LCIs for production of recycled plastics (PP, PS, ABS) from WEEE plastics managed in France and regenerated in Europe

Methodological report

Final version post-critical review for external distribution

V1.2 – November 2020

Original version in French

Bleu Safran
L'expertise pour des produits et des services durables

TABLE OF CONTENTS

Clarification

This report is the “for external distribution” version of the methodological report produced and submitted for critical review.

Confidential information - not presented in this version - is indicated by a colour insert throughout the document. It is important to specify that this confidential information was included and therefore analysed by the critical review team.

GLOSSARY

LCA	Life Cycle Assessment
Allocation	Allocation of incoming or outgoing flows of a process or system of products, between the product system analysed and one or more other product systems.
CRT	Cathode Ray Tube (screen technology)
SRF	Solid Recovered Fuel
WEEE	Waste electrical and electronic equipment
DOM-COM	French overseas departments, French overseas authorities
LHA Cold	Large household cooling appliances
LHA non cold	Large household appliances non cold
GHG	Greenhouse gases
LCI	Life Cycle Inventory
ILCD	International Reference Life Cycle Data System
NHWSF	Non-hazardous waste storage facility
HWSF	Hazardous waste storage facility
LCDN	Life Cycle Data Network
Masterbatch	Highly concentrated mix of pigments or colourants in a macro-molecular substance compatible with the plastic material to be coloured
SHA	Small (mixed) household appliances
PEF	Product Environmental Footprint
SBS	Styrene-butadiene-styrene
WWTP	Wastewater treatment plant
MWIP	Municipal waste incineration plant
HWIP	Hazardous waste incineration plant

TABLES

FIGURES

AIMS OF THIS WORK

A. GENERAL ASPECTS

A.1 CLIENT

ecosystem is a not-for-profit organisation accredited by the French Authorities, for the collection and recycling of household and professional WEEE, lamps and small fire extinguishers.

It ensures that WEEE collection and recovery obligations are observed on behalf of its producer members. It is tasked with the following missions: organise collection networks, select logistics and treatment suppliers, track services to ensure the mechanism delivers good performance in terms of regulatory compliance, personal safety, and environmental protection. Upstream, **ecosystem** is active alongside its members to encourage and support their adoption of eco-design approaches.

The scope of action for **ecosystem** in the plastics recycling chain can be schematically set out as follows:

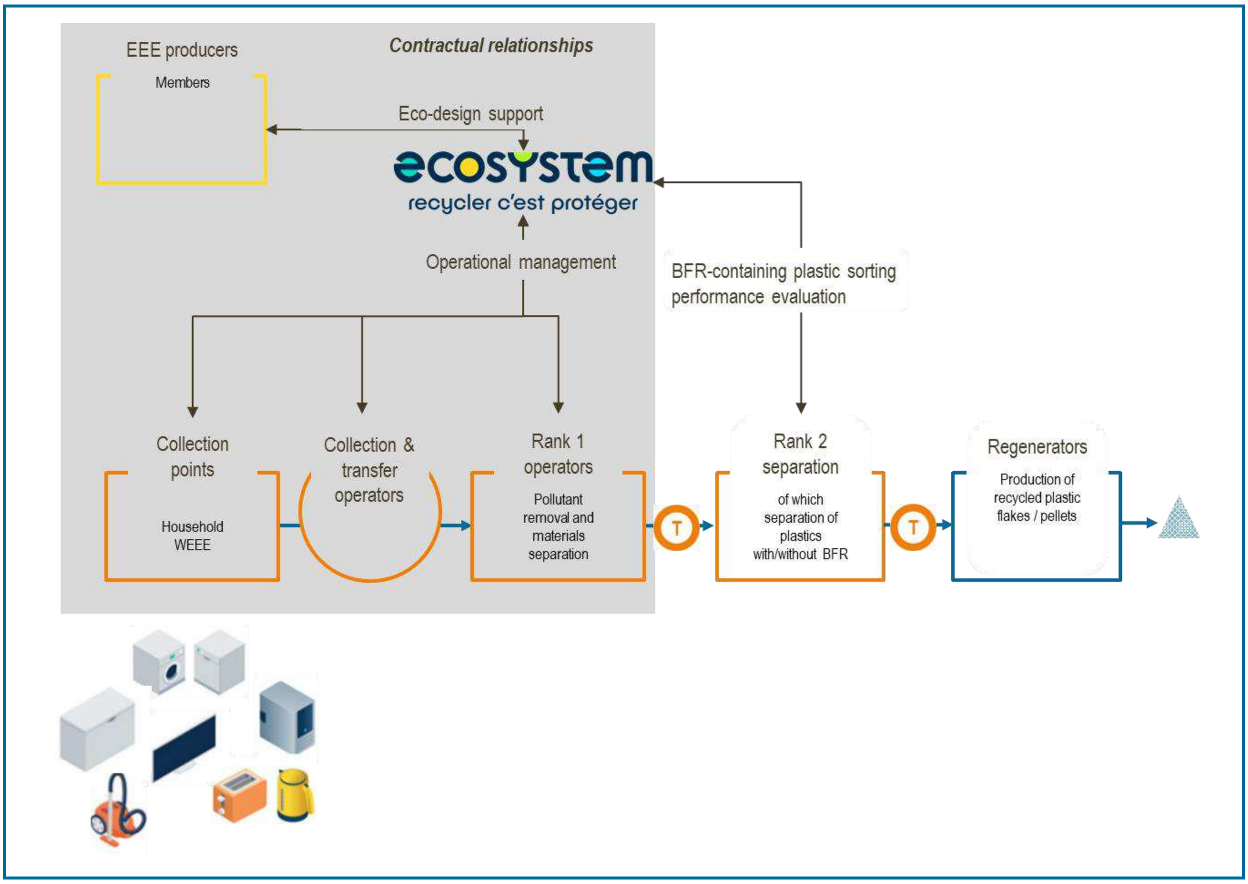


FIGURE 1 – ECOSYSTEM'S SCOPE OF ACTION IN THE PLASTICS RECYCLING CHAIN

ecosystem therefore maintains contractual relationships with multiple players: equipment producers (members), WEEE collection points, logistics operators tasked with collecting and massifying waste streams, rank 1 operators performing the initial equipment decontamination and separation of their constituent materials. In terms of plastics and rank 2 operations, **ecosystem** runs performance measurements on the separation of plastics with and without BFR additives, without there forcibly being contractual relations. These relationships may still exist if these rank 2 operations are carried out by rank 1 operators.

However, no contractual relationships exist between **ecosystem** and operators further downstream in the recycling chain, especially regenerators. Indeed, the recyclable plastic fractions obtained from rank 1 then rank 2 operations belong to the operators (and not to **ecosystem**), who are free to sell them on to the takers they choose.

In 2019, **ecosystem** collected almost 650,000 tonnes of household and professional WEEE, ranking it as a major player in the development of the WEEE channel on a European scale. For household WEEE, this represents over 75 % of the market in France.

A.2 Data owners

To complete our work, various data owners were contacted and agreed to participate in producing representative activity data.

Therefore, in addition to the data provided by **ecosystem**, this work is also based on data collected from rank 1 operators (Figure 1) and from plastics regenerators in Europe.

A.3 Author

The work was carried out by Bleu Safran, specialists in LCA, in particular end-of-life product management.

Between 2014 and 2018, Bleu Safran had already supported **ecosystem** in building a benchmark database to assess the environmental impact of end-of-life electrical and electronic equipment. Several dozen materials were modelled and identified according to the waste streams treated in France, namely the main plastics in household WEEE streams (PP, PS, ABS, ABS-PC, etc.), and separating additive-free plastics, those containing BFRs, and plastics with non-BFR additives.

A.4 Critical review

The work was submitted to a critical review committee[1] comprising two experts in LCA and post-consumer plastics recycling:

- Carole Charbuillet, Research Fellow, eco-design and recycling, circular economy of plastic products Arts et Métiers ParisTech university
- Bertrand Laratte, Research Fellow and LCA expert, Arts et Métiers ParisTech university.

B. Aims of this work

B.1 Origin of the work

This work is part of a wider programme of actions by **ecosystem** to encourage eco-design and the circular economy.

ecosystem works with its members to develop the integration of recycled materials in their products, especially WEEE plastics that can be recycled in a closed loop, for example. One argument concerns the potential environmental benefits of using regenerated plastic instead of virgin plastic.

ecosystem has therefore initiated a study of the various potential benefits of using recycled plastics, with a view to promoting projects to integrate recycled plastics.

<u>Pre-existing works:</u>

Before undertaking this work, we completed an in-depth analysis of a certain number of studies[2] concerning plastics recycling, whether applicable to WEEE or not.

---

[1] The critical review report is appended to final section of this document.

[2] Existing studies examined concerning plastics recycling and LCA:

This prior assessment was undertaken by Bleu Safran for cooperative research association SCORELCA, as part of a study on the consideration of plastic recycling in LCA ("SCORELCA, Recyclage des plastiques et ACV, 2020, n° 2019-02”). This work was completed in late 2020 and can be viewed on the SCORELCA website (in French) (https://www.scorelca.org/scorelca/etudes-acv.php).

Thus it was noted that relevant data concerning the circular use of plastics from electrical and electronic appliances was inadequate. Indeed, although studies have been completed by others to generate inventories of recycled plastics, or these studies do not provide dataset specifically concerning WEEE plastics, or they do not cover certain plastics relevant to EEE (e.g. recycled ABS).

However, concerning the collection and treatment phases upstream of the activities of plastics regenerators, datasets are already available from **ecosystem** works on the end-of-life management of constituent materials of electrical and electronic equipment.

The latest version of this work was published in 2019 and is available on the **ecosystem** node[3]. These inventories were submitted for critical review[4] by a committee of LCA experts and technical experts.

The creation of life cycle inventories for the main recycled WEEE plastics is a preliminary basis for the **ecosystem** study of the potential benefits of using recycled plastics.

B.2 AIMS OF THIS WORK

The primary aim of this work is to create **life cycle inventories for the production of ready-to-use recycled plastics**, which will then be used to manufacture new electrical and electronic equipment. This work therefore concerns recycled plastics in pellet[5] form produced by extrusion / pelletisation.

In terms of geographical representativeness, the work covers recycled plastics from household WEEE collected and managed through activities organised by **ecosystem** in France, and for which regeneration takes place in Europe.

For this first edition, **ecosystem** has opted to focus on the following polymers - polystyrene (PS), polypropylene (PP) and acrylonitrile butadiene styrene (ABS) - which are the main polymers recovered from WEEE - for which it was possible to collect field data from a sufficient number of regenerators to ensure data confidentiality.

B.3 REFERENCE STANDARDS

The work undertaken to build the LCIs is compliant with the requirements of standards ISO 14040: 2006 [1] and ISO 14044: 2006 [2] which provide the principles and framework for Life Cycle Assessment.

- Eco-profiles produced by SRP, France’s national plastic materials regenerators association.
- Franklin Associates. Life cycle impacts for post-consumer recycled resins: PET, HDPE, and PP. Submitted to The Association of Plastic Recyclers. December 2018. 49 p.
- Haupt M., Kägi T., Hellweg S. Life cycle inventories of waste management processes. Data in Brief. Volume 19, August 2018, Pages 1441-1457.
- Patrick A. Wäger, Roland Hischier, Life cycle assessment of post-consumer plastics production from waste electrical and electronic equipment (WEEE) treatment residues in a Central European plastics recycling plant, Science of The Total Environment, Volume 529, 2015, Pages 158-167.

[3] http://weee-lci.ecosystem.eco/Node/

[4] Critical review report available at:
http://weee-lci.ecosystem.eco/Node/showSource.xhtml?uuid=a8213f5f-bbed-47ae-a875-90f9a593765f&stock=ecosystem_WEEE_LCI

[5] The direct use of recycled plastics in flake form (no extrusion or pelletisation) is not widely popular for foreseeable applications in the electrical and electronic equipment sector.

B.4 BACKGROUND FOR DECISIONS AND INTENDED APPLICATIONS

The inventories intend to use a descriptive approach to represent the environmental profile of the production of certain recycled plastics. These inventories are built based on an attributional LCA approach.

They are intended for use **in priority in eco-design approaches adopted by the electrical and electronic equipment sector**. The development of “product environmental footprints” represents a second field of application likely to interest producers.

These inventories will therefore be distributed to producer members of **ecosystem** and more widely to the community of LCA practitioners. The inventories may be made available via the **ecosystem** node accessible via the European Commission’s Life Cycle Data Network.

Furthermore, **ecosystem** may use the inventories to study the potential environmental benefits of using recycled plastic. Note that such work (e.g. the presentation of results of environmental impacts, comparative analysis of recycled plastics vs. virgin plastics) does not fall within the scope of this report.

Aside these applications, the LCI datasets produced may also be used by practitioners in comparative or non-comparative LCA studies. In all events, users of these datasets will have to consider the limits of the work to assess the capacity of the resulting data to satisfy their needs.

B.5 TARGET AUDIENCE

In priority, the work aims to meet the needs of LCA practitioners of **ecosystem** members: the data must enable them to model the integration of recycled WEEE plastics collected in France and regenerated in Europe.

Nonetheless, insofar that the data produced are published on the Life Cycle Data Network, they may also be considered useful to all LCA practitioners.

B.6 EXTERNAL DELIVERABLES PUBLISHED

Two types of deliverable are developed for publication:

- **Inventories**: to observe privacy obligations concerning data collected from contributors (rank 1 operators, plastics regenerators), the inventories are delivered in System format (elementary flows) and in ILCD xml format.
- **Methodological report**: this document provides a summary of the key points of the LCI development work. It is this very document.

B.7 DATE OF ISSUE OF METHODOLOGICAL REPORT

This document is the version approved for external distribution (containing no confidential data) of the final methodological report submitted for critical review, version V1.2 dated 18 November 2020.

SCOPE

C. PRESENTATION OF RECYCLED PLASTICS STUDIED AND THEIR ORIGINATING WEEE STREAMS

C.1 RECYCLED PLASTICS STUDIED

C.1.1 RECYCLED WEEE PLASTICS STUDIED IN THIS WORK

Electrical and electronic equipment is by nature complex, comprising multiple materials and a large variety of plastics.

Plastics present in main currently treated household WEEE steams		
Waste stream	**Average indicative proportion of plastics (all types)**	**Principal polymers (filled or not) – except rigid PU foams**
LHA cold	Approx. 15% (except rigid PU foams)	**PS**, **ABS**, PP
LHA non cold	Approx. 10-15%	**PP**, **ABS**, PA, elastomers
SHA	Approx. 30%	**ABS**, **PP**, **PS**, ABS-PC, PA, POM + many other minority plastics
Flat screens	Approx. 30%	ABS-PC, PMMA, **ABS**, PET, PC, **PS**
CRT screens	Approx. 15%	**PS**, **ABS**, ABS-PC

TABLE 1 - MAIN PLASTICS PRESENT IN END-OF-LIFE WEEE (SOURCE: ECOSYSTEM WORK[6])

At the end of its life, this WEEE will undergo various steps to separate and sort its constituent materials. Throughout the chain from the collection of WEEE to the regeneration of plastics, the integration of regulatory requirements as well as technical and economic arbitrages made by sorting operators and plastics regenerators will lead them to recycle only a part of the plastics originally present in end-of-life products.

For the WEEE sector, regenerators are *in fine* targeting[7] polymers with little or no additives, with densities between 0.9 and 1.08-1.1, and therefore on the following "targets":

- Polyolefins with little or no fillers, and more specifically **polypropylene** in the case of WEEE
- Styrenes with little or no fillers: **polystyrene** and **ABS**.

Indeed, the frequent use of density separation techniques by sorting operators (separation of plastics with and without BFR additives) and by regenerators leads them to prioritise certain plastics.

To highlight the issues involved with density separation techniques, the figure below provides a summary of the density values of the main polymers frequently found in waste containing plastics, including WEEE.

The densities of non-expanded polymers are usually within a range from 0.9 to 1.4, while polyolefins have densities below 1. We also note that the use of fillers is likely to significantly alter the density. For example, a polypropylene containing 20% talc will have a density somewhere around 1.05, while a polypropylene with no fillers will be at around 0.9.

[6] Equipment Material Assessment Programme undertaken annually to analyse the material composition of WEEE input for rank 1 operators.

[7] To our understanding, the targeted approach of regenerators is very certainly a result of the arbitrage criteria and possibly the accessible tonnage for each type of plastic, the costs involved in recycling the plastics, the level of technology expertise, the application markets accessible to / targeted by regenerators.

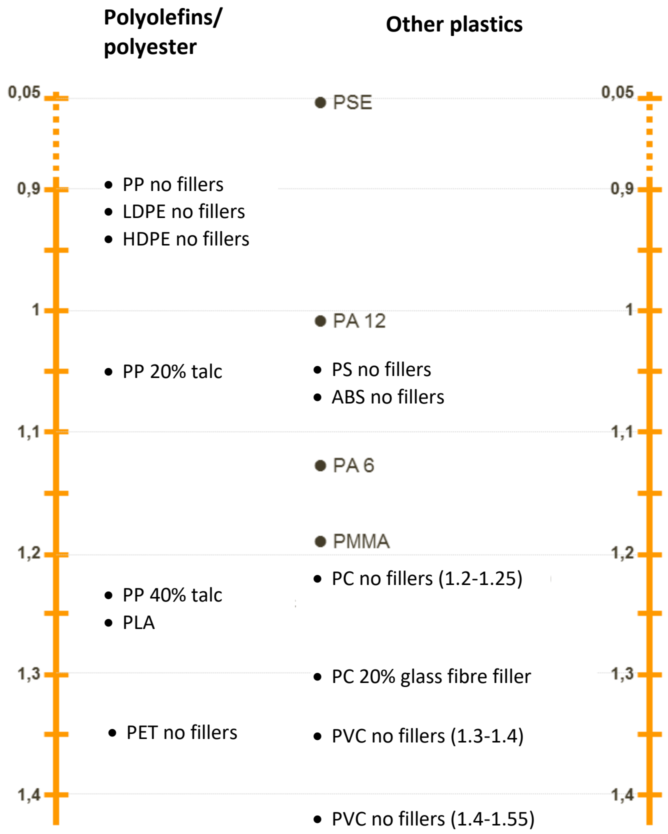


Figure 2 – Density of main polymers used in packaging, EEE and automotive sectors (source: SCORE-LCA study, Plastics recycling and LCA, 2020)

This work was therefore undertaken to determine an **average life cycle inventory of the production of recycled plastic for each of these three WEEE plastics**: **PP, PS and ABS**

C.1.2 Characteristics of the recycled plastics studied

As the aim is to propose inventories for plastics ready for use by producers of electrical and electronic equipment, our work therefore focuses on the production of **recycled plastic pellets** by extrusion/pelletisation.

According to the regenerators interviewed, the polymer separation and flake sorting steps implemented enable them to achieve high grades of purity for the pellets produced, where materials other than the target polymer (e.g. other polymers with similar densities) only represent a few percent.

Depending on the waste from where the plastics originate and the markets available to regenerators, they may decide to sort certain plastics by colour. In the case of recycled WEEE plastics, this may apply to PS from large household cooling appliances, which are mainly white.

In our study, we decided to use a common profile for each plastic without colour distinction. This choice was justified by the need for a sufficient number of regenerators for each inventory (i.e. a minimum of three), which would not have been possible if we opted to distinguish the colours of recycled PS produced.

As the energy requirements for optical colour-based sorting are secondary compared to the energy requirements for other steps (upstream of regeneration, shredding to produce flakes, extrusion-pelletisation), we consider that the choice of an average LCI without colour distinction for PS is suited to the aims of the work.

Summary presentation of the recycled plastics studied			
	PP	**PS**	**ABS**
Target WEEE plastic	PP with little or no fillers	PS with little or no fillers	ABS with little or no fillers
Physical form of recycled material	Pellets, ready for use by producers of EEE		
Colour	All colours, no distinction if different colours exist		
Purity grade	High (> 95% of target polymer) Data source from regenerators		
Types of additives	Masterbatch	Masterbatch Impact modifier	Masterbatch

TABLE 2 – KEY CHARACTERISTICS OF RECYCLED PLASTICS STUDIED

Concerning purity levels, the responses from regenerators surveyed when collecting data report values ranging from 95 % to 98 %. A value of 95 % was therefore used to define this characteristic.

In the case of PS, as the profile created needed to respect minimum technical requirements, it was considered that the PS pellets include an impact modifier, for which a “normalised” content of 2 % is used.

C.1.3 WEEE PLASTICS NOT ADDRESSED IN THIS REPORT

Certain regenerators are likely to produce other recycled plastics from fractions that contain high levels of plastics from WEEE processing.

This is notably the case for certain PP-talc in WEEE (density generally <1.1) and ABS-PC, which is recycled by certain regenerators who have advanced techniques.

According to the information in our possession, these recycled plastics represent lower tonnage than those produced from PP, PS or ABS.

These plastics have not been addressed in this project insofar that the number of regenerators surveyed and producing this type of recycled plastics was not sufficient for suitable control of confidentiality and issues of representativeness.

Similarly, certain types of plastics (e.g. PMMA, PET) extracted during the manual dismantling of flat screens and sent for recycling have not been addressed (e.g. flexible filters, rigid transparent panels) as these polymers are not “core targets” for the project.

C.2 HOUSEHOLD WEEE STREAMS GENERATING PLASTICS SENT FOR RECYCLING

This work addresses the following recycled plastics from household WEEE: Large household appliances non cold (LHA non cold), Large household cooling appliances (LHA cold), Small household appliances (SHA), Flat screens and CRT screens.

To date, the main WEEE streams collected via the organisation set up by **ecosystem** address “household” [8] WEEE, which represented almost 600,000 tonnes collected by **ecosystem** in 2019.

In the field, collection and treatment are organised by waste stream, to enable each WEEE stream to be collected and decontaminated using specific processes according to the contaminants it contains, the characteristics of the facilities or regulatory requirements.

[8] **ecosystem** is also certified to collect certain categories of professional WEEE (almost 40,000 tonnes collected in 2019) and to collect lamps (almost 5,200 tonnes collected in 2019). Note that the plastics contained in lamps are not subject to material recycling but to other recovery or elimination methods.

Dedicated data collection is assured for the following WEEE streams:

- Large household cooling appliances (LHA cold)
- Large household appliances non cold (LHA non cold)
- Small mixed household appliances (SHA)
- CRT screens
- Flat screens

The figure below shows the evolution of annual collection volumes in thousands of tonnes, for household WEEE streams over 2015-2019.

Figure 3 - Evolution of annual tonnage collected by household WEEE stream (Source: ecosystem, 2019 annual report)

The successive collection and treatment steps producing the plastic mixes sent to regenerators differ according to the WEEE stream.

The organisation of these steps for household WEEE has been in place for many years and is therefore considered to be mature (stable production processes).

For small mixed household appliances and screens, certain end-of-life equipment we are currently seeing is likely to contain plastics with flame retardant additives, in particular brominated flame retardants (BFR); to meet regulatory requirements[9], specific management has been implemented to separate plastics containing BFRs and those not containing BFRs, the latter not being recycled and currently sent for incineration as hazardous waste (management system currently in place in France).

D. Reference unit

As the precise function of recycled plastics depends on the fields of application which lie outside the scope of this work, the reference unit is a declared unit.

For the purposes of this work, the reference unit is defined as: "A kilogram of recycled plastic (or PP, PS or ABS), produced from WEEE plastics collected in France and regenerated in Europe, in the form of ready-to-use pellets that can be used by EEE producers, on departure from the regeneration facility".

[9] See circular of 30 November 2012 on the management of plastics from waste electrical and electronic equipment; regulation (EU) 2019/1021 dated 20 June 2019 concerning persistent organic pollutants; RoHS directive 2017/2102/EU.

E. System boundaries: the steps of the recycling process

The work must enable us to create the LCIs of recycled plastics that may provide perspective on the use of virgin plastics, whether it concerns studies by **ecosystem** or application studies undertaken by its members.

It is therefore important that the scope is “comparable”, i.e. from the extraction of raw materials to the production of virgin plastics, and from the collection of waste to the production of recycled plastics.

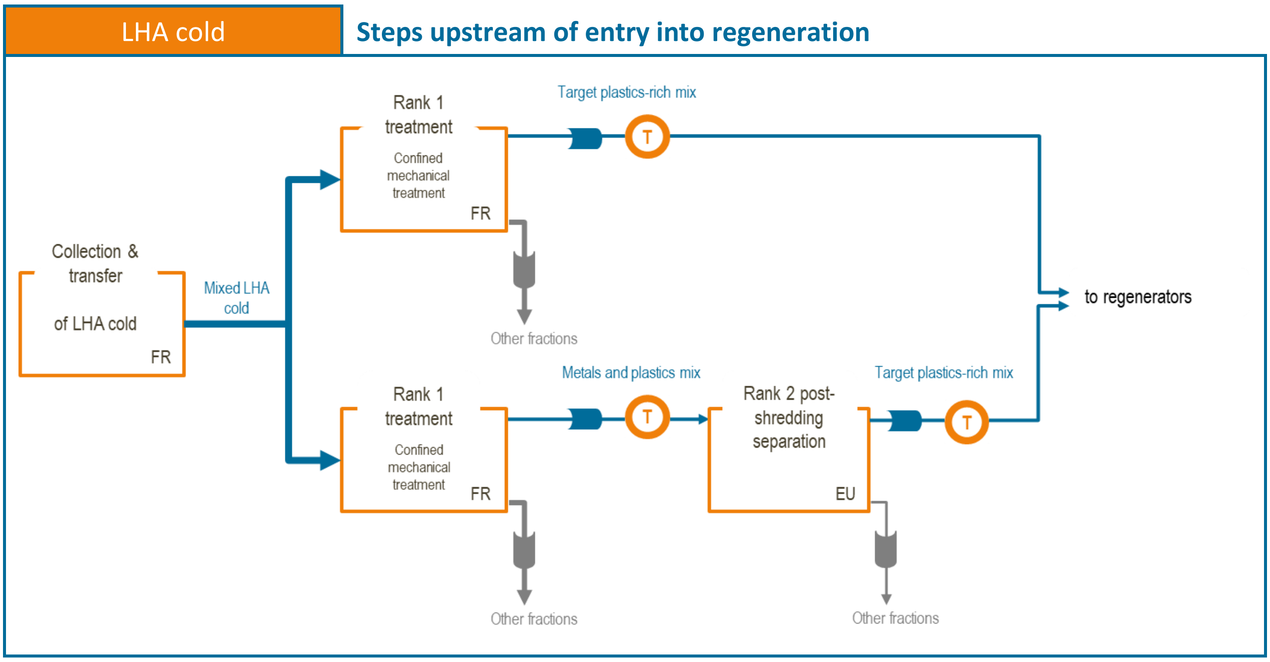
The following diagrams present the steps in the recycling process used to develop the production inventories for recycled WEEE plastics.

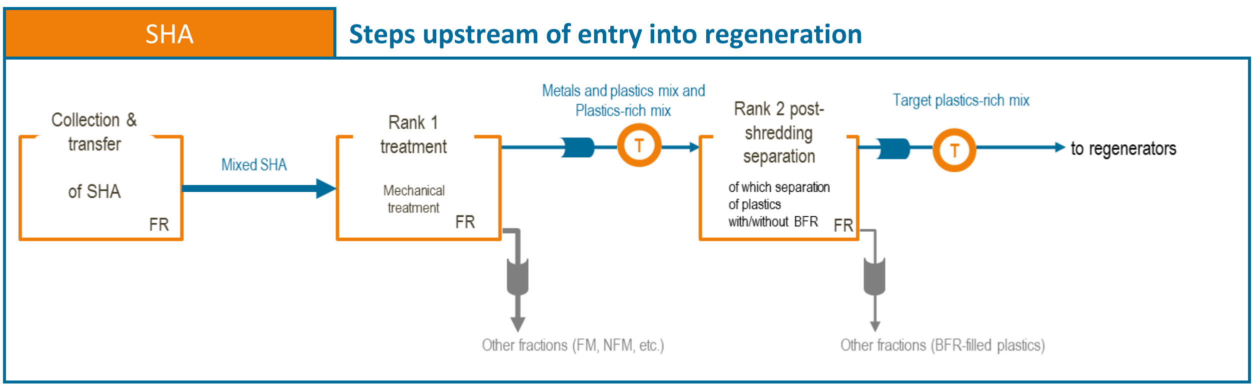
The following diagrams successively describe:

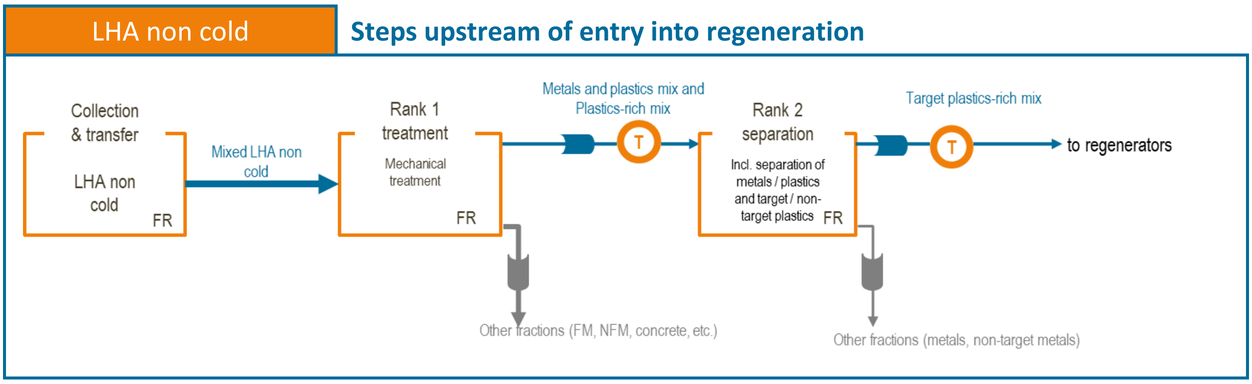
- The upstream management steps prior to dispatch for regeneration for LHA cold, SHA, LHA non cold and screens (CRT and flat).
- The steps taken by plastics regenerators who receive plastic-rich mixes produced in prior steps.

Information concerning the data sources and their representativeness is provided in the “Life Cycle Inventory” chapter, section J, page 27.

E.1 Steps in recycling chain upstream of regeneration







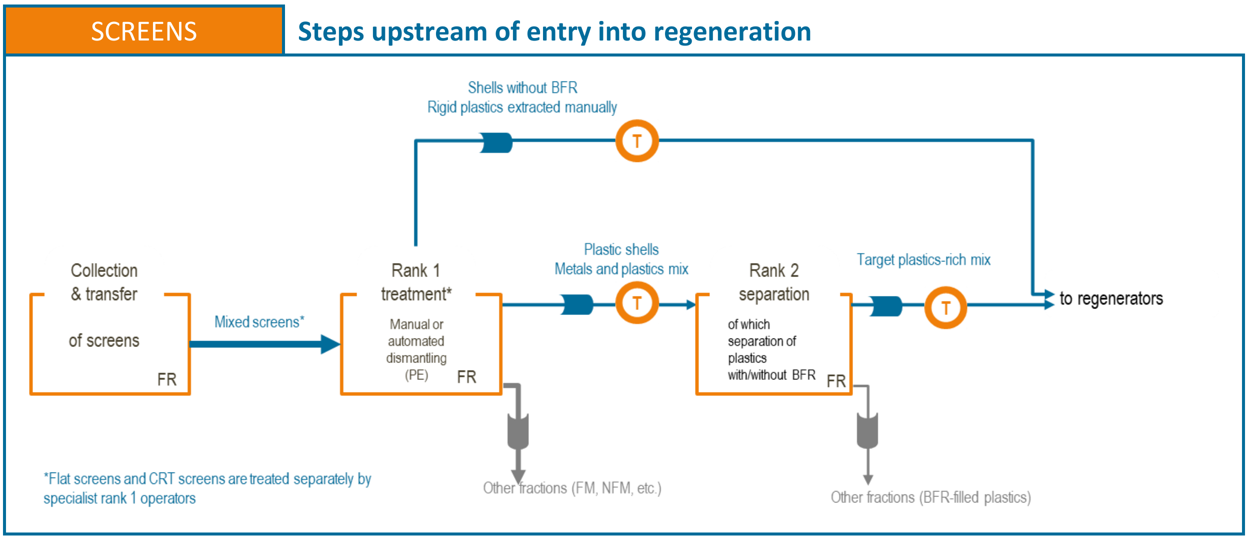


FIGURE 4 - UPSTREAM STEPS APPLICABLE TO HOUSEHOLD WEEE STREAMS PRIOR TO ENTRY INTO REGENERATION

Collection & transfer: this phase includes the collection of WEEE from authorised collection facilities to processing centres, where WEEE are consolidated, then transferred to rank 1 operators; another and often smaller part of the tonnages collected can also be transported directly in bulk form from authorised collection points to the rank 1 operators.

Rank 1 treatment: these operators in France are responsible for the decontamination and first step in WEEE treatment. The treatment applied must meet the regulatory requirements concerning the decontamination of regulated substances, which are removed for specific treatment due to their potential hazardous nature.

In the case of large household cooling appliances, once the refrigerant gases are bled off, oil removed from compressors and certain other target materials removed, the equipment is then crushed mechanically in a confined nitrogen atmosphere.

For the LHA non cold and SHA streams, waste equipment is subjected to mechanical treatment (e.g. smasher or disintegration unit for SHA, ELV shredder for LHA non cold). However, rank 1 treatment of CRT screens is done manually and flat screen management relies on a mix of technologies: workers do either manual or semi-automated work (assistance robot for dismantling), or use a crushing - separation process.

Rank 1 treatment leads to the production of different fractions with varying degrees of complexity: aside a few exceptions (possible with manual sorting), fractions never contain just one material (e.g. PP), nor the same category of materials (i.e. plastics); fractions correspond to:

a) a volume of materials in which one category is dominant (e.g. ferrous metals) but where other materials / components (PCBs, induced components, etc.) distinct from the main category are present as impurities;
b) A genuine mix of various categories of materials (mix of metals and plastics, fluff, crushing residues, etc.).

Transport between rank 1 and rank 2: the fractions produced by rank 1 operators are transported to rank 2 operators if necessary. Several rank 2 operators may be associated with a given rank 1 operator and a given waste fraction.

Rank 2 intermediate treatment: for plastic-rich fractions intended for recycling, rank 2 operators may be:

a) intermediate treatment operators responsible for separating metals and plastics for metal/plastic mixes from rank 1,
b) intermediate treatment operators responsible for separating plastics containing BFR or not, on SHA streams and screens impacted by this regulatory requirement,
c) Consolidation / trade operator (who may play a key role in ensuring the security of supply to subsequent takers).

These operators are mainly located in France and for the majority in the European zone.

Certain rank 1 operators handling LHA cold produce a plastics-rich fraction which is sent directly to plastics regenerators without intermediate treatment.

Transport to plastics regenerators: for the purposes of this work, transport occurs between operators in France or Europe.

E.2 STEPS IMPLEMENTED BY PLASTICS REGENERATORS

Below are the steps commonly used by plastics regenerators receiving mixes rich with WEEE plastics.

Note that regenerators often work with a variety of feedstock, WEEE plastics being just one of them. They can therefore obtain several types of post-consumer waste (e.g. ELV plastics, packaging, etc.) or pre-consumer waste (e.g. production rejects, manufacturing scrap).

As certain regenerators contacted are major players on a European scale, feedstock often originates from multiple, essentially European countries.

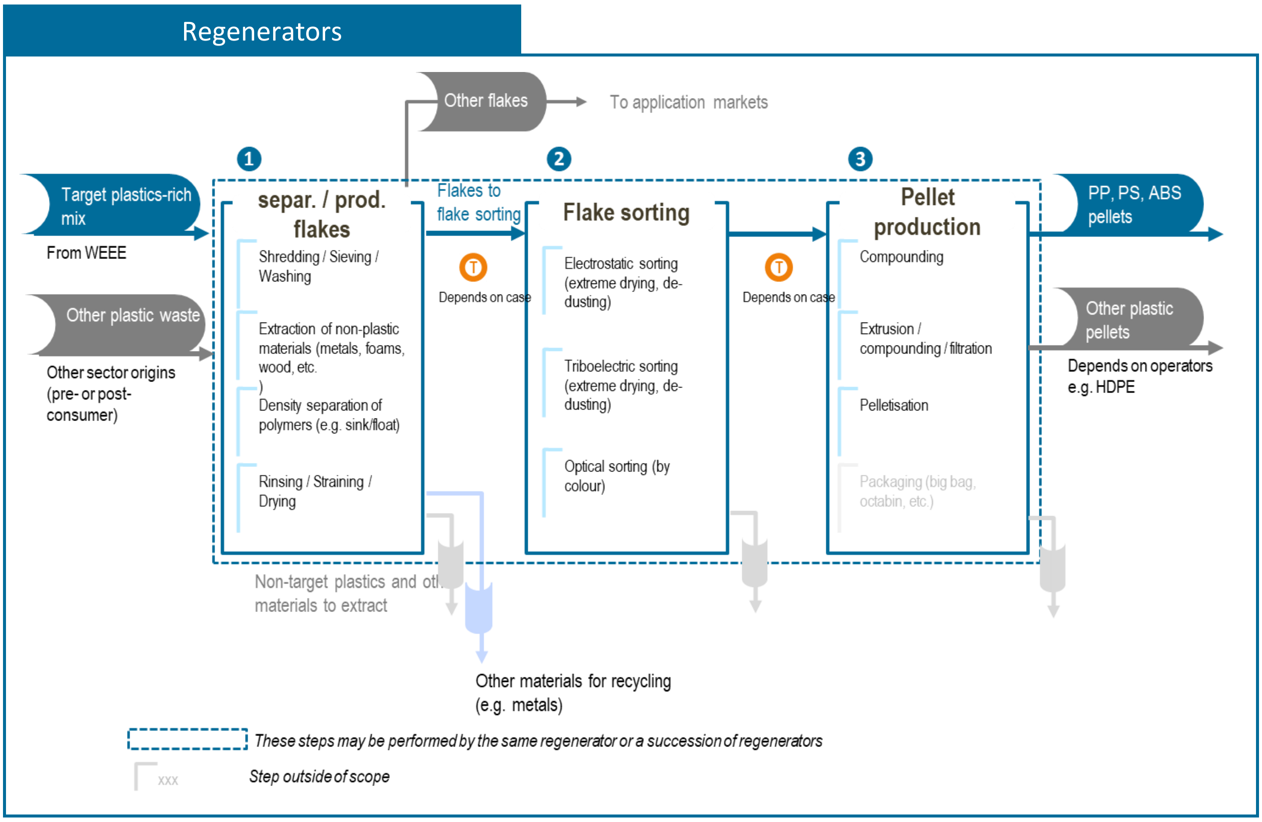


FIGURE 5 - SEQUENCE OF STEPS BY REGENERATORS

Separation of materials in plastic-rich mixes and shredding: a sequence of steps will ensure that:

- materials in waste inputs are removed,
- light materials and metals can be extracted as necessary,
- surface pollutant plastics present can be removed,
- an initial separation of target plastics (from each other and from other non-recyclable plastics). For the regenerators surveyed, the most common technique used in this separation step is a succession of flotation baths.

When output from these steps, the target plastics (PP, PS, ABS) are in flake form. If the waste input comprises a mix of polymers, some of which can have relatively similar densities, it is frequent that the flakes obtained are not "pure". PS flakes can therefore contain a high proportion of ABS and inversely; PP flakes can contain PE. Some regenerators also receive mixed plastics with similar densities such as PS/ABS/PP-talc/other mixes.

Depending on the business choices of regenerators and market conditions, some regenerators will sell some or all of their production as flakes. Such products can either be used directly in applications which accept this type of product, or be processed elsewhere (e.g. compounder, other regenerators).

Other regenerators, including those surveyed for this work, only sell recycled plastics in pellet form, as shredded plastic flakes are simply intermediate products in their production chain.

Flake sorting for extrusion-pelletisation: depending on the characteristics of the flakes obtained earlier, regenerators may implement further steps enabling them to; (I) separate plastics with similar density and obtain high purity levels of flakes (ii) sort by colour (mainly for PS).

A high level of purity will be required if plastics are intended for pelletisation, so that in the end, the pellets[10] have good technical properties (see Table 2– Key characteristics of recycled plastics studied, page 124).

For the regenerators surveyed, the techniques used are as follows:

- Separation using triboelectric or electrostatic sorting. These techniques require that the flakes are very dry and dust-free. Such techniques are often used to separate PS/ABS mixes (see section K, Table 9 - Regenerator sample population: technologies used and type of regenerated plastics sold).
- Optical sorting for colour separation (white flakes are separated from other colours).

These flake sorting techniques may be directly implemented by rank 1 regenerators or by regenerators specialising in the separation of pre-sorted mixes of plastics with similar densities.

Pellet production: To achieve the properties expected by their customers, regenerators will generally use a compound involving the use of various additives (e.g. colour masterbatch, impact modifiers).

Some may also create PP-talc type mixes by adding talc or PP-EPDM by adding EPDM, for certain markets such as automotive applications. These mixes are indicated for information but are not addressed in the scope of this work.

Extrusion / filtration and pelletisation then take place on an extrusion production line specific to the type of polymer produced.

Transport between regenerators: As some regenerators do not perform all the steps in producing pellets, transport is required between the first regenerator and another where the rest of the production process will take place, resulting in pellets ready for use by the electrical and electronic equipment sector.

E.3 EXCLUSIONS

Collection

The journey made by private individuals (or other participants) to the WEEE collection point is excluded from the scope. As journey conditions (distance, vehicle load, reason for travel) can vary enormously, they are also excluded from the scope of eco-organisations.

Packaging

Packaging used for recycled plastic pellets: the packaging of pellets produced by regenerators (big bag, Octabin, etc.) is excluded insofar that the inventories produced by PlasticsEurope[5] for virgin pellets do not include their packaging either.

Concerning the consumables used by sorting operators or regenerators (e.g. consumables for density separation baths, compounding additives), primary and tertiary packaging was not considered and therefore ignored.

Infrastructures

The assessment was made to exclude infrastructures, whether in upstream steps or operations conducted by plastics regenerators. This choice was made as a result of an arbitrage between the foreseeable volume of work necessary to reliably include this component (construction solutions are varied, surface areas occupied by infrastructures of the same activity category can vary considerably in terms of land costs, the amortisation factors may be complex to define, especially when a building

[10] The presence of a notable proportion of other plastics may impair the technical properties of a given plastic due to issues of incompatibility between polymers.

has been successively used in varied activities) and the added value resulting from such information in relation to the foreground system that we are seeking to evaluate in priority.

In a similar way, the PlasticsEurope inventories available to date for polymers such as PP, PS and ABS (publications prior to 2016) were based on methodological rules that did not account for infrastructures[11].

F. Cut-off criteria

No intentional cut-off criterion, whether in terms of mass, energy or environment was applied in foreground data collection concerning the WEEE plastics recycling chain.

Nonetheless, some information requested during the data collection phase has produced little or no results. This concerns especially:

- Environmental emissions caused by rank 1 processes or regeneration activities (e.g. dust, volatile organic compounds not captured and escaping into the open air during extrusion);
- Certain consumables with annual consumption levels below those of main consumables (e.g. consumables used in pre-treating industrial wastewater, oils used in equipment operation) or which are confidential (e.g. certain consumables used in density separation).

Therefore, the consideration of certain material or energy inputs or specific emissions may present limits in terms of environmental impacts and can therefore be improved on.

For some, unavailable data have been replaced with approximations. The reader is advised to refer to the “K.2.2.2 Unavailable data and additional assumptions“ section of the report for further details.

G. Sensitivity analysis to refine system boundaries

Insofar that the steps taken into account are considered to exhaustive in terms of the whole processing sequence, from WEEE collection to the production of recycled plastic pellets, no further investigation was undertaken to refine the system boundaries.

H. Data quality criteria

The applicable quality requirements for our work are those set out in ISO 14 044: 2006.

The criteria we considered to define the requirements and assess the final quality of data are as follows:

- **Time representativeness**
  The work should enable us to produce inventories that will remain valid for around 2 to 4 years insofar that the EEE end-of-life LCIs will probably be updated after this time, which will also offer the opportunity to update the LCIs of recycled plastics. The temporal representativeness should be compatible with this validity time frame.

- **Geographical representativeness**
  The required LCIs must be representative of the plastic waste streams from household WEEE collected in France and forwarded to European regenerators.

- **Technological representativeness**

[11] PlasticsEurope - Life Cycle Inventory (LCI) Methodology and Product Category Rules (PCR) for Uncompounded Polymer Resins and Reactive Polymer Precursors. Version 2.0 (April 2011)

This work aims to consider regeneration operations that are representative of the regeneration activities for plastic mixes with complex compositions.
It also aims to create LCIs suited to modelling recycled plastics that may be used notably by EEE producers (issue concerning compounding).

- **Consistency of method**
  One requirement applicable to this work concerns the need for consistency between this project and the previous project to create end-of-life LCIs for EEE. Indeed, as this pre-existing work was used to model the steps upstream of regeneration, the background databases are strictly the same.

  Another aspect concerns the consistency of method applicable to the consideration of multi-functionality issues, as they arise throughout all steps in the recycling chain (upstream and regeneration as such).

- **Exhaustiveness**
  Another requirement applicable to this work concerns the need for exhaustiveness given the reality of the constituent steps of the plastics recycling sequence, and given the risks of not considering input or output streams (no intentional cut-off criterion, proactive approach to handling unavailable data).

- **Data relevance and precision**
  One expectation of this work is to demonstrate our use of activity data collection work with regenerators handling WEEE plastics, as not all plastics regenerators are capable of handling this type of waste.

  For this first edition of LCIs of recycled WEEE plastics, we expect the best accuracy possible, without it being exceptionally high due to the relative limits on the state of knowledge accessible at the date of this report, i.e.

  - partial identification of European regenerators handling WEEE plastics collected in France (visibility difficult when streams are traded);
  - partial knowledge of the diversity of plastics present in WEEE streams and the rates at which these plastics are sent to regenerators following separation and sorting prior to regeneration.
  - Reporting data from regenerators are relatively limited (e.g. aggregate facility data rather than process step-specific).

The data quality rating is given in section *K.5 Data quality rating and suitability for requirements.*

LIFE CYCLE INVENTORY

I. GENERAL POINTS

I.1 MULTI-FUNCTIONALITY AND ALLOCATION ISSUES

Situation

Throughout the recycling process resulting in the production of recycled plastics, most handling steps receive one or more input waste streams and produce one or more output waste streams, including the stream(s) containing the target plastic in question.

For example, the rank 1 treatment of WEEE streams will enable the production of:

(i) plastic-rich fractions intended for recycling (target stream);
(ii) multiple other fractions with highly different final destinations: regulated pollutants sent for thermal destruction, fractions rich in ferrous or non-ferrous metals intended for recycling, crushing residues sent to landfill etc. (non-target streams).

The same type of situation exists for the later treatment step, which will separate metals from plastics for example, and/or separate polymers with and without BFRs for the WEEE streams in question.

The diagram below uses a fictional composition of a WEEE stream, the multi-functional nature of the treatment steps and the "distribution" of materials initially present in the WEEE to various outputs along the treatment chain.

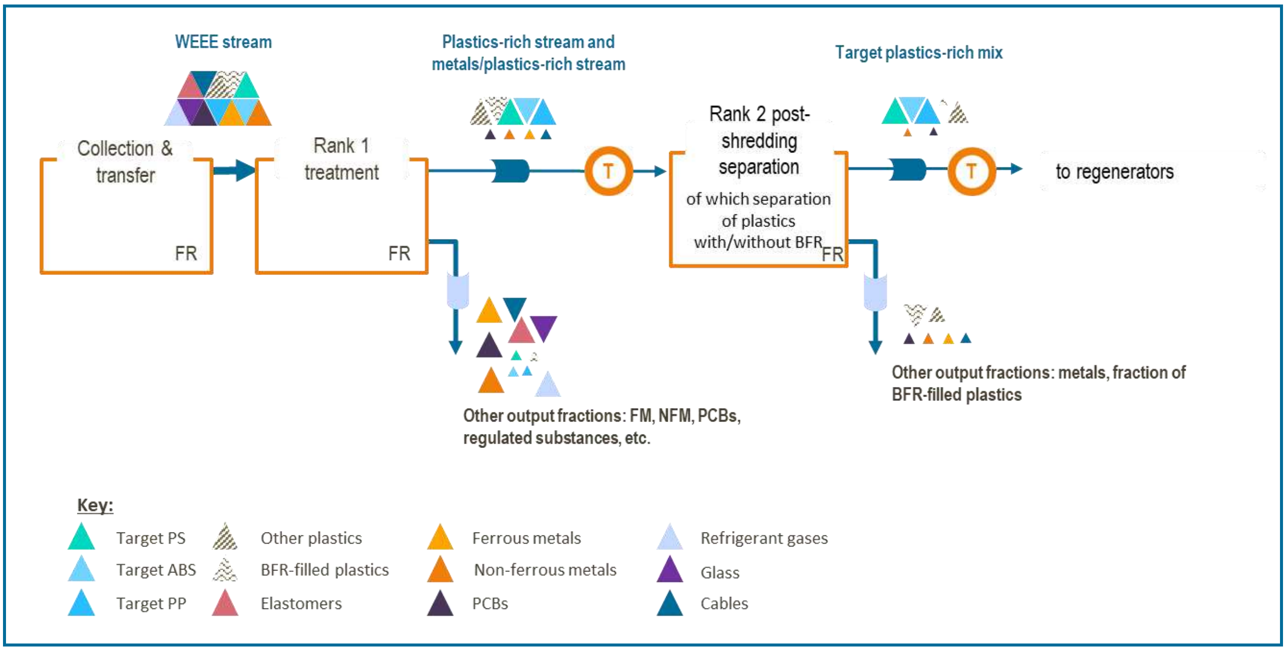


FIGURE 6 - MULTI-FUNCTIONAL NATURE OF RECYCLING CHAIN STEPS: ILLUSTRATION

Similarly, the first treatments by plastics regenerators will separate:

(i) target plastics which will be sent for extrusion / pelletisation
(ii) residual metals sent for recycling,
(iii) other residual recyclable materials (e.g. rigid PU foams from LHA cold plastics).
(iv) a mix or residual materials comprising plastics (e.g. non-target polymers, target plastics but with excessive fillers) and other non-recoverable materials, these fractions usually being sent for incineration or landfill).

Also, depending on the regenerators, they may only sell plastics in pellet form or produce flakes as well as pellets for sale.

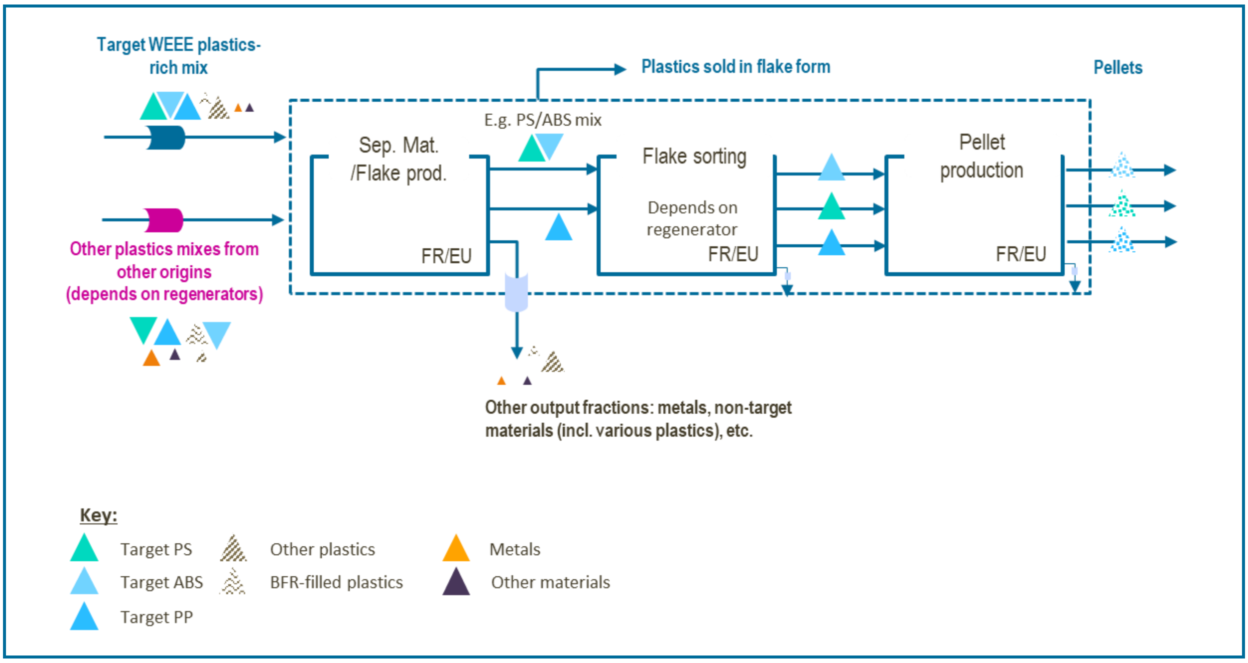


FIGURE 7 - MULTI-FUNCTIONALITY OF REGENERATORS: ILLUSTRATION

There is therefore an issue of multi-functionality which should be addressed consistently with the aims of this work i.e. use an attributional LCI approach to draw up the production inventory of certain recycled materials, namely recycled PP, PS and ABS from WEEE.

This issue raises two types of question:

- Should the impacts and benefits of later treatment of non-target streams be considered as "charges" against the treatment step in question?
  Note: the "charges" for a step must be allocated to the "co-product" streams output from a step.
- What allocation method should be used to allocate charges between co-products of the same step, if these co-products are target or non-target streams?

Thoughts on the specific aspects of waste management

When treating waste, except in certain cases there is no "product" output from a waste treatment step and all output streams are waste. A waste treatment step is therefore to be considered as providing a service.

From our standpoint, the economic value of output streams from a waste treatment step is not an appropriate method to identify the service delivered by a step or to assign a hierarchical order to the services delivered. Some output streams from a waste treatment step represent a cost item, which can vary in value according to the later treatment; while other output streams from this same step are considered to be an income item, the value of which can vary according to the materials making up the stream.

As an example, when treating LHA cold, the streams of refrigerant gases and expansion gases captured represent a cost item, all the more so since these gases must be incinerated as hazardous waste; inversely, metallic and non-ferrous fractions extracted will a priori represent an income item.

From our standpoint, it would be inappropriate to base our work on the observation of the economic attributes of these output streams to conclude that the main service delivered by the treatment of

LHA cold consists primarily in the extraction of metallic fractions for their recycling. Indeed, this would be tantamount to ignoring that regulations impose that the primary mission of some end-of-life channels is waste decontamination and appropriate environmental management of pollutants.

It nonetheless seems legitimate to take account of the services delivered, which may consist in the extraction of pollutants for suitable later treatment but also in the separation and extraction of recoverable metals for suitable recycling.

Methodological orientations

The inventories produced must be able to be used by EEE producers in eco-design approaches or the definition of environmental footprints.

Regarding the production and end-of-life phases in particular, these two uses are based on an analytical approach and case-by-case assessments of materials, notably for key parameters associated with circularity (material end-of-life, integration of recycled materials).

Technical allocation choices depend on the **principle of independence of accounting between the constituent materials** of the products analysed. In other words, the treatment choices for materials other than the recycled plastics studied including the impacts and benefits of their final treatment, should not influence the inventories and therefore the impact results of the target plastics.

A few examples to illustrate the principle: By applying this approach, we do not allocate:

- The treatment of refrigerant gases to recycled PS from LHA cold;
- The benefits of recycling PCBs extracted in rank 1 to the PP recycled from SHA;
- The incineration as hazardous waste of the PP containing BFRs to the recycled additive-free PP from SHA;
- The benefits of recycling metals extracted by plastics regenerators to the recycled plastics they produce;
- The treatment of non-target plastics discarded in the first treatments applied by the regenerators to the recycled plastics produced.

The corollary of the application of this principle is to consider the output streams from a treatment step, whether they are target streams containing plastics to be recycled or non-target streams, such as the co-products of the treatment on which the charges are applied.

Given the specific aspects of waste management discussed earlier, the charges applicable to a treatment step have been allocated across the output streams using a principle of **allocation by mass**.

In the case of treatments applied by regenerators, we note that only the first separation steps are applied to the different output streams (target plastics, extracted metals, non-target materials). Any flake sorting and extrusion/pelletisation steps have been allocated to the recycled plastics alone.

Regeneration scope	Output streams considered for allocation of charges on process steps
Block 1 Materials separation / production of target plastic flakes	▪ Target plastic flakes for regenerator ▪ Non-plastic materials sent for recycling or material recovery e.g. ferrous or non-ferrous metals, rigid PU foam (if necessary) ▪ Separation rejects sent for landfill or incineration e.g. non-target plastics, plastics with additives, other constituent materials of WEEE and present in waste stream inputs to regeneration. These materials can be found in solid waste, treatment sludge or dust captured.
Block 2 Target flake sorting	▪ Target plastic flake sorting
Block 3 Pellet production	▪ Plastic pellets

TABLE3 - TREATMENT STEPS APPLIED BY REGENERATORS: IMPLEMENTATION OF ALLOCATION RULES AND OUTPUT STREAMS CONCERNED

I.2 BACKGROUND INVENTORY DATA SOURCES

This work is based on the two data sources for end-of-life LCIs of WEEE (last update done in H1 2018). It was decided to use the same background inventory database to ensure the consistency of background data.

Therefore, the ecoinvent inventories used for this work are relative to version 3.4 published by ecoinvent in October 2017 and published in SIMAPRO in 2018.

I.3 ELECTRICITY PRODUCTION

Plastics regenerators were asked about the source of the electricity consumed. All responded that they used electricity supplied from the national grid.

We have therefore considered three profiles for the electricity consumed during regeneration steps:

Confidential private information which was nonetheless examined in the critical review.

Concerning the operations upstream of regenerators, they are for a large part conducted in France and their model used the medium voltage profile for France.

For information, the impact on the greenhouse gas effect of the production of a kWh electric is given in the table below (in g equiv. CO_2/kWh). We recall that the inventories used are similar to those used to analyse the upstream phases in the recycling chain.

Grid electricity	Source	g eq CO_2/kWh (IPCC 2013 method)
Confidential private information which was nonetheless examined in the critical review.		

TABLE 4 - ELECTRICITY GENERATION: PRODUCTION INVENTORIES USED AND ORDER OF MAGNITUDE OF GHG IMPACT

Electricity model in France
The ecoinvent V3.4 electricity model for France is based on a single year (2014) which is somewhat atypical given the weather conditions for that year. It was therefore decided to use an LCI over three consecutive years.

This profile represented the 2015-2017 period and was specifically produced using the following data:

- Annual production data published by RTE for metropolitan France, 2015 to 2017;
- Annual import and export figures for physical electricity flows between France and its neighbours (Germany, Italy, Belgium, Switzerland, UK, Spain, Luxembourg);
- High voltage electricity production LCIs available in ecoinvent for each production method (”nuclear”, “natural gas”, “conventional power plant”, “hydro, run-of-river”, etc.).
- Loss assumptions considered by ecoinvent relating to the transformation into medium voltage electricity and transport.

J. Steps upstream of regeneration

J.1 Reminder concerning pre-existing works

Concerning steps prior to regeneration, the activity data were collected during the work to produce the end-of-life LCIs of the constituent materials of household WEEE streams between 2015 and 2018. The LCIs produced are considered valid until 2022.

The reader may refer to the methodological summary of this work “LCIs of end-of-life management of the constituent materials of electrical and electronic equipment in the approved WEEE treatment channel”, version V2.0 June 2018), available on the **ecosystem** node on the Life Cycle Data Network[12].

This summary describes the activity data collected, representativeness, methods, data quality rating and suitability in terms of quality requirements, for treatment steps addressed in this work:

- Upstream logistics (collection & consolidation);
- Rank 1 operator activities;
- Transport between rank 1 and rank 2 operators;
- Rank 2 operations.

J.2 Foreground data sources and representativeness

Upstream logistics and rank 1 operations

The work conducted on the end-of-life LCIs collected specific activity data. The coverage rates of this work in terms of upstream logistics and rank 1 operations relative to WEEE streams are shown in the table below.

[12] http://weee-lci.ecosystem.eco/Node/showSource.xhtml?uuid=a7bee5bf-0449-4d85-9779-8f795e2dc022&stock=ecosystem_WEEE_LCI

	Upstream logistics		Rank 1 operators	
WEEE stream	Overall volume coverage of work	Geographical location	Overall volume coverage of work	Geographical location
LHA cold	≈ 100 % of 2014 collection tonnage	France incl. DOM COM	100 % of 2014 tonnage	France (metropolitan)
LHA non cold	≈ 100 % of 2014 collection tonnage	France incl. DOM COM	≈ 90 % of 2014 tonnage	France (metropolitan)
SHA	≈ 100 % of 2014 collection tonnage	France incl. DOM COM	≈ 95 % of 2014 tonnage	France (metropolitan)
FLAT SCREENS	≈ 100 % of 2014 collection tonnage	France incl. DOM COM	≈ 93 % of 2015 tonnage	France (metropolitan)

TABLE 5 - VOLUME COVERAGE RATE OF UPSTREAM LOGISTICS AND RANK 1 OPERATORS CONSIDERED IN RELATION TO TONNAGE HANDLED BY ECOSYSTEM FOR THE YEAR IN QUESTION

As CRT screens were not included in the work on end-of-life LCIs[13], the upstream steps for this stream were estimated as similar to flat screens.

Transport between rank 1 and rank 2 operators

During the work on end-of-life LCI, rank 1 operators were surveyed in terms of each fraction:

- On the identity and location of rank 2 operators and the breakdown of tonnage sent to each of these takers;
- on the methods of packaging the fractions and their density.

All these data were used to model transport for each fraction between rank 1 treatment operators and rank 2 operators.

For the purposes of this work, only the fractions exiting rank 1 and containing plastics destined for recycling are taken into account. Indeed, the other fractions containing plastics for which the final destination is not recycling (e.g. landfill, incineration) have been disregarded.

Only the following fractions - obtained as rank 1 output - are considered. The weighting key between plastic fractions was built based on the plastics present in these fractions and effectively transferred to plastics regenerators. This key weights the transport distances between ranks 1 and 2.

Waste stream	Waste fractions output from rank 1 considered
LHA cold	▪ Mixed plastics ▪ Metal / plastics mix
LHA non cold	▪ Mixed plastics ▪ Metal / plastics mix ▪ Metal fines / plastic mix
SHA	▪ Mixed plastics ▪ Metal / plastics mix ▪ Metal fines / plastic mix
FLAT SCREENS	▪ Plastic shells ▪ Rigid plastics extracted manually ▪ Post-shredding metal / plastics mix ▪ Bodies managed on SHA treatment line

TABLE 6 – WASTE FRACTIONS OUTPUT FROM RANK 1 AND CONTAINING PLASTICS FOR ORIENTATION TO REGENERATION

[13] As these items have not been produced for some years now, there was no requirement in terms of eco-design.

Rank 2 operators

Concerning recycled WEEE plastics, rank 2 operators are obliged to separate plastic-rich fractions upstream of regenerators (separation of metals and plastics, segregation of plastics with and without BFR additives).

During the work on end-of-life LCIs for WEEE, due to the volume of the work and the difficulty in accessing data, it was not possible to collect activity data for all rank 2 operations and later operations until final destinations using questionnaires (several hundred operators to cover all the WEEE categories surveyed).

We therefore implemented alternative data collection strategies, as indicated in the methodological summary:

- by analogy with certain aspects of rank 1 treatment of the SHA stream, such as electricity consumption, fuel consumption for motorised equipment and dust emissions;
- by validation of consistency with a dataset obtained from a rank 2 operator using a plastics separation process.

A generic model was created for rank 2 operators and covers:

- process energy consumption, including electricity;
- fuel consumption by motorised handling equipment;
- dust emissions.

The geographical location of rank 2 operators used for this work is described below.

WEEE stream	Rank 2 operator location	Location used for recycled plastics LCI
LHA cold	Germany (metals/plastics mix)	Germany
SHA	France (statutory obligation to separate plastics with/without BFRs)	France
LHA non cold	Mainly in France Limited tonnage to operators in Europe outside France (< 5%)	France
FLAT SCREENS	France (statutory obligation to separate plastics with/without BFRs)	France

TABLE 7 – RANK 2 OPERATOR LOCATIONS

As a reminder, for rank 1 operators focused on LHA cold producing a mixed plastics fraction (low proportion of metals), this is transferred directly to the plastics regenerators.

Transport between rank 2 operators and regenerators

As this work addresses only the fractions from rank 1 operators transferred to plastics regenerators, simplified assumptions have been used:

- Rank 2 operator in France - regenerator in France: distance 500 km, transport by tractor-trailer rig with GVW of 40 tonnes at full load. An empty return rate is also considered[14].
- Rank 2 operator in France - regenerator in Europe (principally neighbouring countries): distance 1000 km, transport by tractor-trailer rig with GVW of 40 tonnes at full load. An empty return rate is also considered.

[14]Same data source as for WEEE end-of-life LCIs.

J.3 STEPS PRIOR TO REGENERATION: WEIGHTING KEYS USED TO CREATE AVERAGE "RECYCLED PLASTICS" INVENTORIES

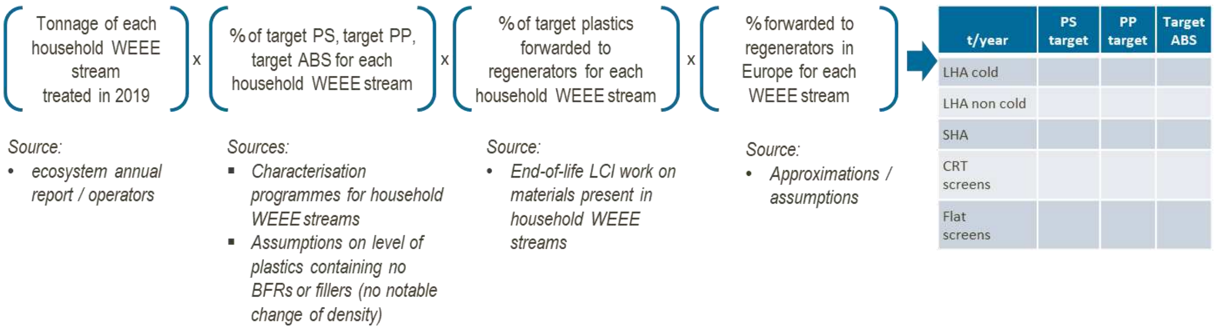
For each of the plastics studied - PP, PS and ABS regenerated in Europe - it is important to establish the household WEEE stream at the source of these plastics as well as the respective contributions of each stream.

Indeed, the differences between household WEEE streams concern both the annual tonnages collected as the composition of plastics mixed transferred for regeneration:

- The principal target plastics vary from one stream to another;
- The proportions of non-target plastics and materials other than plastics in plastics mixes depend on the WEEE stream treated (initial composition of equipment collection, sequence and efficiency of separation treatment steps).

Confidential private information which was nonetheless examined in the critical review.

To take into account these specific aspects, a dedicated average profile was established for each recycled plastic based on the calculation principle and data sources shown in the following diagram:



The "upstream" profiles of the plastics studied are as follows:

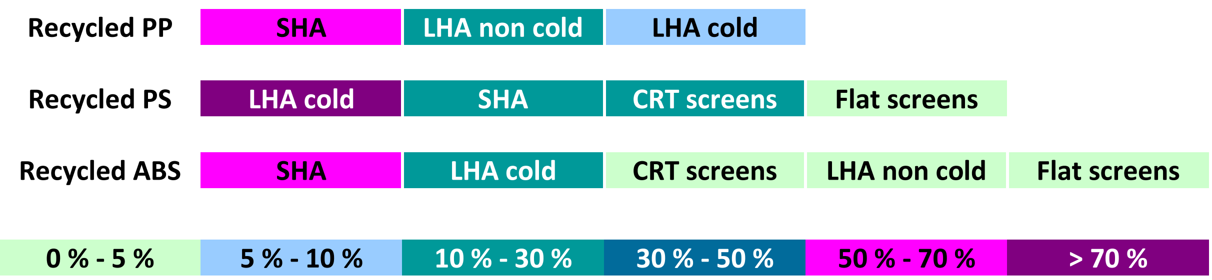


FIGURE 8 - UPSTREAM STEPS: CONTRIBUTION BY HOUSEHOLD WEEE STREAMS TO BUILD THE AVERAGE PROFILES OF THE PLASTICS STUDIED

For reasons of confidentiality, the breakdown by WEEE stream is indicated on the figure using colour codes to represent value ranges. Precise percentages were used to model the inventories.

K. TREATMENT STEPS BY PLASTICS REGENERATORS

Trading WEEE plastics mixes sent to regenerators is done by waste treatment operators under market conditions established jointly with the takers of these fractions (regenerators, traders). **ecosystem** does not have direct contractual relationships with plastics regenerators[15].

ecosystem does however hold information concerning plastics regenerators who receive WEEE plastics, from regular reports by rank 1 operators and through several other specific studies undertaken by **ecosystem**.

This knowledge has enabled us to contact a range of plastics regenerators, with four of them accepting to actively participate in this project.

K.1 SOURCES AND REPRESENTATIVENESS OF WORKS

K.1.1 SAMPLE POPULATION OF REGENERATORS CONTACTED TO COLLECT ACTIVITY DATA

K.1.1.1 Presentation of sample population

For this work, 2019 activity data was collected from a sample population of four plastics regenerators in France or in Europe, receiving plastics mixes from household WEEE collected in France.

Depending on the regenerator profile, the WEEE plastics mixes - from France or other European countries - may represent the sole source of waste input, a majority source or a secondary source of input. The regenerated plastics produced by these regenerators therefore only partly originate from WEEE collected in France.

The table below provides summary information on the types of waste plastics inputs received by the responding regenerators.

Confidential private information which was nonetheless examined in the critical review.

For each of the regenerators, this table provides the following information:

- Portion of WEEE plastics in regenerator plastic waste stream inputs
- Originating sector of other plastic waste stream inputs
- EEE stream source of WEEE plastics in France (LHA cold, SHA, etc.)
- Geographical location of regenerator

TABLE8 - REGENERATOR SAMPLE POPULATION: ORIGINATING SECTOR OF WASTE INPUTS TO REGENERATION

[15] **ecosystem** nonetheless deals with various plastics regenerators in the course of its support on projects to integrate recycled plastics with producer members.

The primary technologies used by the four regenerators and the types of plastics recycled are described below:

Confidential private information which was nonetheless examined in the critical review.

For each of the regenerators, this table provides the following information:

- The primary technologies used to extract non-plastic materials and to separate the different types of plastics from each other.
- Presentation of regenerated plastics traded in terms of polymer and format (pellets, flakes).

TABLE 9 - REGENERATOR SAMPLE POPULATION: TECHNOLOGIES USED AND TYPE OF REGENERATED PLASTICS SOLD

It is important to specify that:

- Certain technologies may apply to all recycled plastics produced or be specifically deployed to separate certain plastics (e.g. electrostatic sorting to separate PS and ABS flakes).
- Certain regenerators trade certain plastics partly or only in flake form. This concerns:

Confidential private information which was nonetheless examined in the critical review.

K.1.1.2 REPRESENTATIVENESS OF SAMPLE POPULATION

As not all regenerators handling plastics from WEEE collected in France were included in this study, it was necessary to estimate the “coverage rate” of the sample.

As the recycled plastics did not only originate from WEEE collected in France, the quantities of target plastics (PS, PP, ABS) sent to the sample population of regenerators were estimated based on:

- the quantities of WEEE plastics mixes collected in France and received by each regenerator. These data apply to 2019.
- the composition profiles of the plastics mixes for each WEEE stream.

The figure below indicates the contribution of the sample population regenerators for each of the three recycled plastics studied.

	Overall sample coverage
Recycled PP	**50%**
Recycled PS	**51%**
Recycled ABS	**60%**

The contribution of each regenerator is confidential information, which was nonetheless examined in the critical review

0 % - 5 %	5 % - 10 %	10 % - 20 %	20 % - 30 %	30 % - 40 %	40% - 50%

FIGURE 9 - OVERALL COVERAGE RATE OF REGENERATOR SAMPLE POPULATION FOR THE THREE RECYCLED PLASTICS STUDIED AND CONTRIBUTION OF EACH REGENERATOR

For reasons of confidentiality, the contribution of each regenerator in the sample population is indicated on the figure using colour codes to represent value ranges. Precise percentages were used to model the inventories.

K.1.2 FURTHER EXTRAPOLATIONS USED TO MEET THE AIMS OF THE WORK

The sample population of regenerators from whom we collected data is somewhat limited in terms of the aims of the work:

- The coverage rate is between 50 % and 60 % depending on the recycled plastic in question, given that the geographical representativeness of this sample is likely to differ from that of all European regenerators of plastics originating from WEEE collected in France.
- The sample population of regenerators do not forcibly apply all of the treatment steps required to produce plastic pellets ready for use by electrical and electronic equipment makers. Indeed, certain regenerated plastics are exclusively or partially produced as flakes.

To improve the representative character of the work, we implemented the following extrapolation approach:

Extrapolation to cover all steps up to pellet production

If the sampled regenerators only produce or partly produce “flake” quality products for a plastic addressed by this study, an additional process block was added to cover the compounding / extrusion / pelletisation steps which are necessary to obtain ready-to-use pellets for electrical and electronic equipment manufacturers.

The following choices were made in this respect:

- As we did not have precise information on the location of suppliers able to implement these additional steps (e.g. same country as regenerator, other European country), a “Europe” location was used. Therefore:
  - Concerning the electricity consumed in these process steps, an average Europe profile was used;
  - A distance of 500 km and bulk transport by tractor-trailer rig was considered between two regenerators.
- The energy and material inputs as well as specific emissions were estimated using data collected from the sample population of regenerators who provided specific data on the “formulation / extrusion / pelletisation” block and using an arithmetical mean of the data. This mean is therefore based on the profiles of the regenerators confidential.

Extrapolation to represent regenerators not included in data sample collection

This work could not cover all European plastics regenerators receiving plastics mixes from WEEE collected in France.

To the extent of **ecosystem** knowledge, these regenerators may be located in France or elsewhere in Europe confidentiel, without it being possible - at the date of publication of this report - to determine their geographical distribution precisely.

As electricity is a significant input in the treatment processes of plastics regenerators, the electricity production profile has a notable impact on the production inventories of recycled plastics.

As the geographical representativeness of regenerators outside the sample population may differ from that of the sample confidentiel, the choice was made to create a “non-surveyed regenerators” profile, with “Europe” as its location. Therefore:

- The profile was created using a 50/50 contribution of the profiles of the two main regenerators in the sample population, namely confidentiel.
- The electricity consumed in the process steps was replaced with a mean Europe profile.

K.1.3 Final representativeness and applicability of data sources

To summarise the points covered above, the figures below describe the representativeness of the data sources used and their applicability to each of the recycled plastics studied.

The identity of regenerators is confidential and not indicated in the following diagrams. The information was nonetheless provided to the critical review.

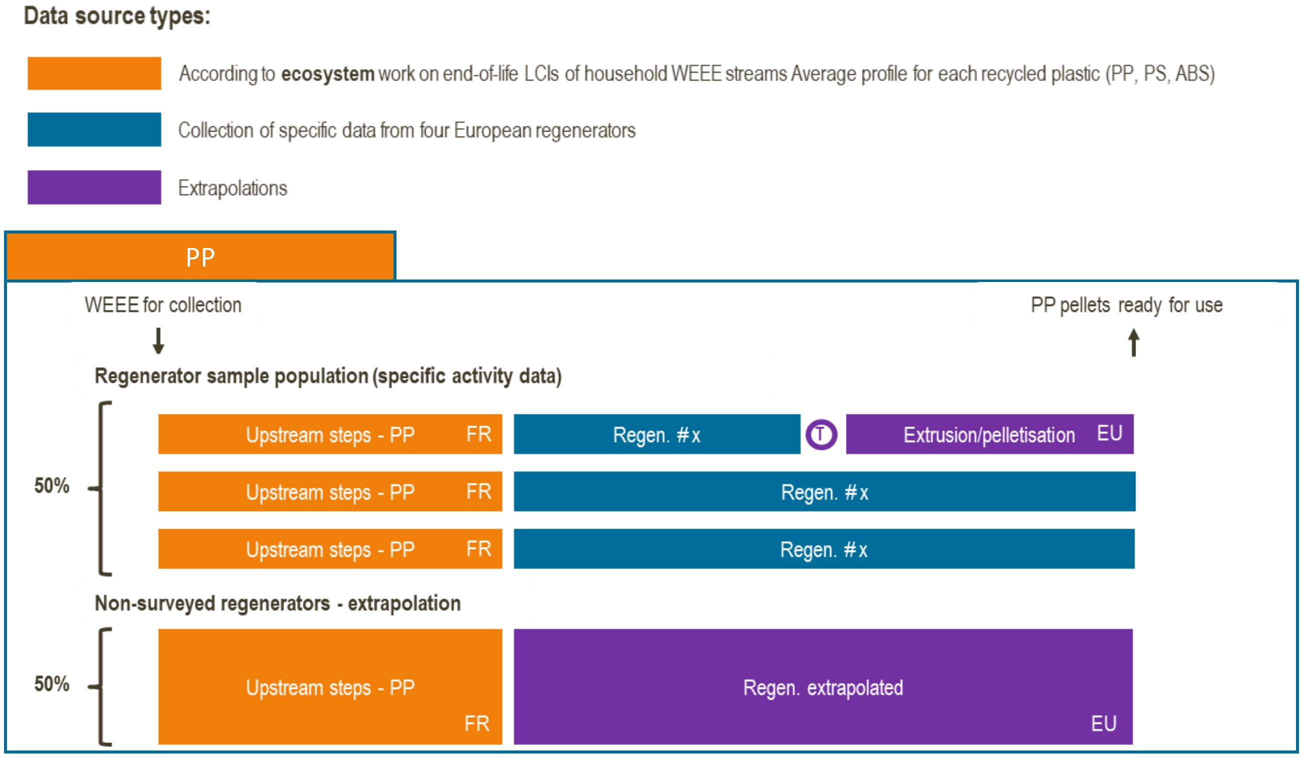


FIGURE 10 - REPRESENTATIVENESS OF INVENTORIES: CONTRIBUTION OF SAMPLE DATA AND OF EXTRAPOLATED DATA

K.2 ACTIVITY DATA COLLECTED FROM REGENERATORS

K.2.1 COLLECTION AND VALIDATION OF ACTIVITY DATA

Data collection was done using questionnaires, organised using the same structure and same approach but adapted to the specific nature of the regenerators where necessary.

To enable this, prior to the development and transmission of questionnaires, we organised field visits and/or phone interviews with regenerators to obtain information on the treatment steps implemented at their facilities and to determine what data could be collected.

Clarifications provided concerning certain methods of data collection from regenerators are confidential, but were nonetheless analysed by the critical review.

Bleu Safran and **ecosystem** ran detailed analyses of the responses to each questionnaire returned and residual questions were sent to the regenerator. This work mainly concerned:

- the consistency of input/output stream reports,
- the reality of the orders of magnitude obtained, notably in terms of primary energy inputs,
- clarifications on the treatment steps applied to all recycled plastics produced and those more specific to certain plastics,
- further information and requests for clarification on certain consumables,
- further information and requests for clarification on certain treatment process emissions and rejects.

Where applicable, further dialogue gave rise to updates to the data collection questionnaire.

K.2.2 Energy and material inputs, specific emissions

K.2.2.1 Data collected

Regenerators were surveyed on the following aspects:

- The mass balance of inputs and mass balance of the fractions output from their facilities;
- their energy consumption by type of source to operate process equipment and motorised equipment;
- Other material inputs;
- Atmospheric emissions and releases into water;
- Waste generated and its subsequent elimination or recovery.

Regenerators receiving waste inputs from different sectors and locations (C.f. Table8) only aggregate data on the scale of the sources were collected.

Furthermore, data collection was organised around requesting this information for the three blocks presented in Figure 5, namely:

- Block 1: successive treatment steps from reception of incoming waste through to the production of unsorted flakes
- Block 2: the additional flake sorting steps to separate pre-sorted polymers from each other
- Block 3: the compounding - extrusion - pelletisation steps

This segmentation was necessary for the reasons indicated below:

- The need to manage the issue of allocation between co-products output (c.f. section I.1 of this report), as some are only impacted by block 1;
- The need to take into account that certain regenerators trade all or part of their production in flake form. Therefore, shredded plastics output from block 1 may not find their way to further sorting or compounding - extrusion - pelletisation steps (c.f. section E.2 of this report).

The table below presents the nature of inputs and outputs taken into account because they were declared by at least one of the regenerators in the sample population.

As the quantitative data returned by regenerators are confidential, such information has not been presented in this report.

Relevant activity data	Remarks
Energy inputs	
Electricity	
Natural gas	Drying steps esp.
Diesel or HFO	Operation of handling equipment
LPG	Operation of handling equipment
Material inputs	
Potable water, process water	e.g. density separation baths, pellet cooling on exit from extrusion
Consumables for density separation baths	e.g. Salts, calcium carbonate
Flocculant	Treatment of process water, cationic polymer
Shredder blades	Wear parts, stainless steel
Steel filters	Dust filtration esp.
Compounding additives: ▪ Peroxides ▪ Masterbatch (with colourants) ▪ Impact modifiers (PS only)	Compounding step for regenerated plastics Carbon black or titanium dioxide (white) type colourants SBS type impact modifiers
Waste, emissions, rejects whose end-of-life management is allocated to the treatment step outputs	
[Air] - dry dust	
[Air] - volatile organic compounds	Process block source of emissions: Compounding - extrusion - pelletisation steps
[Water] - wastewater	
[Waste] - water treatment sludge	Only the portion of sludge resulting from consumable added during the process and water is considered.
[Waste] - filtration residues	Process block source of waste: Compounding - extrusion - pelletisation steps
[Waste] - Condensate	

TABLE 10 - REGENERATION: DATA COLLECTED ON INPUTS AND OUTPUTS

The waste streams detailed in Table 10 represent waste considered as "charges" whose end-of-life management must be accounted for and allocated to the outputs concerned (c.f. Table3). Concerning waste from block 1, only the proportion of sludge resulting from the consumable added during the process (e.g. flocculant, calcium carbonate, water), is accounted for as a charge. This is because the other constituents of the density separation treatment bath sludge are materials already present in the waste inputs.

Let us also clarify that in the case of PS, a "normalised" ratio of impact modifier type additives was considered, at a rate of 2% for each type of pellets produced, rather than the data from regenerators which may correspond to a mean mix of pellets (with and without impact modifiers):

Points for attention:

As indicated earlier, the data were requested by block of processes. However, the regenerators did not all have data specifically concerning each block (e.g. regenerator only knowing the total electricity consumption for its whole facility).

In this context, certain regenerators were able to establish allocation keys used to allocate energy inputs, material inputs or outputs to the separate process blocks.

One regenerator was not able to separate the blocks, given that it only produces regenerated plastics in pellet form. For this case, it was decided to waiver the rules of allocation described earlier. Therefore the inputs and outputs reported for this regenerator for all its process blocks were allocated only to the regenerated plastics produced.

K.2.2.2 Unavailable data and additional assumptions

Unavailable data

The examination of questionnaires returned by the regenerators highlighted the total lack of data or lack of usable data for certain inputs or outputs of regeneration activities. Depending on the case, this unavailable data may concern one or more regenerators.

This concerns in particular:

- Dust likely to be emitted during the initial steps of the regeneration chain (block 1);
- Volatile organic compounds and dust likely to be emitted during compounding - extrusion - pelletisation steps;
- Fuel consumption by motorised handling equipment;
- Condensate and filtration residue handling/elimination channels;
- water volumes used.

Unavailable data		
Items concerned	**Number concerned**	**Assumptions made**
Energy inputs		
Fuel consumption by motorised handling equipment	1 of 4	Approximation using data collected from two main regenerators
Waste, emissions, rejects		
[Air] - dry dust - Block 1	1 of 1	No basis for extrapolation available. Data incomplete
[Air] - dry dust and volatile organic compounds - Block 3	3 of 4	Extrapolated from per-tonne ratios for one of regenerators
[Water] - waste water - quantity and management	4 of 4	Volume considered similar to own water supply consumed Municipal WWTP type treatment
[Waste] - filtration residues - management	2 of 4	Considered similar to transfer for incineration at MWIP
[Waste] - condensate - Qty	1 of 2	Approximation using regulatory permit
[Waste] - condensate - management	2 of 2	Considered similar to transfer for incineration at HWIP

TABLE 11 - REGENERATION: PRESENTATION OF TYPE OF UNAVAILABLE DATA AND APPROXIMATIONS USED

Dialogue with regenerators also highlighted that certain consumables, used in low quantities according to regenerator responses, were not quantified and indicated in the data collection questionnaires.

According to the regenerators, it may concern motor oils, lubricants, degreasing products or acids used in surface cleaning. We did not extrapolate data for these consumables as we have no information on the quantities used. For this reason they are disregarded and excluded from the assessment.

It is also important to point out that the possible issues associated with the environmental dispersion of micro-plastics or nano-plastics, including via water, were not taken into account:

- Due to a lack of foreground data;
- Due to a lack of operational characterisation methods to report on the impact of these streams on ecosystems.

K.3 ADDITIONAL ASSUMPTIONS AND BACKGROUND INVENTORIES

The inventories used to model energy inputs or material inputs and the waste treatment methods are presented below. These inventories are taken from *ecoinvent V3.4 - allocation, cut-off* or Industry data (PlasticsEurope data for virgin plastics), such as those published via Simapro.

K.3.1 ENERGY INPUTS OF REGENERATION STEPS

Inventories relative to electricity production are presented in I.3 and are not recalled here.

Energy inputs	ecoinvent V3.4 inventories
Natural gas - combustion	Heat, district or industrial, natural gas {RER} | Market group for | Cut-off, U
Diesel or HFO - combustion	Derived from Excavation, skid-steer loader {RER} | processing | Cut-off, U
LPG - combustion	Derived from Propane, Burned in building machine {GLO} | propane, burned in building machine | Cut-off, U

TABLE 12 – REGENERATION - ENERGY INPUTS: BACKGROUND INVENTORIES USED

K.3.2 MATERIAL INPUTS OF REGENERATION STEPS

Concerning additives injected during compounding or other consumables used in plastics regeneration activities, it was necessary to make further assumptions insofar that we had no information on the nature or exact composition of these inputs.

These assumptions made by Bleu Safran are therefore approximations and are presented in the table below.

For colour masterbatches, brief online searches on patents for the preparation of these additives showed that colourant content ranges may be fairly wide: 10%-65%, 30%-85%, 20%-50% for example. Given the lack of more precise data, we opted to use an arbitrary value of 25%.

Items concerned	Hypothetical composition
Masterbatch - black colourant for PP	25% carbon black and 75% virgin PP
Masterbatch - black colourant for ABS	25% carbon black and 75% virgin ABS
Masterbatch - white colourant for PS	25% titanium dioxide and 75% virgin PS
Peroxides	Dialkyl peroxide
Flocculant	Cationic polymer type flocculant (according to information forwarded by regenerator)

TABLE 13 - REGENERATION: ADDITIONAL ASSUMPTIONS CONCERNING THE POSSIBLE COMPOSITION OF CERTAIN MATERIAL INPUTS

We therefore used the following background inventories. Concerning the materials, the choice was made to use - when they existed - the “market for” inventories, as they include the supply mixes and generic transport distances.

Material inputs	ecoinvent V3.4 inventories (or PlasticsEurope)	
Potable water		Tap water {Europe without Switzerland}| tap water production, conventional treatment | Cut-off, U
Process water	Proxy	Water, decarbonised, at user {RER}| water production and supply, decarbonised | Cut-off, U
Calcium carbonate		Calcium carbonate, precipitated {GLO}| market for calcium carbonate, precipitated | Cut-off, U
NaCl		Sodium chloride, powder {GLO}| market for | Cut-off, U
Flocculant	Proxy	Polyacrylamide {GLO}| market for | Cut-off, U
Shredder blades / stainless steel	Proxy	Steel, chromium steel 18/8, hot rolled {GLO}| market for | Cut-off, U +Sheet rolling, chromium steel {GLO}| market for | Cut-off, U +Chromium steel removed by milling, dressing {GLO}| market for | Cut-off, U
Steel filters		Steel, low-alloyed {GLO}| market for | Cut-off, U +Sheet rolling, steel {GLO}| market for | Cut-off, U +Steel removed by drilling, conventional {GLO}| market for | Cut-off, U
Masterbatch - black colourant for PP	Proxy	25 % Carbon black {GLO}| market for | Cut-off, U 75 % Polypropylene, PP, granulate, at plant/RER (PlasticsEurope)
Masterbatch - black colourant for ABS	Proxy	25 % Carbon black {GLO}| market for | Cut-off, U 75 % Acrylonitrile butadiene styrene (ABS)/EU-27 (PlasticsEurope)
Masterbatch - white colourant for PS	Proxy	25 % Titanium dioxide {RER}| market for | Cut-off, U 75 % Polystyrene granulate (PS)/EU-27 (PlasticsEurope)
Peroxides	Proxy	2,5-dimethylhexane-2,5-dihydroperoxide {GLO}| market for 2,5-dimethylhexane-2,5-dihydroperoxide | Cut-off, U
Impact modifier (SBSà	Proxy	Acrylonitrile butadiene styrene (ABS)/EU-27 (PlasticsEurope)because no generic inventory available for SBS

TABLE 14 – REGENERATION - MATERIAL INPUTS: BACKGROUND INVENTORIES USED

K.3.3 WASTE TREATMENT

The background inventories used to model the end-of-life management of waste and waste water are given below.

For waste with a calorific power and oriented to incineration for energy recovery (electricity or steam production), the impacts avoided due to the recovered energy were approximated. The performance of MWIP type incinerators gathered for France are also considered as a proxy for other geographical locations confidential.

Waste and rejects		ecoinvent V3.4 inventories
[Water] - wastewater	WWTP	Derived from Wastewater, average {CH}| treatment of, capacity 1.1E10l/year | Cut-off, U replacing the electricity mix by that of the country where the regenerator is located.
[Waste] - Sludge	NHWSF	Consideration only of materials accounted for as charges for the regenerator in question: ▪ Inert waste {Europe without Switzerland}| treatment of inert waste, sanitary landfill | Cut-off, U to model consumables for density separation baths ▪ No impact is associated with the quantity of water in sludge (simplification)

Waste and rejects		ecoinvent V3.4 inventories
[Waste] - Sludge	MWIP with ER	Combination only of materials accounted for as charges for the regenerator in question: ▪ Waste plastic, mixture { Europe without Switzerland }| treatment of, municipal incineration | Cut-off, U to model consumables ▪ Waste glass {Europe without Switzerland}| treatment of waste glass, municipal incineration | Cut-off, U ▪ No impact is associated with the quantity of water in sludge (simplification)
		Avoidance: based on energy recovery performance of MWIP in France* on a gross calorific value taking into account the proportion of water and on the electricity profile of the regenerator's country
[Waste] - filtration residues	MWIP with ER	Waste plastic, consumer electronics {RoW}| treatment of, municipal incineration | Cut-off, U, adapted**
		Avoidance: based on energy recovery performance of MWIP in France* on a gross calorific value for waste of 33 MJ/kg and on the electricity profile of the regenerator's country.
[Waste] - Condensate	HWIP	Hazardous waste, for incineration {Europe without Switzerland}| treatment of hazardous waste, hazardous waste incin. | Cut-off, U

* Data (quantities and profiles of energy use avoided) previously developed as part of the WEEE end-of-life LCI according to ADEME ITOM data.
** This ecoinvent inventory concerns plastics present in WEEE. It considers the presence of antimony (antimony trioxide is a synergist for BFRs used in the past) in the input stream for incineration, and therefore takes into account the release of antimony into water and the air. As filtration residues contain plastics without brominated additives, obtained through the separation of plastics contains BFRs, this inventory was adapted to remove the antimony released into the environment.

TABLE 15 - REGENERATION - WASTE AND REJECTS: BACKGROUND INVENTORIES USED

K.3.4 AIRBORNE EMISSIONS

Regenerators are not aware of the exact nature of their atmospheric emissions. Assumptions were therefore made by Bleu Safran with a view to simplification.

Emissions or rejects concerned	Hypothetical composition - elementary stream
[Air] - dry dust	This dust was considered as particles < 2.5 microns. It is potentially a penalising assumption.
[Air] - volatile organic compounds	These compounds were considered as an emission of acetaldehyde. It is potentially a penalising assumption.

TABLE 16 - REGENERATION - AIRBORNE EMISSIONS: ASSUMPTIONS MADE IN SELECTING THE EMISSIONS

In terms of VOC, work done by INRS[16] identifies the nature of the degradation compounds of plastic matrices, especially PS, PP and ABS for a range of temperatures. It also highlights that many compounds are likely to be emitted when plastics are subjected to temperature ranges from 200 °C to 250 °C: aldehydes, alcohols, ketones, aromatic hydrocarbons, etc.

However, INRS publications do not reveal the relative importance of compounds emitted for temperature ranges representative of extrusion temperatures applied in the production of regenerated plastics.

In this context, our choice was to use a simplified model, considering the quantity of VOC as the profile of a VOC common to the three plastics studied and for which the characterisation factor for photochemical ozone formation[17] is in the high range of the individual VOC values potentially emitted

[16] See: http://www.inrs.fr/publications/bdd/plastiques/polymere.html?refINRS=PLASTIQUES_polymere_22&section=risques
[17] According to the LOTOS-EUROS method (Van Zelm et al, 2008) implemented in ReCiPe 2008 and recommended at European level for product environmental footprints (PEF).

during extrusion. This choice therefore led us to use acetaldehyde, and can be considered as penalising.

K.4 Mass ratios considered between blocks of successive steps in the regeneration sequence

The data collected also enabled us to define the mass ratios used to identify the appropriate quantities transiting between the blocks modelled, to evaluate the regeneration sequence.

The diagram below defines the applicable mass ratios and recalls the inputs and outputs for each block of steps likely to impact the calculation of these ratios.

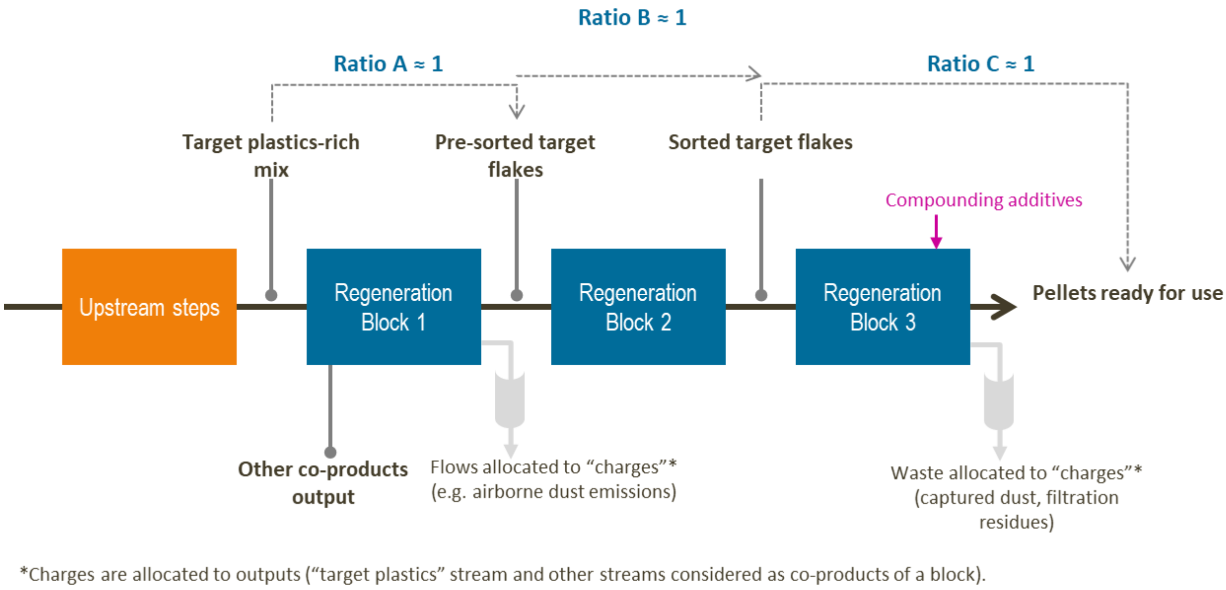


Figure 11 - Sequence of successive process blocks: mass ratios considered

- **Ratio C: separated target flakes / pellets ready for use**
  A portion of the input flakes to the "compounding-extrusion-pelletisation" block will be lost as waste (mainly as filtration residues). This proportion may be in the range of 2 to 3%. During compounding, additives are combined with the recycled plastics to enhance their properties. Depending on the plastics and the regenerators, the applicable additives level for this work may vary between 2% and 4%.
  As these two effects offset each other, a mass ratio of 1 was used between the blocks 2 and 3 of the regeneration sequence.
- **Ratio B: pre-sorted target flakes / separated target flakes**
  As the flake sorting steps aim to separate target plastics from each other (e.g. separate PS from ABS), there is little loss of material during these treatments. A mass ratio of 1 was used between the blocks 1 and 2 of the regeneration sequence.
- **Ratio A: Regeneration input / pre-sorted target flakes**
  The following items were considered as charges to be allocated against co-products output from block 1: airborne dust emissions, post-pretreatment waste water and sludge resulting from consumables added during the process (not as a result of the input). In principle, the co-products output incur these items as charges as well as their upstream treatments. In practice, the proportion of incoming waste in charges is marginal. Therefore the mass ratio between upstream steps and block 1 of the regeneration sequence was considered as 1.

K.5 DATA QUALITY RATING AND SUITABILITY FOR REQUIREMENTS

The foreground and background datasets used to model the steps of the regeneration sequence to produce recycled plastics were evaluated - by expert opinion - taking into account four scoring criteria required by ISO 14044: 2006 and a 5-point rating system:

- Criteria:
  - Geographical Representativeness (GR);
  - Time Representativeness (TiR);
  - Technological Representativeness (TeR);
  - Precision (P) to provide a related level of uncertainty.
- Quality rating scale:
  - 1: very good
  - 2: good
  - 3: adequate
  - 4: acceptable
  - 5: poor

The table below describes our data quality rating for the principal types of data used to build the three average LCI datasets addressed by this project.

Weighting keys used to build mean LCIs

AD: Activity data; LCI: background inventory

		Criteria evaluated				Remarks and points for attention
		GR	TiR	TeR	P	
Weighting keys used to build mean LCIs						
Weighting of upstream steps (WEEE streams) for each polymer	**AD**	1	2	3	4	The key used exhibits significant uncertainties due to the assumptions made concerning the presence of target plastics (with little or no additives) in the WEEE streams and the portion of said plastics oriented to regeneration. The impacts of upstream steps vary according to the WEEE streams (higher profile for LHA cold, with other streams being in a narrower range). The mean profiles are therefore sensitive to the contribution considered for LHA cold.
Weighting of regenerators for each polymer	**AD**	4	2	3	4	The key used exhibits significant uncertainties (P=4). Moreover, it is important to remember the approximations make for extrapolated regenerators (Europe electricity mix) even if the electricity mixes vary significantly from one country to another (GR=4). As several regenerators in the sample population are known for their capacity to treat complex plastic mixes, their profiles seem to be suitable for building extrapolated regeneration profiles (TeR = 3).

TABLE 17 - QUALITY EVALUATION - WEIGHTING KEYS TO BUILD MEAN LCIs

Upstream steps for each WEEE stream

The table below proposes a summary assessment by household WEEE stream. A more detailed step-by-step evaluation is presented in the methodological summary relative to the end-of-life LCI of the WEEE.

AD: Activity data; LCI: background inventory

		Criteria evaluated				Remarks and points for attention
		GR	TiR	TeR	P	
Upstream steps - from collection to rank 2 operations.						
For household streams: – LHA cold – LHA non cold – SHA – Flat screens	**AD and LCI**	1-2	1-2	1-2	1-2 (4)	Scores (=1) are relative to the collection and consolidation steps and to rank 1 operators. Rank 2 operations are scored (=2) The time representativeness remains high although the data collected related to the 2014-2015 period, due to the mature organisation of these streams. Evaluation P=(4): specific case of dust emissions (granule size not known).
CRT screens	**AD and LCI**	2	3	3	4	As CRT screens were not addressed in pre-existing works, they were modelled using the profile created for flat screens. For this reason, the evaluation criteria were downgraded by one point.

TABLE 18 QUALITY EVALUATION - UPSTREAM STEPS OF REGENERATION BY HOUSEHOLD WEEE STREAM

Regeneration

The evaluation of regeneration activities was broken down for each of the main process blocks.

AD: Activity data; LCI: background inventory; EF: Elementary flow

		Criteria evaluated				Remarks and points for attention
		GR	TiR	TeR	P	
Regeneration - Block 1: materials separation of incoming mixes and production of pre-sorted flakes						
Energy inputs (electricity, natural gas, fuel, etc.)	**AD**	2	1	1	2 to 4 Depending on regenerator	The nature of the regenerators' energy inputs was identified to a satisfactory level. The precision of the data obtained nonetheless depends on the capacity of the regenerators to allocate their inputs to the process blocks and the allocation keys used, insofar that they generally have aggregate data which apply to the whole site. For this reason, the score varies according to the regenerators.
	LCI	2	3	3	3	Concerning the generic average LCIs taken from ecoinvent v3.4 (used to represent the electricity production and fossil fuel combustion), a score of "3" seems appropriate.
Material inputs (water, bath consumables, flocculant, etc.)	**AD**	2	1	3	2 to 4	In the same was as energy inputs, the precision of consumption data for certain material inputs depends on the allocation keys.
	LCI	3 - 4	3 - 4	3 - 4	3 - 4	For the consumables, we used generic LCIs (score = 3) or proxies (score = 4).

Waste allocated to charges (sludge)	**AD**	1	1	2 to 4	2 to 4	Imprecisions may affect the composition of this waste (including its water content), its mode of elimination (c.f. unavailable data), its PCI (case of waste sent for incineration with ER). Another point for attention regarding quantities is that only aggregate data for all types of waste inputs was available. The data therefore concern the mix of waste inputs for regenerators and not only the mixes resulting from WEEE.
	LCI	4	4	4	4 (5)	Models derived from generic LCIs available in ecoinvent v.3.4 were used to model incineration, landfill or wastewater treatment (score = 4). Score P = (5): special case of streams considered in generic LCIs and contributing to impacts such as environmental toxicity and human toxicity. They are very probably not representative of waste from regeneration (e.g. possible inclusion of compounds or pollutants not present in this waste).
Direct releases into the environment	**AD**	-	-	-	5	These environmental emissions are little known in terms of annual flow. The parameters the can be monitored concern the work atmospheres more than environmental emissions for these SME industrial operators.
	EF	-	-	-	5	In the case of dust, the lack of data on its composition prevents us from comfortably choosing the most appropriate elementary flows, given that the characterisation methods also have their limits.

TABLE 19 - QUALITY RATING – BLOCK 1 OF REGENERATION

AD: Activity data; LCI: background inventory; EF: Elementary flow

		Criteria evaluated				Remarks and points for attention
		GR	TiR	TeR	P	
Regeneration - Block 2: plastic flake sorting processes						
Energy inputs (electricity, natural gas, fuel, etc.)	**AD**	2	1	1	3	The data come from allocation keys used by regenerators or estimates they calculated (e.g. based on equipment rated power, hourly yield, overall power draw factor). The precision is therefore considered to be overall correct.
	LCI	2	3	3	3	Concerning the generic average LCIs taken from ecoinvent v3.4 (used to represent the electricity production and fossil fuel combustion), a score of “3” seems appropriate.
Material inputs	Little or no material inputs for these steps					
Waste allocated to charges	Little or no waste for these steps, except for low quantities of dry dust					
Direct releases into the environment	Little or no airborne emissions, with the possible exception of non-captured dust, but which is not quantified.					

TABLE 20 - QUALITY RATING – BLOCK 2 OF REGENERATION (FLAKE SORTING)

AD: Activity data; LCI: background inventory; EF: Elementary flow

		Criteria evaluated				Remarks and points for attention
		GR	TiR	TeR	P	
Regeneration - Block 3: compounding - extrusion - pelletisation steps						
Energy inputs (electricity, fuel, etc.)	**AD**	2 to 4 depending on PP, PS, ABS	2	3	2 to 4 Depending on regenerator	The representativeness and precision depend on: – the polymers studied, as we needed to consider an extrapolated step when regenerators stop at flakes and do not produce pellets (consideration of average location as Europe); – The methods of obtaining quantitative data (e.g. allocation key, extrapolation). In the end, uncertainties on geographical representativeness (important aspect due to the production profile of the electricity consumed) are the most important for ABS (“Europe” location = 94%), then PS (“Europe” location” = 65%), then PP (“Europe” location = 57%).
	LCI	2	3	3	3	Concerning the generic average LCIs taken from ecoinvent v3.4 (used to represent the electricity production and fossil fuel combustion), a score of “3” seems appropriate.
Compounding additives (colour masterbatch, impact modifiers)	**AD**	2	2	3	3	For the PS impact modifier, a “normalised” content of 2% was considered. Concerning masterbatches, they mostly exhibit average levels of content like all pellets produced by a regenerator. Few details were available on the composition of masterbatch type additives.
	LCI	4	4	4	4	Hypothetical and proxy compositions were used (score = 4)
Waste allocated to charges (Filtration residues, condensates, etc.)	**AD**	1	1	2 to 4	2 to 3	The average quantities of waste generally refer to all pellets produced by the regenerator and not only those from WEEE (not possible to differentiate). For these steps, the waste ratios remain fairly close from one regenerator to another. Imprecisions may affect the composition of this waste, its mode of elimination, its PCI (case of waste sent for incineration with ER).
	LCI	4	4	4	4 (5)	Models derived from generic LCIs available in ecoinvent v.3.4 were used to model incineration, landfill or wastewater treatment (score = 4). Score P = (4): special case of streams considered in generic LCIs and contributing to impacts such as environmental toxicity and human toxicity. They are very probably not representative of waste from

						regeneration (e.g. possible inclusion of compounds or pollutants not present in this waste).
Direct releases into the environment (COV, dust)	**AD**	-	-	-	5	These environmental emissions are little known in terms of annual flow. The parameters that can be monitored concern the work atmospheres more than environmental emissions for these SME industrial operators.
	EF	-	-	-	5	In the case of dust and VOC, the lack of data on their composition prevents us from comfortably choosing the most appropriate elementary flows, given that the characterisation methods also have their limits.

TABLE 21 - QUALITY RATING - BLOCK 3 OF REGENERATION (COMPOUNDING - EXTRUSION - PELLETISATION)

In terms of the issues of consistency and exhaustiveness - which are transversal -, they are managed in this project through the following aspects:

Consistency:

- Use of a generic database identical to that used to build the end-of-life LCIs of EEE, used to model the upstream steps of the regeneration sequence.
- Adoption of a homogeneous approach:
  - to data collection from regenerators
  - to addressing unavailable data
  - to addressing multi-functionality and allocation issues
  - to modelling in SIMAPRO: use of a transversal background data library for work on WEE, model configured using an identical template for all regenerators.

Exhaustiveness:

- Identification and modelling of all successive steps in the regeneration sequence of the recycled plastics studied.
- Limitations of exclusions and voluntary cut-off criteria.
- Use of extrapolations to improve the coverage rate of the work beyond just the regenerators contributing to data collection.
- Identification of unavailable data (inputs/outputs) concerning regenerators and implementation of an organised approach to addressing unavailable data whenever possible.

LIMITS OF THIS STUDY

L. PRINCIPAL LIMITS

The limits described below deserve to be brought to the attention of future users of these inventories, as these users are encouraged to take account of them for their own work.

Limits inherent to the extrapolations made to meet the aims of this work

Let us remember that the aim of the work was to build LCIs for recycled plastics that may be used by EEE producers, where these LCIs may be used in eco-design projects. For this reason, it was necessary to consider that these recycled plastics are pellets production after compounding, as "flake" formats were not suited to direct use by EEE producers.

To date, the regenerators participating in this work can produce and sell all or part of their production as flakes, which can be used in several applications (direct use in other fields than EEE, compounders, etc.).

It was therefore occasionally necessary to "project" by simulating a further compounding-extrusion-pelletisation step when absent for a given resin for a given regenerator. This simulated additional step systematically featured an electricity production profile corresponding to the European average. This is an incidental hypothesis for the results due to the energy requirements of the compounding - extrusion - pelletisation steps (greater than the previous regeneration steps).

A second type of extrapolation consisted in including in the modelling scope regenerators not included in the sample population, as they may have a different geographical location than those of the sample population confidential. This extrapolation was justified by our desire to avoid "over-weighting" the France electricity profile for LCIs representative of recycled WEEE plastics collected in France but regenerated in France or elsewhere in Europe.

This systematically featured an electricity production profile corresponding to the European average. Nonetheless, precise knowledge of the profiles of the electricity consumed by regenerators not included in the sample population could lead to an average electricity mix for these regenerators different to the Europe electricity mix.

The incidence of these extrapolations on the electricity production profile is different from one recycled plastic to another, as recalled below:

Recycled plastics - EEE closed loop application	Regeneration: weight of "Europe" electricity profile		
	Block 1	Block 2 (segregation)	Block 3 (extrus-pellet.)
PP pellets	50%	50%	57%
PS pellets	49%	49%	65%
ABS pellets	40%	40%	94%

TABLE 22 - REGENERATION - ELECTRICITY PRODUCTION PROFILE: CONTRIBUTION OF AVERAGE EUROPE PROFILE (EXTRAPOLATIONS)

Limits inherent to allocation keys used by regenerators

To respect the granularity of data to collect (by block of steps in the regeneration sequence), certain regenerators had to use allocation keys between blocks when the measured data were only available in aggregate form for the whole facility. Other regenerators were not able to make this distinction or only able to make it partially.

These situations are the source of imprecision in the data collected and therefore represent a limit to this work.

Limits inherent to the background inventories of material inputs and waste

Our modelling of the production steps for material inputs used in regeneration (including compounding additives) was based on:

- a generic inventory, when the input concerned had an inventory in ecoinvent v3.4 (or PlasticsEurope for polymers/elastomers);
- a proxy (generic inventory for another substance) when the input concerned did not have an inventory in ecoinvent v3.4 (or PlasticsEurope for polymers/elastomers).

The same situation was encountered in modelling the treatment steps of waste generated during steps applied by regenerators.

As indicated in the data quality section, these generic inventories are likely to offer an imperfect representation of the impacts associated with the inputs and waste specific to regeneration activities.

M. Points for attention in terms of environmental impacts assessed in LCA

The following points for attention concerning the inventories produced merit an explanation via a reading grid of the types of impact likely to be assessed in LCA.

Impact categories	General appreciation
GHG emissions	Given the geographical representativeness, the technological representativeness, the time representativeness, the methodological aspects, the exhaustiveness and precision of all the data used, the quality of the datasets produced in terms quantification of impact categories is considered to be correct.
Acidification	
Photochemical ozone formation	
Exhaustion of mineral or fossil resources	
Water resources (flow indicator, no regionalisation)	
Eutrophication (various indicators)	
Particle emissions	The limits resulting from imperfect knowledge of dust emissions potentially occurring during the successive steps of the recycling process. Gaps may concern their quantification, granularity, and types of environmental emissions.

Impact categories	General appreciation
Human toxicity	Hard limits result from: – Imperfect knowledge of direct emissions (channelled or diffused) of pollutants with a toxic or eco-toxic effect, which may be generated during the successive steps of the recycling chain; – the generic inventories used to model the end-of-life management of waste and waste water from regeneration steps, as these inventories could be based on compositions and the presence of target substances not representative of the waste specific to these activities.
Environmental toxicity	
Land occupation	As the infrastructures of recycling chain operators were excluded from the scope of the work, the inventories produced do not provide a suitable quantification of this impact.
Ionising radiation Ozone depletion	The elementary flows participating in these impacts are solely controlled by the background data considered. Given the extrapolations and approximations made concerning the geographical location of certain regeneration operations and certain regenerators, this is of a nature to significantly influence the impact results for these indicators.

TABLE 23 – OVERALL QUALITY OF LCIS PRODUCED IN TERMS OF IMPACT CATEGORIES

It is also important to remember that the possible issues associated with the environmental dispersion of micro-plastics or nano-plastics, including via water, cannot be taken into account:

- Due to a lack of foreground data;
- Due to a lack of operational characterisation methods to report on the impact of these streams on ecosystems.

N. PRECAUTIONS ON USING THESE LCIS

We encourage the future users of these LCIs to obtain information on the origin of the recycled plastics they wish to model and thereby check whether these LCIs are suitable to represent their evaluation context or not.

It is also important to remember that the only additives taken into account in these LCIs are colour masterbatches and an impact modifier in the case of PS. If future users of these LCIs use recycled plastics which contain other additives (e.g. flame retardants, anti-oxidants), it is their responsibility to provide the additional modelling themselves.

IMPACT RESULTS - INDICATIVE DATA

O. SUMMARY RESULTS FOR CHARACTERISATION METHODS RECOMMENDED BY THE EUROPEAN PEF METHOD

The table below shows the impact results calculated for the midpoint indicators recommended as part of the PEF method (EF 2.0) as implemented in the SIMAPRO software (EF method adapted, version 1.00).

Impact categories - PEF method recommendations	Units	Recycled PP	Recycled PS	Recycled ABS
		WEEE collected in France regenerated in EU		
		For 1 t	For 1 t	For 1 t
Climate change	kg CO_2 eq	436	617	560
Photochemical ozone formation, HH	kg NMVOC eq	1.33	1.68	1.61
Terrestrial and freshwater acidification	mol H+ eq	2.04	3.13	2.80
Freshwater eutrophication	kg P eq	0.02	0.03	0.02
Marine eutrophication	kg N eq	0.45	0.60	0.56
Terrestrial eutrophication	mol N eq	5.37	7.13	6.84
Resource use, energy carriers	MJ	9,467	12,295	11,009
Resource use, mineral and metals	kg Sb eq	2.95E-04	2.84E-04	3.00E-04
Climate change - fossil	kg CO_2 eq	434.9	615.4	558.7
Climate change - biogenic	kg CO_2 eq	0.71	1.12	1.05
Climate change - land use and transform.	kg CO_2 eq	0.26	0.36	0.40
Indicators for which hard limits in LCI quality must be considered by users				
Ozone depletion	*kg CFC11 eq*	*6.66E-05*	*7.04E-05*	*7.50E-05*
Ionising radiation, HH	*kBq U-235 eq*	*66.1*	*86.5*	*79.5*
Respiratory inorganics	*disease inc.*	*2.36E-05*	*2.46E-05*	*2.67E-05*
Non-cancer human health effects	*CTUh*	*4.89E-05*	*6.06E-05*	*6.16E-05*
Cancer human health effects	*CTUh*	*4.08E-06*	*5.43E-06*	*4.82E-06*
Freshwater ecotoxicity	*CTUe*	*606*	*663*	*695*
Land use	*Pt*	*1,442*	*2,290*	*2,075*
Water scarcity	*m3 depriv.*	*102*	*241*	*154*

CRITICAL REVIEW

Délégation Régionale de Chambéry
4 rue du Lac Majeur – Savoie Technolac
BP 50295
73375 LE BOURGET DU LAC Cedex
chambery@amvalor.eu
☎ +33 (0)479 262 693 - 📠 +33 (0)479 253 670
SIRET No. 820 003 093 000 78

Date: 14 December 2020

Client: **ecosystem**
30-40 rue Henri Régnault
92068 Paris La Défense Cedex

Case no. 1500217

Critical review of the guide "LCIs for production of plastics (PP, PS, ABS) recycled from WEEE plastics managed in France and regenerated in Europe - Methodological report V1.1-2 October 2020"

- Final report of Critical Review
ISO 14040 and ISO 14044
ILCD Data-Entry level

The work providing the foundations of this report was carried out in collaboration with
Institut Arts et Métiers de Chambéry - Scientific Director: Carole Charbuillet

EURO-QUALITY SYSTEM ISO 9001

AMVALOR
151, Boulevard de l'Hôpital 75013 Paris
Tel.: +33(0)142 168 676
Fax: +33(0)142 169 213
email: adv@amvalor.eu

Simplified joint stock company wi
€4,596,010
RCS PARIS 820003093
APE code: 7219 Z
International VAT ID: FR 51820003093

CONTENTS:

1. Introduction

The commissioning eco-organisation **ecosystem** worked with Bleu Safran to build the LCIs of three polymer resins recycled from Waste Electrical and Electronic Equipment (WEEE). The construction of the LCIs required a number of methodological choices and arbitrages in the selection of datasets and their modelling. A methodological guide “LCIs for production of plastics (PP, PS, ABS) recycled from WEEE plastics managed in France and regenerated in Europe V1.1. Date 02 October 2020” was produced. This publication follows on from the creation of LCIs of the end-of-life management of materials contained in WEEE started in 2015 and resulted in the creation of LCIs for WEEE treatment channels in ILCD format, now available to any LCA practitioner desiring to include this end-of-life management in their LCA. These initial LCIs included all the final destinations of the materials but did not contain, for plastic materials, activity data collected directly from WEEE plastics regenerators. The LCIs provided in the aforementioned guide take into account all the stages from the collection of WEEE to the production of ready-to-use recycled plastic.
To ensure compliance with ISO 14040:2006 and ISO 14044:2006 and ensure compatibility with ILCD Data-Entry level requirements, **ecosystem** has requested a critical review of the guide above prior to its publication.
The critical review focused in particular on the modeling of the steps performed by regenerators, the collection of activity data and the methodological choices. Indeed, the end-of-life LCI for WEEE (steps prior to regeneration) were already subjected to critical review in 2018 and the results of the review of the LCI guide for the treatment channel are valid until 2022.

For reasons of confidentiality, the experts providing the critical review did not have access to the detailed quantified data used to model the LCIs. However, they did receive an explanation of the building of the model to calculate the LCIs and the activity data collection questionnaires for regenerators, the collection process and background datasets.
The critical review focused on the methodological choices made in building the LCIs and the exhaustiveness of datasets. This document is the final Critical Review report authored under the direction of Carole Charbuillet and Bertrand Laratte from the Arts et Métiers institute. It is intended for inclusion in the final version of the methodological guide and may also be consulted separately.

2. Critical review experts

The critical review experts are not employed by **ecosystem** and Bleu Safran. They have also not participated in any work conducted to obtain the LCIs. They are presented in the table below.

Expert	Organisation	Title / Speciality	Role in critical review
Carole Charbuillet	Institut Arts et Métiers de Chambéry	Research Fellow PhD Industrial engineering Masters in polymer and composites research, INSA Lyon Engineering degree Materials science and engineering INSA Lyon Areas of expertise: plastic materials, recycling channels, LCA of recycled materials, eco-design	Supervision and drafting critical review report Critical review of report
Bertrand Laratte	Arts et Métiers - Bordeaux campus	Research Fellow PhD in Sciences for engineers Masters Environmental and Sustainable Development Management, UTT Masters Industrial engineering (Operational Reliability), UTT	Critical review of report

		Expertise: LCA, MFA, environmental impact indicators, eco-design	

The experience of our experts covers LCA methodology, LCI construction and also plastics recycling channels. As the guide subject to critical review does not concern a comparative LCA between materials, the experts were selected primarily to ensure the LCIs are compliant with the ILCD Data-Entry level.

3. Critical review process

The critical review experts applied the recommendations of ISO 14040:2006 and ISO 14044:2006 concerning critical reviews.
The aim of the critical review provided below was to verify that:

- The methods used to build the LCIs for their use in LCA applications are consistent with international standards ISO 14040:2006 and ISO 14044:2006;
- The methods used to build the LCIs for their use in LCA applications are valid in scientific and technical terms;
- The datasets used are suitable and reasonable in relation to the aims of the study.

It will also provide:

- An assessment of the internal consistency of the report, especially the consistency between:
    - The stated aims
    - The datasets and methodology
    - The results obtained and their interpretation
- An evaluation of the transparency of the report.

The critical review took place between October and December 2020, involving the following steps:

- Presentation of the context of the study and its aims at the kick-off meeting by **ecosystem** and Bleu Safran.
- Production of detailed observations by critical review experts on the methodological choices, datasets and the guide.
- Responses to observations by Bleu Safran and **ecosystem**, resulting updates to guide
- Closure of critical review and production of critical review report

For the purposes of confidentiality, the activity data used to model the LCIs could not be verified or tested. However, the construction of the model in the LCA software, the interaction between activity (foreground) data and background data as well as the data collection procedure involving operators have been explained in detail to the critical review experts.
The French version of this critical review report was produced using the French guide referred to in the introduction.

The critical review features 90 observations impacting the following areas: general, methodology, datasets and editing (22 observations). The observations were accepted by Bleu Safran and **ecosystem** for integration in the final version of the guide. However, to continue to ensure data confidentiality concerning regenerators supplying activity data, **ecosystem** opted to redact certain sections of the guide intended for publication. It is important to understand that the critical review process and especially the verification of the report's consistency and transparency were carried out with the non-redacted guide.

This critical review report was forwarded by the critical review experts to **ecosystem**. The conclusions apply to the guide indicated in the introduction and not to any other form of the report, extract or publication thereof. The critical review experts shall not be held liable for use of this work by a third party.
The conclusions of the report were made in consideration of the state of the art at the date of the study and of information received from **ecosystem** and Bleu Safran.

4. General observations of the critical review

The report is well crafted and transmits the serious, quality approach adopted to its preparation. The critical review experts consider that the recommendations of international standards ISO 14040:2006 and ISO 14044:2006 concerning methods have been applied and the work undertaken is compliant with these standards. The guide and datasets used are suitable and reasonable in relation to the aims of the study. The work on the LCIs presented in the guide meets the requirements applicable to methodology, datasets, interpretation and communication, taking into account the limits discussed in the next section.

This study is significant in the understanding of impacts of WEEE plastics regeneration. It is important to note that this study presents points which differ from previous studies and bring genuine value to the current best available knowledge:

- the scope of the study of waste collection to the production of ready-to-use pellets,
- the contribution of representative regenerators with appropriate exhaustiveness,
- the methodology applied to allocate charges to the target plastics treatment processes,
- the non-use of process blocks (details of all production steps from shredded material to ready-to-use pellets).

5. Detailed observations

This part highlights certain observations in the critical review to assist the reader in understanding the guide and the construction of LCIs for the regenerated plastics.
These observations apply either to methodological points that merit highlighting, given their contribution to the state of knowledge or how the choices made differ from those made in currently available recycled material LCIs, or to limits in relation to the expectations of the critical review. All the observations (except editing comments) made in the critical review and their responses are appended to this report.

5.1. The methodology of assessing the impacts of the production of recycled plastics

The methodologies used to build the LCIs are consistent with international standards ISO 14040:2006 and ISO 14044:2006. The guide clearly sets out the steps in building the LCI of the multi-functional activity block of regenerators according to their type. The guide presents three LCIs of regenerated plastic materials. These LCIs are not created to enable a comparative LCA of the three materials, even if future users may make use of the LCIs as part of an eco-design approach and compare the impact of several materials. In this case, a critical review of the LCA study based on the LCIs presented in the guide should take place, especially if the LCA results are published and even if the LCIs have been subjected to a critical review.

The methodology applied to allocate the impacts of flows to each individual step of the processes is robust and brings genuine value in relation to previous studies, based as it is on the principle of independent accounting of materials. For example, in the steps where materials are separated from plastics-rich mixes to obtain shredded flakes, only the impacts relating to the treatment of the target plastic are allocated to this plastic. Therefore, the benefits or impacts of treating other extractable materials such as metals or other non-target plastics are not allocated to the plastics stream studied (e.g. PP). The charges applicable to a step are allocated between the output process flows using a principle of allocation by mass.
An important point to mention regarding this study is the scope considered in the calculation of the LCIs; from the collection of the waste from which plastics are removed to the production of ready-to-use pellets.
The methodology applied does not account for benefits to recycling but only the direct impacts of the processes. No recommendation is made in the guide on this point, as the question is not addressed in the aims of the guide. Nonetheless, the allocation choice of a future user of the LCIs must comply with the intended publication format (CFF formula for the PEF).

5.2. Scientific and technical validity

In scientific and technical terms, the guide and the creation of LCIs are highly robust. Indeed, the regenerator models are clearly defined with a high level of detail depending on their nature. Each individual process has been quantified. This provides specific datasets relating to each target regenerated materials stream according to the WEEE source.

The datasets for activities upstream of regeneration are taken from the end-of-life LCIs for WEEE. The same background data were used to ensure consistency between the data used and to ensure homogeneity between the two studies in terms of scientific validity. A question arose concerning the temporal correlation of datasets: the first dates go back to 2014/2015 and the LCIs of recycled materials to 2020. However, the validity period of the end-of-life LCIs is 2014-2022, due to the stability of treatment processes. Certain datasets were updated in 2018. The target LCI datasets have a validity from 2 to 4 years. The link between the datasets of the two studies is therefore appropriate. The datasets should be updated at this time.

The technical validity of the activity data used is ensured by reports on the representative regenerators of the target plastics. When certain regenerators did not produce pellets, the activity block was extrapolated using data from other regenerators surveyed. This choice was also made for the unavailable data. Even if this brings with it a degree of uncertainty, this ensures the exhaustiveness of data.

The resulting level of precision is as high as possible given the state of current knowledge at the time of writing (partial identification of European regenerators, partial knowledge of proportion of plastics sent for regeneration).

The questionnaires used were presented to the critical review experts but without access to the data for reasons of confidentiality. There are no contractual relationships between **ecosystem** and the regenerators. The critical review experts draw your attention to the fact that regenerator data depends on their declarations, which may not always be reliable, as in a certain number of LCAs. Evaluating the quality of this type of data is often difficult as measurements at each step of the process can be complex and time-consuming.

However, if data were unavailable, reasonable extrapolations were made between regenerator facilities (e.g. VOC) and bibliographic research was also done (e.g. compounding of recycled material). The LCI model is exhaustive and robust in the scientific choices made.

It is important to highlight that this study is the most detailed from a modelling standpoint in terms of recycled materials, as it takes into account the collection of the original waste right through tot he production of pellets, with details of all intermediate steps.

5.3. Data choices according to aims of the study

The LCI data were not reviewed for reasons of confidentiality but the elements provided in the guide, the description of how the LCIs were built and the presentation of background data are considered to be reasonable in relation to the aims of the study.

In terms of regenerators, the degree of representativeness may be questioned both in terms of their number and the activities represented. For example, the global coverage of the regenerators sample population for recycled PP is 50%. Extrapolations were made both to complete missing activities (conversion from flakes to pellets in certain cases) and to represent regenerators not included in the sample population.

These extrapolations are consistent with the aims of the study and the regenerators used as references are significant players in the WEEE recycled materials sector.

Even if this may bring a certain degree of uncertainty, the use of these datasets is appropriate as it enables the best possible precision to the current state of knowledge. The datasets must be updated in line with developments in plastics recycling.

The datasets used are consistent with the aim of creating LCIs for the production of recycled plastics from WEEE treated in France and regenerated in Europe, for use by any practitioner wishing to include the impact of this production in LCA applications. It is important to mention certain potential limits on the use of LCIs as recycled materials in a new product: compatibility with the compound modelled in the study and lack of user

knowledge of the origin of the recycled material. However, in this study a standard compound was considered and the regenerators often use mixed material sources. The representativeness is therefore consistent with the intended use.
No intentional cut-off criterion was applied in the collection of activity data from regenerators.

5.4. Relevance of production LCIs for recycled materials related to the limits of the study

The relevance of the LCIs calculated is high, given the intended use of the LCIs.
The user of these LCIs must be aware that the benefits of recycling the materials were not taken into account and should envisage using a CFF formula type allocation model.
The principal limits of the project relate to:

- the extrapolations made (on activities and regenerators) but which are reasonable in relation to the aims of the study,
- the allocation keys used by regenerators when they only held aggregate site data,
- the use of certain background data, notably for compounding,
- the exclusion of certain emissions associated with rank 1 processes or regeneration treatments. Some data were replaced by approximations.
- the exclusion of regenerator infrastructures. The same principle is used in the PlasticsEurope inventories of virgin materials available at this time.

These limits may impact the results of certain indicators. However, the LCIs are relevant to the aims of the study and the exhaustiveness of data was ensured with a method that is scientifically and technically compliant with ISO 14040 requirements.

5.5. Transparency and consistency

The transparency and consistency of the guide subjected to critical review are high and comply with the requirements of ISO 14044:2006. The critical review experts were not able to access data collected from regenerators for reasons of confidentiality. But the presentation of the model and the comparison of the orders of magnitude of the impact results obtained for the LCIs to previous studies enabled us to estimate the consistency of the results.
ecosystem decided to redact certain information in the guide regarding regenerator activities for reasons of confidentiality. This solution was considered optimal to ensure minimal impact on the transparency of the guide. But the report remains consistent. Access to these data would improve the transparency of the publication and highlight this specific value of the study.

6. Data quality rating - ILCD Data-Entry level

The following tables present the critical review actions of the experts and the evaluation of the data quality achieved by the LCIs produced.

	Validation of data sources	Energy data	Mass data (coverage)	Cross-check with other source	Cross-check with other data set	Expert judgement	Compliance with ISO 14040 and ISO 14044	Documentation	Facility visits and questionnaires
Raw data	Yes	Not applicable	Not applicable	No	Not applicable	Yes	Yes	Yes but confidential	Internal to provider
Unit process(es): single operations	Yes	Internal	Internal	Not applicable	Yes but little background data - Extrapolation of activity data	Yes	Yes	Yes	Internal to provider
Unit process(es): black box	No processes are used as black boxes in the construction of the LCIs of regenerated plastics subjected to critical review								
LCI methods	Not applicable					Yes	Yes	Not applicable	Not applicable
LCI results	Not applicable	Internal	Internal	Not applicable	Not applicable	Yes	Yes	Yes	Not applicable
LCA results calculation	Not applicable					Yes	Yes	Yes	Not applicable
Documentation	Not applicable					Yes	Yes	Not applicable	Not applicable

Tableau 1: critical review actions

	LCI regenerated PP	LCI regenerated ABS	LCI regenerated PS
Technological representativeness	Good	Good	Good
Time representativeness	Very good	Very good	Very good
Geographical representativeness	Good	Good	Good
Completeness	Good	Good	Good
Precision	Fair	Fair	Fair
Methodological appropriateness and consistency	Very good	Very good	Very good
Overall quality	Good	Good	Good

Tableau 2: Data quality rating

7. Appendix

The table below presents the detailed observations of the critical review experts and the resulting responses from Bleu Safran and **ecosystem**.

No.	Page	§	Nature of observation	Observation	Proposed modification	Response from Bleu Safran / ecosystem	Follow-up to observation
1	8	A1	Clarification	At this stage it would be interesting to add in the scope of action of **ecosystem** in relation to recycling operators and not only in relation to members.	Adding a diagram of the scope of action would offer better understanding / anticipate the issue of data collection from regenerators.	The diagram presented at the meeting of 27/10 will be added to the report to indicate: - contractual relationships between **ecosystem** and producers, collection facilities, collection operators, rank 1 operators - a relationship more based on performance monitoring for rank 2 operators responsible for sorting plastics with and without BFRs - the lack of contractual relationships with other players, more specifically regenerators. Before the diagram, we will indicate that it is the "majority" case, with certain operators being rank 1 and rank 2, in which case their contracts may also cover the rank 2 operations. So readers may identify early on in the report that the LCIs are based on data collected from regenerators, a "data owners" paragraph will be added in section A. General aspects (after A.1 "Client").	OK
2	8	A2	Clarification	Which materials were studied?	Indicate if the plastics were already in the scope of the first study.	The sentence was completed adding: namely the main plastics in household WEEE streams (PP, PS, ABS, ABS-PC, etc.), and separating plastics containing no fillers, those containing BFRs, and plastics containing non-BFR fillers."	OK
3	8	B1	Scope	It is indicated that the LCIs may be used by **ecosystem** members to develop the use of recycled plastics. But could it not also be a driver for the development of channels?	To be clarified in the scope of application.	To drive and develop channels, **ecosystem** primarily uses the environmental assessment calculated using the end-of-life LCIs, to integrate the final destinations of materials into the evaluation. The work done on the recycled plastics LCIs can be used to refine the model of the "recycling" destination of the end-of-life LCIs when they are next updated. In terms of developing channels, the recycled plastics LCIs and the argument concerning the benefits of recycled plastics will serve to encourage projects to integrate recycled plastics in production (and thereby drive the recycled products market). **Proposal** no modification to the text (item referred to in line 33 of interim report V1.1)	OK

4	8	B1	Term	Within the report, we encounter the term “environmental benefit” and the notion of promoting the environmental, social and economic benefits of using recycled plastic materials. But are we still sure?	Given the results presented with the PEF method, it is indeed the case. But perhaps we should present the ‘potential’ benefits.	We agree with this point. For clarity, the expression was also revised in the report: “**ecosystem** has therefore analysed the **potential benefits** of using recycled plastics, with a view to promoting projects to integrate recycled products” and “Furthermore, **ecosystem** may use the inventories to study the **potential environmental benefits** of using recycled plastic.”	OK
5	8	B1	Clarification	What do you mean by ‘argument’? Indicators?	For clarification	A detailed analysis taking into account a panel of environmental indicators and assessing the potential benefits through different scenarios of using recycled material compared to virgin material. We should also point out that for reasons of clarity, the section was revise (see response to observation no. 4)	OK
6	8	B1	Methodology/State of the art	Pre-existing studies are mentioned. But are not referenced. It lacks more precise analysis of the limits of this study, to reinforce and demonstrate its positioning in relation to legacy findings. The limits of the existing databases are also worthy of mention.	The studies should at least be referenced. A comparative table between the limits of these studies and the WEEE LCIs could be inserted.	The following clarifications were made: "Before undertaking this work, we completed an in-depth analysis of a certain number of studies concerning plastics recycling, whether applicable to WEEE or not. This prior assessment was undertaken by Bleu Safran for cooperative research association SCORE LCA, as part of a study on the consideration of plastic recycling in LCA ("SCORE LCA, Recyclage des plastiques et ACV, 2020, n° 2019-02”). This work was completed in late 2020 and can be viewed on the SCORE LCA website (in French) (https://www.scorelca.org/scorelca/etudes-acv.php).” + footnote: "Existing studies examined concerning plastics recycling and LCA: - Eco-profiles produced by SRP, France’s national plastic materials regenerators association - Franklin Associates. Life cycle impacts for post-consumer recycled resins: PET, HDPE, and PP. Submitted to The Association of Plastic Recyclers. December 2018. 49 p. - Haupt M., Kägi T., Hellweg S. Life cycle inventories of waste management processes. Data in Brief. Volume 19, August 2018, Pages 1441-1457. - Patrick A. Wäger, Roland Hischier, Life cycle assessment of post-consumer plastics production from waste electrical and electronic equipment (WEEE) treatment residues in a Central European plastics recycling plant, Science of The Total Environment, Volume 529, 2015, Pages 158-167.” This analysis was not carried out as part of this study for **ecosystem** but for a study carried out by Bleu Safran on behalf of SCORE-LCA, titled "SCORE LCA, Recyclage des plastiques et ACV, 2020, n°2019-02". The report has not yet been published. We propose to cite this work for SCORE-LCA as it provides a detailed analysis of the pre-existing situation. We will contact SCORE LCA for their assent.	OK

7	9	B.1	Term	“**ecosystem** node”?	Not web page?	The term node is preferred, even in French. The methodological report will be translated into English	OK
8	9	B1	Clarification	Is the critical review report of the previous study available?	Include the principal conclusions of the CR	Yes, this report is available for download from the **ecosystem** node indicated in the report. We would like to include a link offering direct access to the document: http://weee-lci.ecosystem.eco/Node/showSource.xhtml?uuid=a8213f5f-bbed-47ae-a875-90f9a593765f&stock=ecosystem_WEEE_LCI	OK
9	9	B2	Methodology	The impact and formulation of a recycled material will depend on its use (material quality, which EEE). Is the destination of regenerator outputs known?	As the study assumes a closed loop, it would be appropriate to indicate the portion of regenerated plastics that depart regenerators to EEE makers.	Our work on supporting member projects to integrate recycled products and dialogue with regenerators provided the major trends; we are however unable to know the specific tonnages for each sector of use, as the search for trade outlets (and therefore the sectors touched) is a major component of the business strategy of each regenerator.	OK
10	9	B3	Insertion	The data format is not indicated.	Ecospold?	ILCD “wml” format	OK
11	9	B4	Clarification	In what way will the LCIs be used as supportive arguments by **ecosystem**?		Potential use of recycled plastics LCIs to model the “production of recycled plastics”, put into perspective with several scenarios for comparison with virgin plastics. This use is based on scenarios to achieve models that could be used by producers. For clarity, the reference to this work was reformulated in the final report (see response to observation no. 4)	OK

12	10	B5	Application	For members to use the LCIs, they need to know the portion of recyclable plastic materials in the WEEE they acquire. Yet regenerators mix several sources. What portion is allocated to the **ecosystem** LCI? What influence do you think this will have on the results?	To be indicated	Effectively, we do not provide an average value for "mixed recycled plastics from various channels"), as we do not have data on the other channels. The information concerning the proportion of resins from different channels (see virgin / recycled proportion) should be identified by the acquirer of the materials. Note that the recently-published standard EN 45 557 stipulates that the difference between post- and pre-consumer plastics must be made, which means that the acquirer must refer back up the value chain for access to the information. As discussed at the meeting on 27/10, a paragraph on the "precautions on using these LCIs" will be inserted, principally to remind users that it is incumbent on them to obtain information on the origin of the recycled plastics they wish to model and therefore check if these LCIs are suitable to their needs or not. Possible differences that you point out concerning the diversity of sources will above all concern the steps upstream of entry into regeneration. It is difficult to pre-judge these differences as minimal data are available for other sources frequently used by regenerators supplied with WEEE plastics, but it still seems possible to say that: - for post-consumer ELV type waste, the environmental impact of upstream steps are probably significant (ELV collection, dismantling and shredding, separation of post-treatment residues and transport between operators); - for industrial waste procured by regenerators, the upstream steps are "simpler" (sorting at source, transport steps, possibly pre-shredding), and probable entail fewer impacts than the upstream steps of the WEEE treatment channel.	OK
13	10	B.5	Clarification	In the end, who will have access and via which medium? **ecosystem** platform? Agreements with whole supply chain?	To be added	The approach is the same as for the end-of-life LCIs; the data are provided in open access in ILCD format for all practitioners. In parallel, we also contact certain LCA software publishers that we identified to offer to integrate these data directly in their software.	OK
14	11	C1.1	Data	What is the source of the data in table A? **ecosystem**?	Indicate source	Table created using **ecosystem** studies (--> Equipment Material Assessment Programme undertaken annually to analyse the material composition of WEEE input for rank 1 operators). This will be specified.	OK
15	11	C1.1	Data	What portion of plastics is currently sent on for recycling, at first glance low?	Indicate the percentage.	These figures are specific to each "type of plastic / WEEE stream" pairing. As indicated at the meeting on 27/10, these data are confidential. The principle of their production was explained during the meeting.	OK
16	11	C1.1	Clarification	To facilitate understanding, the raw materials retained by the regenerator may be		OK this proposal to reorganised will be implemented.	OK

				indicated from the outset and then the reasons developed.			
17	12	C1.1	Assumptions	Why these target plastics? Non-filled to make it easier to use them after regeneration? PS has a density similar to PP Talc - how is separation done to prevent contamination?	Provide more information on how regenerators select the plastics used.	This is an established fact which will be explained further in the report. The plastics are current targeted by regenerators, their choices very certainly depending on the tonnages accessible, the production costs involved in producing the recycled plastics, their technology expertise, the markets accessible to or targeted by the regenerators. We do not have further information on the arbitrages of regenerators (which is also confidential). The issue of PS contamination by PP-Talc will depend on the source waste plastics and the technical choices made by regenerators. For regenerators who operate a line specifically for LHA cold plastics, this issue is probably limited (because the stream contains little PP). In case of other sources (other WEEE, ELV) the regenerators may use separation techniques. This is for example the case of regenerator #x who uses triboelectrical techniques to separate PS, ABS and PP-Talc.	OK
18	12	C12	Assumptions/methodology	What is a high purity for you, 95%? 98? This information has a direct impact on the coefficient of transfer from one material to another and on its future use. Has the coefficient of transfer been taken into account? It could be covered by a sensitivity analysis.	For clarification	In table 2, we indicated that the level was "high (> 95% of target polymer)". In the responses to the questionnaire, some regenerators mentioned purity levels between 95% and 98% (as declared). We will add a clarification to the report that the level indicated is taken from information provided by the regenerators. In all cases, for this work a purity level is required to enable the minimum technical requirements and ensure the recycled plastic pellets can be used by EEE producers especially. Concerning the coefficient of transfer: for these LCIs, we effectively considered that a small part of the extruded shredded plastics would be lost in the form of filtration residues (the management of which was accounted for).	OK
19	12	C1.2	Clarification	What does an average profile mean? In terms of volume?		This clarification follows the explanation of the choice made by certain regenerators to sort by colour. Thereby, the term "average profile" will be replaced with "common profile", i.e. profile common to white PS, "jazz" PS and PS unsorted by colour.	OK
20	13	C1.2	Clarification	How do you define a sufficient number of regenerators for the LCIs of this study?		Concerning the specific question of non-separation of recycled PS according to colour on page 13, the "sufficient number of regenerators" refers to the commitment made to regenerators to consolidate their data with those of other regenerators, to protect the confidentiality of their profile. A minimum of three therefore.	OK

21	13	C1.2	Data	PS was not separated by colour. But this has a direct impact on the future application.	Justify	Effectively, depending on the colours of the PS pellets, the intended application may differ. Concerning the common LCI created, the report refers to the low usage of optical colour sorting on the LCI: "As the energy requirements for optical colour-based sorting are secondary compared to the energy requirements for other steps (upstream of regeneration, shredding to produce flakes, extrusion-pelletisation), we consider that the choice of an average LCI without colour distinction for PS is suited to the aims of the work". Note that these LCIs are intended to be updated in a few years; perhaps at this time market developments (more regenerators to ensure data confidentiality) will enable us to more finely distinguish separate cases for each polymer, and therefore refine the LCIs.	OK
22	13	C1.2	Data	Are the purity level data provided by regenerators?	Add source	The purity level was requested of regenerators. For pellets, their responses indicated levels between 95% and 98% depending on the case. We therefore used > 95%. The source of this value will be explained in the final report.	OK
23	13	C1.2	Clarification	Why does only PS need to be adapted for closed loop re-use?	Specify source of 2%	To achieve the minimum technical requirements for recycled plastics to be usable by EEE producers especially, the addition of an impact modifier was effectively considered in the case of PS. Only PS is affected by the addition of an impact modifier. The reason for this adaptation is that regenerators can produce PS pellets for different markets, with some being less demanding on the high impact properties of PS.	OK
24	13	C1.3	Clarification	What is the order of magnitude of the tonnages excluded?		Concerning ABS-PC, we do not have this information as the regenerators in the sample population do not produce recycled ABS-PC from waste ABS-PC. For PP-Talc, we have information but it may not be indicated in the report due to its confidentiality.	OK

25	13	C.2	Clarification	Can you clarify the geographical limits? Collection in France then treatment essentially in Europe (what does this mean) for a European market?		In practice, the waste collected in France will be processed by successive operators, who may be based in France or elsewhere in or outside Europe. Concerning the report: 1/ for the collection of WEEE (contain plastics), this clarification is made in the report: we focus on waste collected by in France by **ecosystem**, eco-organisation approved in France (see B.2. Aims of this work and section E "SYSTEM BOUNDARIES: THE STEPS OF THE RECYCLING PROCESS" Therefore, we are only focusing on plastics initially present in WEEE produced in France. 2/ for the other steps upstream of transfer to regeneration, section E.1 "STEPS IN RECYCLING CHAIN UPSTREAM OF REGENERATION" clarifies that these steps are mainly carried out in France and sometimes in Europe, as indicated in the diagrams of figure 3 and in the accompanying text. 3/ for regenerators, the work focused on regenerators located in France or elsewhere in Europe (c.f. B.2 "Aims of this work") and who process plastics from WEEE collected in France, as the aim is to create LCIs specific to the recycled plastics produced via the channel organised by **ecosystem**. Therefore "regenerated in Europe" does not forcibly mean "European market"	OK
26	14	C2	Data	Regulatory obligations (e.g. concerning BFR-filled plastics) are often referred to. To improve the understanding of operator restrictions on raw materials sorting, perhaps they could be mentioned in a footnote. What happens to the BFR-filled streams?	Add regulations	A regulatory reference will be inserted. In France, BFR-filled plastics are sent for incineration as hazardous waste.	OK

27	14	D	Assumptions	A closed loop was selected in relation to the integration of recycled plastic materials by **ecosystem** members. What would be the impacts on the LCI if an open loop was used, which is certainly the most common case?		The reference to the closed loop in the interim report is effectively overly restrictive. It is preferable to speak of recycled pellets achieving minimum technical requirements so that recycled plastics can be used by EEE producers or by other users. The presentation was therefore revised in this respect.	OK
28	16	E1	Scope	In figure 3, the parts removed from screens are included in the scope. This creates confusion with the information that the parts removed from flat screens are not taken into account. Are these parts associated with CRT screens?	For clarification	The report text will be edited. The original phrase “certain plastics extracted during manual dismantling of flat screens and sent for recycling have not been studied (e.g. flexible filters, transparent rigid panels)” will be edited to clarify that these plastics are not made of PP, PS or ABS, but PMMA or PET for example. The plastic parts dismantled, such as shells and rigid plastic, are indeed taken into account because they may be made of ABS (shells) or PS (rigid plastics).	OK
29	16	E1	Assumptions	How many operators are there per step? How is the technology mix for CRT broken down?		Here we are in the “Scope of the study” section; information on the coverage rate for upstream steps is provided in the “Inventory” section “J. Steps upstream of regeneration”. The coverage rate by mass of the collection & transfer steps by rank 1 operators, see Table 5. The reader is also invited to browse the methodological summary of the work on end-of-life LCI of WEEE, as this document is public and provides more detailed information on the number of operators. With regard to the question on the technology mixes of flat screens (rather than CRT), data taken from the confidential report on flat screens were presented at the meeting.	OK

30	17	E.1	Clarification	Can the proportions be indicated?		This information is provided in table 7, in the “Life Cycle Inventory” chapter. Rank 2 operations: still done in France for SHA and screens due to the regulatory obligation to separate plastics containing BFRs. LHA non cold: rank 2 (separation of metals / plastics mixes and metal fines / plastics), for the majority in France (less than 5% outside France) LHA cold: rank 2 only concerns metals / plastics mixes processed in Germany	OK
31	17	E.1	Clarification	The geographical limits seem vague to me.	Clarify the choice of extending it to Europe for regeneration after starting with just a French scope. Highlight the specific aspect of modelling an end-of-life plastics channel where collection and regeneration are done in different geographical scopes (concept of stream consolidation).	The different geographical scopes for collection (forcibly in France, as this work concerns **ecosystem** management), and the post-collection steps reflect the in-field management by participants in the end-of-life WEEE treatment chain (market economy). This reflects the effective practices in the field.	OK
32	17	E.1	Clarification	Indicate why plastics materials are not sorted and regenerated in France: lack of operators, technical nature, etc.		The plastic fractions obtained from rank 1 then rank 2 operations belong to the operators (and not to **ecosystem**), who are free to sell them on to the takers they choose. The market conditions and contractual arrangements between participants therefore apply to the later treatment of these fractions.	OK
33	19	E2	Clarification	What is the level of purity?		We will insert a reference to table 2, page 13 which clarifies this point.	OK
34	19	E2	Clarification	In general the mixes treated by electrostatic sorting feature only two materials. In the study, what mixes is this sorting applied to?	Provide an example	Electrostatic sorting: we will specify that this type of sorting applies to PS/ABS mixes.	OK
35	19	E2	Definition	Provide the definition of a masterbatch in the	Add the definition to the glossary	OK, a definition will be added.	OK

				glossary, for example			
36	19	E2	Clarification	What share of the EEE market is held by regenerators?	Indicate the percentage	The requested information is provided in Table 8 "REGENERATOR SAMPLE POPULATION: ORIGINATING SECTOR OF WASTE INPUTS TO REGENERATION" of the interim report 'Life Cycle Inventory" section, chapter K). Note that table 8 will no longer be available in the final version for third parties, but will be provided in a confidential appendix.	Point for attention: providing certain information in the appendix may impact the transparency of the guide.
37	20	G	Data	Were analyses done in relation to the formulation and coefficient of transfer?		**Average formulation / purity level**: the data provided by regenerators were taken into account (c.f. response to observation 22) **Coefficient of transport in extrusion/pelletisation step**: the material yield / losses during the extrusion/pelletisation steps were requested from regenerators; these losses (filtration residues) and their handling were integrated in the LCIs and allocated to the recycled plastics. **Coefficient of transfer upstream of extrusion/pelletisation step**: the efficiencies of transfer in steps upstream of regeneration were analysed during the creation of the end-of-life LCIs (and integrated in their construction); the efficiencies of transfer during regeneration steps upstream of extrusion/pelletisation were discussed with the regenerators. Nonetheless, these efficiencies are not included in the modelling of the production LCIs for recycled plastics; the treatment of material losses occurring in rank 1 or rank 2 during the first step performed by regenerators (block 1) is not allocated to the recycled plastic. For example, the destination of non-filled PS that is not transferred for recycling by rank 1 operators (because it is present as impurities in the metallic fractions or in the "rigid PU foam" fraction for LHA cold) is not allocated to the recycled PS output by regenerators.	OK
38	21	H	Data	What is the time representativeness of the previous LCI?		Concerning the end-of-life LCI for the constituent materials of WEEE: their time representativeness is indicated in the "Life Cycle Inventory" chapter, TABLE 5 - VOLUME COVERAGE RATE OF UPSTREAM LOGISTICS AND RANK 1 OPERATORS CONSIDERED IN RELATION TO TONNAGE HANDLED BY ECOSYSTEM FOR THE YEAR IN QUESTION - the validity period is as follows: "The LCIs produced are considered valid for the period of 2014-2022" (see methodological summary on end-of-life LCIs).	OK

39	21	H	Clarification	Representative at European level? But the mix originates in France, so is it representative for all products in Europe?		It may be representative of the plastics recovered from WEEE collected in France, but only those sent to regenerators located in Europe and not all over the word (via traders). These LCIs do not seek to be representative of all WEEE generated in Europe.	OK
40	21	H	Clarification	What do you mean by better accuracy, but without seeking to high?		For clarity, the text was revised in the report: “best accuracy possible, without it being exceptionally high due to the relative limits on the state of knowledge accessible at the date of this report”.	OK
41	21	H	Clarification	What part was identified?	Indicate the percentage	This part is difficult to quantify. This is mainly due to the fact that plastics may be traded and leave Europe, or return or remain in this territory. This point is difficult to quantify at this time and therefore sheds doubt on this precise quantification.	OK
42	24	I1	Methodology	The approach used is appropriate from a methodological standpoint. Did you search for scientific publications to support your choices?		This work was undertaken as part of the SCORE-LCA study referred to earlier. It described the diversity of methodological practices of legacy work, especially the question of multi-functionality, modelling materials other than plastics, etc. We may add that studying the case of WEEE (multiple flake sorting steps) raises the complexity in relation to previous studies.	OK
43	24	I1	Methodology	In the study, benefits were considered for energy recovery. How does this apply to the target recycled plastics? What would your recommendations be?		This question is outside the scope of this work, and will be addressed by **ecosystem** in the course of another study in progress at this time (see response to observation 69).	OK
44	26	I2	Data	Can you indicate the contribution of the electricity model created using the ecoinvent dataset?		The ecoinvent V3.5 electricity model for the country concerned is based on a single year (2014) which is somewhat atypical given the weather conditions for that year. It was therefore decided to use an average LCI over three years. Note that the majority of section I.2 “Electricity production” will be transferred to the confidential appendix (the geographical location of the regenerators sample population must remain confidential).	OK

45	26	J1	Data	There is a time lag between the regenerators data and the upstream datasets. What impact does this have on the consistency of data?		The validity period of the end-of-life LCIs is 2014-2022, due to the stability of treatment processes. Moreover, updates were made in 2018 to integrate the latest developments in fraction management, especially concerning plastics. The system is globally stable since 2018. Note that future calls for tenders to select logistics and treatment providers are planned for 2021, to commence operations in 2022. Effectively, this could alter the landscape of market participants with whom **ecosystem** can work. The end-of-life LCIs will then be updated and the recycled plastics LCIs will be aligned with the latest datasets available. We recall that we paid substantial attention to the consistency of background datasets by using the same LCI database (this is indicated in the report).	OK
46	27	J2	Data	Flat screen technologies are vastly different from CRT screens. How do you justify using the same upstream steps?	Provide details of the process	As a reminder, the upstream steps apply to the collection and transfer to rank 1 facilities, rank 1 operators, rank 2 operations applicable to plastics fractions (separation of BFR and non-BFR plastics). Contrary to SHA, LHA cold and LHA non cold (e.g. mechanised treatment by breaking, shredding), a large proportion of flat screens are dismantled manually or with the assistance of a robot to remove the screws. This therefore applies to the household WEEE stream with the rank 1 treatment method most similar to that of CRT screens. From our standpoint, it is therefore the least weak proxy.	OK
47	28	J2	Data	Recall the major lines of acquisition strategies		The datasets considered come from the following sources: - analogy with certain aspects of rank 1 treatment operations (SHA) such as electricity consumption, fuel for motorised equipment and dust emissions - validation of consistency with single value collected from a rank 2 operator applying a plastics separation process.	OK
48	28	J2	Data	Why is the LHA cold located in Germany?		Table 7 provides the geographical location of rank 2 operators (rank 1 operators in LHA cold are located in France, as indicated in the report). In the case of LHA cold, the plastics / metals mixes obtained by some rank 1 operators are indeed sent to an operator located in Germany. This is a result of the choices made by the rank 1 operators, being free to trade the metals/plastics fractions they produce with the takers they select.	OK
49	28	J2	Data	How were the balances defined?		They were defined based on our feedback, separating national transport in France and transport between France and neighbouring countries. We consider that the distances proposed are plausible.	OK
50	29	J3	Data	Are these **ecosystem** datasets?		Indeed this information is owned by **ecosystem**. This information is based on an **ecosystem** study that will remain confidential. The paragraph referred to will be withdrawn from the final report for publication and provided in the confidential appendix.	OK
51	29	J3	Data	Does the content level correspond to fillers such as talc and not additives?		The answer to your question is yes. Same response as to previous observation: the paragraph referred to will be withdrawn from the final report for publication and provided in the confidential appendix.	Point for attention: providing certain information in

							the appendix may impact the transparency of the guide.
52	29	J3	Data	For percentages transferred to regenerators, how were the approximations made?		These values were calculated using our knowledge of the fractions output by rank 1 operators, of their composition, of the takers of these fractions. These aspects are explained in greater detail in the methodological summary on the end-of-life LCI of WEEE.	OK
53	33	K1.3	Methodology	What is the degree of uncertainty brought about by the extrapolations?		This degree may be significant, yet impossible to calculate (otherwise we would have modelled the data collected). However, this aspect has an incidence on the validity period of the LCIs. Indeed, we intend to consider the validity period as 2020-2024.	OK
54	34	K1.4	Assumptions	On output from shredding, are there no intermediate steps prior to extrusion?	Indicate if the flakes stream is ready to use.	Concerning flakes that are transferred directly for extrusion by regenerators, a flake sorting step is applied when available to the regenerator, and when the data collected allow us to consider this. For flakes where extrapolations are needed for the extrusion/pelletisation step, flake sorting was taken into account if performed by the regenerator in the sample population. However, no flake sorting performed by regenerators afterwards prior to extrusion was considered, as the existence of this type of intermediate step was unknown.	OK
55	36	K2.2.1	Data	Has the maintenance of shredder blades been taken into account?		Wear on the blades has been accounted for (materials consumption, including shaping processes)	OK
56	36	K2.2.1	Data	If the recycled plastic materials return to the EEE, has not the use of FR been considered? In general, this is generally added by plastics manufacturers.		No, it applies to recycled plastics not containing FR, as to our knowledge regenerators do not use such additives. Modelling the addition of FR will remain the responsibility of future users of these LCIs, like the injection of specific additives for very specific needs (fibres).	OK

57	36	K2.2.1	Data	Is all filtration waste recycled on site?		The report text will be improved. Indeed, if “Compounding - extrusion - pelletisation steps” is indicated in table 10 for filtration residues, it is to clarify that this waste only applies to these steps and not to preceding steps (blocks 1 and 2). The quantities of filtration waste collected from regenerators concern waste that is not recycled internally but sent for elimination/incineration.	OK
58	37	K2.2.2	Data	What portion of the data is unavailable?		The number of operators concerned by unavailable data is already given in TABLE 11 - REGENERATION: PRESENTATION OF TYPE OF UNAVAILABLE DATA AND APPROXIMATIONS USED", column “Nbr concerned”.	OK
59	37	K2.2.2	Data	These items are indicated as recycled in Table 10.		No, your interpretation of Table 10 is incorrect. It will therefore be revised as the remarks in the table seem to generate confusion in terms of their meaning.	OK
60	37	K2.2.2	Scope	Also indicate this exclusion in the scope.		This point concerning confidential consumables is already covered under cut-off criteria in the “Scope of this study” chapter. C.f. Text "Nonetheless, some information requested during the data collection phase has produced little or no results. This concerns especially: - Certain consumables with annual consumption levels below those of main consumables (e.g. consumables used in pre-treating21 industrial wastewater, oils used in equipment operation) or which are confidential (e.g. certain consumables used in density separation).” From our standpoint, it is more suitable to indicate them in the cut-off criteria rather than in the exclusions, because their non-inclusion is not the result of a choice to exclude them but an issue of access to data, which may vary from one regenerator to another.	OK
61	38	K3.2	Data	Indicate the sources used to quantify the masterbatches. What blend ratio is used (data on p.41)? In general, an anti-oxidant is added to the PP formulation. Additives used will depend on the intended application but certain are added by the plastics manufacturer.		For the formulation of a masterbatch, only partial qualitative information was provided by the regenerators (namely the presence of carbon black or titanium dioxide for white). We ran patent searches on the preparation of masterbatches containing either carbon black or titanium dioxide, which indicate that content ranges could be fairly wide: 10-65%, 30-85%, 20-50%. Failing more precise information, we used an arbitrary value of 25% and made this fact clear in the report to inform the reader. In terms of the addition of anti-oxidants, this type of additive was not reported by regenerators in their responses to the questionnaires.	OK

62	38	K3.3	Data	What are your justifications for choosing the proxies? For example for the flocculant	Justify	We requested the MSDS for the flocculant used by one of the regenerators. It was not possible to obtain it, as it was a special confidential formulation. The regenerator did however indicate that this flocculant belonged to a family of cationic polymer flocculants marketed by R&R Watertechnology, This information will be inserted into the final report.	OK
63	39	K3.3	Data	Is the sludge composition provided by regenerator data? Waste glass? What is the NCV value? And its calculation method?	Specify source	Composition of sludges supplied in approximate form by regenerators. It comprises initially: – plastics – cationic polymers used in treatment (flocculant) – rigid PU – wood – inert substances such as sand – water (humidity) In this composition, the rigid PU, wood and plastics are considered to he output streams and not "charges to apply". The impacts of their treatment are not taken into account. In the case of the regenerator sending sludge to incineration, the NCV is calculated as follows: 1) anhydrous GCV = combination of anhydrous GCV of each material in proportion to their content in the mix 2) anhydrous NCV = anhydrous GCV / 1.1 3) gross NCV = anhydrous NCV x (100 - % hu) / 100 - 2.443 x %hu /100, this second term being the energy consumption necessary to vaporise water (enthalpy of water vaporisation) Example: Sludge = 0.4 polymer + 0.3 inerts + 0.3 water (by mass) GCV polymer = 36 MJ/kg dry GCV inerts = 0 MJ/dry GCV anhydrous sludge = (0.4 x 36 + 0.3 x 0)/0.7 = 20.1 MJ /kg dry sludge NCV anhydrous sludge = 20.1/ 1.1 = 18.7 MJ/ kg dry sludge NCV sludge = 18.7 x 0.7 - 2.443 x 0.3 = 18 MJ/kg dry sludge	OK

64	39	K3.3	Data	What is the source of the 33 MJ/kg information?	Specify source	The source datum is the GCV of 36.29 MJ/kg associated to the inventory Waste plastic, consumer electronics {RoW}| treatment of, municipal incineration | Cut-off, U. We made the assumption of a GCV/NCV ratio of 1.1; for conventional fuels this ratio lies between 1.05 (coal) and 1.1 (natural gas). Its actual value depends on the composition of fuels (hydrogen content) and the quantity of water they will form during combustion. We opted for the high bound of conventional fuels, giving us rather a minimal NCV value.	OK
65	39	K3.4	Data	Explain your choices for VOC.		At the temperatures applied to the plastics, especially polyolefins and polystyrenes, aldehydes may form, especially acetaldehyde, formaldehyde. C.f. INPRS publication on plastics degradation. As we do not know the possible proportions of the VOC, we opted to simplify, namely considering similar to acetaldehyde in the interim report. We propose to alter this simplification in the case of PS and ABS as aromatic hydrocarbon emissions (e.g. styrene) are also possible, yet the breakdown of aldehydes and aromatic hydrocarbons will remain arbitrary.	OK
66	41	K.4	Assumptions	No losses were considered on the line. This assumption seems very favourable. Are they regenerator data? Was a sensitivity analysis done on these data?		The losses in the form of “filtration residues” during extrusion are correctly integrated (consideration of steps upstream of extrusion and consideration of their end of life management, namely transfer for incineration with energy recovery). As indicated on page 41, this represents around 2% of flakes sent to the “compounding - extrusion - pelletisation” block.	OK

67	42	K.5	Clarification	Why not complete this with the Pedigree matrix + basic uncertainty or from the PEF method? What about exhaustiveness? What part does AD have in the LCI datasets? What is the data quality level in relation to the aims of the study?	Justify	Scoring criteria for pedigree matrix rating or its PEF equivalent do not always seem appropriate to us. ISO 14040 / 14044 do not impose the use of the pedigree matrix and we prefer to use the same principle of rating scale and same list of criteria as PEF, but with an “expert opinion” rating, explaining the reasons leading use to use low scores. We evaluated the four criteria of the PEF DQR ‘Data Quality Rating) form and exhaustiveness is not explicitly part of them. We intend to complete the report, clarifying that we have sought to ensure full exhaustiveness: - by identifying and modelling all the successive steps of the regeneration chain for the recycled plastics studied - by limiting exclusions and intentional cut-off criteria - by making extrapolations to improve the coverage rate of our work beyond just the regenerators participating in our data collection - by identifying unavailable data (inputs/outputs) requested from regenerators and by adopting an organised approach to addressing unavailable data whenever possible. The quality of the LCIs meets the aims of the study, namely have a first set of LCIs dedicated to plastics recycled from WEEE as desired by **ecosystem**, notably in terms of geographical representativeness and precision. But beyond this overall appraisal, information that from our point of view is important for the users of these LCIs is to have an idea of the capacity oft these LCIs to evaluate the impacts commonly analysed in LCA. To enable this, we created TABLE 23 - OVERALL QUALITY OF LCIS PRODUCED IN TERMS OF IMPACT CATEGORIES.	OK
68			Clarification	How will these data be updated?		It is intended that updating these LCIs will be combined with updating the end-of-life LCIs (planned starting in 2022). Over time, several **ecosystem** studies that are currently in progress should provide greater robustness of data collection and representativeness of the recycled plastics LCIs.	OK
69			Methodology	What recommendations do you have on using the LCIs in terms of the benefits considered?		In effect, these LCIs will be made available to **ecosystem** members and LCA practitioners. They will also be re-used by **ecosystem** as part of a current study to estimate the environmental benefits of recycled plastics. The report from this study will determine the scenarios used for comparison with virgin material.	OK