered in this study (PP, ABS, PA, EPDM, and silicone) within the ERT refer exclusively to the polymer component.

In addition, the manufacturer did not provide detailed information regarding the composition of the plastic parts—specifically the types and quantities of fillers, additives, and other constituents.[152] Since the ERT does not include datasets for these additional materials, the LCA reflects only the environmental impact of the pure polymer.

As a result:

- For 1 kg of PP plastic listed in the BOM, 1 kg of polymer was considered, excluding any fillers or additives.
- The environmental impact of the polymer is likely overestimated.
- The environmental impact of fillers and additives which are in the plastic parts is neglected.[153]

[152] With evtl. the exception of talcum, which is declared as metal in the ERT

[153] With the exception of the glass fiber in the wash tub.

5.5. Recycling parameters for the EcoReportTool

5.5.1. Simplified Circular Footprint Formula

The 2024 ERT calculates the environmental impacts of raw materials, excluding the end-of-life (EoL) phase, using a simplified version of the Circular Footprint Formula (CFF) [154] [155]:

(1-R1) x Ev + R1 x (A x Erec + (1-A) x Ev).

The impacts at end-of-life due to material recycling are computed from:

(1-A) x R2 x Erec.

The benefits at end-of-life due to material recycling (avoidance of virgin material use) are computed from:

For non-electronics: - (1-A) x R2 x Ev

For electronics: - CF x Amount x (1-A) x R2 x SUM (Credits for Cu, Au, Pd, Pt, Ag)

Where:

Ev the virgin material impact for the environmental parameter, computed as the total input material mass (kg) multiplied by the unit impact for the applicable virgin material dataset for the environmental parameter (impact/kg).

Erec the recycled material impact for the environmental parameter, computed as the total input material mass (kg) multiplied by the unit impact for the applicable recycled material dataset for the environmental parameter (impact/kg).

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

R2 (recycling output rate): the proportion of the material in the product that will be recycled in a subsequent system. R2 considers the efficiencies in the collection and recycling processes. R2 shall be measured at the output of the recycling plant.

A the allocation factor of burdens and credits between supplier and user of recycled materials. 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). It avoids potential double counting due to recycled materials coming from washing machines being subsequently used in other products, or vice versa [156].

For electronics, a more complex formula is used to compute recycling benefits:

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[154] MEErp _Ecoreport tool_v1.7.2.xlsx
European Commission, Joint Research Centre, Eynard, U., Ardente, F., Gama Caldas, M., Spiliotopoulos, C. and Mathieux, F., Ecoreport tool - Manual, Publications Office of the European Union, Luxembourg, 2024, https://data.europa.eu/doi/10.2760/473257, JRC133597.

[155] The ERT does not consider the impacts from incineration (with or without heat recovery), nor of landfilling, fugitive, or missing masses at EoL.

[156] If R1=R2 (e.g. all recycled material coming from a washing machine is reused for a washing machine)

- R1 x A x Erec is counted in raw material input impacts
  (1-A) x R2 x Erec is counted as EoL impact
  Hence, if R1=R2, the entire Erec (impact from recycled materials) is counted.
- (1 - R1 x A) x Ev is counted in raw material input impacts
  -(1 - A) x R2 x Ev is counted as EoL benefit (avoided virgin materials)
  Hence, if R1=R2, (1-R1) x Ev (impact from virgin materials) is counted.

- For electronics the amount of material in input to the production is often defined in m2, m or items. A conversion factor CF is used to convert the amount to a mass in kg.
- Each virgin material dataset for electronics has material credits defined for copper (Cu), gold (Au), palladium (Pd), platinum (Pt) and silver (Ag). These credits can be interpreted as mass shares.
- Each material credit is multiplied by the unit impact for the considered parameter in the virgin material dataset for Cu (61), Au (75), Pd (81), Pt (82) or Ag (84), and the sum is multiplied by the recycled mass share CF x Amount x (1-A) x R2.
- Hence, for electronics, the recycling benefit is not related to e.g. avoided virgin cables, PWBs or LEDs, but to avoided virgin Cu, Au, Pd, Pt and Ag.

The ERT provides default values for R1, R2 and A that the user can accept or overwrite. The values for these parameters are discussed in the following sections. The values used are shown in Table 14.

5.5.2. Allocation factor A

The current study uses the default values for allocation factor A, which are 50% for all material types except metals, and 20% for metals. Hence, for recycling of metals, only 20% of the benefits are assigned to the production phase, and 80% to the EoL phase. For plastic, electronics, and other materials this is 50%-50%.

5.5.3. Factor R1, recycled content

For plastics, the ERT default value for factor R1 (recycled content) is 0%.

PlasticsEurope [157] states that EEE products consumed 3.1 Mt of plastics in 2022, of which 3.2% (0.1 Mt) came from post-consumer recycled plastic. It is uncertain if this share would also be representative for washing machines.

For PP and ABS, which are being recycled, the factor R1 is still kept at the default value 0%. The reason is that only few manufacturers seem to be active in using recycled PP and ABS in washing machines (see 4). In the scenarios setting minimum requirements on recycled plastics content, the factor R1 has been increased and the differences in environmental impacts registered.

For aluminium, the default for R1 (recycled content) in the ERT is 30%. For copper and steel, the default is 0%. The reason for this difference is unknown.

Eurostat [158] provides data for the contribution of recycled materials to raw materials demand, e.g. end-of-life recycling input rates (RIR, Table 15). The shares vary over the years, but the 30% for aluminium could come from here.

[157] https://plasticseurope.org/wp-content/uploads/2024/11/PE_TheFacts_24_digital-1pager.pdf https://plasticseurope.org/knowledge-hub/the-circular-economy-for-plastics-a-european-analysis-2024/

[158] Eurostat online database cei_srm010, accessed January 2025.

An IAI Factsheet [159] confirms that in 2018 the global Recycling Input Rate (RIR) of aluminium was 32%, including recycled pre- and post-consumer scrap contained in the produced aluminium, but not run-around scrap.

Based on the table, 30% has also been used for steel.[160] For ferrite, R1 = 0% is unchanged.

Table 15: End-of-life recycling input rates (source: Eurostat cei_srm010)

	2013	2016	2019	2022
Aluminium	35%	12%	12%	32%
Copper	20%	55%	17%	55%
Iron	22%	24%	32%	31%
Nickel	32%	34%	17%	16%

For copper, values in Table 15 vary over the years, with an average of 37%.

The 2024 Factsheet on copper recycling from the Kupferverband [161] confirms that on average, copper products worldwide contain more than 30 percent recycled content. The share of recycled materials in copper production (classic recycling rate) is around 40 percent in Europe, significantly higher than the global average. The value of 37% has been used in the analyses.

The same factsheet specifies that (see also graph in the source):

> *Scrap that can be reused in the same process in which it arises is generally not considered pre-consumer scrap. Both pre- and post-consumer scraps may require processing before they can be reintroduced into the material cycle. Both types of recycled materials are used in the production of goods and determine their recycled content. A physical separation of these scrap types is therefore useless in terms of their recyclability.*
>
> *Recyclers purchase and collect both types of scrap until economically viable batch sizes are reached, allowing them to transport the loads to processors or larger scrap dealers. The distinction and sorting of scrap are therefore based solely on its quality, such as copper content or material purity, in order to optimize the use of the scrap in follow up refining or remelting processes.*

In a meeting with the study team, a large EU copper recycler [162] confirmed that it is impossible for them to distinguish between pre-consumer and post-consumer inputs for the recycling, because all copper scrap or granules arrive as a mix from both types. To make the distinction, scrap collectors would have to certify (if feasible for them) the proportions pre- and post-consumer scrap that they supply to upstream recyclers.

For glass, the default for R1 (recycled content) in the ERT is 0%. As washing machines used tempered glass, this value is not changed.

For all electronics, the default for R1 (recycled content) in the ERT is 0%, and no information is available to change this.

For all other materials, no default is available in the ERT. The study used R1=0%.

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[159] https://international-aluminium.org/wp-content/uploads/2024/03/wa_factsheet_final.pdf

[160] For stainless steel: this ratio might be too low, According to APERAM (major european stainless steel producer), stainless steel is produced in Europe using in average around 80% of recycling materials.

[161] https://kupfer.de/wp-content/uploads/2024/10/2024_Factsheet_Recycling_EN.pdf

[162] https://www.montanwerke-brixlegg.com/

5.5.4. Factor R2, recycling output rate

The ERT specifies that the value for R2 (recycling output rate) shall consider the efficiencies in the collection and recycling processes.

Based on information presented in section 2.1.5, it can be estimated that for washing machines reaching end-of-life in 2024, 60% is separately collected and 18% is complementary collected. The total collection rate of 78% is lower than the 85% required by the WEEE directive, so it could further increase in future, but for the analyses in this study it is assumed to remain constant.

Plastics

Based on information from a major European fridge recycler, for PP and ABS, 80% of the separately collected mass is recycled. For complementary collected mass the recycling rate is lower. Based on data from Plastics Europe (section 2.1.7) this rate is estimated to be 4%.In total, R2 = 49% (= 80%*60%+4%*18%) can be assumed for ABS and PP, excepted for the 3.9 kg of PP used in the washer tub, as is it reinforced with around 30% of glass fibre and cannot be recycled.

There are other plastic types that are recyclable, but their masses in washing machines are low and spread over many small components, so that it does not seem worthwhile to apply separation processes for them during EoL processing. The analyses therefore assume that nothing is recycled, e.g. R2=0%.

Metals

For aluminium and steel, the ERT gives a default value for R2 of 85%. For washing machines, considering the 78% total collection, this is too high. Based on information presented in section 2.1.6, for steel it is assumed that 98% of the collected mass is recycled (R2=78%*98%=76%), and for aluminium 90% (R2=78%*90%=70%) [163].

For copper, the ERT gives a default value for R2 of 0%, which is too pessimistic. Based on information presented in section 2.1.6, for copper it is assumed that 95% of the collected mass is recycled (R2=78%*95%=74%).

In general, for metals the recycling rates are high, but based on the available information, it is not possible to establish an exact value for metals recycled from washing machines. The recycling rates mentioned above are assumed to be valid both for separate and for complementary collection, and for all alloy types.

Glass

For flat glass, the ERT gives a default value for R2 of 0%, which is realistic for tempered glass.

[163] An IAI factsheets states a global Recycling Efficiency Rate (RER) of aluminium of 76%. The RER defines how efficiently aluminium is recycled throughout the value chain. It is an indicator used to estimate the amount of recycled aluminium produced annually from pre- and post-consumer scrap, as a percentage of the total amount of available scrap sources. This rate includes collection, processing and melting losses, but runaround scrap (re-used in the same process that produced it) is not included. Europe has the highest Recycling Efficiency Rate (RER) of any region in the world, recycling 81% of the aluminium scrap potentially available in the region. https://international-aluminium.org/wp-content/uploads/2024/03/wa_factsheet_final.pdf

Electronics

For all electronics, the ERT gives a default value for R2 of 50%. If total collection is 78%, this implies a recycled vs. collected rate of 64%. Printed circuit boards from household washing machines (including the smaller ones with LEDs), are typically shredded with the rest of the appliance, and then (partially) recovered from the plastics fraction during the separation processes (75% recycled vs. separately collected assumed) [164]. For recycling from complementary collection these values have been halved. Accordingly for electronics: R2 = 60%*75%+18%*37.5% = 52%.

These percentages apply to the end-of-life mass of the electronics and are used in the ERT to compute the EoL benefits for avoided use of virgin Cu, Au, Pd, Pt and Ag (section 5.5.1). Typically, 50-60% of the electronic board mass is for the reinforced plastic support structure, which is often not recycled.

Other materials

For all other materials, where no default R2 value is available from the ERT, R2=0% has been assumed.

5.6. Mass distributions for the baseline

Figure 9 shows the distribution of masses over the material types for base case 1, for the Bill-of-Materials of section 5.4.

Applying the baseline factors R1 (recycled content) of section 5.5.3, Figure 10 shows the proportions of virgin (blue) and recycled (orange) materials in input. Overall, in the baseline 14% of the input mass is recycled content (all from metals).

Applying the baseline factors R2 (recycling output rate) of section 5.5.4, Figure 11 compares the total material inputs (red) to the recycling outputs (green). Overall, 38% of the input mass is recycled at end-of-life (most from metals, but also from PP, PS, ABS, and some electronics[165]).

[164] Commercial and professional appliances have relatively large electronic boards, which are manually removed before shredding (especially when this is easily done), or hand-picked after pre-shredding. Washing machines have smaller boards which are not always easily accessible. These boards are typically shredded together with the rest of the appliance, ending up in the mixed plastic fraction. These boards (or more correctly, the flakes of these boards) are removed on the water separation tables. In all three instances, the circuit boards will end up in special smelters like Umicore, Boliden and their likes.

[165] For electronics the recycling output mass refers to the electronic components available after shredding and separation processes. The amount of recovered Cu, Au, Pd, Pt, Ag and other CRMs is smaller.

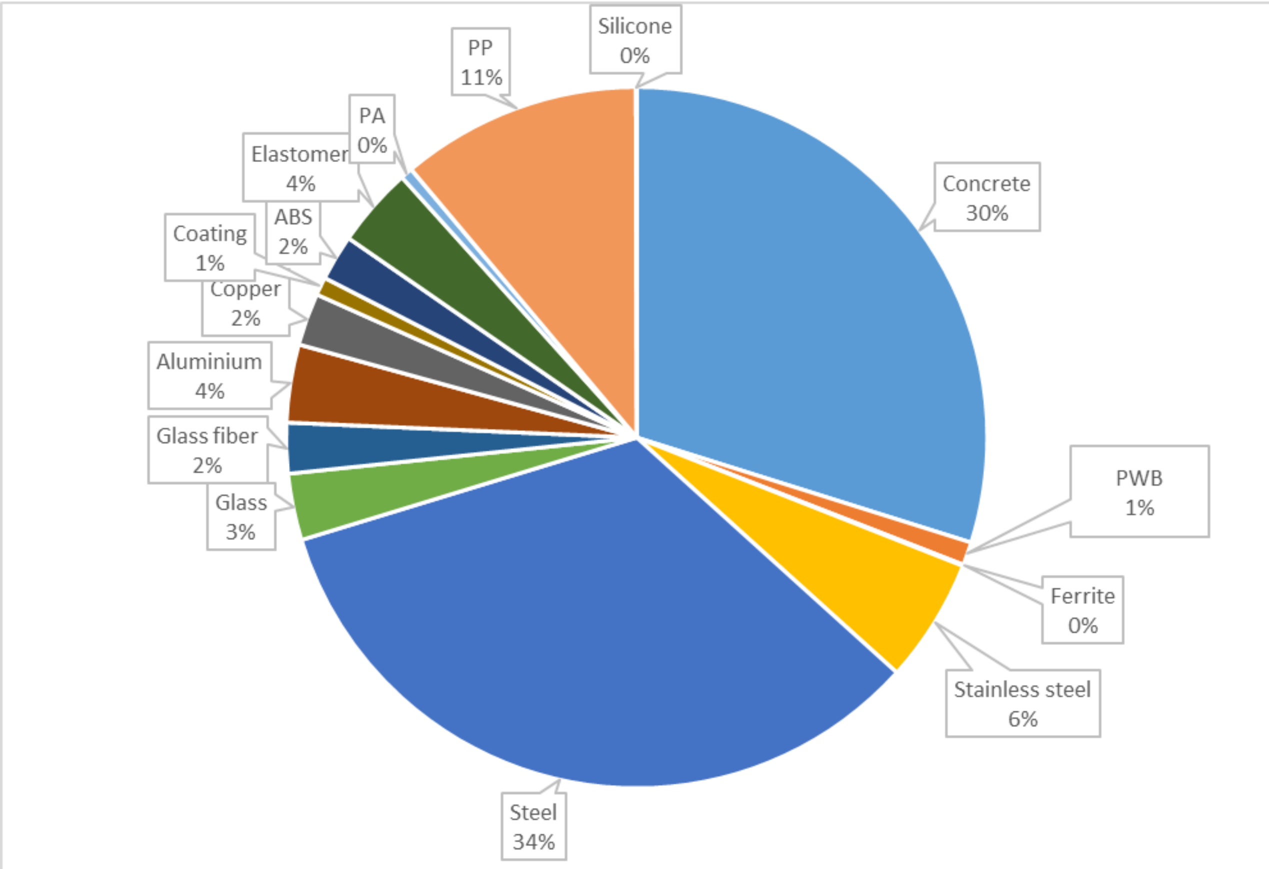


Figure 9: Masses per material type for base case 1

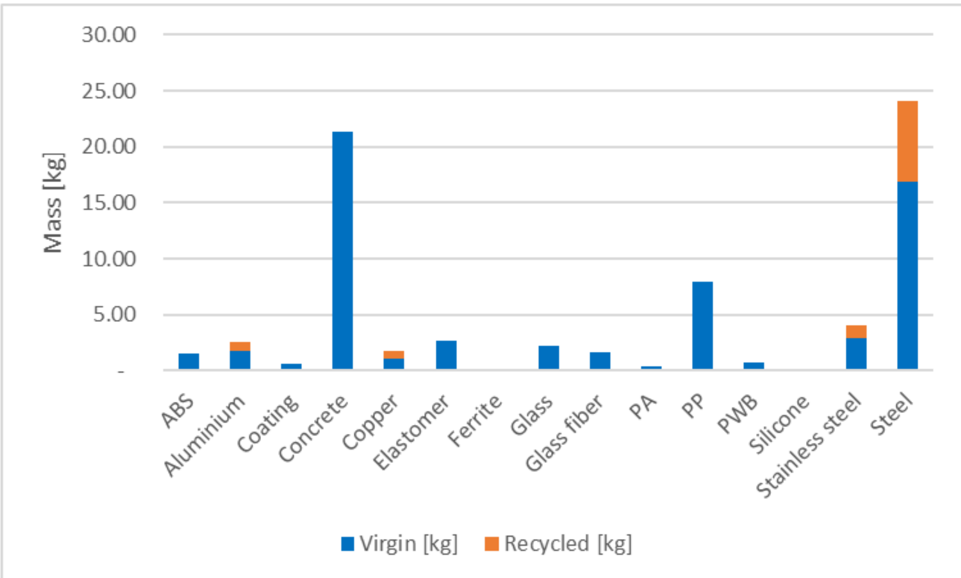


Figure 10: Virgin and recycled material in input, baseline, base case 1

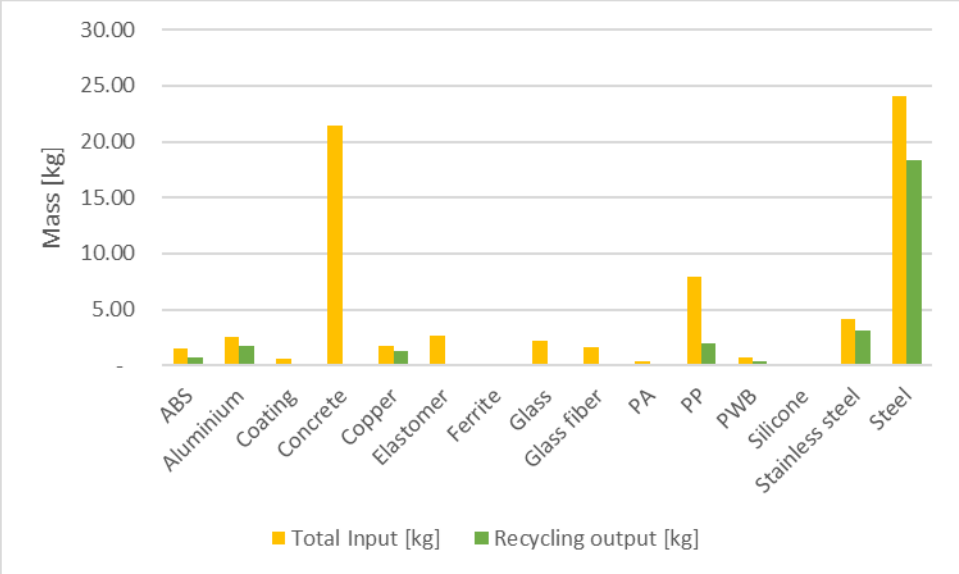


Figure 11: Total material input and recycled material output, baseline, base case 1

5.7. Environmental impacts for the baseline

5.7.1. Impacts from all materials

The baseline environmental impacts for base case 1 (washing machine 8 kg) in Table 16 and Figure 12 have been computed using the 2024 EcoReportTool. They are based on the BoM and factors R1, R2 and A of Table 14. Only impacts from raw materials and end-of-life impacts and credits have been considered [166].

Table 16 is split in two parts. The first part gives the mass and the impacts for the first 7 environmental parameters; the second part gives the impacts for the remaining 8 parameters [167]. The table shows the total impacts, i.e. the sum of raw material impact, EoL impact and EoL credit for virgin material avoidance (negative impact), and the impact shares, per material category. The impacts are for a unit product (over its lifetime).

Figure 12 gives the shares of each material category in the total environmental impacts.

[166] The current study focuses on material aspects. The impacts from manufacturing, distribution, use and repair and maintenance will be added later in the ongoing review study. They are assumed not to change due to requirements on recycled material content or recyclability.

[167] Impacts for 'primary energy consumption' and for 'resource use, fossil' are the same for this product group.

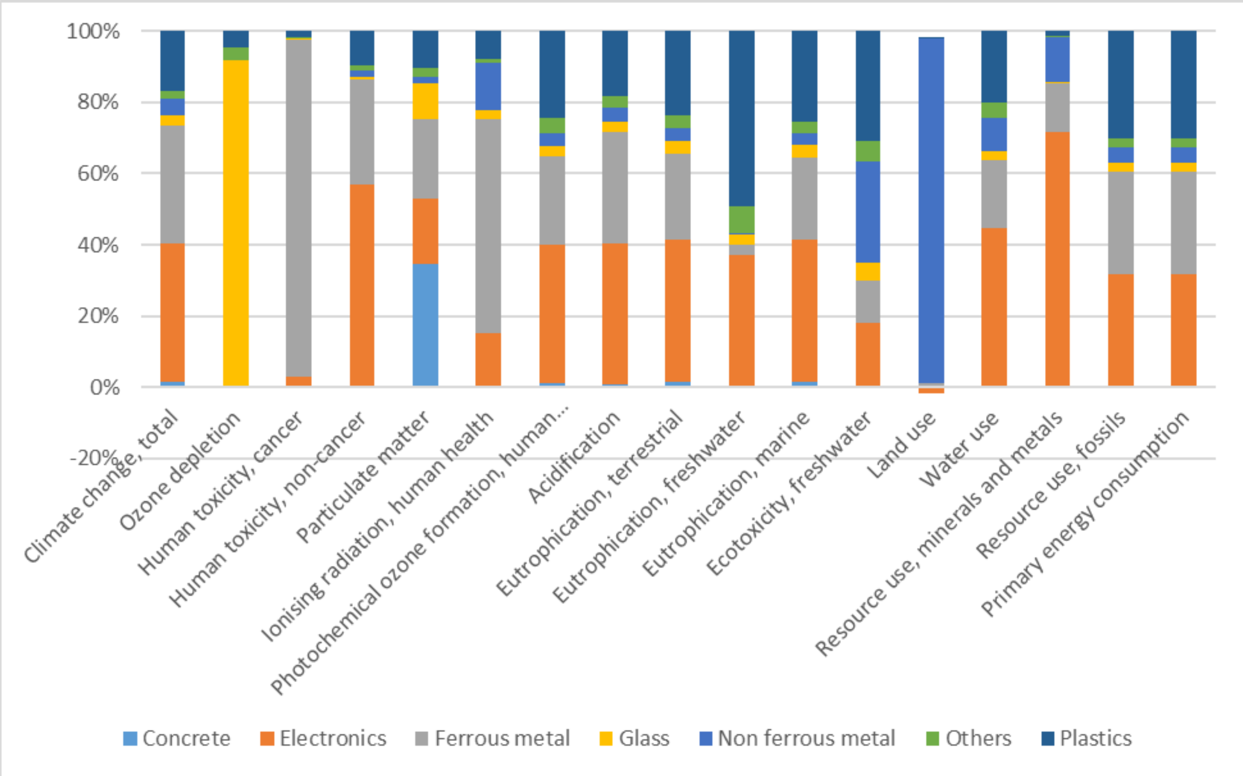


Figure 12: Shares in total environmental impacts per material category, for base case 1 (washing machine 8 kg), for the baseline.

Table 16: Baseline Environmental impacts for base case 1 (washing machine 8 kg), computed using the 2024 EcoReportTool. This considers only impacts from raw materials and end-of-life impacts and benefits. Impacts per unit product (over its lifetime).

Material	Mass [kg]	Climate change, total [kg CO2 eq]	Ozone depletion [kg CFC-11 eq]	Human toxicity, cancer [CTUh]	Human toxicity, non-cancer [CTUh]	Particulate matter [disease incidence]	Ionising radiation, human health [kBq U235 eq]	Photochemical ozone formation, human health [kg NMVOC eq]	Acidification [mol H+ eq]
Concrete	21.40	3.04E+00	9.31E-12	3.69E-10	2.23E-08	8.39E-06	1.82E-02	6.67E-03	7.26E-03
share	*30%*	*2%*	*0%*	*0%*	*1%*	*35%*	*0%*	*1%*	*1%*
Electronics	0.77	7.70E+01	1.08E-08	2.96E-08	2.08E-06	4.39E-06	2.44E+00	1.90E-01	3.44E-01
share	*1%*	*39%*	*0%*	*3%*	*56%*	*18%*	*15%*	*39%*	*40%*
Ferrous metal	28.24	6.47E+01	7.87E-09	1.00E-06	1.09E-06	5.44E-06	9.64E+00	1.23E-01	2.72E-01
share	*39%*	*33%*	*0%*	*95%*	*29%*	*23%*	*60%*	*25%*	*31%*
Glass	3.87	6.07E+00	2.86E-06	1.61E-09	2.74E-08	2.39E-06	4.32E-01	1.48E-02	2.39E-02
share	*5%*	*3%*	*91%*	*0%*	*1%*	*10%*	*3%*	*3%*	*3%*
Non ferrous metal	4.31	8.89E+00	1.96E-09	2.25E-09	6.30E-08	4.20E-07	2.10E+00	1.69E-02	3.48E-02
share	*6%*	*5%*	*0%*	*0%*	*2%*	*2%*	*13%*	*3%*	*4%*
Others	0.60	4.77E+00	1.13E-07	3.19E-09	4.76E-08	5.98E-07	1.81E-01	2.22E-02	2.84E-02
share	*1%*	*2%*	*4%*	*0%*	*1%*	*2%*	*1%*	*5%*	*3%*
Plastics	12.53	3.29E+01	1.45E-07	1.74E-08	3.59E-07	2.53E-06	1.27E+00	1.20E-01	1.58E-01
share	*17%*	*17%*	*5%*	*2%*	*10%*	*10%*	*8%*	*24%*	*18%*
Total	**71.72**	**1.97E+02**	**3.13E-06**	**1.06E-06**	**3.69E-06**	**2.42E-05**	**1.61E+01**	**4.94E-01**	**8.68E-01**

Material	Eutrophication, terrestrial [mol N eq]	Eutrophication, freshwater [kg P eq]	Eutrophication, marine [kg N eq]	Ecotoxicity, freshwater [CTUe]	Land use [pt]	Water use [m3 water eq. of deprived water]	Resource use, minerals and metals [kg Sb eq]	Resource use, fossils [MJ]	Primary energy consumption [MJ]
Concrete	0.03	7.62E-07	2.46E-03	3.92E+00	5.45E+00	1.74E-01	9.51E-08	1.71E+01	1.71E+01
share	*2%*	*0%*	*2%*	*0%*	*0%*	*0%*	*0%*	*1%*	*1%*
Electronics	0.68	9.34E-04	6.54E-02	2.88E+02	-1.77E+02	2.30E+01	5.76E-03	8.90E+02	8.90E+02
share	*40%*	*37%*	*40%*	*18%*	*-2%*	*44%*	*72%*	*31%*	*31%*
Ferrous metal	0.41	7.20E-05	3.76E-02	1.93E+02	1.35E+02	1.00E+01	1.10E-03	8.32E+02	8.32E+02
share	*24%*	*3%*	*23%*	*12%*	*1%*	*19%*	*14%*	*29%*	*29%*
Glass	0.07	7.55E-05	5.67E-03	8.34E+01	6.86E+00	1.19E+00	1.18E-05	7.11E+01	7.11E+01
share	*4%*	*3%*	*3%*	*5%*	*0%*	*2%*	*0%*	*2%*	*2%*
Non ferrous metal	0.06	6.76E-06	5.42E-03	4.58E+02	1.06E+04	4.95E+00	1.03E-03	1.26E+02	1.26E+02
share	*3%*	*0%*	*3%*	*28%*	*100%*	*10%*	*13%*	*4%*	*4%*
Others	0.06	1.93E-04	5.53E-03	9.45E+01	1.57E+01	2.18E+00	1.40E-05	7.13E+01	7.13E+01
share	*3%*	*8%*	*3%*	*6%*	*0%*	*4%*	*0%*	*2%*	*2%*
Plastics	0.40	1.24E-03	4.14E-02	5.00E+02	3.07E+01	1.04E+01	1.13E-04	8.60E+02	8.60E+02
share	*24%*	*49%*	*25%*	*31%*	*0%*	*20%*	*1%*	*30%*	*30%*
Total	**1.70**	**2.52E-03**	**1.63E-01**	**1.62E+03**	**1.06E+04**	**5.19E+01**	**8.03E-03**	**2.87E+03**	**2.87E+03**

5.7.2. Impact comparison, materials versus non-materials

Table 17 and Figure 13 compare the baseline material and end-of-life impacts with the impacts from the whole life cycle, which includes:[168]

- Manufacturing/Assembly
- Packaging
- Distribution
- Use phase (183 cycles/a and 12.5 years per machine)

[168] Assumptions from Task 5 of the Review Study, see: https://ecodesign-washing-machines.eu/ewm/documents/

  - Electricity: 135 kWh/a (0.739 kWh/cycle)
  - Water: 11.39 m^3/a (62 l/cycle)
  - Detergent: 10.4 kg/a (57 gr/cycle)
- Maintenance and repair

The table also indicates the absolute values of the environmental impacts as well as the share for the life cycle phases of the product.

For ‘Human toxicity, cancer’ (44%), ‘Land use’ (49%) and ‘resource use minerals’ (65%), material impacts are high.

Table 17: Baseline Environmental impacts for base case 1, comparison of impacts from raw materials and end-of-life impacts and benefits with impacts from all life phases. Impacts per unit product (over its lifetime).

	Climate change, total [kg CO2 eq]	Ozone depletion [kg CFC-11 eq]	Human toxicity, cancer [CTUh]	Human toxicity, non-cancer [CTUh]	Particulate matter [disease incidence]	Ionising radiation, human health [kBq U235 eq]	Photochemical ozone formation, human health [kg NMVOC eq]	Acidification [mol H+ eq]
Material & EoL	1.96E+02	3.13E-06	1.06E-06	3.68E-06	2.42E-05	1.61E+01	4.91E-01	8.66E-01
share	*15.0%*	*17.9%*	*43.9%*	*18.2%*	*29.0%*	*4.5%*	*17.4%*	*17.3%*
Manufacturing/Assembly	1.25E+01	4.43E-09	5.32E-11	1.31E-07	7.25E-07	5.08E+00	2.55E-02	4.16E-02
share	*1.0%*	*0.0%*	*0.0%*	*0.6%*	*0.9%*	*1.4%*	*0.9%*	*0.8%*
Packaging	2.90E+00	1.94E-09	2.47E-09	2.61E-08	9.91E-08	1.29E-01	9.31E-03	8.66E-03
share	*0.2%*	*0.0%*	*0.1%*	*0.1%*	*0.1%*	*0.0%*	*0.3%*	*0.2%*
Distribution	8.17E+00	9.38E-11	2.17E-09	5.27E-08	2.62E-07	1.47E-01	2.90E-02	3.19E-02
share	*0.6%*	*0.0%*	*0.1%*	*0.3%*	*0.3%*	*0.0%*	*1.0%*	*0.6%*
Use phase	1.09E+03	1.44E-05	1.32E-06	1.62E-05	5.78E-05	3.39E+02	2.27E+00	4.05E+00
share	*83.0%*	*81.9%*	*54.8%*	*80.4%*	*69.4%*	*94.0%*	*80.2%*	*80.8%*
Maintenance and repair	2.50E+00	3.15E-08	2.78E-08	5.46E-08	3.03E-07	1.58E-01	6.43E-03	1.26E-02
share	*0.2%*	*0.2%*	*1.2%*	*0.3%*	*0.4%*	*0.0%*	*0.2%*	*0.3%*
Total	**1.31E+03**	**1.75E-05**	**2.41E-06**	**2.02E-05**	**8.34E-05**	**3.60E+02**	**2.83E+00**	**5.01E+00**
Material & EoL	1.96E+02	3.13E-06	1.06E-06	3.68E-06	2.42E-05	1.61E+01	4.91E-01	8.66E-01
share	*15.0%*	*17.9%*	*43.9%*	*18.2%*	*29.0%*	*4.5%*	*17.4%*	*17.3%*
Other	1.11E+03	1.44E-05	1.35E-06	1.65E-05	5.92E-05	3.44E+02	2.34E+00	4.15E+00
share	*85.0%*	*82.1%*	*56.1%*	*81.8%*	*71.0%*	*95.5%*	*82.6%*	*82.7%*
	Eutrophication, terrestrial [mol N eq]	**Eutrophication, freshwater [kg P eq]**	**Eutrophication, marine [kg N eq]**	**Ecotoxicity, freshwater [CTUe]**	**Land use [pt]**	**Water use [m3 water eq. of deprived water]**	**Resource use, minerals and metals [kg Sb eq]**	**Resource use, fossils [MJ]**
Material & EoL	1.69E+00	2.52E-03	1.63E-01	1.61E+03	1.06E+04	5.29E+01	8.03E-03	2.84E+03
share	*15.3%*	*4.7%*	*10.3%*	*14.9%*	*48.7%*	*1.8%*	*64.8%*	*13.6%*
Manufacturing/Assembly	1.01E-01	2.98E-05	9.44E-03	6.52E+01	8.51E+01	4.77E+00	4.61E-06	2.36E+02
share	*0.9%*	*0.1%*	*0.6%*	*0.6%*	*0.4%*	*0.2%*	*0.0%*	*1.1%*
Packaging	2.43E-02	3.12E-05	2.39E-03	3.92E+01	2.30E+02	3.96E-01	1.41E-06	7.72E+01
share	*0.2%*	*0.1%*	*0.2%*	*0.4%*	*1.1%*	*0.0%*	*0.0%*	*0.4%*
Distribution	1.53E-01	4.91E-05	1.37E-02	7.55E+01	6.30E+01	7.57E-01	5.41E-06	1.17E+02
share	*1.4%*	*0.1%*	*0.9%*	*0.7%*	*0.3%*	*0.0%*	*0.0%*	*0.6%*
Use phase	9.09E+00	5.13E-02	1.39E+00	8.99E+03	1.05E+04	2.95E+03	4.23E-03	1.76E+04
share	*82.0%*	*95.1%*	*87.9%*	*83.2%*	*48.2%*	*98.0%*	*34.1%*	*84.2%*
Maintenance and repair	2.18E-02	2.72E-05	2.07E-03	2.45E+01	2.96E+02	6.36E-01	1.24E-04	3.36E+01
share	*0.2%*	*0.1%*	*0.1%*	*0.2%*	*1.4%*	*0.0%*	*1.0%*	*0.2%*
Total	**1.11E+01**	**5.40E-02**	**1.58E+00**	**1.08E+04**	**2.17E+04**	**3.01E+03**	**1.24E-02**	**2.09E+04**
Material & EoL	1.69E+00	2.52E-03	1.63E-01	1.61E+03	1.06E+04	5.29E+01	8.03E-03	2.84E+03
share	*15.3%*	*4.7%*	*10.3%*	*14.9%*	*48.7%*	*1.8%*	*64.8%*	*13.6%*
Other	9.39E+00	5.14E-02	1.42E+00	9.20E+03	1.11E+04	2.96E+03	4.36E-03	1.81E+04
share	*84.7%*	*95.3%*	*89.7%*	*85.1%*	*51.3%*	*98.2%*	*35.2%*	*86.4%*

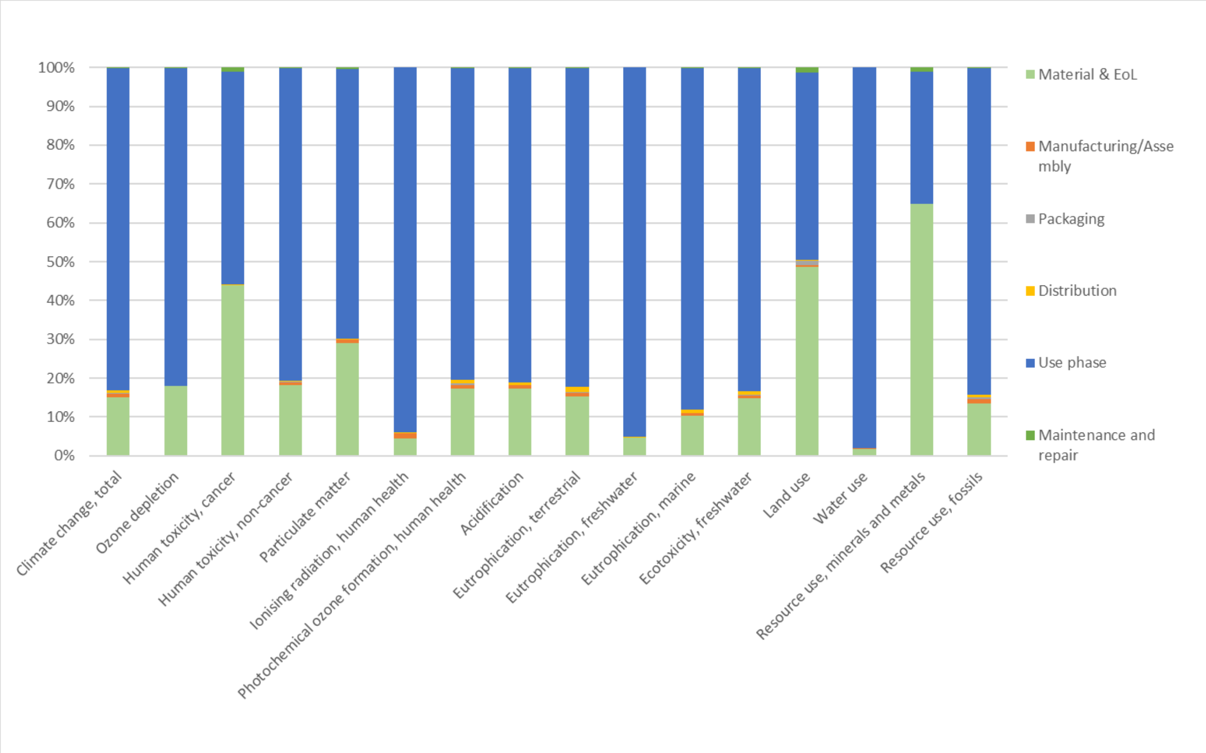


Figure 13: Impact shares from materials & end-of-life and from use-phase electricity consumption, per environmental impact category, for base case 1, for the baseline.

5.7.3. Impacts from plastics

Table 18 shows details for the impacts from plastics. Like the previous table, it is split in two parts, covering different parameters. For the major types of plastics used in washing machines, the table shows the raw material impact (mat), the end-of-life impact (eol-i), the end-of-life credit (eol-c), the sum of these (total), and the share of the total impact in the overall impact from all materials (including also non-plastics; in blue).

Figure 14 shows the shares in total environmental impacts from plastics per type of plastic (top), and the shares per plastic type in total environmental impacts of all materials.

For ABS, the impact of virgin material on 'water use' is negative and consequently, the EoL credit is positive [169]. No evidence was found that the production of ABS produces water. The ERT datasets for ABS should be verified for this.

[169] For this reason, the bar graph for water use does not total 100%

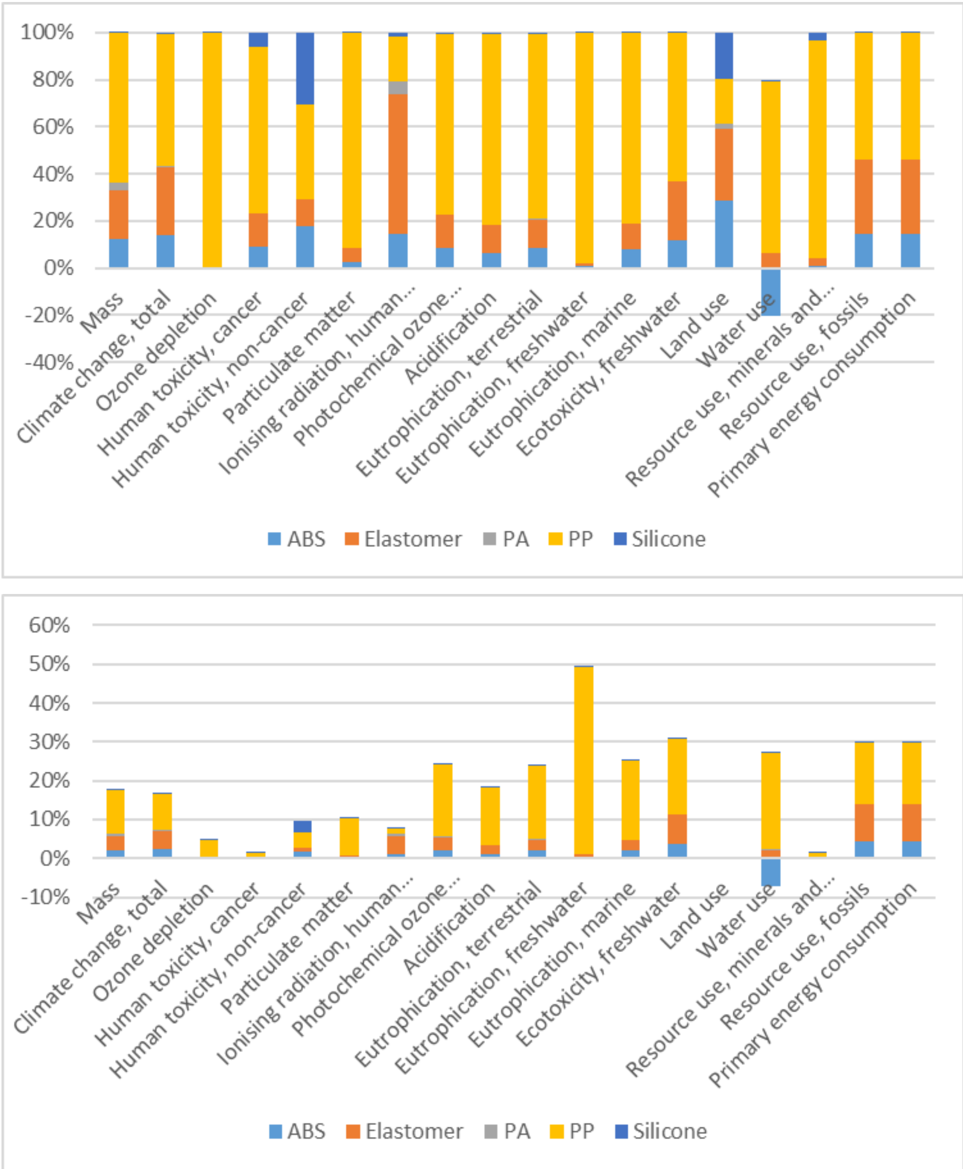


Figure 14: Shares in total environmental impacts from plastics per type of plastic (top), and shares per plastic type in total environmental impacts, for base case 1, for the baseline.

Table 18: Baseline Environmental impacts from plastics for base case 1.

		Mass [kg]	**Climate change, total [kg CO2 eq]**	**Ozone depletion [kg CFC-11 eq]**	**Human toxicity, cancer [CTUh]**	**Human toxicity, non-cancer [CTUh]**	**Particulate matter [disease incidence]**	**Ionising radiation, human health [kBq U235 eq]**	**Photochemical ozone formation, human health [kg NMVOC eq]**	**Acidification [mol H+ eq]**
ABS	Mat	1.51	4.66E+00	1.34E-10	1.58E-09	6.45E-08	6.67E-08	1.82E-01	1.03E-02	9.69E-03
ABS	EoL-i	1.51	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ABS	EoL-c	1.51	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ABS	Total	1.51	4.66E+00	1.34E-10	1.58E-09	6.45E-08	6.67E-08	1.82E-01	1.03E-02	9.69E-03
ABS	*Share*	*2.1%*	*2.4%*	*0.0%*	*0.1%*	*1.7%*	*0.3%*	*1.1%*	*2.1%*	*1.1%*
Elastomer	Mat	2.64	9.42E+00	5.62E-10	2.43E-09	3.93E-08	1.46E-07	7.55E-01	1.68E-02	1.89E-02
Elastomer	EoL-i	2.64	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Elastomer	EoL-c	2.64	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Elastomer	Total	2.64	9.42E+00	5.62E-10	2.43E-09	3.93E-08	1.46E-07	7.55E-01	1.68E-02	1.89E-02
Elastomer	*Share*	*3.7%*	*4.8%*	*0.0%*	*0.2%*	*1.1%*	*0.6%*	*4.7%*	*3.4%*	*2.2%*

PA	Mat	0.4	1.72E-01	6.06E-11	1.87E-11	6.36E-10	4.83E-09	6.74E-02	3.33E-04	4.75E-04
PA	EoL-i	0.4	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PA	EoL-c	0.4	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PA	Total	0.4	1.72E-01	6.06E-11	1.87E-11	6.36E-10	4.83E-09	6.74E-02	3.33E-04	4.75E-04
PA	*Share*	*0.6%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.4%*	*0.1%*	*0.1%*
PP	Mat	7.95	2.06E+01	1.64E-07	1.38E-08	1.62E-07	2.55E-06	2.76E-01	1.04E-01	1.44E-01
PP	EoL-i	7.95	4.82E-01	4.57E-10	2.49E-10	2.39E-09	7.71E-08	1.69E-03	8.66E-04	1.98E-03
PP	EoL-c	7.95	-2.57E+00	-2.05E-08	-1.72E-09	-2.02E-08	-3.18E-07	-3.44E-02	-1.30E-02	-1.80E-02
PP	Total	7.95	1.85E+01	1.44E-07	1.23E-08	1.44E-07	2.31E-06	2.43E-01	9.22E-02	1.28E-01
PP	*Share*	*11.1%*	*9.4%*	*4.6%*	*1.2%*	*3.9%*	*9.6%*	*1.5%*	*18.7%*	*14.8%*
Silicone	Mat	0.03	1.85E-01	5.65E-13	1.06E-09	1.10E-07	6.81E-09	2.33E-02	4.80E-04	6.20E-04
Silicone	EoL-i	0.03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Silicone	EoL-c	0.03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Silicone	Total	0.03	1.85E-01	5.65E-13	1.06E-09	1.10E-07	6.81E-09	2.33E-02	4.80E-04	6.20E-04
Silicone	*Share*	*0.0%*	*0.1%*	*0.0%*	*0.1%*	*3.0%*	*0.0%*	*0.1%*	*0.1%*	*0.1%*
Sum	Mat	12.53	3.50E+01	1.65E-07	1.89E-08	3.77E-07	2.78E-06	1.30E+00	1.32E-01	1.74E-01
Sum	EoL-i	12.53	4.82E-01	4.57E-10	2.49E-10	2.39E-09	7.71E-08	1.69E-03	8.66E-04	1.98E-03
Sum	EoL-c	12.53	-2.57E+00	-2.05E-08	-1.72E-09	-2.02E-08	-3.18E-07	-3.44E-02	-1.30E-02	-1.80E-02
Sum	Total	12.53	3.29E+01	1.45E-07	1.74E-08	3.59E-07	2.53E-06	1.27E+00	1.20E-01	1.58E-01
Sum	*Share*	*17.5%*	*16.7%*	*4.6%*	*1.6%*	*9.7%*	*10.5%*	*7.9%*	*24.3%*	*18.2%*

		Eutrophication, terrestrial [mol N eq]	Eutrophication, freshwater [kg P eq]	Eutrophication, marine [kg N eq]	Ecotoxicity, freshwater [CTUe]	Land use [pt]	Water use [m3 water eq. of deprived water]	Resource use, minerals and metals [kg Sb eq]	Resource use, fossils [MJ]	Primary energy consumption [MJ]
ABS	Mat	3.51E-02	1.09E-05	3.35E-03	5.80E+01	8.72E+00	-3.66E+00	7.79E-07	1.26E+02	1.26E+02
ABS	EoL-i	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ABS	EoL-c	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ABS	Total	3.51E-02	1.09E-05	3.35E-03	5.80E+01	8.72E+00	-3.66E+00	7.79E-07	1.26E+02	1.26E+02
ABS	*Share*	*2.1%*	*0.4%*	*2.1%*	*3.6%*	*0.1%*	*-7.0%*	*0.0%*	*4.4%*	*4.4%*
Elastomer	Mat	4.76E-02	1.55E-05	4.43E-03	1.25E+02	9.51E+00	1.14E+00	4.07E-06	2.69E+02	2.69E+02
Elastomer	EoL-i	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Elastomer	EoL-c	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Elastomer	Total	4.76E-02	1.55E-05	4.43E-03	1.25E+02	9.51E+00	1.14E+00	4.07E-06	2.69E+02	2.69E+02
Elastomer	*Share*	*2.8%*	*0.6%*	*2.7%*	*7.7%*	*0.1%*	*2.2%*	*0.1%*	*9.4%*	*9.4%*
PA	Mat	1.24E-03	4.26E-07	1.16E-04	9.01E-01	6.49E-01	2.10E-02	6.84E-08	3.18E+00	3.18E+00
PA	EoL-i	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PA	EoL-c	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
PA	Total	1.24E-03	4.26E-07	1.16E-04	9.01E-01	6.49E-01	2.10E-02	6.84E-08	3.18E+00	3.18E+00
PA	*Share*	*0.1%*	*0.0%*	*0.1%*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.1%*	*0.1%*
PP	Mat	3.61E-01	1.38E-03	3.78E-02	3.58E+02	4.56E+00	1.45E+01	1.18E-04	5.21E+02	5.21E+02
PP	EoL-i	3.30E-03	6.55E-06	2.91E-04	1.44E+00	1.77E+00	1.28E-01	1.43E-06	2.94E+00	2.94E+00
PP	EoL-c	-4.51E-02	-1.72E-04	-4.72E-03	-4.47E+01	-5.69E-01	-1.82E+00	-1.47E-05	-6.51E+01	-6.51E+01
PP	Total	3.20E-01	1.21E-03	3.34E-02	3.15E+02	5.77E+00	1.29E+01	1.05E-04	4.59E+02	4.59E+02
PP	*Share*	*18.8%*	*48.1%*	*20.4%*	*19.4%*	*0.1%*	*24.8%*	*1.3%*	*16.0%*	*16.0%*
Silicone	Mat	1.50E-03	2.88E-07	1.38E-04	8.03E-01	6.08E+00	5.76E-02	3.62E-06	2.99E+00	2.99E+00
Silicone	EoL-i	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Silicone	EoL-c	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Silicone	Total	1.50E-03	2.88E-07	1.38E-04	8.03E-01	6.08E+00	5.76E-02	3.62E-06	2.99E+00	2.99E+00
Silicone	*Share*	*0.1%*	*0.0%*	*0.1%*	*0.0%*	*0.1%*	*0.1%*	*0.0%*	*0.1%*	*0.1%*
Sum	Mat	4.47E-01	1.40E-03	4.58E-02	5.43E+02	2.95E+01	1.21E+01	1.27E-04	9.22E+02	9.22E+02
Sum	EoL-i	3.30E-03	6.55E-06	2.91E-04	1.44E+00	1.77E+00	1.28E-01	1.43E-06	2.94E+00	2.94E+00
Sum	EoL-c	-4.51E-02	-1.72E-04	-4.72E-03	-4.47E+01	-5.69E-01	-1.82E+00	-1.47E-05	-6.51E+01	-6.51E+01
Sum	Total	4.05E-01	1.24E-03	4.14E-02	5.00E+02	3.07E+01	1.04E+01	1.13E-04	8.60E+02	8.60E+02
Sum	*Share*	*23.8%*	*49.2%*	*25.3%*	*30.9%*	*0.3%*	*20.1%*	*1.4%*	*30.0%*	*30.0%*

5.7.4. Impacts from metals

Table 19 shows details for the impacts from ferrous metals, aluminium and copper. The type of information is the same as in the previous table for plastics.

Figure 15 shows the shares in total environmental impacts from metals per type of metal (top), and the shares per metal type in the total environmental impacts of all materials.

Note that for metals, the baseline assumes 30% (aluminium, steel) or 37% (copper) recycled content in input (R1=30%/37%) and that the allocation factor A is 20% (i.e. 20% of the impacts/benefits of EoL recycling is assigned to the inputs for the production, and 80% to the EoL processing). This means that the raw material impacts ('mat') are a mix of the impacts from virgin materials e.g. (1-R1*A = 1-30%*20% = 94%) and recycled materials e.g. (R1*A = 30%*20% = 6%). In addition, for metals, the recycling output rate R2 is high (70-76%).

Comments:

- Stainless steel has a dominant share of environmental impacts in the category 'human toxicity, cancer' (95%)'.
- For copper, the share of environmental impacts in the total impact from all materials is lower than its mass share (2.4%), except for 'land use' (99%) and 'resource use, minerals and metals' (52%). The high 'land use' share for non-ferrous signalled in Table 16 comes from the copper. The ERT dataset 61 should be verified for this [170].

[170] The study team compared the ERT dataset 61 for copper against datasets from other sources. In the other datasets, land use impacts are 2 or 3 orders of magnitude lower than in the ERT. However, the other datasets have much higher impacts for most of the other impact categories, especially for ozone depletion, ionising radiation and eutrophication freshwater.

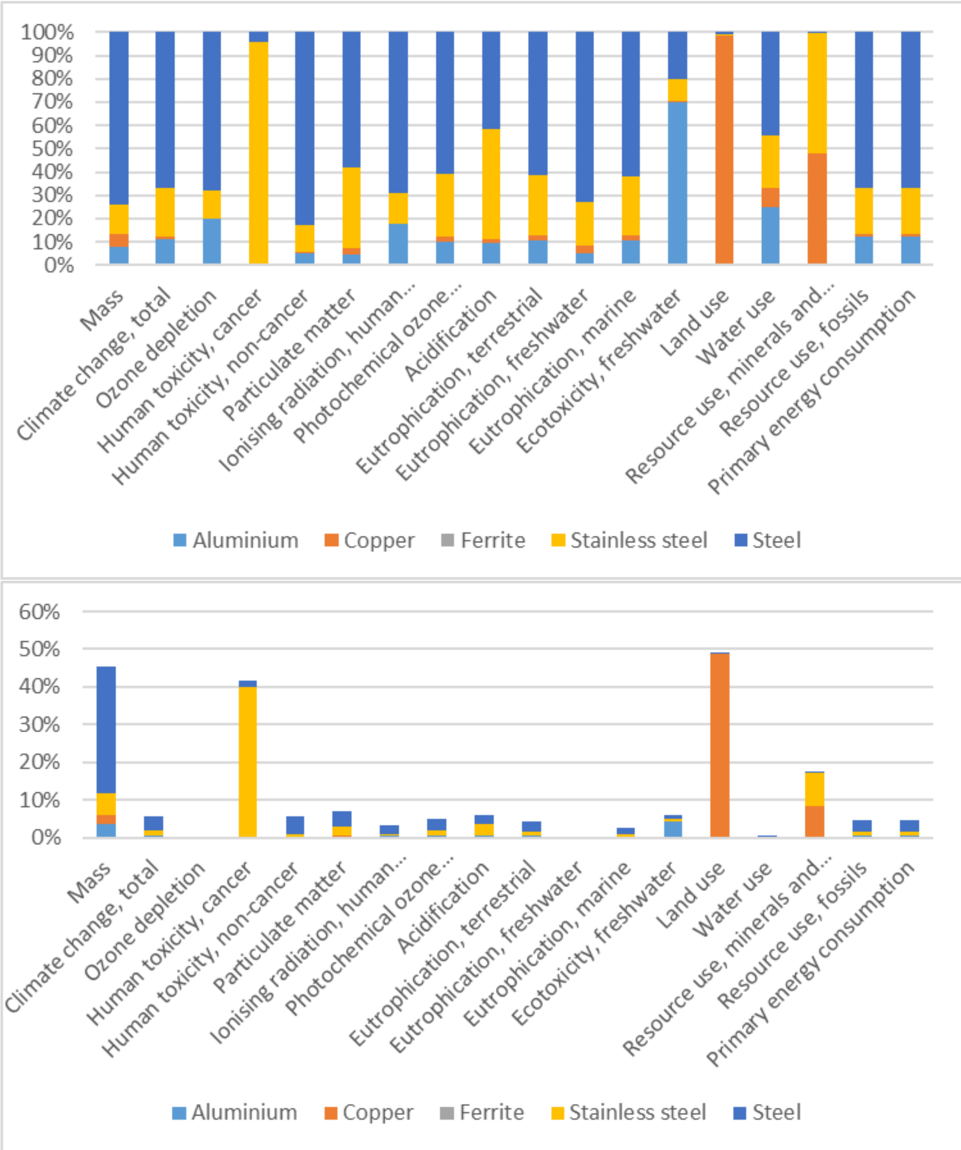


Figure 15: Shares in total environmental impacts from metals per type of metal (top), and shares per metal type in total environmental impacts, for base case 1, for the baseline.

Table 19: Baseline Environmental impacts from ferrous metals, aluminium and copper for base case 1.

		Summe von Mass [kg]	Summe von Climate change, total	Summe von Ozone depletion	Summe von Human toxicity, cancer	Summe von Human toxicity, non-cancer	Summe von Particulate matter	Summe von Ionising radiation, human health	Summe von Photochemical ozone formation, human health	Summe von Acidification
Aluminium	Mat	2.58	1.85E+01	4.80E-09	4.50E-09	1.42E-07	6.55E-07	5.13E+00	3.21E-02	6.99E-02
Aluminium	EoL-i	2.58	7.89E-01	1.78E-12	8.68E-11	2.10E-09	1.50E-08	8.57E-03	1.11E-03	1.42E-03
Aluminium	EoL-c	2.58	-1.09E+01	-2.86E-09	-2.67E-09	-8.47E-08	-3.89E-07	-3.06E+00	-1.90E-02	-4.15E-02
Aluminium	Total	2.58	8.30E+00	1.94E-09	1.91E-09	5.98E-08	2.81E-07	2.08E+00	1.42E-02	2.97E-02
Aluminium	*Share*	*3.6%*	*4.2%*	*0.1%*	*0.2%*	*1.6%*	*1.2%*	*13.0%*	*2.9%*	*3.4%*
Copper	Mat	1.73	1.51E+00	9.63E-12	9.17E-10	7.73E-09	3.83E-07	1.12E-02	7.32E-03	1.37E-02
Copper	EoL-i	1.73	3.53E-02	9.08E-12	8.04E-12	3.30E-10	1.26E-09	1.05E-02	9.44E-05	1.38E-04
Copper	EoL-c	1.73	-9.64E-01	-5.43E-12	-5.86E-10	-4.92E-09	-2.45E-07	-6.30E-03	-4.67E-03	-8.74E-03
Copper	Total	1.73	5.84E-01	1.33E-11	3.39E-10	3.14E-09	1.40E-07	1.54E-02	2.74E-03	5.09E-03

Copper	*Share*	*2.4%*	*0.3%*	*0.0%*	*0.0%*	*0.1%*	*0.6%*	*0.1%*	*0.6%*	*0.6%*
Ferrite	Mat	0.04	9.92E-04	3.63E-14	4.76E-13	6.86E-12	1.59E-09	3.15E-05	4.81E-06	8.40E-06
Ferrite	EoL-i	0.04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ferrite	EoL-c	0.04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ferrite	Total	0.04	9.92E-04	3.63E-14	4.76E-13	6.86E-12	1.59E-09	3.15E-05	4.81E-06	8.40E-06
Ferrite	*Share*	*0.1%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
Stainless steel	Mat	4.11	3.01E+01	2.11E-10	2.70E-06	3.21E-07	5.01E-06	5.20E-01	8.64E-02	3.79E-01
Stainless steel	EoL-i	4.11	4.46E+00	1.05E-09	5.78E-09	2.24E-08	2.65E-07	1.26E+00	6.67E-03	1.04E-02
Stainless steel	EoL-c	4.11	-1.92E+01	-6.97E-11	-1.74E-06	-2.06E-07	-3.22E-06	-2.56E-01	-5.55E-02	-2.45E-01
Stainless steel	Total	4.11	1.54E+01	1.19E-09	9.59E-07	1.37E-07	2.05E-06	1.53E+00	3.76E-02	1.45E-01
Stainless steel	*Share*	*5.7%*	*7.8%*	*0.0%*	*90.8%*	*3.7%*	*8.5%*	*9.5%*	*7.6%*	*16.7%*
Steel	Mat	24.09	6.08E+01	3.84E-10	1.89E-08	2.30E-06	4.93E-06	6.53E-01	1.23E-01	1.75E-01
Steel	EoL-i	24.09	2.61E+01	6.15E-09	3.39E-08	1.31E-07	1.55E-06	7.41E+00	3.91E-02	6.10E-02
Steel	EoL-c	24.09	-3.76E+01	1.44E-10	-1.01E-08	-1.48E-06	-3.09E-06	5.09E-02	-7.68E-02	-1.09E-01
Steel	Total	24.09	4.93E+01	6.68E-09	4.27E-08	9.52E-07	3.39E-06	8.11E+00	8.49E-02	1.27E-01
Steel	*Share*	*33.6%*	*25.0%*	*0.2%*	*4.0%*	*25.8%*	*14.0%*	*50.4%*	*17.2%*	*14.6%*
Sum	Mat	32.55	1.11E+02	5.41E-09	2.72E-06	2.77E-06	1.10E-05	6.31E+00	2.48E-01	6.38E-01
Sum	EoL-i	32.55	3.14E+01	7.21E-09	3.97E-08	1.56E-07	1.83E-06	8.69E+00	4.70E-02	7.30E-02
Sum	EoL-c	32.55	-6.87E+01	-2.79E-09	-1.76E-06	-1.78E-06	-6.95E-06	-3.27E+00	-1.56E-01	-4.04E-01
Sum	Total	32.55	7.35E+01	9.83E-09	1.00E-06	1.15E-06	5.87E-06	1.17E+01	1.39E-01	3.07E-01
Sum	*Share*	*45.4%*	*37.3%*	*0.3%*	*95.1%*	*31.2%*	*24.3%*	*73.0%*	*28.3%*	*35.3%*

		Summe von Eutrophication, terrestrial	**Summe von Eutrophication, freshwater**	**Summe von Eutrophication, marine**	**Summe von Ecotoxicity, freshwater**	**Summe von Land use**	**Summe von Water use**	**Summe von Resource use, minerals and metals**	**Summe von Resource use, fossils**	**Summe von Primary energy consumption**
Aluminium	Mat	1.11E-01	9.38E-06	1.02E-02	1.12E+03	1.98E+01	9.19E+00	1.15E-05	2.63E+02	2.63E+02
Aluminium	EoL-i	3.96E-03	2.53E-07	3.60E-04	1.58E+00	7.85E-01	1.01E-02	8.37E-08	1.16E+01	1.16E+01
Aluminium	EoL-c	-6.60E-02	-5.57E-06	-6.05E-03	-6.65E+02	-1.18E+01	-5.47E+00	-6.86E-06	-1.56E+02	-1.56E+02
Aluminium	Total	4.92E-02	4.06E-06	4.50E-03	4.53E+02	8.84E+00	3.73E+00	4.75E-06	1.18E+02	1.18E+02
Aluminium	*Share*	*2.9%*	*0.2%*	*2.8%*	*28.0%*	*0.1%*	*7.2%*	*0.1%*	*4.1%*	*4.1%*
Copper	Mat	2.69E-02	7.18E-06	2.43E-03	1.22E+01	2.92E+04	3.36E+00	2.83E-03	1.81E+01	1.81E+01
Copper	EoL-i	4.39E-04	1.07E-07	4.03E-05	1.97E-01	1.70E-01	9.45E-03	9.82E-09	5.68E-01	5.68E-01
Copper	EoL-c	-1.72E-02	-4.58E-06	-1.55E-03	-7.81E+00	-1.87E+04	-2.15E+00	-1.81E-03	-1.15E+01	-1.15E+01
Copper	Total	1.02E-02	2.70E-06	9.21E-04	4.63E+00	1.05E+04	1.22E+00	1.02E-03	7.14E+00	7.14E+00
Copper	*Share*	*0.6%*	*0.1%*	*0.6%*	*0.3%*	*99.8%*	*2.4%*	*12.7%*	*0.2%*	*0.2%*
Ferrite	Mat	1.80E-05	3.67E-08	1.76E-06	1.12E-02	2.21E-02	1.33E-04	1.57E-09	1.14E-02	1.14E-02
Ferrite	EoL-i	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ferrite	EoL-c	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ferrite	Total	1.80E-05	3.67E-08	1.76E-06	1.12E-02	2.21E-02	1.33E-04	1.57E-09	1.14E-02	1.14E-02
Ferrite	*Share*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*
Stainless steel	Mat	2.72E-01	2.14E-05	2.38E-02	1.34E+02	3.90E+01	6.62E+00	3.10E-03	3.32E+02	3.32E+02
Stainless steel	EoL-i	2.46E-02	6.49E-06	2.29E-03	1.49E+01	1.41E+01	1.01E+00	8.99E-07	7.20E+01	7.20E+01
Stainless steel	EoL-c	-1.74E-01	-1.34E-05	-1.52E-02	-8.56E+01	-2.43E+01	-4.22E+00	-2.00E-03	-2.10E+02	-2.10E+02
Stainless steel	Total	1.22E-01	1.45E-05	1.08E-02	6.30E+01	2.88E+01	3.41E+00	1.10E-03	1.94E+02	1.94E+02
Stainless steel	*Share*	*7.2%*	*0.6%*	*6.6%*	*3.9%*	*0.3%*	*6.6%*	*13.6%*	*6.8%*	*6.8%*
Steel	Mat	3.82E-01	4.83E-05	3.52E-02	1.04E+02	4.96E+01	9.40E-01	6.63E-06	5.37E+02	5.37E+02
Steel	EoL-i	1.44E-01	3.80E-05	1.34E-02	8.71E+01	8.29E+01	5.89E+00	5.27E-06	4.22E+02	4.22E+02

Steel	EoL-c	-2.38E-01	-2.88E-05	-2.19E-02	-6.18E+01	-2.68E+01	-2.32E-01	-3.95E-06	-3.20E+02	-3.20E+02
Steel	Total	2.88E-01	5.75E-05	2.67E-02	1.29E+02	1.06E+02	6.60E+00	7.95E-06	6.38E+02	6.38E+02
Steel	Share	*16.9%*	*2.3%*	*16.4%*	*8.0%*	*1.0%*	*12.7%*	*0.1%*	*22.3%*	*22.3%*
Sum	Mat	7.92E-01	8.63E-05	7.16E-02	1.37E+03	2.93E+04	2.01E+01	5.95E-03	1.15E+03	1.15E+03
Sum	EoL-i	1.73E-01	4.49E-05	1.61E-02	1.04E+02	9.80E+01	6.92E+00	6.26E-06	5.06E+02	5.06E+02
Sum	EoL-c	-4.95E-01	-5.24E-05	-4.47E-02	-8.21E+02	-1.88E+04	-1.21E+01	-3.83E-03	-6.98E+02	-6.98E+02
Sum	Total	4.70E-01	7.88E-05	4.30E-02	6.50E+02	1.07E+04	1.50E+01	2.13E-03	9.58E+02	9.58E+02
Sum	Share	*27.6%*	*3.1%*	*26.3%*	*40.2%*	*101.1%*	*28.8%*	*26.5%*	*33.4%*	*33.4%*

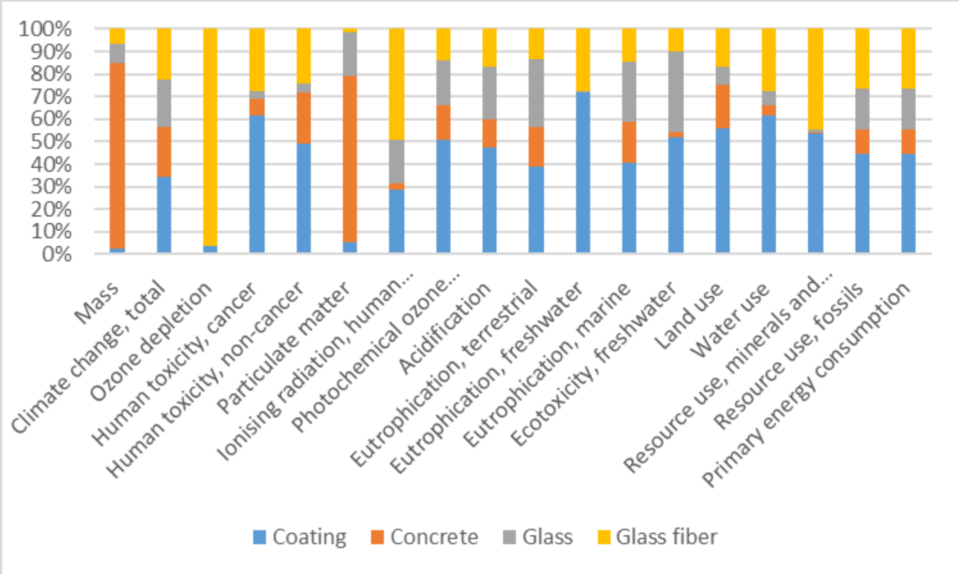
5.7.5. Impacts from other materials

Table 20 shows details for the impacts from other materials than plastics and metals. The type of information is the same as in the previous tables for plastics and metals.

Figure 16 shows the shares in total environmental impacts from other materials than plastics and metals (top), and the shares per material type in the total environmental impacts of all materials.

Comments:

- Glass fibre has a dominant share of environmental impacts in the category 'ozone depletion' (96%)'. The ERT datasets might need reviewing.
- Concrete has a dominant share of environmental impacts in the category 'particulate maters' (74%)', but represents 83% of the weight of the "others" materials.
- For coating, the share of environmental impacts in the total impact from "other" materials is much higher than its mass share (2.3%). It is the material with a dominating share in 13 of 16 impact categories.



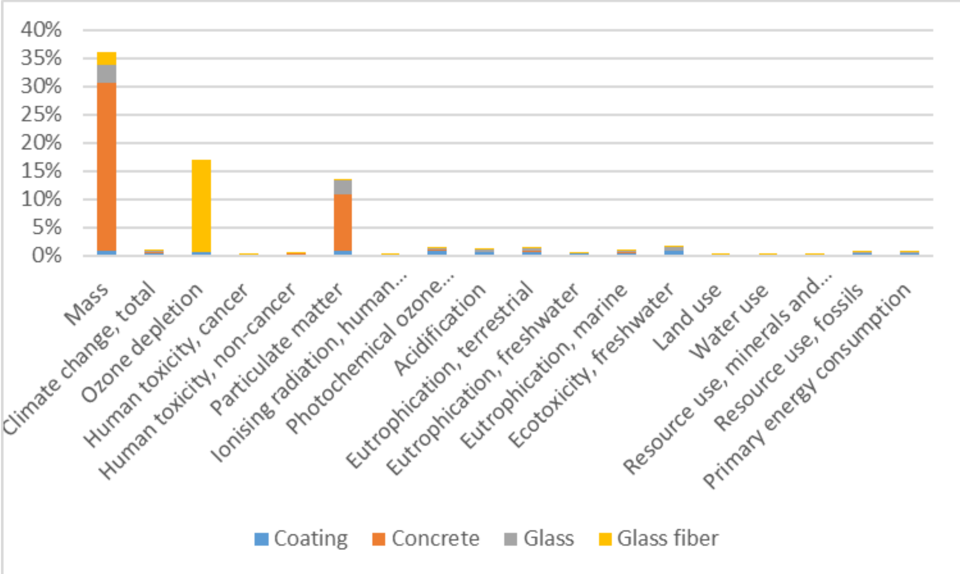


Figure 16: Shares in total environmental impacts from "others" per type of material (top), and shares per material type in total environmental impacts, for base case 1, for the baseline.

Table 20: Baseline Environmental impacts from "others" for base case 1.

		Mass [kg]	Climate change, total [kg CO2 eq]	Ozone depletion [kg CFC-11 eq]	Human toxicity, cancer [CTUh]	Human toxicity, non-cancer [CTUh]	Particulate matter [disease incidence]	Ionising radiation, human health [kBq U235 eq]	Photochemical ozone formation, human health [kg NMVOC eq]	Acidification [mol H+ eq]
Coating	Mat	0.60	4.77E+00	1.13E-07	3.19E-09	4.76E-08	5.98E-07	1.81E-01	2.22E-02	2.84E-02
Coating	EoL-i	0.60	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Coating	EoL-c	0.60	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Coating	Total	0.60	4.77E+00	1.13E-07	3.19E-09	4.76E-08	5.98E-07	1.81E-01	2.22E-02	2.84E-02
Coating	*Share*	*0.8%*	*2.4%*	*3.6%*	*0.3%*	*1.3%*	*2.5%*	*1.1%*	*4.5%*	*3.3%*

		85.6	6.0724941	1.86246E-11	7.38875E-10	4.46098E-08	1.67784E-05	0.036406412	0.013333194	0.014522473
Concrete	Mat	21.40	3.04E+00	9.31E-12	3.69E-10	2.23E-08	8.39E-06	1.82E-02	6.67E-03	7.26E-03
Concrete	EoL-i	21.40	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Concrete	EoL-c	21.40	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Concrete	Total	21.40	3.04E+00	9.31E-12	3.69E-10	2.23E-08	8.39E-06	1.82E-02	6.67E-03	7.26E-03
Concrete	*Share*	*29.8%*	*1.5%*	*0.0%*	*0.0%*	*0.6%*	*34.7%*	*0.1%*	*1.4%*	*0.8%*
		8.8	5.962286061	1.79201E-10	3.83968E-10	7.22804E-09	4.42116E-06	0.246122471	0.017543749	0.027781465
Glass	Mat	2.20	2.98E+00	8.96E-11	1.92E-10	3.61E-09	2.21E-06	1.23E-01	8.77E-03	1.39E-02
Glass	EoL-i	2.20	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Glass	EoL-c	2.20	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Glass	Total	2.20	2.98E+00	8.96E-11	1.92E-10	3.61E-09	2.21E-06	1.23E-01	8.77E-03	1.39E-02
Glass	*Share*	*3.1%*	*1.5%*	*0.0%*	*0.0%*	*0.1%*	*9.1%*	*0.8%*	*1.8%*	*1.6%*
		6.68	6.182706376	5.71168E-06	2.84397E-09	4.74784E-08	3.64663E-07	0.617249317	0.011969289	0.019985027
Glass fiber	Mat	1.67	3.09E+00	2.86E-06	1.42E-09	2.37E-08	1.82E-07	3.09E-01	5.98E-03	9.99E-03
Glass fiber	EoL-i	1.67	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Glass fiber	EoL-c	1.67	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Glass fiber	Total	1.67	3.09E+00	2.86E-06	1.42E-09	2.37E-08	1.82E-07	3.09E-01	5.98E-03	9.99E-03
Glass fiber	*Share*	*2.3%*	*1.6%*	*91.1%*	*0.1%*	*0.6%*	*0.8%*	*1.9%*	*1.2%*	*1.2%*
		3.072	154.045185	2.16203E-08	5.92284E-08	4.1699E-06	8.77819E-06	4.880494497	0.380747226	0.688394711
PWB	Mat	0.77	7.75E+01	1.08E-08	2.97E-08	2.09E-06	4.47E-06	2.45E+00	1.93E-01	3.51E-01
PWB	EoL-i	0.77	1.08E-01	4.35E-13	1.12E-11	1.18E-09	5.39E-10	5.18E-04	1.35E-04	7.17E-05
PWB	EoL-c	0.77	-6.04E-01	-9.90E-12	-6.03E-11	-2.01E-09	-7.71E-08	-7.94E-03	-3.07E-03	-6.89E-03
PWB	Total	0.77	7.70E+01	1.08E-08	2.96E-08	2.08E-06	4.39E-06	2.44E+00	1.90E-01	3.44E-01
PWB	*Share*	*1.1%*	*39.0%*	*0.3%*	*2.8%*	*56.4%*	*18.2%*	*15.2%*	*38.6%*	*39.7%*
Sum	Mat	26.64	9.14E+01	2.98E-06	3.48E-08	2.18E-06	1.58E-05	3.08E+00	2.37E-01	4.11E-01
Sum	EoL-i	26.64	1.08E-01	4.35E-13	1.12E-11	1.18E-09	5.39E-10	5.18E-04	1.35E-04	7.17E-05
Sum	EoL-c	26.64	-6.04E-01	-9.90E-12	-6.03E-11	-2.01E-09	-7.71E-08	-7.94E-03	-3.07E-03	-6.89E-03
Sum	Total	26.64	9.09E+01	2.98E-06	3.48E-08	2.18E-06	1.58E-05	3.07E+00	2.34E-01	4.04E-01
Sum	*Share*	*37.1%*	*46.1%*	*95.1%*	*3.3%*	*59.1%*	*65.2%*	*19.1%*	*47.4%*	*46.5%*

		Eutrophication, terrestrial [mol N eq]	Eutrophication, freshwater [kg P eq]	Eutrophication, marine [kg N eq]	Ecotoxicity, freshwater [CTUe]	Land use [pt]	Water use [m3 water eq. of deprived water]	Resource use, minerals and metals [kg Sb eq]	Resource use, fossils [MJ]	Primary energy consumption [MJ]
Coating	Mat	0.06	1.93E-04	5.53E-03	9.45E+01	1.57E+01	2.18E+00	1.40E-05	7.13E+01	7.13E+01
Coating	EoL-i	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Coating	EoL-c	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Coating	Total	0.06	1.93E-04	5.53E-03	9.45E+01	1.57E+01	2.18E+00	1.40E-05	7.13E+01	7.13E+01
Coating	*Share*	*3.5%*	*7.7%*	*3.4%*	*5.8%*	*0.1%*	*4.2%*	*0.0%*	*0.0%*	*0.0%*
		0.053931794	1.52311E-06	0.004923741	7.849407564	10.90410005	0.348866891	1.90206E-07	34.24297736	34.24297736
Concrete	Mat	0.03	7.62E-07	2.46E-03	3.92E+00	5.45E+00	1.74E-01	9.51E-08	1.71E+01	1.71E+01
Concrete	EoL-i	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Concrete	EoL-c	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Concrete	Total	0.03	7.62E-07	2.46E-03	3.92E+00	5.45E+00	1.74E-01	9.51E-08	1.71E+01	1.71E+01
Concrete	*Share*	*1.6%*	*0.0%*	*1.5%*	*0.2%*	*0.1%*	*0.3%*	*0.0%*	*0.0%*	*0.0%*
		0.090166922	2.74512E-06	0.007448686	131.0677101	4.197585451	0.442823693	4.24285E-07	58.67113886	58.67113886
Glass	Mat	0.05	1.37E-06	3.72E-03	6.55E+01	2.10E+00	2.21E-01	2.12E-07	2.93E+01	2.93E+01
Glass	EoL-i	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Glass	EoL-c	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Glass	Total	0.05	1.37E-06	3.72E-03	6.55E+01	2.10E+00	2.21E-01	2.12E-07	2.93E+01	2.93E+01
Glass	*Share*	*2.6%*	*0.1%*	*2.3%*	*4.0%*	*0.0%*	*0.4%*	*0.0%*	*0.0%*	*0.0%*
		0.041088989	0.000148306	0.003886458	35.80267276	9.528006166	1.933080055	2.32261E-05	83.48922282	83.48922282
Glass fiber	Mat	0.02	7.42E-05	1.94E-03	1.79E+01	4.76E+00	9.67E-01	1.16E-05	4.17E+01	4.17E+01

Glass fiber	EoL-i	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Glass fiber	EoL-c	0.00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Glass fiber	Total	0.02	7.42E-05	1.94E-03	1.79E+01	4.76E+00	9.67E-01	1.16E-05	4.17E+01	4.17E+01
Glass fiber	*Share*	*1.2%*	*2.9%*	*1.2%*	*1.1%*	*0.0%*	*1.9%*	*0.0%*	*0.0%*	*0.0%*
		1.352745044	0.001867389	0.130734233	575.452566	-354.4416391	46.05025251	0.011513373	1779.879578	1779.879578
PWB	Mat	0.69	9.34E-04	6.63E-02	2.89E+02	1.50E+02	2.31E+01	6.30E-03	8.97E+02	8.97E+02
PWB	EoL-i	0.00	1.17E-07	6.64E-05	1.19E-01	2.56E-01	3.62E-02	1.06E-08	-1.20E-01	-1.20E-01
PWB	EoL-c	-0.01	-1.94E-07	-1.04E-03	-8.95E-01	-3.27E+02	-1.07E-01	-5.41E-04	-6.55E+00	-6.55E+00
PWB	Total	0.68	9.34E-04	6.54E-02	2.88E+02	-1.77E+02	2.30E+01	5.76E-03	8.90E+02	8.90E+02
PWB	*Share*	*39.7%*	*37.0%*	*40.0%*	*17.8%*	*-1.7%*	*44.3%*	*0.0%*	*0.0%*	*0.0%*
		0	0	0	0	0	0	0	0	0
Sum	Mat	0.84	1.20E-03	8.00E-02	4.70E+02	1.78E+02	2.66E+01	6.32E-03	1.06E+03	1.06E+03
Sum	EoL-i	0.00	1.17E-07	6.64E-05	1.19E-01	2.56E-01	3.62E-02	1.06E-08	-1.20E-01	-1.20E-01
Sum	EoL-c	-0.01	-1.94E-07	-1.04E-03	-8.95E-01	-3.27E+02	-1.07E-01	-5.41E-04	-6.55E+00	-6.55E+00
Sum	Total	0.83	1.20E-03	7.90E-02	4.70E+02	-1.49E+02	2.66E+01	5.78E-03	1.05E+03	1.05E+03
Sum	*Share*	*48.6%*	*47.7%*	*48.4%*	*29.0%*	*-1.4%*	*51.1%*	*0.0%*	*0.0%*	*0.0%*

6. MEERP TASK 6, DESIGN OPTIONS

6.1. Impact reduction due to recycled content

6.1.1. Increasing the recycled content of plastics

6.1.1.1. Reduction of material and end-of-life impacts

This paragraph discusses the reduction in environmental impacts for a product when the (post-consumer) recycled content (factor R1) for plastics (PP and ABS) is raised from 0% (baseline) to the following levels:

- 5%: low level
- 10%: moderate level
- 30%: ambitious level
- 100%: “max”, to show the theoretical potential[171]

Like the previously reported impacts for the baseline, only impacts from input materials, EoL impacts and EoL benefits are considered (no manufacturing, distribution, use, repair and maintenance).

Compared to the baseline, only the factors R1 for recycled content have been changed. Factors R2 (recycling output) and A (allocation factor) remain the same. This implies that EoL impact and EoL benefit do not change compared to the baseline: only the impact of materials in input to the production changes with R1.

Table 21 gives an overview of the reduction of environmental impacts compared to the baseline, when for different levels of recycled contents for plastics. As before, the table is split in two parts, showing results for different impact categories.

The total input mass for production is 71.7 kg (see section 5.5). In the baseline scenario, 61.8 kg of this consists of virgin material. This amount can be reduced by between 0.6 kg (-1%) and 12.1 kg (-19.6%) depending on the levels of recycled plastic content.

Increasing the plastic recycled content leads to reduced impacts across all categories, with the greatest benefit observed in the category ‘Photochemical ozone formation, human health’.

Table 21: Summary of the reduction of environmental impacts from materials and end-of-life, compared to the baseline, when using 5%, 10%, 30% and 100% recycled content in input to the production for plastics, for base case 1.

Scenario	Virgin Mass in input [kg]	Climate change, total [kg CO2 eq]	Ozone depletion [kg CFC-11 eq]	Human toxicity, cancer [CTUh]	Human toxicity, non-cancer [CTUh]	Particulate matter [disease incidence]	Ionising radiation, human health [kBq U235 eq]	Photochemical ozone formation, human health [kg NMVOC eq]	Acidification [mol H+ eq]
BAU	61.85	1.96E+02	3.13E-06	1.06E-06	3.68E-06	2.42E-05	1.61E+01	4.91E-01	8.66E-01
5%	-1.0%	-0.4%	-0.1%	0.0%	-0.2%	-0.2%	-0.2%	-0.6%	-0.4%
10%	-2.0%	-0.8%	-0.3%	-0.1%	-0.3%	-0.4%	-0.3%	-1.2%	-0.9%
30%	-5.9%	-2.3%	-0.8%	-0.2%	-1.0%	-1.3%	-1.0%	-3.7%	-2.7%
Max	-19.6%	-7.6%	-2.6%	-0.7%	-3.3%	-4.4%	-3.3%	-12.4%	-9.0%

[171] See also remark and limitations of the analysis at the end of section 5.4

Scenario	Eutrophication, terrestrial [mol N eq]	Eutrophication, freshwater [kg P eq]	Eutrophication, marine [kg N eq]	Ecotoxicity, freshwater [CTUe]	Land use [pt]	Water use [m3 water eq. of deprived water]	Resource use, minerals and metals [kg Sb eq]	Resource use, fossils [MJ]	Primary energy consumption [MJ]
BAU	1.69	2.52E-03	1.63E-01	1.61E+03	1.06E+04	5.29E+01	8.03E-03	2.84E+03	2.84E+03
5%	-0.6%	-1.3%	-0.7%	-0.8%	0.0%	-0.5%	0.0%	-0.8%	-0.8%
10%	-1.2%	-2.7%	-1.3%	-1.6%	0.0%	-1.0%	-0.1%	-1.6%	-1.6%
30%	-3.6%	-8.0%	-3.9%	-4.9%	0.0%	-3.1%	-0.2%	-4.7%	-4.7%
Max	-12.1%	-26.8%	-13.1%	-16.4%	0.0%	-10.2%	-0.7%	-15.6%	-15.6%

6.1.2. Reduction of material, end-of-life and life cycle impacts

Table 22 shows the same savings as above but compared to the baseline impacts including also the whole lifecycle of the product (see also section 5.7.2).

In this assessment, the overall impact of increasing recycled plastic content is limited. The most significant improvement is observed in the category 'ecotoxicity, freshwater', showing a reduction of -2.5% in the (theoretical) scenario 'Max'.

Table 22: Summary of the reduction of environmental impacts from the whole product lifecycle, compared to the baseline, when using, 10%, 30% and 100% recycled content in input to the production for plastics, for base case 1.

Scenario	Virgin Mass in input [kg]	Climate change, total [kg CO2 eq]	Ozone depletion [kg CFC-11 eq]	Human toxicity, cancer [CTUh]	Human toxicity, non-cancer [CTUh]	Particulate matter [disease incidence]	Ionising radiation, human health [kBq U235 eq]	Photochemical ozone formation, human health [kg NMVOC eq]	Acidification [mol H+ eq]
BAU	61.85	1.31E+03	1.75E-05	2.41E-06	2.02E-05	8.34E-05	3.60E+02	2.83E+00	5.01E+00
5%	-1.0%	-0.1%	0.0%	0.0%	0.0%	-0.1%	0.0%	-0.1%	-0.1%
10%	-2.0%	-0.1%	0.0%	0.0%	-0.1%	-0.1%	0.0%	-0.2%	-0.2%
30%	-5.9%	-0.3%	-0.1%	-0.1%	-0.2%	-0.4%	0.0%	-0.7%	-0.5%
Max	-19.6%	-1.1%	-0.5%	-0.3%	-0.6%	-1.3%	-0.1%	-2.2%	-1.6%
Scenario	Eutrophication, terrestrial [mol N eq]	Eutrophication, freshwater [kg P eq]	Eutrophication, marine [kg N eq]	Ecotoxicity, freshwater [CTUe]	Land use [pt]	Water use [m3 water eq. of deprived water]	Resource use, minerals and metals [kg Sb eq]	Resource use, fossils [MJ]	Primary energy consumption [MJ]
BAU	11.08	5.40E-02	1.58E+00	1.08E+04	2.17E+04	3.01E+03	1.24E-02	2.09E+04	2.14E+04
5%	-0.1%	-0.1%	-0.1%	-0.1%	0.0%	0.0%	0.0%	-0.1%	-0.1%
10%	-0.2%	-0.1%	-0.1%	-0.2%	0.0%	0.0%	0.0%	-0.2%	-0.2%
30%	-0.6%	-0.4%	-0.4%	-0.7%	0.0%	-0.1%	-0.1%	-0.6%	-0.6%
Max	-1.9%	-1.3%	-1.4%	-2.5%	0.0%	-0.2%	-0.5%	-2.1%	-2.1%

6.1.3. Replacing glass fibre with recycled plastic

6.1.3.1. Reduction of non-recycled material and end-of-life impacts

As mentioned in 4.1.4, to produce PP reinforced washer tubs, one manufacturer replaces 1/3 of the glass fibres by (PCR)PET.[172]

[172] See Leopet https://www.bekocorporate.com/en/technology/r-d/recycled-pet-tub/

This paragraph discusses the reduction in environmental impacts for a washing machine when replacing 33% of the glass fibre with (PCR)PET (see ‘33% rPET’) in a PP washer tub. It assumes in the baseline that the washer tub contains 30% glass fibre. In addition, a theoretical example assuming a full shift from glass fibres to (PCR)PET (100% rPET) is provided.

To take into account these design options, parameter changes had to be considered in the ERT (see Table 23).

Table 23: Parameter setting of the ERT to consider a switch from glass fibre to (PCR)PET in washer tubs

Component	**Mass kg**	**Material category**	**Virgin material dataset**	**Recycled material dataset**	**R1**	**R2**	**A**
BAU							
Oscillating system - Glass fibre	**1.67**	04-Others	222-glass fiber technology mix production mix, at plant 1 kg	not available	0%	0%	50%
33% rPET							
Oscillating system - Glass fibre	**1.12**	04-Others	222-glass fiber technology mix production mix, at plant 1 kg	not available	0%	0%	50%
Oscillating system - Glass fibre alternative	**0.55**	01-Plastics	12-Polyethylene terephthalate (PET), petrochemical based polymerisation of ethylene glycol and terephthalic acid production mix, at plant petrochemical based	41-Polyethylene terephthalate (PET) granulate secondary ; no metal fraction from post-consumer waste, via washing, granulation, pelletization production mix, at plant 90% recycling rate	100 %	0%	50%
100% rPET							
Oscillating system - Glass fibre alternative	**1.67**	01-Plastics	12-Polyethylene terephthalate (PET), petrochemical based polymerisation of ethylene glycol and terephthalic acid production mix, at plant petrochemical based	41-Polyethylene terephthalate (PET) granulate secondary ; no metal fraction from post-consumer waste, via washing, granulation, pelletization production mix, at plant 90% recycling rate	100 %	0%	50%

Like the previously reported impacts for the baseline, only impacts from input materials, EoL impacts and EoL benefits are considered (no manufacturing, distribution, use, repair and maintenance).

Table 21 gives and overview of the reduction of environmental impacts compared to the baseline, when for different scenarios. As before, the table is split in two parts, showing results for different impact categories.

The total input mass for production is 71.7 kg (see section 5.4). In the baseline scenario, 61.8 kg of this consists of virgin material. This amount can be reduced by between 0.6 kg (-0.9%) and 1.7 kg (-2.7%) depending on the level of substitution.

Replacing glass fibres with (PCR)PET has a limited environmental impact, generally resulting in increase across most categories. For 'climate change,' the effect is nearly neutral. The most significant benefit is a substantial decrease in the 'ozone depletion' impact, with a reduction of 91% in the 100% scenario where glass fibres are fully replaced by (PCR)PET. However, this result should be verified, as highlighted in section 5.7.5, the ERT datasets for glass fibre might need reviewing.

Table 24: Summary of the reduction of environmental impacts from materials and end-of-life, compared to the baseline, when replacing 33% and 100% of the glass fibres by recycled PET in input to the production for the washer tub of base case 1.

Scenario	Virgin Mass in input [kg]	Climate change, total [kg CO2 eq]	Ozone depletion [kg CFC-11 eq]	Human toxicity, cancer [CTUh]	Human toxicity, non-cancer [CTUh]	Particulate matter [disease incidence]	Ionising radiation, human health [kBq U235 eq]	Photochemical ozone formation, human health [kg NMVOC eq]	Acidification [mol H+ eq]
BAU	61.84	1.96E+02	3.13E-06	1.06E-06	3.68E-06	2.42E-05	1.61E+01	4.91E-01	8.66E-01
33%	-0.9%	0.0%	-30.0%	0.0%	0.0%	0.4%	-0.4%	0.8%	0.6%
100%	-2.7%	0.0%	-90.8%	0.1%	-0.1%	1.2%	-1.1%	2.5%	1.9%
Scenario	**Virgin Mass in input [kg]**	**Eutrophication, terrestrial [mol N eq]**	**Eutrophication, freshwater [kg P eq]**	**Eutrophication, marine [kg N eq]**	**Ecotoxicity, freshwater [CTUe]**	**Land use [pt]**	**Water use [m3 water eq. of deprived water]**	**Resource use, minerals and metals [kg Sb eq]**	**Resource use, fossils [MJ]**
33%	61.84	1.69E+00	2.52E-03	1.63E-01	1.61E+03	1.06E+04	5.29E+01	8.03E-03	2.84E+03
100%	-0.9%	0.9%	0.5%	0.9%	0.4%	0.0%	0.2%	0.1%	0.3%
BAU	-2.7%	2.8%	1.6%	2.6%	1.4%	0.0%	0.5%	0.2%	0.8%

6.1.4. Reduction of material, end-of-life and life cycle impacts

Table 22 shows the same savings as above but compared to the baseline impacts including also the whole lifecycle of the product (see also section 5.7.2).

In this assessment, the overall impact of substitution rate of glass fibre by (PCR)PET recycled is not noticeable, with the exception of the impact category 'ozone depletion'. A full replacement of glass fibres with (PCR)PET would result in a 16.4% reduction of the impact. However, ERT datasets for glass fibres might need reviewing.

Table 25: Summary of the reduction of environmental impacts from the whole product lifecycle, compared to the baseline, when replacing 33% and 100% of the glass fibres by recycled PET in input to the production for the washer tub of base case 1.

Scenario	Virgin Mass in input [kg]	Climate change, total [kg CO2 eq]	Ozone depletion [kg CFC-11 eq]	Human toxicity, cancer [CTUh]	Human toxicity, non-cancer [CTUh]	Particulate matter [disease incidence]	Ionising radiation, human health [kBq U235 eq]	Photochemical ozone formation, human health [kg NMVOC eq]	Acidification [mol H+ eq]
BAU	61.84	1.31E+03	1.75E-05	2.41E-06	2.02E-05	8.34E-05	3.60E+02	2.83E+00	5.01E+00
33%	-0.9%	0.0%	-5.4%	0.0%	0.0%	0.1%	0.0%	0.1%	0.1%
100%	-2.7%	0.0%	-16.4%	0.0%	0.0%	0.4%	-0.1%	0.4%	0.3%
Scenario	**Virgin Mass in input [kg]**	**Eutrophication, terrestrial [mol N eq]**	**Eutrophication, freshwater [kg P eq]**	**Eutrophication, marine [kg N eq]**	**Ecotoxicity, freshwater [CTUe]**	**Land use [pt]**	**Water use [m3 water eq. of deprived water]**	**Resource use, minerals and metals [kg Sb eq]**	**Resource use, fossils [MJ]**
33%	61.84	1.11E+01	5.40E-02	1.58E+00	1.08E+04	2.17E+04	3.01E+03	1.24E-02	2.09E+04
100%	-0.9%	0.1%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%
Scenario	-2.7%	0.4%	0.1%	0.3%	0.2%	0.0%	0.0%	0.1%	0.1%

6.1.5. Metals

For base case 1, metals represent 46% of the mass (sections 5.3 and 5.6). Most of this is ferrous metal (various types of steel and stainless steel, 39.4%). Non-ferrous metals are 6.0% of the total washing machine mass, split in 3.6% aluminium and 2.4% copper [173], in addition, there is 0.1% ferrite.

For the baseline scenario it has been assumed that the recycled metal content in the input to washing machine manufacturing is 30% for ferrous metal and aluminium, and 37% for copper (see section 5.5.3).

During the stakeholder meeting following phase 1 of the present study, there seemed to be agreement that setting minimum recycled content requirements on metals is not useful. The recycling chain for metals is well established. Due the limited availability of waste metal supply (as it depends on the volume of old cars and appliances, etc., that are scrapped), , introducing minimum ecodesign requirements for recycled metals in home appliances might lead to a shift of supply of metals with recycled content between sectors that use steel, such as e.g. the construction industry. . Hence, such requirements were believed not to assist the recycling industry, resolve waste stream problems, or reduce environmental impacts. Consequently, setting minimum recycled content requirements on metals used in washing machines has not been a study focus.

This was confirmed by interviews carried out in the phase 2 of the project with some manufacturers and one EEE recycler. Solely a specialist EU copper recycler [174] explained that copper is a scarcity market, where demand is higher than supply. The main issue would be to increase end-of-life collection rates and adequately regulate exports of copper scrap and recycled copper, so that the supply of recycled material can be increased. Setting minimum recycled content requirements for copper in e.g. appliances or electric motors was anyway judged positively by the copper recycler. They indicated that, to be meaningful, the required recycled content should be at least 60%, for pre- and post-consumer recycled content together (see also remarks in section 5.5.3). For comparison, the battery regulation [175], requires a recycled copper content of 85% from 2031 (sum of pre- and post-consumer recycled).

In the view of the marginal amount of copper in washing machine and as the LCA dataset in the ERT needs to be corrected, no separate calculation has been made to investigate the impact of increasing the recycled content of copper in washing machines.

6.1.6. Electronics

For base case 1, electronics represents less than 2% of the mass (sections 5.3 and 5.6).

A recycler stated to the study team that the most important aspect in materials recycling, and in electronics recycling in particular, is economic viability. For metals different from the precious Cu, Au, Pd, Pt, Ag, this is still a problem. This should be resolved first, before setting minimum recycled content requirements on electronics.

Indicatively, recycled material content requirements on electronic boards seem to have limited environmental benefits[176], but this is uncertain. In addition, costs for the manufacturers to document and certify recycled content (traceability) and costs for market surveillance to verify

[173] Some additional copper is present in the electric cables and wiring, and in the printed circuit boards, but that is counted under electronics, not under metals.

[174] https://www.montanwerke-brixlegg.com/

[175] REGULATION (EU) 2023/1542 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 12 July 2023 concerning batteries and waste batteries, amending Directive 2008/98/EC and Regulation (EU) 2019/1020 and repealing Directive 2006/66/EC, OJ L 191/1, 28.7.2023

[176] See mini-study on refrigerators

recycled content claims seem relevant. Except for the precious metals, availability of recycled material can also be an issue. If recycled materials have lower costs, manufacturers will not need legislative requirements to increase the recycled content. For critical raw materials, higher recycled content would be necessary mainly to reduce the supply risk.

Taking all factors together, for the moment no design options are considered for the recycled material content of electronic parts in washing machines.

6.1.7. Concrete

As stated in 4.1.1 and 5.4, counterweights are typically made of concrete, a material that is difficult to recycle[177]. Furthermore, although concrete represents a significant share of a washing machine's weight (approximately 30%), the absolute quantities of concrete of the washing machine market remains marginal compared to the construction sector. Accordingly, recycled content of concrete is not further investigated in this study.

From a circular economy perspective, the best approach for counterweights is to manufacture them from cast iron rather than concrete — an approach that some manufacturer like Miele[178] continues to follow. In other words, when it comes to counterweights, the choice of material (cast iron vs. concrete) plays a critical role in achieving circularity.[179]

6.1.8. Permanent magnets

As stated in 4.1.7.1, a washing machine typically contains less than 200 grams of ferrite-based permanent magnets and well below 100 grams (if any) of rare earth-based permanent magnets. The market for recycled permanent magnets remains niche, even for ferrite, as recycling costs are relatively high compared to the price of permanent magnets produced from virgin materials.

According to Article 29(3) of the CRM Act[180], by end of 2031 the latest, minimum shares of neodymium, dysprosium, praseodymium, terbium, boron, samarium, nickel, and cobalt recovered from post-consumer waste that must be present in permanent magnets in specified products, containing more than 0.2 kg of neodymium-iron-boron (NdFeB), samarium-cobalt (SmCo), or aluminium-nickel-cobalt (AlNiCo) based permanent magnets, will be set in a delegated act.

As a result, this study does not further examine the recycled content of permanent magnets in washing machines. Instead, it investigates requirements that facilitate the collection of NdFeB, SmCo, and AlNiCo permanent magnets.

[177] only downcycling is possible

[178] In addition, Miele recycles weights to produce new one. The cast-iron bearing crosses and weights from Dutch washing machines are remelted at Miele's foundry in Gütersloh, achieving a recycling rate of nearly 100 percent, see: https://www.miele.de/de/m/repair-refurbish-recycle-miele-bringt-internationale-pilotprojekte-auf-dem-weg-7380.htm

[179] However, the environmental impact of the material should be also taken into account. Cast iron is much more energy-intensive than concrete.

[180] Regulation (EU) 2024/1252 of the European Parliament and of the Council of 11 April 2024 establishing a framework for ensuring a secure and sustainable supply of critical raw materials and amending Regulations (EU) No 168/2013, (EU) 2018/858, (EU) 2018/1724 and (EU) 2019/1020Text with EEA relevance.

6.2. Economic aspects of recycled content

6.2.1. Material costs

See the general, horizontal part of the study report on recycled contents and CRMs.

According to information used in the phase 2 study on personal computers and imaging equipment, for ABS and HIPS[181], the difference between virgin and post-consumer recycled material costs were small at the end of 2024 (Figure 17), but market prices can change rapidly over time.

However, as stressed by stakeholders in the context of the 3rd stakeholder meeting, price information must be considered with cautions for the following reasons:

- For near-white applications required for washing machines (“white goods”), the price of recycled plastic might be higher than the average.
- When using recycled plastics, additional costs —often difficult to quantify— must be taken into account, among others (see also example in 6.2.3):
  - Testing and quality control efforts to ensure consistency in the rather heterogeneous recycled plastic.
  - Higher plastic consumption and/or higher demand for additives in order to meet the same requirements as virgin plastics.
  - Possible need for new injection molding tools[182] and modifications to the manufacturing process.
  - Costs associated with supply chain volatility, including fluctuations in price, quality, and availability.

[181] Not used in washing machines but shown as example here.

[182] This cost category might be relevant only for the transition period when a manufacturer switches from virgin plastics to a mix of virgin and recycled plastics.

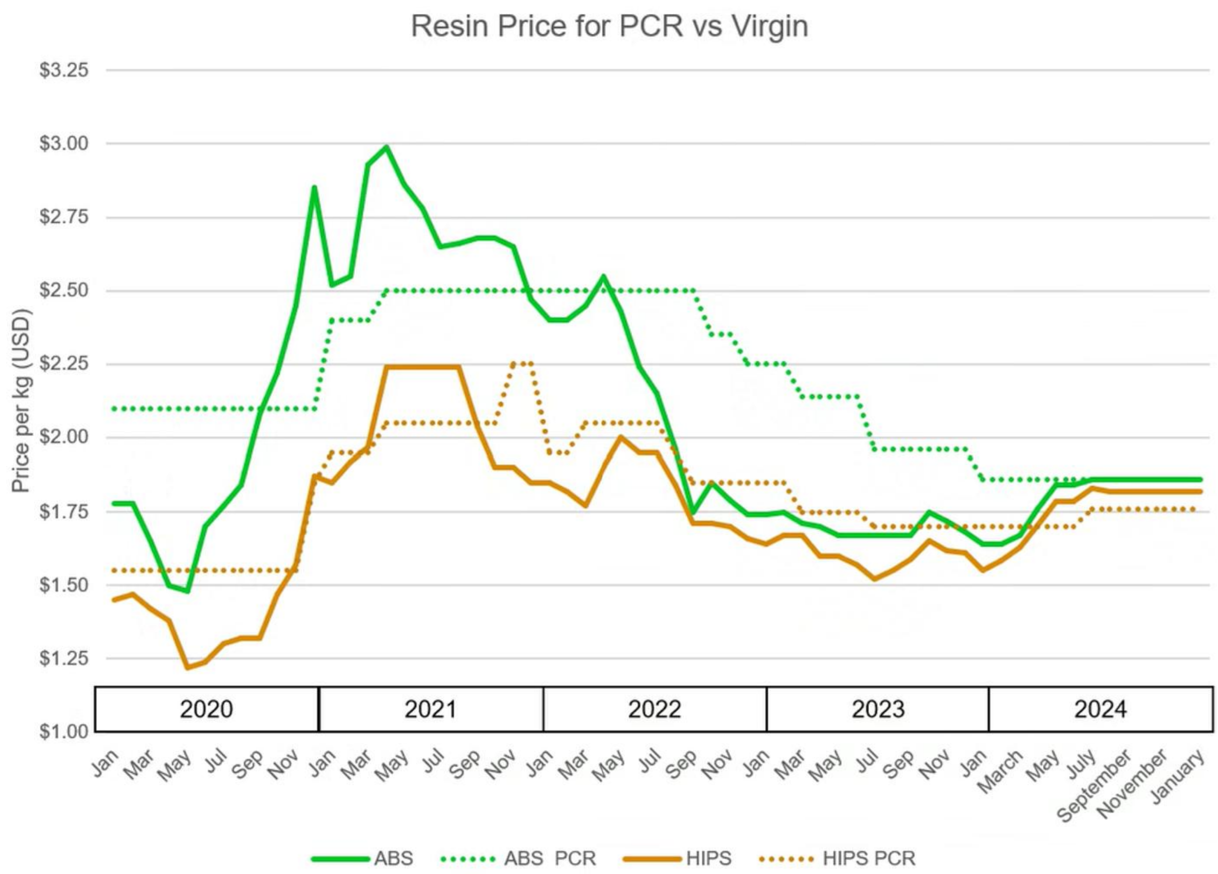


Figure 17: Comparison of prices for virgin and post-consumer recycled materials for HIPS and ABS (source: phase 2 study on imaging equipment and personal computers)

Regarding Figure 17, a stakeholder stressed that the figures may not accurately reflect the specific grades required for household appliances, which must meet stringent performance standards. Due to limited availability, regulatory hurdles, and market instability, suitable recycled materials are often more expensive than virgin plastics, raising concerns about the feasibility of mandatory recycled content requirements.

6.2.2. Development and testing costs

6.2.3. Example of Electrolux (from the mini-study on refrigerators)

Questioned on cost aspects of the use of r-HIPS, Electrolux commented that the overall handling and creation of a new material costs more compared to virgin HIPS and does increase complexity. Pricing strategies could not be disclosed, but the appliances with the recycled inner liner are sold at a premium price that is considered interesting by some consumers, and that does not generate a loss to Electrolux.

The solution based on the barrier cap layer required a specifically designed extrusion line, also due to a change in the cap layer thickness. The related investment is in the range of some millions of euros.

In addition, certification costs of € 0.5 million were sustained to be compliant with EU regulation 2022/1616 [183], as recycled plastic materials and articles intended to come into contact with foods is a relevant topic for refrigerators.

For virgin material, a continuous material quality monitoring program is not necessary. The use of recycled plastic, especially in a food contact application, requires an ongoing quality monitoring process, with costs up to at least 100,000 €/year, including personnel and certification.

The above costs are for using 70% recycled plastic in one fridge component (the body inner liner) of one fridge model (a fridge-freezer combi), and for one material type (HIPS). As declared by the manufacturer) they lead to 13% of the total fridge plastic mass coming from recycled material.

If regulation requirements on recycled plastic content are set higher, e.g. to 20 or 30%, more fridge components and more material types will likely be involved, and costs will increase. The additional costs can at least partially be shared between components of the same product (e.g. using r-HIPS for the door liner will benefit from the work already done for the body inner liner), or between similar products (e.g. built-in and free-standing models, models with different volumes or different energy classes). For a single component, e.g. body inner liner, the development and testing costs are not expected to vary much with the % of recycled content, e.g. it seems to make little difference if the body inner liner contains 30%, 50% or 70% r-HIPS.

The costs per product (potentially affecting the consumer purchase price) of increased use of recycled material depend on the number of products sold per year and on the number of years in which the additional costs are planned to be amortized.

For the estimate of the additional costs per product, it has been assumed that research and development costs are amortized in 3 years and process certification costs in 2 years. Quality monitoring costs will occur every year.

Table 26: Annual development and testing costs for obtaining 10% recycled plastic content in fridges

Cost type	Total cost (million euros)	Amortization (years)	Cost per year (million euros)
Research and development	2.5 M€	3	0.83 M€
Process certification	0.5 M€	2	0.25 M€
Quality monitoring			0.10 M€
Sum			**1.18 M€**

The above costs are assumed to be indicative for 10% recycled plastic content.

For 20% recycled content, costs have been multiplied by a factor 1.8.

For 30% recycled content, costs have been multiplied by a factor 2.4.

The annual product sales will differ between large players and smaller companies. The global players can amortize costs also over models sold outside Europe. In 2024, 9 million refrigerator-freezer combis were sold in the EU, by a large number of different manufacturers. The market research company Mordor Intelligence [184] lists 10 major players on the European refrigeration market: Liebherr, Samsung, Whirlpool, LG, Haier, Bosch, Midea, Electrolux,

[183] Commission Regulation (EU) 2022/1616 of 15 September 2022 on recycled plastic materials and articles intended to come into contact with foods, and repealing Regulation (EC) No 282/2008 : eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32022R1616

[184] https://www.mordorintelligence.com/industry-reports/europe-household-refrigerator-market/companies

Miele, Brandt. But there are many others [185]: e.g. GE, KitchenAid, Sub-Zero, Monogram, Siemens, Beko, V-zug, Gorenje, Bauknecht, Sharp, Smeg, Sibir, Severin, Domo. The market is fragmented and competitive.

Estimates for product cost variations due to increased use of recycled material in fridges have been made for 500, 250 and 100 thousand annual sales per manufacturer (regardless of sales being inside or outside EU27). Table 27 shows the resulting potential price increases.

Table 27: Annual development and testing costs per product sold for obtaining 10%, 20% or 30% recycled plastic content in fridges, depending on manufacturer's annual sales

Additional costs for development and testing, per product sold (euros)	Annual sales		
	500 thousand units / year	250 thousand units / year	100 thousand units / year
10% recycled plastic	€ 2.36	€ 4.72	€ 11.80
20% recycled plastic	€ 4.25	€ 8.50	€ 21.25
30% recycled plastic	€ 5.66	€ 11.33	€ 28.30

Considering the average purchase price of a refrigerator-freezer combi in 2024 around € 600 (excl. VAT, in 2020 euros), for large players the price increase due to development and testing costs could be 0.5-1.0%, and for small players 2-5% per unit.

6.2.4. Example of a washing machine manufacturer

One manufacturer is very active in the field of recycled plastic, sourcing both PCR and PIR materials. As mentioned in 2.2.3, they uses? (PIR)PP, which constitutes around 50% of the polymer content in many washing machine components.

No specific price figures were provided, however, according to the manufacturer, the price of (PIR)PP is in the range of that of virgin PP. Since the manufacturer uses its own formulation for rPP, it has some cost advantage when transitioning from virgin materials. However, achieving higher recycled content requires additional additives, which increase overall production costs.

One challenge is plastic certification, the stakeholder currently relies on supplier declaration and is working on certification from third parties for recycled content. However, there is a lack of standards regarding recycled content declaration for plastics in products.

Additionally, a lack of mandatory calculation method was raised, so that comparison with other competitors is not possible. The manufacturer follows ISO 14021:2016 to assess the recycled content but this standard is not mandatory.

Regarding (PCR)ABS: it is already used for other appliances and will be introduced soon for washing machines. This requires important effort for testing and validation (and accordingly some additional costs).

[185] https://www.topten.eu/private/products/refrigerators

6.2.5. Experience from the automotive sector

JRC analysed the situation of the automotive sector with regard to recycled plastics[186]. According to the report, the integration of recycled plastics in automotive applications is economically viable, with secondary plastics often cheaper than virgin materials, allowing suppliers to increase profit margins. Pre-consumer plastics are preferred due to their lower cost and higher purity, despite limited availability.

However, price fluctuations complicate long-term planning. Virgin plastic costs are influenced by crude oil prices, while recycled plastic prices vary based on factors like availability and quality control.

Increased demand for recycled plastics could lead to higher costs and supply chain challenges, prompting competition among suppliers. Initially, the transition to recycled materials may not be cost-effective due to necessary investments in manufacturing. Over time, however, the use of recycled plastics is expected to become profitable.

6.3. Design options for recyclability

6.3.1. Recyclability

6.3.2. Introduction

To increase the amount of material recycled from end-of-life washing machines, the most important factor is the separate collection rate, here intended as the mass share of washing machines reaching EoL that is collected, and possibly pre-sorted and pre-processed, in dedicated, well-organized schemes, usually set up by manufacturers or by third parties for them. As shown in section 2.1.1, the separate collection rate for washing machines is estimated to be around 60%, with an additional 18% of complementary collection (with a lower recycling efficiency). Increasing the collection rate is outside of the scope of this study.

Another factor is the recycling rate, i.e. the share of collected washing machines waste that leaves the recycling plant(s) as ready-to-use recycled material. The removal and sorting of washing machines components before shredding is relevant for the recycling rate, although separation of material types after shredding seems to work quite well, and recycling rates for many materials in washing machines are already high in the baseline scenario. Aspects of this are discussed below.

6.3.2.1. Recycler practice

The decision on separation before shredding is made by recyclers mainly on economic grounds. If a component or material is valuable and easy to access and separate, this will be done, otherwise it will be shredded together with the rest, and the materials will be recovered from post-shredder separation processes as far as possible.

Separation before shredding would be useful especially if the separated components or materials are subsequently sent to a specialist recycler, e.g. for electronic boards. If the separated components must anyway be processed in-house, additional parallel processing lines would be necessary, or the main processing lines would alternately have to process the

[186] Maury, T., Tazi, N., Torres De Matos, C., Nessi, S., Antonopoulos, I. et al., *Towards recycled plastic content targets in new passenger cars and light commercial vehicles – Technical proposals and analysis of impacts in the context of the review of the ELV Directive*, Publications Office of the European Union, 2023, https://data.europa.eu/doi/10.2838/834615

different material types. As the common shredding and separation processes seem to work quite satisfactory, separation before shredding is typically not economical. In the practice and in the case of washing machines, separation or dismantling before shredding is rarely performed.[187]

A major EU EEE[188] recycler was interviewed by the study team and declared that in the current situation, recyclers cannot scan labels, check online model information on structure, presence of valuable components and dismountability instructions, and then separate components accordingly.[189]

Recyclers are also sceptic on the usefulness (for them) of information in the Digital Product Passports introduced by the ESPR. They do not have time to consult such information, and they also fear that it may be outdated by the time the washing machine reaches EoL.

Notwithstanding the situation sketched above, some recyclers anyway seem in favour of measures facilitating the identification (e.g. via label or marking) and separation of components before shredding. The reason for this is probably that it increases their options for the future, and that it could increase the economic viability for further process automation.

6.3.2.2. Current recycling rates

Section 5.5.4 estimated the factors R2 (recycling output rate) of the CFF for use in the EcoReportTool baseline scenario. These factors are the combination of washing machine collection rates and material recycling rates. Table 28 provides a summary.

For metals, recycling rates are already high. The overall amount of recyclate can only be increased by improving the collection of EoL washing machines. Requirements to improve recyclability of metals from washing machines do not seem necessary.

For PP and ABS, the recycling rate for separate collection is already high (80%) and mainly depends on the efficiency of separation processes after the shredding. The recycling rate for complementary collection is low, but uncertain (see sections 5.5.4 and 2.1.7). The overall amount of recyclate can mainly be increased by improving the separate collection of EoL washing machines.

The recycling rate of glass from washing machines is nearly 0% due to the use of tempered glass.

[187] Especially in MS with high labour costs.

[188] All types of EEE, excluding refrigerators and air conditioners.

[189] This is in line with the findings from the fridge recycler visited by the team conducting the mini-study on refrigerators.

Table 28: Collection rates for washing machines and recycling rates for washing machine materials

	Mass share in WM	Separate collection rate	Complementary collection rate	Recycling rate for separate collection	Recycling rate for complementary collection	Recycling output rate (R2 of CFF)
PP and ABS	13.2%	60%	18%	80%	4%	49%
Steel	39.4%			98%	98%	76%
Aluminium	3.6%			90%	90%	70%
Copper	2.4%			95%	95%	74%
Glass (and glass fibre)	5.4%			70%	35%	48%
PCBs	0.8%			75%	37.5%	52%
Concrete	29.9%			0%	0%	0%
Other materials	5.3%			0%	0%	0%

6.3.3. Washing machine components' recyclability

6.3.4. Top panel and door

Top panels may still contain some woody materials like MDF and doors of washing machines contain a glass window. According to recyclers, both materials should be separated before shredding the machine machines as they are considered as "impurities" (see 4.2.2) and are in practice separated during handling at the EoL facility.

For large recycling facilities with limited share of manual work, it might be difficult to recognize if the top panel contains some wood, accordingly it could be useful to require a marking for the top panel that indicates if the presence of woody material, like what is done for packaging.

The legislator could also require that wood based top panel be designed in such a way that this component is easily separable from the washing machine at end-of-life.

Finally, the legislator could also require that glass parts be designed in such a way that glass parts are is easily separable from the washing machine at end-of-life.

However, the removal of top panels and doors from waste appliances is a treatment requirement, accordingly, it falls within the scope of the WEEE directive, not the ESPR.

6.3.5. Oscillating unit

In most of the washing machines, the outer drum (washer tub) is manufactured in PP reinforced with a filler (typically: glass fibre or $CaCO_3$), which is currently not recyclable when the filler content is higher than 10% (see 6.3.8). To improve the watertightness and robustness of the outer drum, the outer drum can hardly be dismantled as mentioned by one manufacturer in an interview. This practice appears to be applied by other manufacturers, in view of the spare parts lists of various manufacturers, as the oscillating unit is offered as a single unit (outer and inner drums cannot be purchased separately).

In order to increase the recyclability of the oscillating unit, it would be useful to separate outer drums, which has a filling material content of more than 10%, before shredding. To this end, it may be useful to be able to dismantle the outer drum and to indicate whether the filling material content is greater than 10%.

6.3.6. Motors and permanent magnets

Dismantling washing machine motors is currently not part of the standard end-of-life (EoL) process, as washing machines are typically shredded as a whole.

Regarding permanent magnets, they are not used only in drum drive motors but also in few other components (pumps, sensors, valves, EMC[190] filter…), few grams may be based on rare-earth (RE) permanent magnets.

The EU supports a few projects focused on recycling RE magnets.[191] Among them, SUSMAGPRO[192] has developed a pilot supply chain for recycled RE magnets, using hydrogen-based separation technologies. Startups like HyProMag[193] have begun recycling RE magnets from the automotive industry, electric motors, robots, and hard disks, but not from washing machines or, more generally, large household appliances. Nevertheless, by the time washing machines regulated under the forthcoming ecodesign regulation reach end of life, collecting and recycling RE magnets may become economically viable or even more strategically necessary than it is today. Accordingly, the collection of RE permanent magnets (based on NdFeB, SmCo, and AlNiCo) should be facilitated to improve resource recovery.

6.3.7. Dispenser, trays, hoses

These parts, which weigh a total of approximately 3 kg in the base case 1, are mainly made of PP and ABS. Some are typically mobile components that can be taken out of the washing machine by users (e.g. for cleaning) and that are thus easily removable also at end-of-life. The recycler can choose whether to separate them or shred them with the rest of the washing machine.

Recyclers will probably recognize the type of plastic from experience, but it could be useful to require a marking on the parts that indicates the type of plastic, like what is done for packaging. However, it is not expected that this will significantly raise the recycling rates, and for economic reasons recyclers might anyway decide to not separate the types of plastic before shredding. A manufacturer reported to work in a project on the close-loop recycling of dispenser trays but stressed that the labour cost to sperate the dispenser trays is a major economic barrier.

Aiming at recyclability, designers should avoid using a mix of different materials in the same component. In order not to obstruct functionality and innovation, the legislator should not forbid this, but it could be required to design for ease of separation of the material types used in a single component. This is an aspect that could be reflected in a recyclability index.

6.3.8. Additives and fillers in plastics

Almost all plastics contain additives and fillers for functional reasons. Examples include [194] [195] [196]:

[190] To reduce electromagnetic interferences

[191] E.g. under the Call for proposal H2020_CE-SC5-07-2018-2019-2020

[192] https://www.susmagpro.eu/

[193] https://hypromag.com/

[194] Plastic Additives Complete Guide (2025), https://www.immould.com/plastic-additives/

[195] https://sunrisecolour.com/what-are-plastic-additives-l-en?l=en

[196] https://europlas.com.vn/en-US/blog-1/recycled-abs-plastic-recycling-code-process-advantages-and-disadvantages

- Stabilizers (heat stabilizers, antioxidants, anti-aging, UV absorbers [197])
- Processing aids (plasticizers, lubricants, hardeners)
- Fillers [198]
- Coupling agents (improve interfacial properties between filler and polymer material).
- Cross-linking agents (mainly used in rubber and thermosetting resins)
- Nucleating Agents (accelerate the crystallization rate, increase the density of crystallization, and promote finer crystal grain size)
- Colorants (Inorganic or organic pigments)
- Antimicrobials
- Flame retardant [199]
- Anti-static agents (avoid the accumulation of static electricity caused by friction)
- Anti-stick (anti-block, anti-clumping, anti-caking, slippery additives) [200]
- Optical: transparency, anti-fog, bleaching
- Biodegradability [201]
- Additives to increase porosity
- Deodorants / Odor-removing additive additives
- Desiccants
- Fiber reinforcements

Fossil fuels are the raw material that makes plastic, and more than 13,000 chemicals are added to change durability, flexibility, colour, UV-protection and more. Roughly 3,200 of those chemicals are considered a concern for human health, and an additional 6,000 have never

[197] E.g. Hindering Amine Light Stabilizer (HALS). They do not absorb UV but work by reacting with free radicals (which cause polymer breakdown)

[198] Common fillers include inorganic materials like graphite, calcium carbonate, and aluminates, as well as natural organic fillers like wood flour, coconut shell powder, and cotton.

[199] The additives that slow down the burning performance of plastics are called flame retardants, and most of the plastics containing flame retardants are self-extinguishing or have the effect of slowing down the burning rate.

The principle of flame retardant used in plastics can be roughly divided into three kinds:
- Reactive type flame retardant can react with oxygen to form an inert gas, shrouded in the burning material around, reducing the oxygen content of the burning material, in order to achieve the purpose of terminating combustion. Where the combustion can produce CO, CO2, NH3 and halogen compounds, such as PVC, PU foam, polyester or epoxy resin are selected for this method.
- Non-reactive type of flame retardant is containing halogen, phosphorus, nitrogen or boron compounds. When combustion occurs, it can decompose a kind of inert material, phi cover in the surface of the plastic combustion material, forming a layer of obstacles to isolate the outside world of oxygen, to achieve the purpose of flame retardant. Water-containing oxides such as alumina flame retardant encountered when burning, can release water, absorb the heat of the combustion process. So that the temperature around the burning material to inhibit the spread of flame, to prevent the formation of smoke.

[200] E.g. Diatomaceous earth, Talc, Calcium carbonate (CaCO3), Synthesis of silicas and silicates

[201] The complete decomposition of plastic will take a long time, which is an alarming environmental problem today. A decomposition additive controls the breakdown and turns the plastic at the end of the cycle into a material with a completely different molecular structure. This structure is capable of breaking down into simple molecules such as: CO2, H2O, CH4, inorganic compounds or biomass. E.g. Reverte additives

been screened, according to a report from the United Nations Environment Program [202]. It is estimated that by 2050, 2 billion tons of chemical additives will have been used in plastic [203].

Plastic additives and fillers in washing machines

Based on the work carried out by the team working on the mini study on refrigerator [204] and on interviews with washing machines manufacturers:

- Flame retardants are found in fridges near high voltage parts, near the motor, in the power supply cable and its plug. Some are still allowed; some have been banned. Brominated flame retardants may pollute material in the quantity banned by RoHS - thinking of future restrictions that may get stricter and stricter, they might contaminate plastics recycling. It is expected that this is the case for plastic parts closed to the motor and to the heating element of washing machines.
- Some plastic parts (in particular the washer tub) contain glass fibre reinforcement.
- Talcum or calcium carbonate are used as fillers in polypropylene.
- Pigments and colorants use mainly titanium dioxide (for parts in white)
- Zinc stearate is used as releasing agent.
- Fibers and fillers may have a negative impact on the future recycling. E.g. PP is recyclable if it is unfilled or with maximum 10% chalk, talcum, or fibre glass filler.
- During extrusion, melt filters are used to separate polymers with different melting points. Fast and high-pressure extrusion like for virgin plastics will degrade the polymers while recycling. This must be compensated by adding additives.

Impact of additives and fillers on plastic recycling

Various sources signal the large quantity of chemicals added to plastics, and their potential harms to human health and to the environment [205]. This study cannot address the thousands of chemicals potentially present in plastics and assess their impact on recyclability. It is assumed that RoHS and REACH regulations already address the most dangerous substances and that these will no longer be present in currently manufactured washing machines.

Except for the presence of brominated flame retardants [206], and for the maximum 10% chalk, talcum, or fibre glass filler in polypropylene, washing machine manufacturers and recyclers have not signalled recycling problems due to additives and fillers.

The WEEE directive already specifies that plastic containing brominated flame retardants have to be removed from any separately collected WEEE. Question remains how recyclers

[202] Environmental Health News, Recycling plastics "extremely problematic" due to toxic chemical additives: Report, https://www.ehn.org/plastic-recycling-2660739413.html

[203] Chemicals of concern in plastics, https://www.dcceew.gov.au/environment/protection/chemicals-management/chemicals-of-concern-plastics

[204] Personal communications of Electrolux and CoolRec to the study team.

[205] See e.g. Hahladakis, J., et al. (2017). "An overview of chemical additives present in plastics: Migration, release, fate and environmental impact during their use, disposal and recycling." Journal of Hazardous Materials, 344:179-199. https://foodpackagingforum.org/news/plastics-additives-and-recycling

[206] Brominated flame retardants (BFRs) are mixtures of man-made chemicals that are added to a wide variety of products, including for industrial use, to make them less flammable. They are used commonly in plastics, textiles and electrical/electronic equipment. In the European Union the use of certain BFRs is banned or restricted. Research and additional regulation development is ongoing, see e.g. https://www.efsa.europa.eu/en/topics/topic/brominated-flame-retardants#milestones

can recognize these parts and if they have time to identify and remove them. If not already addressed in other EU regulation, the review of the Ecodesign regulation on washing machines could consider forbidding the use of halogenated flame retardants, and require a marking for plastics containing flame retardants, like the regulation for electronic displays [207] [208]. However, considering the limited number of parts to which this would apply, and their low mass, this might not be worthwhile for washing machines.

Setting requirements on the amount and type of fillers or reinforcement fibres in washing machine plastics (or specifically for PP) would need further study.

For coated plastics, see section 4.3.2 on recycling of coated ABS.

Plastic additives can have both positive and negative effects on recycling.[209] Some additives can enhance the recyclability of plastics by improving their stability, compatibility, or processability. Additives can e.g. enhance the quality of recycled plastics, improve the compatibility between different types of plastic, or facilitate recycling of hard-to-recycle plastics [210].

There are several ways to reduce the impact of plastic additives on recycling, such as [210]:

- Designing for recycling: Choose plastic materials and additives compatible with each other and the recycling process. Use biodegradable or compostable additives [211], non-halogenated flame retardants, or easily removable pigments.
- Improving sorting and separation: Develop more efficient and accurate methods to separate different types of plastics and additives from each other and other contaminants. Use near-infrared spectroscopy, magnetic density separation, or enzymatic degradation.
- Enhancing recycling technologies: Develop more advanced and innovative techniques to process recycled plastics and additives without compromising their quality or performance. Use supercritical fluids, microwave heating, or nanocomposites.

Researchers of the Imperial College of London [212] recommend reducing the number of permissible additives for use in plastics. Simplifying and standardising the range of plastic additives would simplify and standardise the range of circulating plastic formulations, enabling

[207] The Ecodesign regulation 2019/2021 on electronic displays in Annex II.D.4 forbids the use of halogenated flame retardants in the enclosure and stand of electronic displays.

[208] The Ecodesign regulation 2019/2021 on electronic displays requires a marking. Annex II.D.2(a) requires plastic components heavier than 50 g to be marked by specifying the type of polymer. Point (b) requires that: Components containing flame retardants shall additionally be marked with the abbreviated term of the polymer followed by hyphen, then the symbol 'FR' followed by the code number of the flame retardant in parentheses. The marking on the enclosure and stand components shall be clearly visible and readable.

[209] APPLiA

[210] Further details in https://phoenixplastics.com/plastic-additives-recycling/

[211] The Association of Plastic Recyclers does not agree with this: Plastic items, packages or film that contain Degradable Additives, Nutrients, and Supplements are not recyclable. A package containing degradable additives cannot be detected using commercially available technologies and will affect both the quality and yield of post-consumer recycled resin (PCR) when they perform as designed. Based on APR's definition, Degradable Additives, Nutrients, and Supplements are now in the "RENDERS THE PACKAGE NON-RECYCLABLE" category in the APR Design® Guide. An item, package or film that contains ANY design feature that is considered non-recyclable renders the entire item, package or film Not Recyclable. The design guide gives detailed indications for packaging in PET, HDPE, PE and PP. https://plasticsrecycling.org/wp-content/uploads/2024/08/APR-Position-Degradable-Additives.pdf

[212] Imperial College London, Institute for Molecular Science and Engineering, Briefing Topic No 10 , November 2023, Addressing plastic additives – policy recommendations, Jason Hallett, Agi Brandt-Talbot, and Isabella von Holstein, doi.org/10.25561/105699, https://dspace.library.uu.nl/bitstream/handle/1874/436969/10_Addressing_plastic_additives_Nov_2023_policy_recommendations_URLs.pdf?sequence=2

a more circular economy for plastics. Representatives from academia and waste management companies have already indicated that this would enable more effective and efficient post-consumer processing and a closed-loop recycling system. These changes should focus in the first instance on those plastics used in the greatest bulk. These are polyethylene (PE) and polypropylene (PP), mostly from food packaging, and polyester (PET) from clothes.

6.3.9. Printed circuit boards

For the reference washing machine (section 5.2), 1.1% of the mass (0.77 kg) is in the printed circuit boards.

Printed circuit boards from washing machines are always recycled, and there would not be a significant advantage of removing them before shredding. Yet, recyclers are increasingly detecting high-energy (Li-ion) batteries on these boards, which pose a fire hazard in shredders. This trend and the associated risk of fire would justify a need to make PCB with batteries easy to identify and to remove manually (without the use of screwdrivers).

6.3.10. Other

Plastic waste is often contaminated with other materials, such as adhesives, glue or paints, which complicates the recycling process and may require extensive cleaning. This issue has been identified as a significant barrier to increasing both the recycling rate and the quality of recycled materials.

Therefore, any measures that reduce the use of such contaminants will contribute to improving the recyclability of the product. However, it is assumed that adhesives and glue are used less frequently in products designed for easy repair, where screws or clips are preferred over adhesives to secure parts. Consequently, this aspect will be taken into account in relevant policies.

6.4. Economical aspects linked to recyclability

For some manufacturers and recyclers, Stichting OPEN[213] assessed the costs of few 5 design options linked to recyclability aspects in Belgium and NL. Table 29 provides the expected additional costs. These figures are indicative and therefore might need to be checked with other stakeholders and the situation in other Member States.

[213] https://www.stichting-open.org/

Table 29: Overview of measures and impact

Measure	Description	Impact on recycling process	Expected additional costs (indicative)
1. Design for disassembly	Products must be designed in such a way that components are easy to disassemble.	Disassembly replaces automated shredding. This requires manual labor and significantly reduces throughput.	**€150–€250/ton** - Extra labor: 10-15 min per device - Guidance & ergonomics - Capacity loss & extra infrastructure
2. Marking of plastics	Plastics must be provided with a type designation.	Sorting is no longer done on the basis of density or NIR detection techniques, but manually after which the sorting takes place. This leads to a reduction in capacity.	**€50–€100/tonne** - Purchase/adaptation of sorting technology - Lower sorting efficiency - Additional control staff
3. Removability-ness PCBs and capacitors	Large circuit boards and wet capacitors should be easily removable.	Additional disassembly steps per device, low degree of automation, risk of damage.	**€100–€150/ton** - Extra labor (5–10 min/device) - Limited mechanization possible - Training and protective measures
4. Tag/ban flame retardants	Halogen-containing flame retardants must be sorted out, and their presence must be marked.	Adjustment of sorting procedures, need for detection and separate processing.	**€30–€60/ton** - Slower processing speed - Risk of contamination of output - Higher storage costs
5. Recyclability index	An index based on, among other things, disassembly steps for priority parts.	If required: significant additional labor, increased traceability, delay in processing line.	**€150–€300/ton** - Per device: multiple manual steps - Documentation & reporting obligation

6.5. Impact reduction due to recycling

As shown in Section 6.1, the environmental impact of increasing the recycled content of some materials was directly assessed with the ERT by modifying the R1 factor.[214]

A similar analysis cannot be carried out on recycling aspects, as assessing the impact of the design options for recyclability listed in Section 6.3 on the recycling output rate (R2) in the ERT is very challenging.

[214] In case of substitution: the mass of some materials was also modified

7. MEErP Task 7, Scenarios

7.1. Policy

7.1.1. Introduction and timeline

This chapter describes and discusses the potential future Ecodesign requirements, for:

- Recycled material content of washing machines (section 7.1.2), subdivided in materials
- Recyclability of washing machines (section 7.1.14)

The current mini preparatory study on recycled content and CRM for washing machines has a limited time-budget. **The study therefore provides recommendations, supported by preliminary data gathering and analyses, that will feed into the review study on washing machine and washer-dryer regulations that started mid. 2024 and is projected to end by end of 2026. That study will further complete the data gathering and analysis and integrate the recommendations in a Commission Working Document for a revised regulation.**

The timeline of the review study implies that a reviewed regulation potentially containing requirements on recycled content, recyclability and CRMs from washing machines could be published in 2027.

As manufacturers will need preparation time (even if they can anticipate), any requirements cannot enter into force before 2029. E.g. a first tier of requirements could be set for 2029, and a second tier for 2032. This timeline has to be checked and will depend on the type and level of ambition of the requirements adopted.

Note that requirements on recycled material content will have almost immediate effects in the year from which they apply. Requirements on recyclability will have impacts much later, when the first washing machines sold in 2029 reach their end-of-life, on average around 12.5 years later, i.e. 2042.

7.1.2. Policy options for recycled content

7.1.2.1. Context

7.1.2.1.1. Sourcing

Definitions:

- pre-consumer material: as defined in EN 45557:2020. Pre-consumer recyclates are also named post-industrial recyclates (PIR)
- post-consumer material: as defined in EN 45557:2020. Post-consumer recyclates are PCR.

JRC provided a comparison of PCR and PIR for plastics in the automotive sector, which is instructive for the appliance sector as well (see Table 30).[215]

Table 30: Main comparison criteria for pre-consumer and post-consumer recyclates used in the automotive sector (Source: JRC own elaboration based on CPA (2021))

Automotive sector	Pre-consumer plastics materials	Post-consumer plastics materials
Sources	Injection purges or sprues, post-processing overflow of part, punch scrap, start and stop of production, offspec materials (material that does not satisfy quality requirements)	Dismantled ELV parts or Automotive shredder residue (ASR)
Environmental benefits of recycling[16]	Reducing emissions in the environment and resource use after production phase only (avoided virgin production)	Reducing emissions in the environment and resource use after use phase (avoided virgin production)
Availability	Limited availability, also due to higher production efficiency, sources already well identified by stakeholders	Much broader availability in closed but also open-loop
Market price	Generally lower than virgin material– depends on the material composition and market demand. Price is higher than post-consumer materials due to its better purity.	Generally lower than virgin material – depends on the material composition and market demand.
Composition	Known material composition (single origin collected material) with less (or no) contaminants compared to post-consumers sources	Uncertainties on composition, impurities level, potential presence of restricted substance to be removed
Quality of the feedstock	Defined material quality (stable physical properties) Very limited degradation/ageing of polymers	Batch-to-batch potential variation Ageing depending on the lifespan of the product (depending of the sector of origin)
Potential applications in the automotive sector	May be suitable for interiors, aesthetics, or even safety plastics parts	Used most of the times, for non-aesthetics and non-safety parts. Technical applications may be more limited than for pre consumer materials

While recycled plastics can be sourced from PCR or from PIR, it is desirable to foster the use of PCR rather than from PIR due to the significantly limited availability of PIR materials.[216]

[215] Maury, T., Tazi, N., Torres De Matos, C., Nessi, S., Antonopoulos, I. et al., Towards recycled plastic content targets in new passenger cars and light commercial vehicles – Technical proposals and analysis of impacts in the context of the review of the ELV Directive, Publications Office of the European Union, 2023, https://data.europa.eu/doi/10.2838/834615

[216] This approach is followed in some EU regulations: Article 7 of the packaging and packaging waste regulation (PPWR) and article 29 of the Critical Raw Materials Act focus on PCR. However, article 8 of the regulation on batteries and waste batteries refers to materials ‘recovered from battery manufacturing waste or post-consumer waste’.

The appliance industry emphasizes the need to consider both PIR and PCR materials[217] even though some major washing machines manufacturers define recycled content exclusively as PCR-based.

While the primary goal is to promote the use of PCR, the recycled content requirements outlined below include both PIR and PCR materials.

As a result, the recycled content requirements are more ambitious than if only PCR material was considered. The reasoning is as follows:

- Setting ambitious recycled content requirement will anyway encourage the use of PCR materials.
- Reducing risks associated with sourcing challenges (e.g., quality, quantity, market volatility) compared to PCR-only requirements.[218]
- Ensuring that proactive industry players who have already reduced virgin material usage (e.g. with PIR content) are not penalized for their efforts.

In addition, it is not desirable to prescribe that recycled plastics have to come from mechanical recycling processes. Due to its typically higher costs and higher environmental impacts, chemical recycling will be used only where mechanical recycling is not available and can thus be a useful addition.

7.1.2.1.2. Insight from the automotive sector

Extensive work has been done in the automative sector in the context of the review of the Directive on end-of-life vehicles[219]. An insight in this proposal is provided here for the following reasons:

- For passenger cars and washing machines, PP is the most commonly used plastic, accounting for 35%[220] and 65%[221] of the plastic share, respectively.[222]
- Washing machines are usually shredded in the same facilities as passenger cars.
- Appliance and automotive sectors are competitive and international.

[217] See APPLiA Position paper 2025-05-26: „A Strategic Approach to Recycled Content in Home Appliances".

[218] Many stakeholders (incl. APPLiA) raised multiple risks pointing out that the adoption of recycled plastics in the appliance sector is limited by the need for long-term confidence in recompounds, the time-intensive nature of material qualification for durable electronics, and inconsistent availability and quality of recyclate feedstocks. The issue linked to the content of "legacy substances" was also mentioned.

[219] DIRECTIVE 2000/53/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 18 September2000 on end-of life vehicles, see: https://eur-lex.europa.eu/resource.html?uri=cellar:02fa83cf-bf28-4afc-8f9f-eb201bd61813.0005.02/DOC_1&format=PDF

[220] See: https://euric.org/images/Position-papers/EuRIC-Call_for_Recycled_ContentPlastics.pdf

[221] See BoM of Base Case 1

[222] One stakeholder mentioned that for washing machines, the required polymer types (mainly PP homopolymer) are not available on the market and cannot be obtained from packaging waste or end-of-life vehicles, for example, as PP copolymers are normally used in these applications. Furthermore, the recovery of PP from WEEE is unlikely to become a reliable or scalable market within the limited timeframe proposed in this study.

The current Proposal for a Regulation Of The European Parliament And Of The Council on circularity requirements for vehicle design and on management of end-of-life vehicles[223], addresses among other plastics and CRM.

In terms of requirements, the proposal states:

> "The preferred policy package contains a combination of the following options.
>
> - Design circular. The preferred option contains short-term obligations for vehicle manufacturers to make available detailed and user-friendly dismantling and recycling information, including the use and location of CRMs in vehicles and information on the share of recycled content in new vehicles. Actions for the medium term include revising the methodology to calculate recyclability and reusability of new vehicles at type-approval stage and developing a circularity vehicle passport. Overall, this anchors circularity requirements into the type-approval of new vehicle types.
> - Recycled content. The preferred option is to set a medium level of ambition with target for **recycled plastics content of 25% by 2030**, of which 25% from closed loop ELV treatment. For steel, this option empowers the Commission to set a target for recycled steel content in newly approved vehicles within three years after the regulation enters into force, based on a feasibility study. The option to set recycled content targets for other materials such as aluminium and CRMs will be assessed in the future, based on changes to automotive designs and the availability of recycling capacity."

And precises:

> "In view of the low recycling rate for plastics, especially from end-of-life vehicles, and the overall negative impacts of other forms of treatment of plastic waste, it is appropriate to increase the uptake of recycled plastics in vehicles. To this end, a mandatory target for plastic recycled from post-consumer waste should be included in new vehicles. Accordingly, each vehicle type should contain twenty-five percent of plastic recycled from post-consumer plastic waste. Twenty-five percent of this recycled content target for plastics should be achieved by including plastics recycled from end-of-life vehicles in the vehicle type concerned. In order to ensure uniform conditions for the implementation this obligation, implementing powers should be conferred on the Commission to establish methodology for the calculation and verification of the share of plastics recovered from post-consumer waste, and from end-of-life vehicles respectively, present in and incorporated into the vehicle type."

The proposal was based on works carried out by JRC[224]. Please note that EuRIC (2020)[225] recommended even tighter requirements:

> "Gradual and fully achievable recycled content targets for post-consumer thermoplastics in new cars should be set as follows:

[223]amending Regulations (EU) 2018/858 and 2019/1020 and repealing Directives 2000/53/EC and 2005/64/EC https://eur-lex.europa.eu/resource.html?uri=cellar:8e016dde-215c-11ee-94cb-01aa75ed71a1.0001.02/DOC_1&format=PDF

[224] Maury, T., Tazi, N., Torres De Matos, C., Nessi, S., Antonopoulos, I. et al., Towards recycled plastic content targets in new passenger cars and light commercial vehicles – Technical proposals and analysis of impacts in the context of the review of the ELV Directive, Publications Office of the European Union, 2023, https://data.europa.eu/doi/10.2838/834615

[225] See: https://euric.org/images/Position-papers/EuRIC-Call_for_Recycled_ContentPlastics.pdf

- 25% by 2025,
- 30% by 2030 and,
- 35% by 2035."

7.1.2.1.3. Overview of the current or possible recycled content levels

Based on the previous sections, Table 31 provides an overview of:

- max. recycled content observed during the study
- recycled content requirement assumed to be reasonable on mid term
- possibility of substitution for some specific components

Table 31: Maximum recycled content observed for each material and opportunity of substitution

Material	**Highest recycled content reported within this mini study**	**Recycled content requirement proposed**	**Substitution (possibility of)**
PP	50%[226]	60%[227]	Washer tub (only): 100% by stainless steel
ABS	up to 100%[228]	60%[229]	n.a.
Elastomer	10% - 25%	20%	n.a.
Glass fibre	0%	0%	33% by r-PET
Concrete	*not applied*	*not applied*	100% by cast iron (recycled)
Aluminium	*not applied*	*not applied*	*n.a.*
Copper	*not applied*	*not applied*	*n.a.*
Steel	*not applied*	*not applied*	*n.a.*
Stainless steel	*not applied*	*not applied*	*n.a.*
Glass	*not applied*	*not applied*	*n.a.*
Electronics	*not applied*	*not applied*	*n.a.*

Accordingly, Table 32 presents the amount and share of recycled content materials in a business-as-usual situation (BAU), when applying the recycled content (rEco) and when applying the recycled content rEco in combination with substitution (rEco+Sub).

[226] 30% (PCR)PP and 50% (PIR)PP have been reported by manufacturers of washing machines.

[227] In the "mini study on refrigerators", minimum requirement of 50% (PCR)PP has been assessed as possible. Accordingly, 60% for rPP is assumed to be reasonable as PIR & PCR are eligible

[228] Mentioned by one manufacturer but not yet on the market for washing machines

[229] In the "mini study on refrigerators", minimum requirement of 50% (PCR)PP has been assessed as possible. Accordingly, 60% for rPP is assumed to be reasonable as PIR & PCR are eligible

Table 32: Recycled contents in a washing machine. Scenarios: BAU, Eco and Eco+Sub

			BAU		Eco		**Eco + Sub**	
Material		**Mass [kg]**	**R1 [%]**	**Mass r-M [kg]**	**R1 [%]**	**Mass r-M [kg]**	**R1 [%]**	**Mass r-M [kg]**
ABS		1.51	0%	-	60%	0.91	60%	0.91
PP		4.05	0%	-	60%	2.43	60%	2.43
PP	Washer tub	3.90	0%	-	60%	2.34	80%[230]	3.12[231]
Elastomer		2.64	0%	-	20%	0.53	20%	0.53
PA		0.40	0%	-	0%	-	0%	-
Silicone		0.03	0%	-	0%	-	0%	-
Total plastics		***12.10***	***0%***	***-***	***51.3%***	***6.20***	***57.7%***	***6.98***
Glass		2.20	0%	-	0%	-	0%	-
Glass fibre		1.67	0%	-	0%	-	33%	0.55
Total glass		***3.87***	***0%***	***-***	***0%***	***-***	***14%***	***0.55***
Concrete		21.40	0%	-	0%	-	30%[232]	6.42[233]
PWB		0.77	0%	-	0%	-	0%	-
Aluminium		2.58	30%	0.77	30%	0.77	30%	0.77
Copper		1.73	37%	0.64	37%	0.64	37%	0.64
Stainless steel		4.11	30%	1.23	30%	1.23	30%	1.23
Steel		24.09	30%	7.23	30%	7.23	30%	7.23
Ferrite		0.04	0%	-	0%	-	0%	-
Coating		0.60	0%	-	0%	-	0%	-
Total		**71.72**	**13.8%**	**9.87**	**22.4%**	**16.08**	**33.2%**	**23.83**

7.1.3. Plastics

7.1.4. Approaches

Requirements regarding the minimum recycled plastic content of washing machines can be set on 5 levels:

1. On the washing machine as a whole
2. On the total plastic mass in the washing machine
3. On a part of the plastic mass in the washing machine
4. For specific types of plastic used in the washing machine
5. For specific (plastic) components of washing machine

These options are further discussed below.

As a complement, an information requirement on the recycled content could be considered. It might be also interesting to provide this information on the label (as %-figure or as an index); however, this option was not included in this study, which focuses on ecodesign requirements.

[230] Assuming PP is replaced by stainless steel (up to 80% recycled stainless steel content possible).

[231] rM corresponds to the mass of recycled stainless steel (it is not recycled PP) in this case

[232] Assuming concrete is replaced by cast iron (conservative assumption of 30% recycled content, like for steel).

[233] rM corresponds to the mass of recycled cast iron (it is not recycled concrete) in this case

7.1.5. Option 1: Recycled content requirement, entire washing machine

At this level, the requirements could be e.g.:

By 1 January 2029, any washing machine placed on the market shall contain at least X1 % of recycled content.

By 1 January 2032, any washing machine placed on the market shall contain at least X2 % of recycled content.

The recycled content share shall be computed as the mass of non-virgin material divided by the total mass of the washing machine as sold, excluding packaging.

As shown in section 5, in the baseline scenario, 14% of the washing machine input mass is recycled material, most from metals (ferrous, aluminium, copper).

X1 could be set to 14% + 4% = 18%

X2 could be set to 14% + 8% = 22%

The chosen +4% and +8% are based on the estimated realistic recycled plastic content, see section 7.1.2.1.3. However, with this type of requirement, the manufacturer would be free to choose how the recycled material content is increased, i.e. using recycled plastics, metals.

Considering that manufacturers could switch from material with limited potential for recycled content (e.g. weight in concrete to weight in cast iron), X2= 20% would be technically possible.

The type of requirement could lead to designers preferring types of materials where a high recycled content is easier to obtain, e.g. using metals instead of plastics. This could also increase the overall washing machine mass. However, such a behaviour would be limited by functional and cost constraints (material, manufacturing processes, distribution) and possibly by consumer preferences.

This type of requirement might be less adequate if the legislator wants to specifically target plastics recycling.[234]

Administrative costs for manufacturers and market surveillance costs will be high, because all materials have to be traced for their recycled content, including metals and glass.

Important remark: In case such an approach is chosen, the level of requirements should be carefully rechecked, as there remains some uncertainty regarding the R1 factors of metals. Due to the large share of metals in a typical washing machine, the impact on the baseline, X1, and X2 would be significant.

7.1.6. Option 2: Recycled content requirement, total plastics mass

At this level, the requirements could be e.g.:

By 1 January 2029, any washing machines placed on the market shall contain at least X1% of recycled plastic, recovered from pre- and post-consumer waste.

[234] However, comprehensive understanding of the recycled plastics supply chain, including feedstock quality and technically viable volumes would be necessary to fully assess this option.

By 1 January 2032, any washing machines placed on the market shall contain at least X2% of recycled plastic content, recovered from pre- and post-consumer waste.

The recycled content share shall be computed as the mass of recycled plastics contained in the product divided by the total plastics mass contained in the washing machines as sold, excluding packaging.

In the baseline scenario, 0% recycled plastic content has been assumed.

X1 could be set to 0%+ 30% = 30%

X2 could be set to 0% + 60% = 60%

The chosen +30% and +60% are based on the estimated realistic recycled plastic content, see section 7.1.2.1.3.

The targets are high as:

- High rate of recycled plastic rates are already achieved by some manufacturers on some plastic parts
- Both PIR and PCR are taken into account
- Many plastic parts of a washing machine are not visible, the colour of r-plastics should be less challenging than for other products like refrigerators.[235]

This type of requirements is less adequate if the legislator wants to specifically target certain types of plastic, e.g. for reasons of verification of recycled content.

It might be necessary to exactly define what is meant by 'plastic'.

7.1.7. Option 3: Recycled content requirement, part of plastics mass

At this level, the requirements could be e.g.:

By 1 January 2029, any washing machine placed on the market shall contain at least X1% of recycled content for the plastics PP, ABS, and elastomer together, recovered from pre- and post-consumer waste.

By 1 January 2032, any washing machine placed on the market shall contain at least X2% of recycled content for the plastics PP, ABS, and elastomer together, recovered from pre- and post-consumer waste.

The recycled content share shall be computed as the mass sum of recycled PP, ABS, and elastomer contained in the product divided by the total mass sum of PP, ABS, and elastomer contained in the washing machine as sold, excluding packaging.[236]

In the baseline scenario, 0% recycled plastic content has been assumed.

X1 could be set to 0%+ 30% = 30%

X2 could be set to 0% + 30% = 60%

[235] No requirements linked to the Regulation (EC) No 1935/2004 of the European Parliament and of the Council of 27 October 2004 on materials and articles intended to come into contact with food and repealing Directives 80/590/EEC and 89/109/EEC apply for washing machines.

[236] As PP, ABS and elastomer represent >96% of the plastics mass, the requirements are the same as in Option 3.

The selection of plastic is based on the BOM but excludes PA and silicone which are difficult to recycle.

This type of requirement focuses on the main plastics used in washing machine. The manufacturer would be free to choose for which type of targeted plastic the recycled content is increased. However, for the BoM of the washing machine (Table 14), by far the highest mass is PP, so this would be a mandatory choice. The limits would need further study and discussion.

As different manufacturers might be using different types of plastics in their washing machines, the type of requirement could create an unlevel playing field, where some manufacturers have more difficulties in meeting the requirements than others. BoMs of more models would have to be studied to get an impression of the variety of plastics used. Studying a single BoM as done in the current study is not sufficient.

Designers could have the tendency to avoid using the regulated plastic types, trying to substitute them by:

- other types of plastics, which might have a lower recycled content
- other types of materials, which might have a higher recycled content (in the case of metals). Substituting materials with a lower recycled content are unlikely.

It will be necessary to adequately define the regulated plastic types.

7.1.8. Option 4: Recycled content requirement, specific plastic types

At this level, the requirements could be e.g.:

By 1 January 2029, any washing machine placed on the market shall contain at least the following percentages of recycled content recovered from pre- or post-consumer waste, for the plastic types indicated, if they are present in the product:

- *Polypropylene (PP)* *30%*
- *Acrylonitrile butadiene styrene (ABS)* *30%*
- *Elastomer (EPDM)* *10%*

By 1 January 2032, any washing machine placed on the market shall contain at least the following percentages of recycled content recovered from pre- or post-consumer waste, for the plastic types indicated, if they are present in the product:

- *Polypropylene (PP)* *60%*
- *Acrylonitrile butadiene styrene (ABS)* *60%*
- *Elastomer (EPDM)* *20%*

The recycled content shares shall be computed as the mass of pre- or post-consumer recycled plastic contained in the product for the plastic type concerned divided by the total plastic mass contained in the washing machine as sold, for the plastic type concerned, excluding packaging.

The difference with the previous option is that masses for each plastic type are considered separately, and not as a sum. This means that recycled content requirements can be differentiated per type.

As regards to risks and definitions, the same remarks apply as for the previous option.

7.1.9. Option 5: Recycled content requirement, specific plastic components

At this level, the requirements could be e.g.:

By 1 January 2029, the listed components of washing machines placed on the market shall contain at least the indicated percentage of recycled <u>plastic</u> content recovered from pre- or post-consumer waste:

- *Washer tub (outer drum): 30%*
- *Gasket: 10%*
- *Visible parts: 30%*
- *Other non-visible parts (back panel…): 40%*

By 1 January 2032, the listed components of washing machines placed on the market shall contain at least the indicated percentage of recycled <u>plastic</u> content: recovered from pre- or post-consumer waste

- *Washer tub (outer drum): 60%*
- *Gasket: 20%*
- *Visible parts: 60%*
- *Other non-visible parts (back panel…): 80%*

A distinction is made here between visible and non-visible parts. Non-visible parts have low/no aesthetic requirements and minimal/no user interaction; accordingly, it is assumed that a slightly higher recycled content is reasonable.

The recycled content share shall be computed as the mass of pre- or post-consumer recycled *<u>plastic</u>* in the component divided by the total *<u>plastic</u>* mass of the component. If the component consists of more than one part, the sum of masses of the parts shall be considered.

If desired, the requirements can be made more general by replacing <u>plastic</u> by <u>material</u>.

It will be necessary to adequately define the regulated components.

7.1.9.1. Metals

During the stakeholder meeting following phase 1 of the present study, there seemed to be agreement that setting minimum recycled content requirements on metals is not useful. This was confirmed during by interviews carried out with different manufacturers, recyclers and experts.

Consequently, setting minimum recycled content requirements on metals used in washing machines has not been a study focus.

7.1.10. CRMs (permanent magnets)

Already covered by Art. 29 point (2) of the CRM Act. However, as mentioned in 4.1.7.1, washing machines will be unlikely subject to that provision.

7.1.11. Glass

Washing machines mainly contain glass in the form of tempered glass (in the door) and some glass fibre (typically in the PP-based washer drum). Based on the information gathered in previous tasks, the potential to use recycled glass or recycle glass in washing machines is low.

However, there is potential to reduce the glass fibre content by partially replacing it with materials such as rPET. This approach can be addressed through policy options aimed at increasing the recycled content of plastics (see e.g. 7.1.5, 7.1.6 or 7.1.9).

7.1.11.1. Concrete

No direct design option relevant for concrete could be identified; therefore, no specific requirement will be proposed.

Remark: there is potential to reduce the concrete content by substituting it with materials such as cast iron, which can be manufactured from recycled materials and easily recycled. This approach can be addressed through policy options aimed at increasing the recycled content of washing machines in general (see 7.1.5).

7.1.12. Electronics

Taking all factors mentioned in 6.1.6 together, no policy option targeting electronic parts in washing machines is considered in this study.

7.1.13. Other

Recycled content requirements for e.g. adhesives and lubrication oil have not been studied.

7.1.13.1. Verification of recycled material content

The ESPR introduces a Digital Product Passport (DPP, section 1.4.4). Depending on the chosen type of recycled content requirements, manufacturers can declare in the DPP e.g.:

- The total mass of the washing machine as sold, excluding packaging.
- The total plastic mass and recycled share present in the washing machine.
- The mass and recycled share for each type of plastic present in the washing machine.
- Evidence to support the recycled share.

It is acknowledged that standards and methodologies for measuring and verifying recycled content —particularly for plastics— are currently lacking.[237] Nevertheless, establishing such methodologies is not a precondition for introducing minimum requirements in regulation. As illustrated by the following examples, regulatory measures must ensure that rules for calculation and verification are defined before minimum requirements become legally binding, while allowing for an adequate transition period:

- Article 29.2 of the CRM Act (section 1.4.5): "The calculation and verification rules shall specify the applicable conformity assessment procedure from among the modules set out in Annex II to Decision No 768/2008/EC of the European Parliament and of the Council (45), with the adaptations necessary in view of the products concerned."
- Article 7.6-7.13 of the PPWR (section 1.4.7) mentions that the Commission shall establish rules for the calculation and verification of the recycled content.
- Article. 6 of the proposal End-of-life vehicles Regulation[238] mentions that 4 years before the recycled content are enforced, a methodology for the calculation and verification of the share of plastics recovered from post-consumer waste, and from end-of-life vehicles respectively, present in and incorporated into the vehicle type shall be adopted by the Commission.[239]

Such rules should ideally be published at the same time as the reviewed ecodesign regulation for washing machines, around 2028. It is beyond the scope of this mini preparatory study to develop such rules [240] [241].

Remark:

Few stakeholders emphasized the importance of establishing robust methodologies for measuring, calculating, and verifying recycled content prior to initiating regulatory discussions. Experience from previous regulatory frameworks indicates that significant implementation delays often occur when essential methodologies - such as those for measurement, calculation, and verification - are developed only after the regulation has been adopted.

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[237] For the calculation, the standard EN 45557:2020 „General method for assessing the proportion of recycled material content in energy-related products" is already available and can be used for washing machines.

[238] https://eur-lex.europa.eu/resource.html?uri=cellar:8e016dde-215c-11ee-94cb-01aa75ed71a1.0001.02/DOC_1&format=PDF

[239] JRC recommended that both EU-produced and imported recycled plastics must be counted equally. A certification and verification system should be established for EU and non-EU production and made available within five years after the legislation is adopted.

[240] There are companies performing third-party certification of recycled content claims. See e.g. https://www.scsglobalservices.com/services/recycled-content-certification
SCS Certification Standard for Recycled Content SCS-103, version 8.0, May 2024

[241] https://www.wieland.com/en/content/download/18725/file/White-Paper-Recycled-Content-Wieland_01.2023.pdf :
Since the relevant standards for the definition of recycled content leave room for interpretation, further specifications must be made to enable a transparent and comparable product claim regarding the recycled content of semi-finished products made from copper and copper alloys.
This document specifies the method used by the Wieland Group for evaluating the recycled contents in their products. It is also proposed that this methodology be used as a guiding principle across the copper industry to foster comparability. The method follows the approach of EN 45557:2020 and applies the provisions of ISO 14021:2016 to the manufacture of semi-finished products.

7.1.14. Policy options for recyclability

7.1.15. Material and component specific policy options

The Design Options reviewed in Task 6 were directly linked to policy options. Accordingly, they are not repeated here and can be found in Section 6.3. Only following additional points are discussed.

7.1.15.1. CRMs

Critical and strategic raw materials present in washing machines are listed in section 6.1.8.

Article 28 of the CRM Act (see section 1.4.5) already requires a labelling indicating whether washing machines incorporate one or more permanent magnets, and if so, whether those permanent magnets belong to any of the following types:

(i) neodymium-iron-boron;
(ii) samarium-cobalt;
(iii) aluminium-nickel-cobalt;
(iv) ferrite.

There will also be a data carrier providing access to information on the weight, location and chemical composition of all individual permanent magnets included in the product, and on the presence and type of magnet coatings, glues and any additives used, and to information enabling access and safe removal of all permanent magnets incorporated in the product, at least including the sequence of all removal steps, tools or technologies required for the access and removal of the permanent magnet (see CRM Act, Art. 28, point 4).

Still, in order to facilitate the collection of NdFeB, SmCo, and AlNiCo[242] permanent magnets in washing machines (see 6.1.8), in addition, it is proposed to make these 3 types of permanent magnets (or the components where they are mounted):

- easy to identify (using a standardized marking)
- easy to access
- easy to remove manually (with no tool or with basic tools)

7.1.16. Recyclability index

In the context of the Ecodesign preparatory study on photovoltaic panels and inverters, a recyclability index is being developed. The interim report of September 2024 presents a literature summary of various methods being used or proposed [243]. Some of the parameters that are being considered for a recyclability index are shown in Figure 18.

The ESPR [244] mentions the following design-for-recycling parameters:

- use of easily recyclable materials.

[242] Permanent magnets falling under Art. 28 (1), point (b), (i), (ii) and (iii), of the CRM Act

[243] Interim Report, Technical support for the development of a recyclability index for photovoltaic products, September 2024, Viegand Maagøe, in collaboration with Universidad de Murcia and Centro Nacional de Energias Renovables (CENER), for the European Climate, Infrastructure and Environment Executive Agency (CINEA), https://www.pv-recyclability-index.eu/ .

[244] Ecodesign for Sustainable Products Regulation (Regulation (EU) 2024/178), see also section 1.4.4, Annex A (d)

- safe, easy and non-destructive access to recyclable components and materials or components and materials containing hazardous substances.
- material composition and homogeneity.
- possibility for high-purity sorting.
- number of materials and components used.
- use of standard components.
- use of component and material coding standards for the identification of components and materials.
- number and complexity of processes and tools needed.
- ease of non-destructive disassembly and re-assembly.
- conditions for access to product data.
- conditions for access to or use of hardware and software needed.

Type	#	Parameter
Service-related Parameters	1	Information on presence (or absence) of substances of concern
	2	Dismantling information and condition for access
	3	Information on composition
	4	Information on CRMs and SRMs
Dismantling Related Parameters	5	# of steps for dismantling of priority parts (dismantling depth)
	6	Type of tools needed to dismantle priority parts
Material based parameters	7	Level of concentration of hazardous substances and other substances affecting the recycling process
	8	Selection of materials based on recyclability complexity
	9	Combination of materials used / homogeneity

Figure 18: Parameters considered for a recyclability index for photovoltaic panels and inverters

Reflecting on the applicability of these recyclability parameters to washing machines, considering the recycler practices and washing machine components' recyclability discussed in previous sections:

- Washing machines collectors, (pre-)sorters and recyclers do not have the time to consult product information. They are sceptic on the usefulness (for them) of the Digital Product Passport introduced by the ESPR. In the current washing machine recycling practice, it is difficult to see how product information provision could increase recyclability.
- In the current washing machine recycling practice, shredding the whole appliance is the main EoL process.

Accordingly, <u>the usefulness of a recyclability index for washing machines seems limited</u>.

7.1.17. Overview of the potential requirements

Table 33 provides an overview of all potential requirements on recycled content, recyclability (incl. for CRMs) for washing machines that have been identified in the previous chapters and which would be relevant for the review of the Ecodesign regulation for household washing machines and household washer-dryers. For each requirement the reference section where more information can be found is indicated. The recommendations are preliminary, for discussion with stakeholders, and to be further assessed in the review study on regulations 2019/2023 and 2019/2014 that started in 2024.

Recycled content (RC) requirements are recommended only for plastics, not for other materials. Two tiers are proposed, in 2029 and 2032 (see section 7.1.1). The intention is to apply the minimum requirements to pre- and post-consumer recycled material.

The RC requirement for plastics can be set either on the entire plastics mass in the washing machine (1.2 in the table), or on the sum of masses of PS, PP and ABS (1.3), or on the separate masses of these plastic types (1.4). In the latter option it is proposed to evaluate latest by 2030 if a minimum requirement for PUR should be added. This depends, e.g. on the economic viability of chemical PUR recycling and on the development of the use of vacuum insulation panels.

The amount of recycled material from washing machines can be increased mainly by increasing the separate collection rate, which is beyond the scope of this study. Recycling rates for washing machine materials are already high (section 6.3.2.2) and the current practice of shredding many materials together seems to work satisfactorily (section 6.3.2.1).

Recyclers would only apply separation before shredding if this is economically worthwhile or necessary to protect their equipment. In those cases, they prefer using shears, saws or axes rather than time-consuming screwdrivers.

For this reason, a recyclability index for washing machines has not been developed yet. Some potential requirements to facilitate separation before shredding have been identified (see the table), but several need further study and discussion. Setting these requirements does not automatically imply that recyclers will also apply pre-shredding separation.

As regards critical and strategic raw materials, copper and aluminium are present in relevant quantities in washing machines, but their recycling rates are already high, and their recycled content in washing machine depends on the general market situation. In previous consultations, most stakeholders were not in favour of setting recycled content requirements on metals.

Regarding permanent magnets (based on NdFeB, SmCo, and AlNiCo), the demand in a washing machine is typically low (some manufacturers don’t use any, only rely on ferrite), but requirements to ease possible separation are proposed (see 7.1.15.1).

Table 33: Overview of potential requirements on washing machines

	Potential requirement	reference	recommendation
1	**Recycled content requirements**		
1.1	Minimum recycled content (all materials) for entire WM. > 18% in 2029, > 22% in 2032	7.1.5	no
1.2	Minimum recycled content for entire plastics WM mass. > 30% in 2029, > 60% in 2032	7.1.6	likely, thresholds to be further checked
1.3	Minimum recycled content for sum of, PP, ABS, and elastomer mass in WM. > 30% in 2029, > 60% in 2032	7.1.7	alternative to 1.2
1.4	Minimum recycled content per type of plastic in a WM. - PP > 30% in 2029, > 60% in 2032 - ABS > 30% in 2029, > 60% in 2032 - Elastomer > 10% in 2029, 20% in 2032	7.1.8	alternative to 1.2
1.5	Minimum recycled content per (plastic) WM component. - Washer tub (outer drum) > 30% in 2029, > 60% in 2032 - Gasket: > 10% in 2029, > 20% in 2032 - Visible parts: > 30% in 2029, > 60% in 2032 - Other non-visible parts (back panel…): > 40% in 2029, > 80% in 2032	7.1.9	no
1.6	Minimum recycled content for ferrous metals in WM	7.1.9.1	no
1.7	Minimum recycled content for aluminium in WM	7.1.9.1	no
1.8	Minimum recycled content for copper in WM	7.1.9.1	no
1.9	Minimum recycled content for glass in WM	7.1.11	no
1.10	Minimum recycled content for concrete in WM	7.1.11.1	no
1.11	Minimum recycled content for electronics in WM	7.1.12	no
1.12	Minimum recycled content for CRM		no (covered by CRM Act)
1.12	Recycled content on the label	7.1.4	maybe, but needs further study
2	**Recyclability requirements**		
2.1	Top panel containing woody material: require a marking and design for ease of separation of top panel from the WM (e.g. spacers, frames)	6.3.4	maybe, needs further study
2.2	Door with tempered glass: design for ease of separation of glass from the WM (e.g. spacers, frames)	6.3.4	maybe, needs further study
2.3	PP washer tub: information requirement if > 10% filler	6.3.5	maybe
2.4	Dispensers/trays/hoses, drums, etc.: require a marking on the components and accessories that indicates the type of plastic, like what is done for packaging.	6.3.7	maybe, needs further investigation
2.5	Dispensers/trays/hoses, drums, etc.: design for ease of separation of different material types used in a single component.	6.3.7	maybe, but needs further study
2.6	Printed circuit boards containing batteries should be easy to identify and to remove for recyclers (without the use of screwdrivers)	6.3.9	maybe, but needs further study
2.7	Additives and fillers: set a maximum 10% mass content for chalk, talcum, or fibre glass filler in polypropylene	6.3.8	maybe, but needs further study
2.8	Additives and fillers: forbid the use of halogenated flame retardants, and require a marking for plastics containing flame retardants, like the regulation for electronic displays	6.3.8	maybe
2.9	Recyclability index: develop a recyclability index for washing machines	7.1.1	no
2.10	Adhesives and glue…: limit the amount on plastic parts	6.3.10	no, indirectly addressed in case of reparability requirements
2.11	Recyclability requirements for CRM	7.1.15.1	no (partly covered by CRM Act)
2.12	Standardized marking for permanent magnets based on NdFeB, SmCo, and AlNiCo	7.1.15.1	Yes
2.13	Disassembly requirements for parts containing permanent magnets based on NdFeB, SmCo, and AlNiCo	7.1.16	Yes

The main comments addressed by the stakeholders during and after the 4th stakeholder meeting are:

- Requirement 1:
    - Two stakeholders flagged out that minimum recycled plastic content poses challenges due to limited availability of high-quality, compliant recycled materials - especially for household appliances. In addition, stricter chemical regulations are expected to further reduce supply, while demand continues to rise, creating long-term supply concerns
    - Numerous stakeholders have expressed serious concerns that the proposed recycled plastic content thresholds - Tier 1 at 30% and Tier 2 at 60% - are too high and being implemented too rapidly. However, no alternative thresholds have been proposed.
    - Given the market uncertainties regarding both the quantity and quality of recycled plastic, as well as the absence of methodologies for its verification, numerous industry stakeholders have expressed significant concerns about the introduction of mandatory recycled content requirements in general. Instead, they are supporting mandatory information requirement on recycled content.
    - For washing machines in particular, the required polymer types (mainly PP homopolymer) are not available on the market and cannot be obtained from packaging waste or end-of-life vehicles, for example, as PP copolymers are normally used in these applications

  ➔ In general, the proposed requirements - particularly the Tier 1 and Tier 2 thresholds - will need to be further evaluated during the review of the current regulation, taking into account stakeholder inputs and the ongoing work on recycled plastics being conducted for DG GROW.

- Requirement 1.12: One stakeholder explained that minimum recycled content requirements make additional labelling redundant and may even negatively impact consumer perception. It advocates for transparent information on recycled content as a first step (with careful consideration of the labelling approach) before any mandatory thresholds are introduced.
- Requirements 2.1 and 2.2 were reassessed (weaker recommendation), due to the reasons stressed in 4.1.5 and in 6.3.4.
- Requirement 2.4: the industry mentioned that although labelling of such parts is largely in place and hard plastics are recyclable with modern sorting technology, the practical impact remains limited due to the complexity of manually sorting mixed-material assemblies.
- Requirement 2.6: two stakeholders mentioned that regardless of the removal method, batteries must already be extracted and recycled separately. In line with this practice, it recommended that all PCBs be removed prior to shredding and treated as separate recyclable components, just as is currently required for batteries.

  Another stakeholder expressed a different view, noting that PCBs from washing machines management systems are generally low to medium grade and not economically viable to remove before shredding. The labour required for pre-shredding removal is disproportionate to the limited financial return from recovering any precious metals or valuable materials they may contain. Moreover, designing PCBs to be easily removable could compromise product reliability.

- Requirement 2.8: One stakeholder stressed that techniques can sort 95% of the BFRs[245] and therefore the requirement 2.8 should be reconsidered.
- Requirement 2.11: One stakeholder suggested for non-ferrous CRM the following approach:
    - Developing design-for-recycling criteria to facilitate the recovery of NF-CRMs
    - Setting ambitious collection targets,
    - Establishing high-quality recycling standards

  Remark: Only the first part of the approach can be captured by ESPR.
- Requirements 2.12 and 2.13: Two stakeholders suggested to have a minimum weigh of 25g of magnet material with REE in order to exclude small applications and referred to the CEN TC 472 proposal[246]. Furthermore, double regulation through ESPR and CRM Act should be avoided.

7.2. Analysis of the requirements

The recommended requirement is 1.2, i.e. a minimum percentage of pre- and post-consumer recycled plastic content compared to the entire washing machine plastics mass, because this leaves more freedom for manufacturers (see ERT assumptions in Table 34).

Table 34: Parameters considered in the EcoReport Tool

	From 1.1.2029 (Tier 1)	**From 1.1.2032 (Tier 2)**
Requirement (1.2)		
Minimum recycled content for entire plastics WM mass	30%	60%
Corresponding R1 setting in the EcoReport Tool		
PP and ABS	R1 = 30%	R1 = 60%
Elastomer	R1 = 10%	R1 = 20%

The impacts of the recyclability are not assessed here, as the policy options can not be directly translated in an increase of the R2 factor.

[245] Based on a study carried out for BSEF: https://www.consultdss.com/48d30c/globalassets/assets/documents/ar-bsef-report.pdf

[246] Discussions are ongoing regarding the suitability of labelling products that contain permanent magnets with rare earth element (REE) content. The CEN/TC 472 working group has proposed specific thresholds for mandatory labelling: 25 g for NdFeB, SmCo and AlNiCO and 250 g for ferrite.

See: https://denuo.be/sites/default/files/Consultation%20on%20recyclability%20and%20recycled%20content%20of%20permanent%20magnets.pdf.

For permanent magnets based on rare earths[247], it is already challenging to assess the amount of material in a washing machine. As mentioned in section 4.1.7.1, 3 grams of Nd per washing machine in the EU market might be a realistic estimate. Considering that 12 million washing machines and washer-dryers are placed on the EU market each year, this corresponds to an annual Nd demand of 36 tonnes and the same amount could need to be recovered when end-of-life (EoL) is reached. The proposed CRM requirements 2.12 and 2.13, in combination with the CRM Act, would contribute to recovering some of the 36 tonnes of Nd each year.

7.2.1. Impact reduction on product level

Table 35 shows the environmental impacts of a washing machine (Base Case 1) according to different levels of requirements: BAU (business-as-usual, i.e. no requirement), Tier 1, and Tier 2. The table also presents the recycled content: +31% in Tier 1 and +63% in Tier 2 compared to BAU.

Plastic recycled content requirements contribute to reducing the environmental impact of the product across all categories. However, the improvements achieved by Tier 2 are relatively limited and range from 0.00% (land use) to 15.95% (eutrophication, freshwater)—with 3.63% for climate change—when considering the material phase including end-of-life (EoL). When evaluating the entire life cycle of the product, the improvements range from 0.00% (land use) to 1.25% (eutrophication, freshwater), with 0.55% for climate change.[248]

Tier 1 achieves half the impact reduction of Tier 2, as Tier 2 is twice as ambitious.

In general, stakeholders highlighted that the impact of the recycled plastic on the LCA results is very limited and does not justify the stringent requirements being proposed.

[247] NdFeB, SmCo, and AlNiCo

[248] Important remark: the requirements are based on pre- and post-consumer recyclates. However, the ERT datasets for recycled plastics refer to post-consumer recyclates.

Table 35: Impact (on product level) of the washing machine according to the level of requirements

Level	Life stage	Recycled content [kg]	Climate change, total (kg CO2 eq)	Ozone depletion (kg CFC-11 eq)	Human toxicity, cancer (CTUh)	Human toxicity, non-cancer (CTUh)	Particulate matter (disease incidence)	Ionising radiation, human health (kBq U235 eq)	Photochemical ozone formation, human health (kg NMVOC eq)	Acidification (mol H+ eq)
BAU	Material (excl. EoL)	9.87	2.37E+02	3.15E-06	2.78E-06	5.33E-06	2.96E-05	1.07E+01	6.18E-01	1.22E+00
BAU	Other plases (use...)		1.11E+03	1.44E-05	1.35E-06	1.65E-05	5.92E-05	3.44E+02	2.34E+00	4.15E+00
BAU	EoL-i		3.22E+01	7.69E-09	4.00E-08	1.60E-07	1.91E-06	8.72E+00	4.85E-02	7.53E-02
BAU	EoL-c		-7.30E+01	-2.33E-08	-1.76E-06	-1.81E-06	-7.36E-06	-3.35E+00	-1.75E-01	-4.31E-01
BAU	**All stages**		**1.31E+03**	**1.75E-05**	**2.41E-06**	**2.02E-05**	**8.34E-05**	**3.60E+02**	**2.83E+00**	**5.01E+00**
BAU	**Material (incl. EoL)**		**1.96E+02**	**3.13E-06**	**1.06E-06**	**3.68E-06**	**2.42E-05**	**1.61E+01**	**4.91E-01**	**8.66E-01**
BAU	**Share material**		**15.0%**	**17.9%**	**43.9%**	**18.2%**	**29.0%**	**4.5%**	**17.4%**	**17.3%**
Tier 1	Material (excl. EoL)	12.98	2.34E+02	3.13E-06	2.77E-06	5.30E-06	2.93E-05	1.06E+01	6.01E-01	1.20E+00
Tier 1	Other plases (use...)		1.11E+03	1.44E-05	1.35E-06	1.65E-05	5.92E-05	3.44E+02	2.34E+00	4.15E+00
Tier 1	EoL-i		3.22E+01	7.69E-09	4.00E-08	1.60E-07	1.91E-06	8.72E+00	4.85E-02	7.53E-02
Tier 1	EoL-c		-7.30E+01	-2.33E-08	-1.76E-06	-1.81E-06	-7.36E-06	-3.35E+00	-1.75E-01	-4.31E-01
Tier 1	**All stages**		**1.31E+03**	**1.75E-05**	**2.40E-06**	**2.01E-05**	**8.31E-05**	**3.60E+02**	**2.82E+00**	**4.99E+00**
Tier 1	**Material (incl. EoL)**		**1.93E+02**	**3.11E-06**	**1.05E-06**	**3.65E-06**	**2.38E-05**	**1.60E+01**	**4.75E-01**	**8.45E-01**
Tier 1	**Share material**		**14.8%**	**17.8%**	**43.8%**	**18.1%**	**28.7%**	**4.4%**	**16.9%**	**16.9%**
Tier 2	Material (excl. EoL)	16.08	2.30E+02	3.10E-06	2.77E-06	5.27E-06	2.90E-05	1.05E+01	5.84E-01	1.18E+00
Tier 2	Other plases (use...)		1.11E+03	1.44E-05	1.35E-06	1.65E-05	5.92E-05	3.44E+02	2.34E+00	4.14E+00
Tier 2	EoL-i		3.22E+01	7.69E-09	4.00E-08	1.60E-07	1.91E-06	8.72E+00	4.85E-02	7.53E-02
Tier 2	EoL-c		-7.30E+01	-2.33E-08	-1.76E-06	-1.81E-06	-7.36E-06	-3.35E+00	-1.75E-01	-4.31E-01
Tier 2	**All stages**		**1.30E+03**	**1.75E-05**	**2.40E-06**	**2.01E-05**	**8.28E-05**	**3.60E+02**	**2.80E+00**	**4.97E+00**
Tier 2	**Material (incl. EoL)**		**1.89E+02**	**3.09E-06**	**1.05E-06**	**3.61E-06**	**2.35E-05**	**1.59E+01**	**4.58E-01**	**8.23E-01**
Tier 2	**Share material**		**14.5%**	**17.7%**	**43.8%**	**18.0%**	**28.4%**	**4.4%**	**16.4%**	**16.6%**
Tier1 vs BAU	**Material (incl. EoL)**	**31.51%**	**-1.82%**	**-0.77%**	**-0.20%**	**-0.89%**	**-1.26%**	**-0.54%**	**-3.40%**	**-2.47%**
Tier1 vs BAU	**All stages**		**-0.28%**	**-0.14%**	**-0.09%**	**-0.16%**	**-0.37%**	**-0.02%**	**-0.60%**	**-0.43%**
Tier 2 vs. BAU	**Material (incl. EoL)**	**62.92%**	**-3.63%**	**-1.54%**	**-0.40%**	**-1.78%**	**-2.53%**	**-1.09%**	**-6.79%**	**-4.95%**
Tier 2 vs. BAU	**All stages**		**-0.55%**	**-0.28%**	**-0.18%**	**-0.33%**	**-0.74%**	**-0.05%**	**-1.19%**	**-0.86%**

Level	Life stage	Eutrophication, terrestrial (mol N eq)	Eutrophication, freshwater (kg P eq)	Eutrophication, marine (kg N eq)	Ecotoxicity, freshwater (CTUe)	Land use (pt)	Water use (m3 water eq. of deprived water)	Resource use, minerals and metals (kg Sb eq)	Resource use, fossils (MJ)	Primary energy consumption (MJ)
BAU	Material (excl. EoL)	2.08	1.97E-01	2.69E-03	2.38E+03	2.95E+04	5.88E+01	1.24E-02	3.13E+03	3.13E+03
BAU	Other plases (use...)	9.390E+00	1.42E+00	5.14E-02	9.20E+03	1.11E+04	2.96E+03	4.36E-03	1.81E+04	1.85E+04
BAU	EoL-i	1.780E-01	1.66E-02	5.19E-05	1.06E+02	1.01E+02	7.11E+00	7.73E-06	5.11E+02	5.11E+02
BAU	EoL-c	-5.605E-01	-5.13E-02	-2.27E-04	-8.80E+02	-1.91E+04	-1.31E+01	-4.38E-03	-8.00E+02	-8.00E+02
BAU	**All stages**	**1.108E+01**	**1.58E+00**	**5.40E-02**	**1.08E+04**	**2.17E+04**	**3.01E+03**	**1.24E-02**	**2.09E+04**	**2.14E+04**
BAU	**Material (incl. EoL)**	**1.695E+00**	**1.63E-01**	**2.52E-03**	**1.61E+03**	**1.06E+04**	**5.29E+01**	**8.03E-03**	**2.84E+03**	**2.84E+03**
BAU	**Share material**	**15.3%**	**10.3%**	**4.7%**	**14.9%**	**48.7%**	**1.8%**	**64.8%**	**13.6%**	**13.3%**
Tier 1	Material (excl. EoL)	2.02	1.91E-01	2.49E-03	2.31E+03	2.95E+04	5.73E+01	1.24E-02	3.02E+03	3.02E+03
Tier 1	Other plases (use...)	9.389E+00	1.42E+00	5.14E-02	9.20E+03	1.11E+04	2.96E+03	4.36E-03	1.81E+04	1.85E+04
Tier 1	EoL-i	1.780E-01	1.66E-02	5.19E-05	1.06E+02	1.01E+02	7.11E+00	7.73E-06	5.11E+02	5.11E+02
Tier 1	EoL-c	-5.605E-01	-5.13E-02	-2.27E-04	-8.80E+02	-1.91E+04	-1.31E+01	-4.38E-03	-8.00E+02	-8.00E+02
Tier 1	**All stages**	**1.103E+01**	**1.57E+00**	**5.37E-02**	**1.07E+04**	**2.17E+04**	**3.01E+03**	**1.24E-02**	**2.08E+04**	**2.13E+04**
Tier 1	**Material (incl. EoL)**	**1.638E+00**	**1.57E-01**	**2.32E-03**	**1.54E+03**	**1.06E+04**	**5.13E+01**	**8.01E-03**	**2.73E+03**	**2.73E+03**
Tier 1	**Share material**	**14.9%**	**10.0%**	**4.3%**	**14.3%**	**48.7%**	**1.7%**	**64.7%**	**13.1%**	**12.9%**
Tier 2	Material (excl. EoL)	1.96	1.85E-01	2.29E-03	2.25E+03	2.95E+04	5.58E+01	1.24E-02	2.92E+03	2.92E+03
Tier 2	Other plases (use...)	9.389E+00	1.42E+00	5.14E-02	9.20E+03	1.11E+04	2.96E+03	4.36E-03	1.81E+04	1.85E+04
Tier 2	EoL-i	1.780E-01	1.66E-02	5.19E-05	1.06E+02	1.01E+02	7.11E+00	7.73E-06	5.11E+02	5.11E+02
Tier 2	EoL-c	-5.605E-01	-5.13E-02	-2.27E-04	-8.80E+02	-1.91E+04	-1.31E+01	-4.38E-03	-8.00E+02	-8.00E+02
Tier 2	**All stages**	**1.097E+01**	**1.57E+00**	**5.35E-02**	**1.07E+04**	**2.17E+04**	**3.01E+03**	**1.24E-02**	**2.07E+04**	**2.11E+04**
Tier 2	**Material (incl. EoL)**	**1.580E+00**	**1.51E-01**	**2.12E-03**	**1.47E+03**	**1.06E+04**	**4.98E+01**	**7.99E-03**	**2.63E+03**	**2.63E+03**
Tier 2	**Share material**	**14.4%**	**9.6%**	**4.0%**	**13.8%**	**48.7%**	**1.7%**	**64.7%**	**12.7%**	**12.4%**
Tier1 vs BAU	**Material (incl. EoL)**	**-3.37%**	**-3.68%**	**-7.97%**	**-4.15%**	**0.00%**	**-2.86%**	**-0.20%**	**-3.72%**	**-3.72%**
Tier1 vs BAU	**All stages**	**-0.52%**	**-0.38%**	**-0.38%**	**-0.62%**	**0.00%**	**-0.05%**	**-0.13%**	**-0.51%**	**-0.50%**
Tier 2 vs. BAU	**Material (incl. EoL)**	**-6.75%**	**-7.35%**	**-15.95%**	**-8.30%**	**0.00%**	**-5.72%**	**-0.41%**	**-7.45%**	**-7.45%**
Tier 2 vs. BAU	**All stages**	**-1.04%**	**-0.77%**	**-0.75%**	**-1.25%**	**0.00%**	**-0.10%**	**-0.27%**	**-1.02%**	**-1.00%**

7.2.2. Impact reduction on market level

Table 36 shows the environmental impacts of the washing machine market according to different levels of requirements: BAU (business-as-usual: no requirement), Tier 1 and Tier 2. To estimate the impact of the market, the environmental impacts of base case 1 have been multiplied by the whole EU market volume (12 Mio of units), considering all three base cases (BC1: WM 8 kg, BC2: WM 10 kg, BC3: WD 9 kg). As the BOMs of the base cases are similar (the total weights range from 71.1 kg to 80.7 kg and comparable materials) and BC1 accounts for 79% of EU-sales, this is a reasonable simplification for such a mini study. With Tier 1, 37 kt of virgin plastics could be saved per year; from 2022 (Tier 2), it would be even 74 kt.

According to some stakeholders, the required quantity of recycled plastic that meets the necessary quality standards (for appliances) is currently not available on the market. Scaling up the recycled plastics sector to an industrial level - capable of delivering consistent, high-quality material flows - is essential, but will take time.

Table 36: Impact (on market level) of the washing machine according to the level of requirements

Level	Life stage	Recycled content [kt]	Climate change, total (kt CO2 eq)	Ozone depletion (kt CFC-11 eq)	Human toxicity, cancer (MCTUh)	Human toxicity, non-cancer (MCTUh)	Particulate matter (disease incidence in Mio.)	Ionising radiation, human health (GBq U235 eq)	Photochemical ozone formation, human health (kt NMVOC eq)	Acidification (Mio. mol H+ eq)
BAU	Material (excl. EoL)	118.44	2.85E+03	3.78E-05	3.33E-05	6.40E-05	3.55E-04	1.28E+02	7.41E+00	1.47E+01
BAU	Other plases (use...)		1.34E+04	1.73E-04	1.62E-05	1.98E-04	7.11E-04	4.13E+03	2.81E+01	4.97E+01
BAU	EoL-i		3.86E+02	9.23E-08	4.80E-07	1.92E-06	2.29E-05	1.05E+02	5.81E-01	9.04E-01
BAU	EoL-c		-8.76E+02	-2.80E-07	-2.11E-05	-2.18E-05	-8.83E-05	-4.02E+01	-2.10E+00	-5.18E+00
BAU	**All stages**		**1.57E+04**	**2.10E-04**	**2.89E-05**	**2.42E-04**	**1.00E-03**	**4.33E+03**	**3.40E+01**	**6.01E+01**
BAU	**Material (incl. EoL)**		**2.36E+03**	**3.76E-05**	**1.27E-05**	**4.41E-05**	**2.90E-04**	**1.93E+02**	**5.90E+00**	**1.04E+01**
BAU	**Share material**		**15.0%**	**17.9%**	**43.9%**	**18.2%**	**29.0%**	**4.5%**	**17.4%**	**17.3%**
Tier 1	Material (excl. EoL)	155.76	2.80E+03	3.75E-05	3.33E-05	6.36E-05	3.52E-04	1.27E+02	7.21E+00	1.44E+01
Tier 1	Other plases (use...)		1.34E+04	1.73E-04	1.62E-05	1.98E-04	7.11E-04	4.13E+03	2.81E+01	4.97E+01
Tier 1	EoL-i		3.86E+02	9.23E-08	4.80E-07	1.92E-06	2.29E-05	1.05E+02	5.81E-01	9.04E-01
Tier 1	EoL-c		-8.76E+02	-2.80E-07	-2.11E-05	-2.18E-05	-8.83E-05	-4.02E+01	-2.10E+00	-5.18E+00
Tier 1	**All stages**		**1.57E+04**	**2.10E-04**	**2.88E-05**	**2.42E-04**	**9.97E-04**	**4.32E+03**	**3.38E+01**	**5.99E+01**
Tier 1	**Material (incl. EoL)**		**2.31E+03**	**3.73E-05**	**1.26E-05**	**4.37E-05**	**2.86E-04**	**1.92E+02**	**5.70E+00**	**1.01E+01**
Tier 1	**Share material**		**14.8%**	**17.8%**	**43.8%**	**18.1%**	**28.7%**	**4.4%**	**16.9%**	**16.9%**
Tier 2	Material (excl. EoL)	192.96	2.76E+03	3.72E-05	3.33E-05	6.32E-05	3.48E-04	1.26E+02	7.01E+00	1.42E+01
Tier 2	Other plases (use...)		1.34E+04	1.73E-04	1.62E-05	1.98E-04	7.11E-04	4.13E+03	2.81E+01	4.97E+01
Tier 2	EoL-i		3.86E+02	9.23E-08	4.80E-07	1.92E-06	2.29E-05	1.05E+02	5.81E-01	9.04E-01
Tier 2	EoL-c		-8.76E+02	-2.80E-07	-2.11E-05	-2.18E-05	-8.83E-05	-4.02E+01	-2.10E+00	-5.18E+00
Tier 2	**All stages**		**1.56E+04**	**2.10E-04**	**2.88E-05**	**2.41E-04**	**9.93E-04**	**4.32E+03**	**3.36E+01**	**5.96E+01**
Tier 2	**Material (incl. EoL)**		**2.27E+03**	**3.70E-05**	**1.26E-05**	**4.34E-05**	**2.83E-04**	**1.91E+02**	**5.50E+00**	**9.88E+00**
Tier 2	**Share material**		**14.5%**	**17.7%**	**43.8%**	**18.0%**	**28.4%**	**4.4%**	**16.4%**	**16.6%**
Tier1 vs BAU	**Material (incl. EoL)**	**31.51%**	**-1.82%**	**-0.77%**	**-0.20%**	**-0.89%**	**-1.26%**	**-0.54%**	**-3.40%**	**-2.47%**
Tier1 vs BAU	**All stages**		**-0.28%**	**-0.14%**	**-0.09%**	**-0.16%**	**-0.37%**	**-0.02%**	**-0.60%**	**-0.43%**
Tier 2 vs. BAU	**Material (incl. EoL)**	**62.92%**	**-3.63%**	**-1.54%**	**-0.40%**	**-1.78%**	**-2.53%**	**-1.09%**	**-6.79%**	**-4.95%**
Tier 2 vs. BAU	**All stages**		**-0.55%**	**-0.28%**	**-0.18%**	**-0.33%**	**-0.74%**	**-0.05%**	**-1.19%**	**-0.86%**

Level	Life stage	Eutrophication, terrestrial (Mmol N eq)	Eutrophication, freshwater (kt P eq)	Eutrophication, marine (kt N eq)	Ecotoxicity, freshwater (MCTUe)	Land use (M. pt)	Water use (Mm3 water eq. of deprived water)	Resource use, minerals and metals (kt Sb eq)	Resource use, fossils (TJ)	Primary energy consumption (TJ)
BAU	Material (excl. EoL)	24.93	2.37E+00	3.23E-02	2.86E+04	3.55E+05	7.06E+02	1.49E-01	3.75E+04	3.75E+04
BAU	Other plases (use...)	1.127E+02	1.70E+01	6.17E-01	1.10E+05	1.34E+05	3.55E+04	5.23E-02	2.17E+05	2.22E+05
BAU	EoL-i	2.136E+00	1.99E-01	6.23E-04	1.27E+03	1.21E+03	8.53E+01	9.27E-05	6.13E+03	6.13E+03
BAU	EoL-c	-6.726E+00	-6.16E-01	-2.73E-03	-1.06E+04	-2.29E+05	-1.57E+02	-5.26E-02	-9.60E+03	-9.60E+03
BAU	**All stages**	**1.330E+02**	**1.89E+01**	**6.47E-01**	**1.30E+05**	**2.60E+05**	**3.62E+04**	**1.49E-01**	**2.51E+05**	**2.56E+05**
BAU	**Material (incl. EoL)**	**2.034E+01**	**1.95E+00**	**3.02E-02**	**1.93E+04**	**1.27E+05**	**6.34E+02**	**9.63E-02**	**3.41E+04**	**3.41E+04**
BAU	**Share material**	**15.3%**	**10.3%**	**4.7%**	**14.9%**	**48.7%**	**1.8%**	**64.8%**	**13.6%**	**13.3%**
Tier 1	Material (excl. EoL)	24.24	2.30E+00	2.99E-02	2.78E+04	3.55E+05	6.88E+02	1.49E-01	3.63E+04	3.63E+04
Tier 1	Other plases (use...)	1.127E+02	1.70E+01	6.17E-01	1.10E+05	1.34E+05	3.55E+04	5.23E-02	2.17E+05	2.22E+05
Tier 1	EoL-i	2.136E+00	1.99E-01	6.23E-04	1.27E+03	1.21E+03	8.53E+01	9.27E-05	6.13E+03	6.13E+03
Tier 1	EoL-c	-6.726E+00	-6.16E-01	-2.73E-03	-1.06E+04	-2.29E+05	-1.57E+02	-5.26E-02	-9.60E+03	-9.60E+03
Tier 1	**All stages**	**1.323E+02**	**1.89E+01**	**6.45E-01**	**1.29E+05**	**2.60E+05**	**3.61E+04**	**1.48E-01**	**2.49E+05**	**2.55E+05**
Tier 1	**Material (incl. EoL)**	**1.965E+01**	**1.88E+00**	**2.78E-02**	**1.85E+04**	**1.27E+05**	**6.16E+02**	**9.61E-02**	**3.28E+04**	**3.28E+04**
Tier 1	**Share material**	**14.9%**	**10.0%**	**4.3%**	**14.3%**	**48.7%**	**1.7%**	**64.7%**	**13.1%**	**12.9%**
Tier 2	Material (excl. EoL)	23.55	2.23E+00	2.75E-02	2.70E+04	3.55E+05	6.70E+02	1.48E-01	3.50E+04	3.50E+04
Tier 2	Other plases (use...)	1.127E+02	1.70E+01	6.17E-01	1.10E+05	1.34E+05	3.55E+04	5.23E-02	2.17E+05	2.22E+05
Tier 2	EoL-i	2.136E+00	1.99E-01	6.23E-04	1.27E+03	1.21E+03	8.53E+01	9.27E-05	6.13E+03	6.13E+03
Tier 2	EoL-c	-6.726E+00	-6.16E-01	-2.73E-03	-1.06E+04	-2.29E+05	-1.57E+02	-5.26E-02	-9.60E+03	-9.60E+03
Tier 2	**All stages**	**1.316E+02**	**1.88E+01**	**6.43E-01**	**1.28E+05**	**2.60E+05**	**3.61E+04**	**1.48E-01**	**2.48E+05**	**2.54E+05**
Tier 2	**Material (incl. EoL)**	**1.897E+01**	**1.81E+00**	**2.54E-02**	**1.77E+04**	**1.27E+05**	**5.98E+02**	**9.59E-02**	**3.15E+04**	**3.15E+04**
Tier 2	**Share material**	**14.4%**	**9.6%**	**4.0%**	**13.8%**	**48.7%**	**1.7%**	**64.7%**	**12.7%**	**12.4%**
Tier1 vs BAU	**Material (incl. EoL)**	**-3.37%**	**-3.68%**	**-7.97%**	**-4.15%**	**0.00%**	**-2.86%**	**-0.20%**	**-3.72%**	**-3.72%**
Tier1 vs BAU	**All stages**	**-0.52%**	**-0.38%**	**-0.38%**	**-0.62%**	**0.00%**	**-0.05%**	**-0.13%**	**-0.51%**	**-0.50%**
Tier 2 vs. BAU	**Material (incl. EoL)**	**-6.75%**	**-7.35%**	**-15.95%**	**-8.30%**	**0.00%**	**-5.72%**	**-0.41%**	**-7.45%**	**-7.45%**
Tier 2 vs. BAU	**All stages**	**-1.04%**	**-0.77%**	**-0.75%**	**-1.25%**	**0.00%**	**-0.10%**	**-0.27%**	**-1.02%**	**-1.00%**

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