

End-of-life management LCI of constituent materials of Electrical and Electronic Equipment (EEE) within the framework of the French WEEE take-back scheme

Methodological summary

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GLOSSARY

Allocation	Attribution of input or output streams of a process or a product system between the product system studied and one or more other product systems.
BTEX	Benzene, Toluene, Ethylene, Xylene
CENELEC	European Committee for Electrotechnical Standardization
CFC	Chlorofluorocarbons
CFF	Circular Footprint Formula
CP	Collection Point
CRT	Cathode Ray Tube (screen technology)
DNM	Data Need Matrix
DOM/TOM	French Overseas Department/Overseas Territory
FS	Flat screen
HC	Hydrocarbons
HCFC	Hydrochlorofluorocarbons
HFC	Hydrofluorocarbons
HT	Heavy trucks
HWIP	Hazardous waste incineration plant
(N)HWSF	(Non-) Hazardous waste storage facility
ILCD	International Reference Life Cycle Data System
JRC	Joint Research Centre
LCA	Life cycle analysis
LHA Cold	Large Cooling Household Appliances
LCDN	Life Cycle Data Network
LCI	Life cycle inventory
LHA non cold	Large Household Appliances Non Cold
LPA	Large Professional Appliances

MWIP	Municipal waste incineration plant
PEF	Product Environmental Footprint
PEP Ecopassport [®]	Environmental impact declaration programme for electrical, electronic and HVAC system products
SCEL	Self-contained emergency lighting
SHA	Small household appliances
SPA Build & Med & Ind & Research	Small professional appliances from building, medical, Industry and Research sectors
SRF	Solid recovered fuel
TF	Treatment facility
T&L	Lamps
WEEE	Waste electrical and electronic equipment
WWTP	Waste water treatment plant

SUMMARY OF KEY POINTS

OBJECTIVES

[Objectives 1 Sponsors] ► The work has been sponsored by ESR.....	19
[Objectives 2 Co-funding] ► The work received co-funding from Ademe within the scope of its joint production process of new sets of inventory data through partnerships.....	19
[Objectives 3 Contractor] ► The work was conducted by Bleu Safran, in association with Hélène Cruypenninck on the final destinations modelling.....	20
[Objectives 4 Duration] ► The project was organised in several work phases, between 2014 and 2018.....	20
[Objectives 5 Steering Committee] ► The work conducted benefited from the perspective and guidelines of a Steering Committee including experts from Ademe, Eco-systèmes and Réylum (and then ESR)	20
[Objectives 6 Origin of work] ► When work began in 2014, the data available in LCA databases/tools were not suitable for modelling the end-of-life management of electrical and electronic equipment.....	21
[Objectives 7 Origin of work] ► Provide members of ESR, and more generally LCI professionals concerned, with LCI data, meeting the requirements of the standards ISO 14040:2006 [1] and ISO 14044:2006 [2] and the "entry level" requirements of ILCD [3], enabling them to model the end-of-life of electrical and electronic equipment placed on the French market	21
[Objectives 8 Work objective] ► Differentiate LCIs according to eco-design criteria where relevant.....	22
[Objectives 9 Work objective] ► Maintain this work over time and be able to update the data published	22
[Objectives 10 Work objective] ► The work conducted aims to meet the requirements of the standards ISO 14040:2006 and ISO 14044:2006 along with the "entry level" requirements of ILCD.....	22
[Objectives 11 Decision-context] ► With reference to the ILCD typology, the decision-context in respect of the production of these data is that of accounting with interactions (C1) and that of accounting without interactions (C2) .	22
[Objectives 12 Envisaged applications] ► The envisaged applications are: (i) priority 1: eco-design assistance, (ii) priority 2: comparative or non-comparative LCA studies, environmental product declarations such as PEP Ecopassport®, environmental labelling (via LCI integration in Ademe's Base IMPACTS®)	23
[Objectives 13 External audience] ► This work is intended for the LCA professionals of ESR members and more generally for the LCA professionals concerned by WEEE management	24
[Objectives 14 External deliverables] ► Three types of deliverables are released publicly following the work: 1/ the LCI data in ILCD and system format (<i>LCI results</i>) comply with the standards ISO 14040:2006 and ISO 14044:2006 along with the <i>Entry Level</i> requirements of the ILCD handbook; 2/ a methodological summary; 3/ a data usage guide.....	24
[Objectives 15 Internal deliverables] ► Deliverables – which are internal and confidential – were drafted throughout the project in order to ensure work traceability, reproducibility and durability.....	24

SCOPE OF STUDY

[Scope of study 1 Management within the framework of the accredited take-back scheme] ► The aim of the study is to represent the management of waste electrical and electronic equipment (WEEE) within the framework of the accredited take-back scheme, as implemented by the ESR collective take-back schemes (see section A.1) within the scope of its accreditation by the authorities, pursuant to the Extended Producer Responsibility (EPR) based on Directive 2012/19/EU.....	27
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[Scope of study 2] Management outside scheme excluded ► The EEE end-of-life process conducted outside the take-back scheme is excluded from the scope of the work.....	28
[Scope of study 3] WEEE streams covered ► Lot 1: Five household WEEE streams – Tubes & Lamps, SHA, LHA cold, LHA non cold and Flat Screens – and two professional WEEE streams – SCEL and SPA MED&BUILD; Lot 2: Eight professional WEEE streams – LPA&Mobiles MED&BUILD, Professional Lighting Equipment, Professional Inverters, Electrical Motors for industrial applications, Water Fountains, Professional Cold Cabinets, Rooftop Air-conditioners and Small Heat Pumps & Air-conditioners.	29
[Scope of study 4] WEEE streams excluded ► In respect to household WEEE streams, CRT screens, which are no longer put on the market, are excluded from the scope of the work. In the case of lamps, xenon and mercury short-arc lamps are also excluded from the work.	30
[Scope of study 5] Object granularity ► The LCIs are defined at the scale of a material/WEEE stream pair	30
[Scope of study 6] Functional Unit ► Perform end-of-life management with the framework of the scheme of one kilogram of the material under study belonging to the WEEE category studied, from collection points set up by the French collective take-back schemes in charge of this WEEE category to the final destinations reached by this material.	32
[Scope of study 7] Reference flow ► The reference flow is defined as one kilogram of material under study belonging to the WEEE category studied; this kilogram is measured as the collection points set up by the French collective take-back schemes in charge of this WEEE category.....	33
[Scope of study 8] Boundaries ✕ General case ► The end-of-life management system for a material/WEEE stream pair under study covers all transport and treatment operations between the collection points for this WEEE stream and the range of final destinations reached by the material under study accounting for the treatment methods in this WEEE stream	34
[Scope of study 9] Boundaries ✕ Specific cases ► In the specific case of cooling gases and oil from LHA cold and Professional appliances cold, as well as mercury contained in CFL Lamps and tubes in T&L and in tubes from Flat screens, the system boundaries also include the outcome of the losses arising upstream from the input to rank 1 operators.....	36
[Scope of study 10] Boundaries ✕ Specific cases & reference flow ► Upstream losses were counted as if these losses arose between the collection points and rank 1 operators; the reference flow is thus not modified by incorporating upstream losses.	37
[Scope of study 11] Boundaries, inclusions ► Energy and material inputs and outputs as well as direct elementary emissions were taken into account for each of the foreground system phases of the management of the WEEE streams studied.	38
[Scope of study 12] Boundaries, exclusion ► Travel by consumers, or by other stakeholders, upstream from the collection points are excluded from the boundaries	38
[Scope of study 13] Boundaries, exclusion ► Infrastructures are excluded from the boundaries	38
[Scope of study 14] Boundaries, electricity production ► The modelling of the electricity consumed by the foreground system phases is conducted as specifically as possible in view of the level of visibility in respect of the location of the various successive operations	38
[Scope of study 15] Boundaries, cut-off criteria ► No cut-off criterion was applied in the study of the foreground system phases of WEEE management. All the fractions produced following rank 1 WEEE treatment and the specific emissions and resources used at each of the WEEE management phases were particularly taken into account.	40
[Scope of study 16] Cut-off criteria ✕ Studies of fractions ► No cut-off criterion was applied in respect of accounting for the fractions produced by rank 1 operators; the composition and management of the fractions, even the most minimal, were studied	55
[Scope of study 17] Rank 1 treatment ✕ Exclusion ► Water consumption for sanitary purposes by rank 1 treatment operators was excluded from the system boundaries.....	59

[Scope of study 18| **Boundaries** ✕ **Final destinations**] ► Where relevant, the end-of-life management LCIs of the constituent materials/components of electrical and electronic equipment are broken down according to two final destination accounting methods: 1/ With benefits: the impacts associated with the behaviour of the material/component in the final destinations reached and the benefits provided by material and/or energy substitution effects are taken into account; 2/ Without benefits :only the impacts associated with the behaviour of the material/component in the final destinations reached are taken into account; the benefits provided by material and/or energy substitution effects are not taken into account. 79

INVENTORY ✕ MODELLING IMPERATIVES BY PHASE

[Key Modelling Imperative 1| **Identification of materials under study**] ► Determine for each of the WEEE categories studied the list of priority materials. Gaps in the available data have however led to certain specific materials in certain professional streams not being studied. 31

[Key Modelling Imperative 2| **Upstream logistics**] ► Prepare a quantified description of the upstream logistics procedure in terms of distances travelled, modes of transportation, HT gauges and their load rates in the case of road transport 49

[Key Modelling Imperative 3| **Rank 1 treatment**] ► The two key imperatives of this phase are: 1/quantifying energy and material inputs as well as specific environmental emissions associated with rank 1 treatment ; 2/quantifying the manner in which each of the materials studied is distributed between the various fractions output from rank 1 treatment 54

[Key Modelling Imperative 4| **Transport between rank 1 and rank 2 operators**] ► Establish a quantified description accounting for the key modelling points relating to transport (e.g. distances travelled, modes of transportation, HT load rates in the case of road transport) 65

[Key Modelling Imperative 5| **Other treatment and transport operations prior to final destinations**] ► The sequence of any intermediate treatment and transport operations between rank 1 and the final destinations of the fractions should be determined. For each intermediate treatment operation, it is as such necessary to quantify its specific inputs and emissions and account for the outcome of the materials following the treatment. 68

[Key Modelling Imperative 6| **Final destinations**] ► Two key imperatives were identified for this phase: 1/ modelling the behaviour of the materials/components studied in the various final destinations reached as specifically as possible; 2/ developing the modelling of the behaviour of the materials/components studied in the various final destinations with and without accounting of the benefits provided by substitution effects 77

INVENTORY ✕ DATA

[Data 1| **Main activity data** ✕ **Validation data**] ► Various data validation procedures making it possible to determine the final destinations of the materials and the successive phases to be taken into consideration between rank 1 and these final destinations were applied 48

USPTREAM LOGISTICS

[Data 2| **Upstream logistics** ✕ **Nature of activity data**] ► Tonnage involved, distances, HT gauge, load rate, empty return rate, methods of packaging 50

[Data 3| **Upstream logistics** ✕ **Assumptions**] ► In the case of household WEEE, some rare assumptions were required to make up for the lack of some activity data; these assumptions relate to non-critical aspects 51

[Data 4| **Upstream logistics** ✕ **Source and representation of activity data**] ► Internal ESR data and data collected by interviews with waste management operators: the data processed cover almost 100% of the tonnage collected by ESR or by the waste management operators; the data are representative of 2014, 2015, 2016 or 2017 according to the WEEE streams studied. 51

[Data 5| **Upstream logistics** ✕ **Data processing**] ► The calculation of the HT fuel consumption, over a given distance, is modulated according to their load rate and their empty return rate 52

[Data 6] Upstream logistics \bowtie Mass allocation] ► For common phases to multiple WEEE streams, a mass allocation of impacts is applied between the streams.....	52
[Data 7] Upstream logistics \bowtie Mass allocation] ► The impacts associated with the upstream logistics of a given WEEE category are allocated in mass between the constituent materials of this WEEE category	53
[Data 8] Upstream logistics \bowtie Source of background inventory data] ► The background inventory data are based on ecoinvent V3.4 – allocation, cut-off.....	53

RANK 1 TREATMENT

[Data 9] Rank 1 treatment \bowtie Nature of activity data] ► Nature and quantity of energy inputs, nature and quantity of other material inputs, specific emissions.....	55
[Data 10] Rank 1 treatment \bowtie Source and representation of activity data] ► The data in respect of energy and material inputs as well as emissions – with the exception of cooling gases and expansion gases emitted by LHA cold treatment operators and Hg emitted by T&L treatment operators – were compiled using questionnaires from operators; according to the WEEE stream, the data processed cover between 45% and 100% of the tonnages handled by the operators working for ESR and reflect the diverse range of the main treatment technologies used in Europe; according to the WEEE stream, the data are representative of 2014, 2015 or 2016.	56
[Data 11] Rank 1 treatment \bowtie Assumptions] ► In the case of oil consumption and fugitive dust emissions, the arithmetic mean of the data compiled was applied to make up for any gaps created due to a lack of responses. For professional lighting equipment directed to mechanical treatment, in the absence of any available specific data, the data were approximated by using data from SPA MED&BUILD	58
[Data 12] Rank 1 treatment \bowtie Source and representation of activity data] ► The results of standardised performance tests conducted in 2012 or 2013 on LHA cold treatment operators were used to determine the fugitive cooling gas and expansion gas emissions generated.....	59
[Data 13] Rank 1 treatment \bowtie Source and representation of activity data] ► The results of reports in respect of monitoring conducted in 2012 or in 2014 were used to estimate fugitive mercury emissions from T&L treatment operators.....	59
[Data 14] Rank 1 treatment \bowtie Type of activity data] ► For each WEEE stream, tonnage and composition of the fractions produced following treatment by rank 1 operators	59
[Data 15] Rank 1 treatment \bowtie Source and representation of activity data] ► For each WEEE stream studied, the annual tonnage of each fraction produced following rank 1 treatment is characterised and known for each of the operators included. Depending on the streams studied, the data are representative of 2014, 2015 or 2016.	60
[Data 16] Rank 1 treatment \bowtie Source and representation of activity data] ► For each WEEE stream studied, the composition of the fractions was determined via internal analysis data from ESR and data compiled using questionnaires from operators, the latter possibly corresponding to analyses or expert opinions from the operator. These data are considered to be representative of the period studied, i.e. 2014, 2015, 2016 or 2017 according to the streams.....	61
[Data 17] Rank 1 treatment \bowtie Data processing] ► On the basis of detailed data relating to the tonnage of the fractions produced by each operator at the rank 1 output and the composition of these fractions, the calculation of the distribution of each of the materials studied was consolidated at the scale of each WEEE category; this consolidated distribution is processed in the model developed in Simapro	62
[Data 18] Rank 1 treatment \bowtie Critical analysis of data] ► For each household WEEE stream, a critical analysis of the plausibility of the data relating to the fractions was conducted by comparing the composition of this stream as calculated on the basis of the tonnage and the composition of the fractions and the composition of this stream as known from other sources.....	62
[Data 19] Rank 1 treatment \bowtie Allocation] ► In the case of facilities treating multiple WEEE categories, the inputs, other than nitrogen and activated carbons, associated with rank 1 treatment are allocated in mass between the various WEEE categories; in the particular case of nitrogen and activated carbons, these inputs were specifically allocated to the WEEE categories involving these inputs.	63

[Data 20] Rank 1 treatment ✕ Allocation] ► The inputs associated with the rank 1 treatment of a given WEEE category are allocated in mass between the various constituent materials of that category. Dust emissions are allocated in mass between the various materials except in the case of concrete and glass from LHA non cold to which the average differential observed between LHA non cold and SHA dust emissions is specifically allocated.	63
[Data 21] Rank 1 treatment ✕ Source of background inventory data] ► The background inventory data are based on ecoinvent V3.4 – allocation, cut-off, except the electricity inventory for France. The electricity mix is specific to the country in which each of the operators is located.	63
[Data 22] Rank 1 treatment ✕ Source of background inventory data] ► In the case of metals, dust emissions are modelled using particulate emissions of the metal studied; in other cases, the emissions are modelled in the form of unspecified particulates.	64

TRANSPORT BETWEEN RANK 1 AND RANK 2 OPERATORS

[Data 23] Transport between rank 1 and rank 2 operators ✕ Nature of activity data] ► Tonnage involved, distances, HT gauge, load rate, empty return rate, methods of packaging.	65
[Data 24] Transport between rank 1 and rank 2 operators ✕ Assumptions] ► The HT gauge and empty return rates are based on assumptions.	65
[Data 25] Transport between rank 1 and rank 2 operators ✕ Source and representation of activity data] ► The activity data were compiled using questionnaires from rank 1 operators. This information is representative of the years 2014, 2015, 2016 or 2017 depending on the WEEE categories.	65
[Data 26] Transport between rank 1 and rank 2 operators ✕ Data processing] ► The detailed data relating to the identity, location and breakdown of the tonnages between the various handlers, were processed and consolidated so as to obtain for each WEEE category a road distance and a maritime distance representative of the transport of each of the fractions.	66
[Data 27] Transport between rank 1 and rank 2 operators ✕ Data processing] ► The calculation of the HT fuel consumption, over a given distance, is modulated according to their load rate and their empty return rate.	66
[Data 28] Transport between rank 1 and rank 2 operators ✕ Mass allocation] ► For each WEEE category, the impacts associated with the transport of a given fraction between rank 1 treatment operators and the rank 2 handlers of this fraction are allocated in mass between the constituent materials of that fraction.	66
[Data 29] Transport between rank 1 and rank 2 operators ✕ Source of background inventory data] ► The background inventory data are based on ecoinvent V3.4 – allocation, cut-off.	66

RANK 2 AND SUBSEQUENT OPERATIONS UNTIL FINAL DESTINATIONS

[Data 30] Rank 2 and subsequent operations until final destinations ✕ Nature of activity data] ► The identification of the sequence of treatment operations enabling the constituent materials of the fractions produced by the rank 1 treatment operators to reach final destinations is an essential preliminary requirement with a view to the qualification and quantification of the activity data relating to these phases.	68
[Data 31] Rank 2 and subsequent operations until final destinations ✕ Assumptions] ► Besides rank 2 operators, it was necessary to formulate assumptions on the nature of the operations conducted downstream from these rank 2 operators and until the final destinations. The fraction management diagrams presented in the reports for each WEEE category – confidential reports – ensure traceability between the factual information and the assumptions.	69
[Data 32] Rank 2 and subsequent treatment operations ✕ Source and representation of activity data] ► The data were compiled using questionnaires from rank 1 operations and related to all rank 2 operators involved for each of the fractions; depending on the WEEE category, the data are representative of 2014, 2015, 2016 or 2017 (in the case of electrical motors).	71
[Data 33] Rank 2 and subsequent treatment operations ✕ Nature of activity data] ► The modelling of the treatment operations conducted by rank 2 and subsequent treatment operators is based on the identification of target materials to be recovered and accounting for extraction rates of these target materials.	71

[Data 34] Rank 2 and subsequent treatment operations ✕ Source and representation of activity data] ► According to the nature of the fractions and the WEEE stream in question, the identification of the target materials and the extraction rates in question are based either on data produced following characterisation work, or on expert opinions.	72
[Data 35] Rank 2 and subsequent treatment operators ✕ Nature of activity data] ► Nature and quantity of energy inputs, nature and quantity of other material inputs, specific emissions	72
[Data 36] Rank 2 and subsequent treatment operations ✕ Source and representation of activity data] ► The activity data for operations conducted at rank 2 and later are based on analogies with some aspects of the operations conducted at rank 1, on bibliographic data or on in-house data acquired during prior studies; their temporal representation is deemed to be suitable with respect to an objective of representation of the 2014-2016 period.	73
[Data 37] Transport downstream from rank 2 operators ✕ Nature of activity data] ► Tonnage involved, distances, HT gauge, load rate, empty return rate	74
[Data 38] Transport downstream from rank 2 operators ✕ Source and representation of activity data] ► Typical scenarios for each geographic region or each market were defined. For market-based scenarios, the distances determined are based on statistics relating to the regions of use (domestic national market, European market, Asian market) of various waste categories (e.g. ferrous metals, copper, etc.). For typical scenarios, the PEP Ecopassport™ handbooks and the French environmental labelling handbook were used as points of reference to determine the distances travelled.	74
[Data 39] Downstream transport from rank 2 operators ✕ Data processing] ► The calculation of the HT fuel consumption, over a given distance, is modulated according to their load rate and their empty return rate	75
[Data 40] Rank 2 and subsequent treatment operations ✕ Allocation] ► Applying the same logic as that applied for rank 1 treatment operators, the inputs associated with the treatment of a fraction/sub-fraction by a rank 2 operator or by an operator of a subsequent rank, are allocated in mass between the various constituent materials of that fraction/sub-fraction	75
[Data 41] Downstream transport from rank 2 operators ✕ Allocation] ► Applying the same logic as that applied for transport between rank 1 and rank 2 operators, the impacts associated with the downstream transport from rank 2 operators, of a fraction/sub-fraction, are allocated in mass between the various constituent materials of that fraction/sub-fraction	75
[Data 42] Rank 2 and subsequent treatment operations ✕ Source of inventory data] ► Applying the same logic as that applied for rank 1 treatment operators, the inventory data are based on ecoinvent V3.4 – allocation, cut-off; the electricity mix is specific to the country in which each of the operators is located; in respect of dust emissions, they are modelled using particulate emissions of the metal studied in the case of metals and they are modelled in the form of unspecified particulates in the case of other materials.	76
[Data 43] Downstream transport from rank 2 operators ✕ Source of inventory data] ► Applying the same logic as that applied for transport between rank 1 and rank 2 operators, the inventory data are based on ecoinvent V3.4 – allocation, cut-off	76

FINAL DESTINATIONS

[Data 44] Final destinations ✕ Allocation] ► The modelling of the behaviour of a given material in a given final destination was conducted as specifically as possible in view of the accessible data. It preferentially applies allocation rules dependent on the nature of the elements as well as energy allocation rules; according to the final destinations, mass allocation rules were also applied in order to account for certain specific aspects.	78
[Data 45] Final destinations ✕ Geographic representation of inventory data] ► The inventory data in respect of the behaviour of the materials/components in the final destinations reached were constructed: 1/ At the scale of the Europe region (RER) for all destinations corresponding to material and/or recovery operations except for incineration with energy recovery ; 2/ At the scale of the France (FR), Europe (RER) and China (CN) regions for destinations corresponding to storage or incineration operations with energy recovery.	80
[Data 46] Final destinations ✕ Source of inventory data] ► The inventory data in respect of the behaviour of materials/components in the final destinations reached were constructed by processing the data and information	

obtained from various data sources: existing databases (ecoinvent V3.4 and V3.2), specific software for the environmental evaluation of household waste management (Wisard™), data and information published by Material Federations (European Aluminium Association, WorldSteel, European Copper Institute, etc.), technical and scientific literature..... 81

[Data 5 | **Adaptation of existing data to the specific treatment characteristics of professional WEEE**] ► Situations for which direct reuse of the data established for household streams was not possible or relevant were identified and led to modifying the final destination profiles of certain constituent materials of professional appliances cold. 86

POSITIONING OF WORK WITH RESPECT TO CFF

[Position with respect to CFF 1 | **Scope**] ► The scope studied within the scope of the work excludes terms referring to the production phase which are covered within the framework of the CFF 91

[Position with respect to CFF 2 | **Scope**] ► The scope studied within the framework of the work only applies to a portion of the end-of-life covered within the framework of the CFF: management of WEEE not collected within the framework of the take-back scheme is excluded from the work 91

[Position with respect to CFF 3 | **Allocation parameters A and B**] ► The allocation parameter of the benefits provided by material recovery and the allocation parameter provided by energy recovery are 0 for all the material/WEEE stream pairs studied 93

[Position with respect to CFF 4 | **Recycling rate R2**] ► Each of the recycling rates R2 processed in the project was calculated in compliance with CFF requirements: the calculation was conducted taking into consideration, along the entire chain between the collection points of the take-back scheme and the recycling process output, the various potential losses and the proportion of materials directed to non-recovered fractions 94

[Position with respect to CFF 5 | **Quality ratio Q_{sout}/Q_p**] ► The quality ratio Q_{sout}/Q_p which compares the quality of the end-of-life recycled material and the quality of the virgin material substituted by the recycled material was systematically determined on the basis of physical considerations. 95

[Position with respect to CFF 6 | **Point of substitution**] ► Within the scope of the work, the point of substitution is systematically determined in line with the point of calculation of the recycling rate and that of the quality ratio Q_{sout}/Q_p; this point is situated at the output of the recycling process and thus corresponds to the most downstream point possible of the waste management value chain. 96

[Position with respect to CFF 7 | **Calculation of terms ErecyclingEoL, EER, ED**] ► Within the scope of the work, the specific emissions and resources used by the recycling (ErecyclingEoL), energy recovery (EER) and disposal (ED) processes were accounted at all the treatment, massification and transport phases from the collection points to the final destinations reached by the materials. 96

[Position with respect to CFF 8 | **Teachings from work on WEEE LCI**] ► Without calling into question the various requirements stated within the scope of the CFF, the CFF should not close the possibility of accounting for, in the case of the end-of-life of a given material: i/several recycling processes; ii/several energy recovery processes; iii/several disposal processes. 98

[Position with respect to CFF 9 | **Teachings from work on WEEE LCI**] ► The end-of-life management of complex products is based, not on a single level of treatment/sorting, but on a tree structure of various treatment/sorting and intermediate transport operators; CFF requirements should be broken down at the scale of this tree structure. 100

LIMITATIONS OF THE WORK

Limitations of work 1 | **Exclusions** ► The aspects excluded from the scope of the study should be taken into account by users in order to check whether they represent a limitation or not in respect of the envisaged use of the data

Limitations of work 2 | **LCIs that cannot be performed for certain materials** ► The aspects excluded from the scope of the study should be taken into account by users in order to check whether they represent a limitation or not in respect of the envisaged use of the data

Limitations of work 3 [Impacts] ► The data produced and released exhibit limitations in their ability to account for impacts relating to particulate emissions, toxicity, ecotoxicity, land use and ionising radiation. Users should account for these limits in terms of data use and interpretation

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WORK OBJECTIVES

A. GENERAL ASPECTS

A.1 SPONSORS

A.1.1 ESR

[Objectives 1|Sponsors] ► The work has been sponsored by ESR

ESR is a non-profit collective take-back scheme accredited by the public authorities since 1st January 2018. It includes collection and recycling activities by Eco-systèmes for household WEEE, and by Récyllum for professional WEEE, lamps, and small extinguishers.

It ensures compliance with WEEE collection and recovery requirements on behalf of its producer members. It particularly takes on the following roles: collection network organisation, logistic and treatment service provider selection, monitoring of services provided to ensure good performance of the system in compliance with regulations and the security of people and the environment. Upstream, ESR engages with its members in order to encourage and guide them towards eco-design processes.

A few key figures:

- In 2016, Récyllum collected 4,900 tonnes of lamps, representing approximately 47 million lamps and tubes, and 16,000 tonnes of professional WEEE (take-back scheme started in 2012), positioning the company as a major player in lamp and professional WEEE recycling in France and in Europe.
- In 2016, Eco-systèmes collected nearly 525,000 tonnes of domestic and professional WEEE, which positions the company as a major player in the development of the WEEE take-back scheme Europe-wide. For household WEEE, this represents more than 75% of this market in France.

A.1.2 ADEME

[Objectives 2|Co-funding] ► The work received co-funding from Ademe within the scope of its joint production process of new sets of inventory data through partnerships

Ademe is the French State's operator for supporting environmental and energy transition. It is an industrial and commercial public establishment (EPIC) placed under the joint administrative supervision of the French Ministry of Environment, Energy and Sea and the Ministry of National Education, Higher Education and Research.

In order to enable them to advance in their environmental approach, Ademe offers its expertise and advice to businesses, municipalities, authorities and the general public. Furthermore, it helps fund projects, from research to implementation, in the following areas: waste management, soil conservation, energy efficiency and renewable energies, air quality, eco-design, sustainable consumption, mobility, sustainable building, sustainable urban development, etc.

In respect of eco-design and environmental labelling, Ademe develops and provides tools and data aimed at users (Base IMPACTS® in particular).

The Steering Committee met ten times during the work conducting phase between January 2015 and May 2018; conference calls focussing on specific issues also took place in addition to the Steering Committee meetings.

B. WORK OBJECTIVES

B.1 ORIGIN OF WORK

[Objectives 6 | Origin of work] ► When work began in 2014, the data available in LCA databases/tools were not suitable for modelling the end-of-life management of electrical and electronic equipment

Due to the recent nature of this take-back scheme, WEEE management is an area that has seen relatively little study in terms of Life Cycle Analysis. As such, in 2014, the databases routinely used by LCA professionals on a European level did not contain any LCI data suitable for satisfactory modelling of the end-of-life management of the electrical or electronic product(s) of interest.

This project has arisen from the aim to fill in the current gaps in standard databases by providing professionals, and more particularly members of ESR, with LCI data suitable for modelling the end-of-life of their electrical and electronic products in a detailed and reliable manner.

B.2 WORK OBJECTIVES

[Objectives 7 | Origin of work] ► Provide members of ESR, and more generally LCI professionals concerned, with LCI data, meeting the requirements of the standards ISO 14040:2006 [1] and ISO 14044:2006 [2] and the "entry level" requirements of ILCD [3], enabling them to model the end-of-life of electrical and electronic equipment placed on the French market

This project is primarily aimed at meeting the expectations of the many ESR producer members who have undertaken environmental evaluation and eco-design approaches in respect of their product, by improving the existing technical foundations in terms of environmental evaluation of WEEE management.

These objectives are aligned with those of Ademe in terms of contributing to the development and eco-design and environmental labelling approaches. For ADEME, this contribution is particularly materialised by the provision of environmental information via Base IMPACTS®, and by the production of information via joint data production processes with third-party partners.

The preparatory phase of the project, conducted in 2014, confirmed that Récylum and Eco-systèmes producer members at that time were expecting robust LCIs, representative of the collection, depollution and treatment procedures set up in France for WEEE management. The LCIs expected should enable them to improve the environmental modelling of the end-of-life management of the products currently on the market.

The preparatory phase also led to the understanding that in order to meet producers' expectations:

- LCI production work should account for users' various requirements, and particularly the rules and methodological requirements of the PEP Ecopassport [4], this reference guide being used by a significant proportion of producers with a view to producing Environmental Product Declarations;
- The LCI structure should be devised such that the LCIs issued help optimise the time devoted by members to modelling their end-of-life products;
- The LCIs produced following this work should be issued publicly and their format should allow them to be incorporated in various generic LCA tools (SIMAPRO, GABI, EIME, etc.) or those

more specific to certain sectors such as the construction sector (ELODIE, COCOON, etc.): the latter portion directed the work towards LCIs issued in ILCD format via LCDN (see section B.6).

[Objectives 8 | Work objective] ► Differentiate LCIs according to eco-design criteria where relevant

Eco-systèmes and Récyllum, and then ESR, expressed the wish that the LCIs produced could be differentiated by accounting for eco-design criteria with regard to end-of-life management where relevant from an environmental point of view.

By way of example, if fillers or additives present in certain plastics impede the sorting of these materials and/or are liable to result in them being directed to a less advantageous downstream application in terms of final substitution, the LCIs created should be able to account for these differences in direction.

[Objectives 9 | Work objective] ► Maintain this work over time and be able to update the data published

ESR and Ademe aim to maintain this work over time and be able to regularly update the LCIs produced following this initial project: data update requirements will be reviewed every 3 years approximately, particularly taking into consideration:

- Changes in collection rates;
- Changes in rank 1 treatment operators enlisted for the various WEEE categories;
- Changes in treatment processes and their performances with regard to depollution and recycling and recovery rates;
- Changes in the background data suitable for being processed during the modelling work.

Reproducibility of the process and maintainability of modelling at the source of the database thus represent a key imperative to be taken into account. This issue determines the major directions in terms of:

- Structuring the LCA models developed to produce LCIs;
- Organisation and traceability of the documentation processed along with data processing processes;
- Transparency of the reports produced throughout the work (section B.6 and section B.7).

B.3 NORMATIVE REFERENCES

[Objectives 10 | Work objective] ► The work conducted aims to meet the requirements of the standards ISO 14040:2006 and ISO 14044:2006 along with the "entry level" requirements of ILCD

The LCI construction work is conducted in compliance with the standards ISO 14040:2006 [1] and ISO 14044:2006 [2] which frame the Life Cycle Analysis and aims to meet to the "entry level" requirements of ILCD [3].

B.4 DECISION-CONTEXT AND ENVISAGED APPLICATIONS

[Objectives 11 | Decision-context] ► With reference to the ILCD typology, the decision-context in respect of the production of these data is that of accounting with interactions (C1) and that of accounting without interactions (C2)

The data are intended to represent, according to a purely descriptive approach, the environmental profile of the end-of-life management of each material/WEEE stream pair as these material/WEEE stream pairs are managed within the framework of the French WEEE take-back scheme.

For each of the WEEE materials/streams pair studied, the LCIs are constructed according to two methods:

- without integration of the benefits provided by the effects of material or energy substitution in the case of final destinations consisting of recovery operations; this process refers to the decision-context C2 as per the typology defined by ILCD [3];
- with integration of the benefits provided by the effects of material or energy substitution in the case of final destinations consisting of recovery operations; this process refers to the decision-context C1 as per the typology defined by ILCD [3];

These two accounting methods are detailed in the section relating to final destinations (section 0).

In any case, the LCI data are produced according to an attributional LCA process.

[Objectives 12|Envisaged applications] ► The envisaged applications are: (i) priority 1: eco-design assistance, (ii) priority 2: comparative or non-comparative LCA studies, environmental product declarations such as PEP Ecopassport®, environmental labelling (via LCI integration in Ademe's Base IMPACTS®)

WEEE management LCIs are **primarily intended for use in the context of eco-design initiatives**.

They will also be integrated in the tools developed by Ademe (Base IMPACTS®, and Product Profile tool) and thus suitable for processing via these tools.

Moreover, throughout the work, special attention has been paid to other handbooks, particularly sector-specific ones, currently being drawn up or likely to be revised, which are used or intended for use by a significant number of ESR members with a view to producing product environmental profiles or environmental footprints. These handbooks are listed below:

- The Product Environmental Footprint Categories Rules or PEFCR (provisional version 6.3 dated December 2017);
- The EN 15804+A1 standard (April 2015)¹;
- The PEP Ecopassport handbook (April 2015);
- A handbook being drawn up in the framework of CENELEC.

Certain methodological rules for these handbooks may be different from those applied to draw up the LCIs concerned by the present work. To help users identify synergies or differences, the FAQ (Frequently Asked Questions) guide includes various sections intended to make them aware of these methodological issues:

- Can I use LCIs in the context of eco-labelling as stipulated via the Product Environmental Footprint (PEF)?
- Can I use LCIs in the framework of the EN 15804 standard?
- Can I use LCIs in the framework of PEP Ecopassport?

In addition to these applications, the LCI data produced can be processed by users in comparative or non-comparative LCA studies.

¹ Note that an amendment A2 is currently undergoing a public inquiry (May 2018).

In any case, the users of these data should take care to account for the boundaries of the work in order to assess the ability of the data produced to meet their needs.

B.5 AUDIENCE CONCERNED

[Objectives 13|External audience] ► This work is intended for the LCA professionals of ESR members and more generally for the LCA professionals concerned by WEEE management

The work is primarily aimed at meeting the needs of LCA professionals of ESR members: it should enable them to model the end-of-life management of the electrical and electronic equipment that they currently put on the market in France.

However, insofar as the data produced are released publicly via the Life Cycle Data Network, they may also be useful data for any LCA professionals involved in WEEE management.

B.6 PUBLICLY RELEASED EXTERNAL DELIVERABLES

[Objectives 14|External deliverables] ► Three types of deliverables are released publicly following the work: **1/** the LCI data in ILCD and system format (*LCI results*) comply with the standards ISO 14040:2006 and ISO 14044:2006 along with the *Entry Level* requirements of the ILCD handbook; **2/** a methodological summary; **3/** a data usage guide.

Three types of deliverables are drafted with a view to public release:

- **Data:** the LCIs of the material/WEEE stream pairs studied released on the Eco-systèmes and Récylum nodes of the LCDN: these data are released in ILCD format and in *system* format (*LCI results*); they were constructed in order to comply with the standards ISO 14040:2006 and ISO 14044:2006 [1][2] and the *Entry Level* of the ILCD handbook [3].
- **Methodological summary version V2.0 dated June 2018:** this document gives an overview of the key points of the LCI definition project and its positioning with respect to CFF (Circular Footprint Formula) requirements. This document is an updated version of the initial version V1.0 dated January 2017.
- **Usage guide in FAQ form:** this guide is aimed at facilitating the correct understanding and use of the released data by LCA professionals

B.7 CONFIDENTIAL INTERNAL DELIVERABLES

[Objectives 15|Internal deliverables] ► Deliverables – which are internal and confidential – were drafted throughout the project in order to ensure work traceability, reproducibility and durability

A number of confidential internal deliverables were produced during the project in order to ensure traceability of the work carried out, its reproducibility and durability.

	Content	Volume	Accessibility
LHA cold report*	In each of the reports: <ul style="list-style-type: none"> ▪ Identification of the materials to be taken into account for the WEEE category ▪ Collection/transfer method ▪ Rank 1 treatment principle ▪ Identification of fractions obtained from rank 1 treatment ▪ Composition of fractions obtained from rank 1 treatment 	≈100 pages	ESR, Ademe, Peer Review
T&L report*		≈100 pages	
SHA report*		≈200 pages	
LHA non cold report*		≈200 pages	

	Content	Volume	Accessibility
Flat Screens report*	<ul style="list-style-type: none"> Management of each of the fractions from rank 1 treatment operator output to final destinations Synoptic of materials/fractions 	≈100 pages	
SCEL report*		≈100 pages	
SPA Med & Build & Ind & Research report*		≈100 pages	
Professional Lighting Equipment report		≈110 pages	
LPA Med & Build Ind & Research report		≈110 pages	
Professional Inverters report		≈100 pages	
Electrical Motors for industrial applications report		≈35 pages	
Professional appliances cold report		≈65 pages	
Main report on background LCI* - August 2016	<ul style="list-style-type: none"> General modelling guidelines in Simapro Documentation of inventory data processed at each stage Documentation of construction of inventory data relative to final destinations 	≈200 pages	ESR, Ademe, Peer Review
Supplement to the background LCI report* – June 2018		≈20 pages	
Note concerning the update to plastic management rules – June 2018		≈5 pages	
Model	<ul style="list-style-type: none"> Model developed in Simapro 		ESR, in Peer Review work session

* An organised set of sources of data processed in each of the reports (questionnaire, data produced by collective take-back schemes, bibliographic articles) is also furnished to the sponsors

TABLE 1 – SUMMARY OF INTERNAL DELIVERABLES

B.8 METHODOLOGICAL SUMMARY ISSUE DATE

This document corresponds to the Methodological Work Summary version V2.0 dated June 2018.

SCOPE OF STUDY

At the present time, waste electrical and electronic equipment (WEEE) is considered to be one of the waste streams experiencing the most rapid growth in the EU. This waste contains various substances which need to be extracted and handled suitably in order to prevent environmental and health risks; furthermore, it represents major potential with a view to the production of secondary raw materials (metals, plastics, precious metals, glass, etc.) and/or solid recovered fuels.

European legislation promoting the collection and recycling of such equipment (WEEE directive 2002/96/EC) has been in force since February 2003. This legislation provides for the set-up of collection systems where consumers take back their used waste equipment free of charge, the objective of these systems being to:

- Prioritise systems ensuring satisfactory extraction of pollutants and their management within the framework of suitable take-back schemes;
- Increase recycling and/or reuse of electrical and electronic equipment.

Directive 2012/19/EU of 4 July 2012 (transposed to French law by decree No. 2014-928 of 19 August 2014) sets the following collection targets:

- Target as at 2016: 45% by mass of equipment sold over the previous three years;
- 2019 target: 65% by mass of the equipment sold over the previous years or 85% by mass of the waste produced.

The status of WEEE recycling in the European Union was analysed in a study conducted by the Countering Illegal WEEE Trade Project – CWIT – [8]; this study shows that, in 2012, on a European scale:

- 35% of WEEE was handled and managed by official collection and recycling schemes;
- 65% of WEEE was managed outside accredited collective take-back schemes:
 - Approximately 50% was recycled under non-compliant conditions;
 - Approximately 25% was exported;
 - Approximately 12.5% was sorted to recover materials of value;
 - Approximately 12.5% was thrown away.

In terms of the collection rate specifically achieved on a French scale, the latest figures published by Ademe [9] relates to the **year 2016**: 667,000 tonnes of household WEEE were collected and managed within the framework of the take-back scheme (four take-back scheme accredited), representing a **collection rate of 45.2%** approximately with respect to the average of the equipment placed on the market over the previous three years.

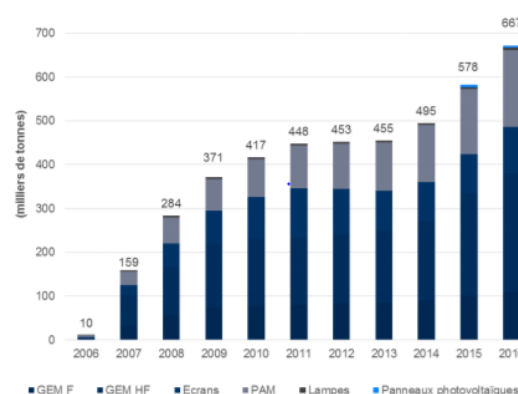


FIGURE 1 – PROGRESSION OF HOUSEHOLD WEEE TONNAGES COLLECTED IN FRANCE BETWEEN 2006 AND 2016

C. SYSTEM STUDIED

C.1 WEEE MANAGEMENT WITHIN THE FRAMEWORK OF THE ACCREDITED TAKE-BACK SCHEME

[Scope of study 1 | Management within the framework of the accredited take-back scheme]

► The aim of the study is to represent the management of waste electrical and electronic equipment (WEEE) within the framework of the accredited take-back scheme, as implemented by the ESR collective take-back schemes (see section A.1) within the scope of its accreditation by the authorities, pursuant to the Extended Producer Responsibility (EPR) based on Directive 2012/19/EU.

Under French law, a collective take-back scheme is a non-profit structure to which EEE producers – subject to EPR obligations – transfer their collection and recycling obligations in exchange for the payment of a financial contribution.

The accreditation procedure, and the resulting obligations of the collective take-back schemes in respect of WEEE management, are based on:

- a specifications document² drafted by the authorities following consultation with all stakeholders;
- the submission of accreditation applications by the collective take-back schemes and their approval by the authorities;
- periodic inspection of compliance by the collective take-back schemes with the requirements of the specifications document and their application, by accredited third-party organisations.

Within the framework of this accredited take-back scheme, the organisational, funding and monitoring procedures in respect of WEEE management are particularly characterised by:

- The **provision of a public service**, adherence by the collective take-back schemes to the non-profit-making principle, and seeking a high environmental, social and economic quality favouring the creation of local jobs;
- The **development WEEE collection resources**, adapted to profiles, from all owners, in order to meet the minimum collective rate targets, based on Directive 2012/19/EU and specified under national law³:
 - *Used appliances collected should be clearly identifiable as WEEE (not sheared or compacted, and separated from other types of waste), and are systematically sorted by stream, according to their nature, so as to be directed to specialised facilities.*
- Selection of logistic and treatment operators on the basis of calls for tender and the set-up of contracts prioritising **the best treatment processes available**, ensuring suitable extraction and treatment of the hazardous substances and components contained in WEEE, and making it possible to meet the target recycling and recovery rates stipulated by Directive 2012/19/EU:
 - *The containers and handling equipment are suitable for preserving the condition of the WEEE collected with a view to effective depollution, for example: use of specific containers for the collection and transportation of fluorescent lamps, lamps and flat*

² Appended to the order dated 2 December 2014 relating to the accreditation procedure and containing the specifications in respect of collective take-back schemes in the household waste electrical and electronic equipment sector pursuant to articles R. 543-189 and R. 543-190 of French environmental legislation.

³ Minimum collection rate of 45% in 2016, 52% in 2017, 59% in 2018 and 65% in 2019 (as a % of the average weight of EEE put on the market over the previous three years), including a minimum annual collection proportion to be achieved from new channels.

screens limiting breakage, handling of large cooling household appliances with clamp trucks in order to prevent damage to the cooling circuit);

- *Each collected WEEE stream is depolluted by means of processes specifically adapted on the basis of the pollutants it contains and the equipment characteristics, for example: depollution and treatment of refrigerators at specific facilities recovering the fluids contained in the cooling circuit and capturing expansion gases from insulating foams by shredding in a confined chamber, treating linear lamps and lamps in confined areas with continuous extraction of the ambient air which passes through dust extraction and mercury extraction systems;*
- *Each collected WEEE stream is treated with processes adapted to optimise the sorting of the materials it contains and their recovery, for example: for SHA or SPA, set-up of disintegrators suitable for breaking the appliances in order to carry out initial sorting prior to shredding, optimising the recovery of mineral and plastic fractions.*
- **Monitoring of depollution, recycling and recovery performances** via a rigorous monitoring process as per WEEE-LABEX and/or CENELEC standards:
 - *WEEE streams are tracked from their collection to the depollution and treatment facilities. Output fraction take-back applications are also subject to traceability and monitoring by the collective take-back schemes;*
 - *Independent audits and internal inspections are conducted to evaluate the performances of the processes on all treatment facilities;*
 - *Depollution monitoring is carried out by means of performance tests, characterisations and pollutant concentration analyses of fractions, the results of which are compared to target values defined on the basis of the best techniques available and detailed sampling.*
- **Research and Development** and investment support aimed at optimising waste recycling, improving the quality of recycled materials and limiting the environmental impacts of activities.

C.2 EXCLUSION OF MANAGEMENT OUTSIDE SCHEME

[Scope of study 2 | Management outside scheme excluded] ► The EEE end-of-life process conducted outside the take-back scheme is excluded from the scope of the work

The WEEE management LCIs defined within the scope of this project include the management phases as carried out within the framework of the take-back scheme managed by ESR: **the management of these WEEE conducted outside the take-back scheme is excluded from the scope of the LCI structure.**

The exclusion of WEEE management outside the take-back scheme from the scope of the study is a choice justified in that:

- The trajectory and the outcome of WEEE outside the take-back scheme is generally, and by definition, very poorly elucidated; in particular, unlike WEEE management within the framework of the take-back scheme for which ESR has a significant volume of information and data, ESR has no profile of effective operations carried out outside the take-back scheme.
- With a view to using the data produced following this work in eco-design approaches, the perspective "outside the take-back scheme" does not appear to be of much relevance: indeed, it would appear to be more reasonable to seek to improve the design of the electrical and

electronic equipment placed on the market with regard to the operations conducted within the framework of the take-back scheme, and which are in compliance with regulatory requirements particularly in terms of depollution rather than conceiving this design with regard to operations conducted outside the take-back scheme, in respect of which it is currently difficult to know whether they are in compliance with depollution requirements or are organised so as to optimise material recovery rates.

It is also important to highlight that the WEEE take-back scheme is recent: the collection rates, and thus the quantities managed within the framework of this take-back scheme, are seeing a constant rise. Collection rates should continue to increase in the years to come in order to meet the targets of directive 2012/19/EU of 4 July 2012 (transposed to French law by decree No. 2014-928 of 19 August 2014).

In view of this significant increase in collection rates, the representation of WEEE management LCIs within the framework of the scheme should increase with respect to a scope covering management within the scheme and outside the scheme.

C.3 WEEE STREAMS COVERED BY THE WORK AND WEEE STREAMS EXCLUDED FROM THE WORK

C.3.1 STREAMS COVERED

[Scope of study 3 | WEEE streams covered] ► Lot 1: Five household WEEE streams – Tubes & Lamps, SHA, LHA cold, LHA non cold and Flat Screens – and two professional WEEE streams – SCEL and SPA MED&BUILD; Lot 2: Eight professional WEEE streams – LPA&Mobiles MED&BUILD, Professional Lighting Equipment, Professional Inverters, Electrical Motors for industrial applications, Water Fountains, Professional Cold Cabinets, Rooftop Air-conditioners and Small Heat Pumps & Air-conditioners.

The various WEEE stream categories concerned for LCI definition are as follows:

Lot 1 (years 2015/2016):

- T&L: lamps (bulbs and linear);
- LHA cold: large cooling household appliances;
- SHA: small household appliances;
- LHA non cold: large household appliances non cold;
- Flat Screens;
- SCEL: self-contained emergency lightings;
- SPA Building and Medical and Industry & Research: small professional appliances from building and medical sectors.

Lot 2 (years 2017/2018):

- LPA&Mobiles building and medical: and Industry & Research: large professional appliances (>250 kg) and mobiles (50 to 250 kg) from building and medical sectors;
- Professional lighting equipment: Indoor and outdoor professional lighting equipment;
- Professional inverters;
- Electrical motors for industrial applications;
- Professional appliances cold:
 - Water fountains: water fountains including tank and network water fountains;
 - Professional cold cabinets: professional cold cabinets with compressor;
 - Rooftop air-conditioners;
 - Small heat pumps & air-conditioners: heat pumps and air-conditioners containing less than 2 kg of fluid filler.

C.3.2 STREAMS EXCLUDED

[Scope of study 4 | WEEE streams excluded] ► In respect to household WEEE streams, CRT screens, which are no longer put on the market, are excluded from the scope of the work. In the case of lamps, xenon and mercury short-arc lamps are also excluded from the work.

In view of the objectives of the work – LCIs are intended to offer ESR members the possibility of improving the environmental modelling of the products that they place on the market – the WEEE streams currently managed within the framework of the take-back scheme but which no longer fall under the technologies placed on the market are excluded from the scope of the work: this applies to the case of CRT (Cathode Ray Tube) screens.

In the same vein, certain components – mercury contactors, PCB capacitors, PCB oil from dissipators, etc. – are also excluded from the work relating to each of the WEEE streams as they are no longer included in the composition of new appliances.

In the specific case of lamps, short-arc lamps (xenon and mercury) used for cinematographic and event-related projection, lithography and semiconductor production and fluorescent microscopy applications. These lamps were excluded from the scope of the study due to the decisions made on the WEEE streams to be studied as a matter of priority: these lamps represent a very small minority in terms of quantity and are treated under a very specific scheme.

C.4 OBJECT GRANULARITY

[Scope of study 5 | Object granularity] ► The LCIs are defined at the scale of a material/WEEE stream pair

An analysis was conducted in the preparatory phase of this project in order to determine the granularity whereby WEEE management is studied. The following alternative was considered:

1. Define average LCIs representing the end-of-life management of each of the WEEE streams studied, for example average LCI of LHA cold or average LCI of lamps;
2. Define average LCIs for a material/WEEE stream pair, e.g. steel for LHA non cold or glass for lamps.

The choice selected consists of defining average LCIs for material/WEEE stream pairs, or at a WEEE component/stream scale.

▪ Average LCI for a WEEE stream

The construction of an average LCI on a scale of each of the WEEE streams studied was ruled out because:

- It does not allow a user to adjust end-of-life modelling according to the design and effective composition of its product: in the case of SHA for example, a toaster would have the same LCI per unit of mass as a mobile phone whereas the design and composition of these products are radically different; for the same reasons, such "average" data would furthermore not be relevant in terms of an environmental labelling process.
- It likewise does not allow such a user to understand which components or which material of its product represent the main contributors to the environmental profile of the end-of-life management of its product: this would represent a major limitation for the use of the data in an eco-design approach.

- Finally, constructing an average LCI corresponding to a WEEE stream also makes it difficult or even impossible to account for eco-design criteria with regard to management within the scheme: the data rendering level is too macroscopic and general to be able to modulate it on the basis of such criteria.

▪ **Average LCI for a material/WEEE stream pair**

The construction of LCIs at the scale of material/WEEE stream pairs selected within the scope of this project makes it possible to overcome the various limitations pointed out with respect to an "average LCI for a WEEE stream". In exchange for these advantages, it is an approach involving a much greater volume of work due to the high quantity of data to be produced.

Without deviating from this refined approach and in order to facilitate the subsequent use of data - for example within the scope of a first screening on a product - it was also decided to construct, for some complex components such as printed circuit boards, LCIs both at the scale of their main materials and also at the scale of these complex components.

D. IDENTIFICATION OF THE MATERIALS UNDER STUDY

[Key Modelling Imperative 1] Identification of materials under study ► Determine for each of the WEEE categories studied the list of priority materials. Gaps in the available data have however led to certain specific materials in certain professional streams not being studied.

For each of the WEEE categories studied, it was first necessary to identify the list of materials under study, i.e. the materials for which it was a priority to define end-of-life management LCIs.

These materials were selected so as to anticipate compliance with the cut-off criteria encountered by a professional processing LCIs produced in order to model the end-of-life management of a specific item of electrical and electronic equipment:

- the information and data available in terms of composition of each of the WEEE categories studied, which may be based on analyses conducted by ESR, the bibliography or expert opinions were processed according to the mass and environmental range recommended in the standard ISO 14044:2006; for each of the WEEE categories studied, the list of materials selected as work subjects was defined taking into consideration:
 - materials/components covering at least 95% by mass of the average composition of the WEEE category;
 - materials/components below 5% of the mass of each WEEE category but liable to have a noteworthy environmental relevance; this particularly applies to printed circuit boards and some of the materials that they contain (gold, silver, platinoid, lead), Hg used in the composition of lamps of various WEEE categories or LHA cold and professional appliances cold cooling gases and LHA cold and LHA non cold expansion gases.
- materials/components which are no longer put on the market at the present time were excluded from the list of materials/components under study; on this basis, all materials/components (mercury contactor, PCB capacitors, oil containing PCBs, etc.) which are still found in the WEEE currently managed but which can no longer be included in electrical and electronic equipment due to RoHS requirements were excluded from the work.

Accounting for the eco-design objective particularly resulted in the LCIs of some plastic resins being broken down according to the presence of BFR or not and according to the density achieved due to the presence of filler.

It is also important to point out that in the specific case of certain professional WEEE streams, and because of a lack of available data, **it was not possible to offer an end-of-life LCI for certain materials or components** even though they might make a significant contribution to the composition of certain devices:

- **non-ferrous stainless steel** usable in industrial motors as well as professional appliances cold e.g. agri-food applications, specific markets for oil rigs and naval applications);
- **constituent materials of x-ray tube bulbs** used in certain medical applications;
- **constituent materials of lead-acid batteries** that may be present in industrial inverters.

E. FUNCTIONAL UNIT AND REFERENCE FLOW

E.1 FUNCTIONAL UNIT

[Scope of study 6] Functional Unit ► Perform end-of-life management with the framework of the scheme of one kilogram of the material under study belonging to the WEEE category studied, from collection points set up by the French collective take-back schemes in charge of this WEEE category to the final destinations reached by this material.

End-of-life management within the framework of the scheme particularly involves compliance with the regulatory depollution requirements applicable to the WEEE category studied and routing of the pollutants extracted to suitable treatment applications.

The standards ISO 14040:2006 and ISO 14044:2006, governing LCAs – and also LCIs –, stipulate that a Functional Unit is defined for each of the products or services covered by the study. Similarly, within the scope of the Specific guide for Life Cycle Inventory data sets, the ILCD Handbook requires the detailed definition of a functional unit.

Within the scope of this work, the Functional Unit is defined as:

"Ensure end-of-life management with the framework of the take-back scheme of one kilogram of the material under study belonging to the WEEE category studied, from collection points set up by the French collective take-back schemes in charge of this WEEE category to the final destinations reached by this material"

As specified in the introduction to this section, management within the framework of the take-back scheme offers guarantees, particularly – but not solely – in respect of compliance with regulatory requirements in terms of depollution and treatment of the pollutants extracts in suitable applications, which are not necessarily offered by management "outside the scheme".

WEEE depollution within the framework of the take-back scheme

At least the following substances, preparations and components shall be removed from waste electrical and electronic equipment subject to selective collection.

- Capacitors containing polychlorinated biphenyl (PCB), as per Council directive 96/59/EC of 16 September 1996 on the disposal of polychlorinated biphenyls and polychlorinated terphenyls (PCBs and PCTs)(1)
- Components containing mercury, such as switches or backlighting lamps

- Batteries and storage batteries
- Printed circuit boards from mobile phones, generally, and other devices if the surface area of the printed circuit board is greater than 10 centimetres squared
- Liquid or paste toner cartridges, and colour toners
- Plastics containing brominated flame retardants
- Waste asbestos and components containing asbestos
- Cathode ray tubes
- Chlorofluorocarbons (CFCs), hydrochlorofluorocarbon (HCFC) or hydrofluorocarbon (HFC), hydrocarbons (HCs)
- Discharge lamps
- Liquid crystal displays (and their housing if applicable) covering a surface area greater than 100 centimetres squared and all screens backlit with discharge lamps
- External electrical wires
- Components containing refractory ceramic fibres as described in Commission directive 97/69/EC of 5 December 1997 adapting to technical progress Council directive 67/548/EEC relating to the classification, packaging and labelling of dangerous substances(2)
- Components containing radioactive substances with the exception of components in quantities not exceeding the exemption values stipulated in article 3 and annex I of Council directive 96/29/Euratom of 13 May 1996 laying down basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionizing radiation(3)
- Electrolytic capacitors containing hazardous substances (height 25 mm, diameter 25 mm or proportionally similar volume).

The substances, preparations and components cited above shall be disposed of or recovered as per article 4 of Council directive 75/442/EEC.

For example, the LCI constructed for PP (polypropylene) in SHA thus addresses the Functional Unit "Ensure end-of-life management with the framework of the take-back scheme of one kilogram of PP belonging to SHA, from collection points set up by the French collective take-back schemes in charge of SHA to the final destinations reached by the PP".

E.2 REFERENCE FLOW

[Scope of study 7 | Reference flow] ► The reference flow is defined as one kilogram of material under study belonging to the WEEE category studied; this kilogram is measured as the collection points set up by the French collective take-back schemes in charge of this WEEE category

In view of the work objectives and the general definition of the Functional Unit, the reference flow corresponding to a published data item is defined by:

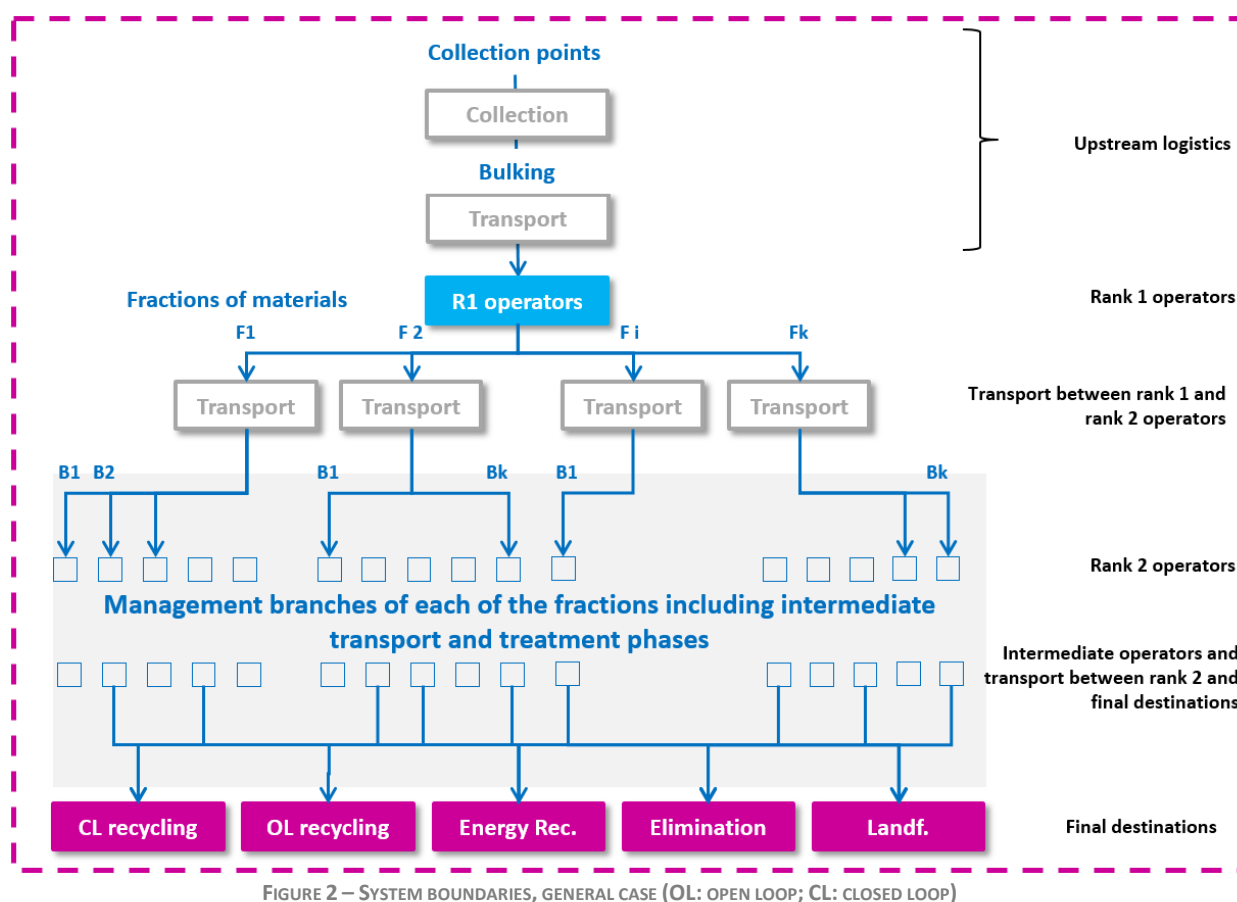
"One kilogram of material belonging to the WEEE category studied, this kilogram is measured at the collection points set up by the French collective take-back schemes in charge of these WEEE category"

As such, in the case of the LCI constructed for PP in SHA, the reference flow corresponds to one kilogram of PP belonging to SHA and measured at the collection points set up by the French collective take-back schemes in charge of SHA management.

F. SYSTEM BOUNDARIES

F.1 GENERAL CASE

[Scope of study 8 | Boundaries ≠ General case] ► The end-of-life management system for a material/WEEE stream pair under study covers all transport and treatment operations between the collection points for this WEEE stream and the range of final destinations reached by the material under study accounting for the treatment methods in this WEEE stream



The figure above illustrates the main principles and phases of WEEE management:

Upstream logistics: this phase includes WEEE collection from collection points and to massification facilities where the WEEE undergoes massification followed by the transfer of WEEE from massification facilities to rank 1 treatment operators; a further portion of the tonnages collected, which is often smaller, may also be transported directly once it has undergone massification from the collection points to rank 1 treatment operations.

Rank 1 treatment operators: these operators, located in France, are responsible for depollution (see section E.1) and the first WEEE treatment phase. This phase results in the product of various fractions of different levels of complexity: indeed, other than in exceptional cases, the fractions never consist of a single material (e.g. PP resin), or of a single material category (plastics); the fractions correspond:

- to a set of materials in which one category is dominant (ferrous metals) but whether other materials/components (printed circuit boards, inductors, etc.) separate from the main category are present in the form of impurities;
- to a genuine mixture of various material categories (mixture of metals/plastics, fluff, shredding residue, etc.).



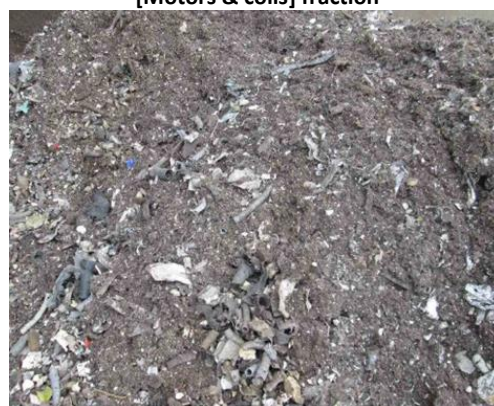
[Boards] fraction



[Motors & coils] fraction



[Mixed Metals/Plastics] fraction



[Fluff] fraction

FIGURE 3 – ILLUSTRATION OF SOME FRACTIONS OBTAINED FROM RANK 1 TREATMENT OF LHA NON COLD

Transport between rank 1 and rank 2 operators: the various fractions produced by rank 1 treatment operators are transported to rank 2 treatment operators. For a given rank 1 operator and a given fraction, several rank 2 operators may be involved (from 1 to 7 handlers maximum per fraction with a majority of cases where the number of handlers is between 1 and 3); by way of example, the wire fraction of the 9 LHA cold operators studied is handled by 16 different operators.

Rank 2 operators: the rank 2 operators are essentially located in France and for the most part in the European region. Depending on the case, rank 2 operators may consist of:

- operators in respect of final destinations reached by the materials (incineration with energy recovery, thermal destruction, storage and recycling for some fractions with low levels of impurities);
- intermediate treatment operators (sorting of plastics, sorting of fine metals/plastics, shredding/sorting of compressors, etc.);
- massification/trading operators (these operators may play an important role in ensuring continuity of supply to subsequent handlers).

Transport and intermediate operators between rank 2 treatment operators and final destinations: according to the nature of the operations carried out by rank 2 operators, further transport and treatment phases may be required before reaching the final destinations. For example, if a rank 2 operator carries out sorting of a final metal/plastic fraction, this implies downstream transport of the ferrous metals extracted to a steelworks, transport of copper alloys to a copper refinery, transport of printed circuit boards to a copper/precious metal refinery, etc., transport of non-recovered shredding residue to an NHWSF.

Final destinations: the final destinations consist either of material recovery operations (steelworks, aluminium refinery, direct reuse of copper, copper/precious metal refinery, plastic regeneration, inert material recovery in the construction sectors, etc.), or energy recovery operations (incineration with energy recovery, use of SRF in cement works, etc.), or of incineration operators (incineration of hazardous waste) or storage operators (storage of hazardous waste or storage of non-hazardous waste).

F.2 SPECIFIC CASE OF COOLING GASES AND OIL FROM LHA COLD AND PROFESSIONAL APPLIANCES COLD AND CASE OF MERCURY CONTAINED IN T&L TUBES AND TUBES FROM SCREENS

[Scope of study 9] Boundaries vs Specific cases ► In the specific case of cooling gases and oil from LHA cold and Professional appliances cold, as well as mercury contained in CFL Lamps and tubes in T&L and in tubes from Flat screens, the system boundaries also include the outcome of the losses arising upstream from the input to rank 1 operators

When WEEE is delivered to rank 1 treatment operators, the WEEE may not be intact in some cases:

- it may be broken: broken tubes and lamps may be found in containers for lamps and in flat screens delivered to treatment operators;
- it may be damaged: the cooling circuit of some LHA cold or some professional appliances cold may be perforated;
- it may have been partially looted: LHA cold or professional appliances cold may arrive at rank 1 treatment operators without their compressor.

The damage observed affect the end-of-life of electrical and electronic equipment without the possibility of determining whether this damage occurred between the collection points and the rank 1 operators, i.e. within the framework of the boundaries previously described, or upstream from the collection points:

- Lamps may have been accidentally broken by their users or during the collection logistics;
- cooling circuits may have been perforated by users using a knife or a screwdriver to speed up defrosting of the freezer compartment of their LHA cold; they may also have been damaged when the appliances were being handled (loading/unloading of the appliances in logistic trucks).

In respect of the loss of integrity of a portion of the WEEE reaching rank 1 operators, current knowledge does not allow a distinction to be made between:

- the proportion of WEEE damaged on users' premises, accidental damage which could also explain why the appliances are being disposed of;
- the proportion of WEEE damaged at collection points or massification centres or during logistics.

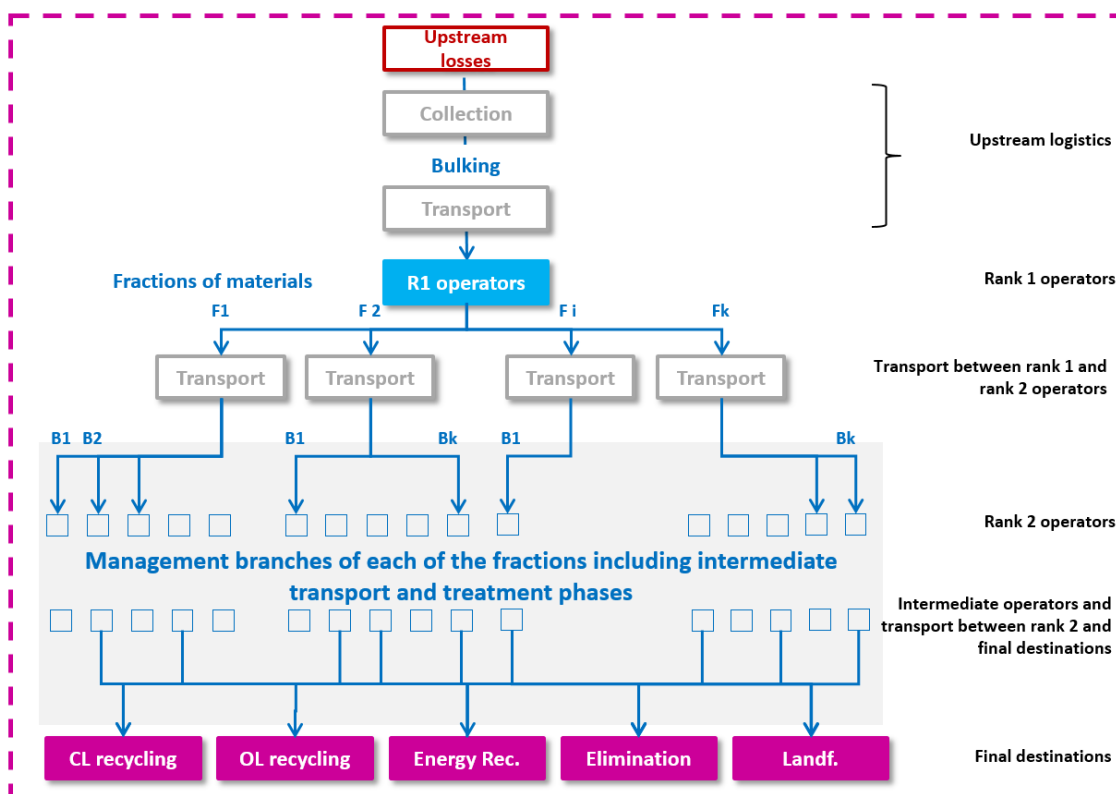


FIGURE 4 – SYSTEM BOUNDARIES, CASE OF COOLING GASES AND OIL FROM LHA COLD AND PROFESSIONAL APPLIANCES COLD AND CASE OF MERCURY CONTAINED IN T&L AND FLAT SCREENS TUBES (OL: OPEN LOOP; CL: CLOSED LOOP)

Following discussions of these aspects with Eco-systèmes and Récylum, the decision was thus made to take into consideration all the specific emissions liable to arise due to a loss of integrity observed on WEEE, even if the damage was not necessarily caused within the scope of action of the take-back scheme per se.

With this in mind, losses, referred to as upstream losses, were taken into account in the system boundaries (Figure 4):

- cooling gas and oil emissions due to damaged appliances cold or appliances cold in which the compressor is missing;
- mercury emissions due to T&L found broken in containers and mercury emissions due to tubes found broken in SCREENS.

These losses were quantified and modelled in the form of specific emissions (case of mercury and cooling gases) or via their incineration (case of oil) in order to include the impacts that they are liable to generate.

[Scope of study 10] Boundaries \propto Specific cases & reference flow ► Upstream losses were counted as if these losses arose between the collection points and rank 1 operators; the reference flow is thus not modified by incorporating upstream losses.

It should be noted that incorporating upstream losses in the accounting system does not give rise to any modification of the reference flow for the cases affected: indeed, these upstream losses were systematically taken into account as if they arose between the collection points and the arrival at the rank 1 operators.

As such, in the case of cooling gases, if the upstream loss rate was estimated at 5% (illustrative value, the actual value being confidential), this means that, for one kilogram of cooling gas (e.g. R600A) taken into consideration at LHA cold collection points, 50 g are considered as upstream losses and 950 g are considered to actually reach rank 1 LHA cold treatment operators.

Similarly, for mercury from T&L, if the upstream loss rate was estimated at 3% (illustrative value, the actual value being confidential), this means that, for one tonne of mercury taken into consideration at T&L collection points, 30 g are considered as upstream losses and 970 g are considered to actually reach rank 1 T&L treatment operators.

F.3 GENERAL ON INCLUSIONS

[Scope of study 11|Boundaries, inclusions] ► Energy and material inputs and outputs as well as direct elementary emissions were taken into account for each of the foreground system phases of the management of the WEEE streams studied.

For each of the foreground system phases of management of the WEEE streams identified within the system boundaries – these phases being presented schematically in Figure 2 and Figure 4 –, the energy and material inputs and outputs were taken into account; similarly, the direct emissions corresponding to elementary flows were quantified.

Anthropic inputs and outputs (electricity, nitrogen, oil, propane, etc.) were associated with background inventory data essentially obtained from the ecoinvent v3 database for all the transport and treatment phases. In the case of final destinations, specific modelling of the materials in each of the final destinations reached was developed based on various data sources.

The aspects taken into account are detailed according to the phase hereinafter in this document.

F.4 GENERAL ON EXCLUSIONS

[Scope of study 12|Boundaries, exclusion] ► Travel by consumers, or by other stakeholders, upstream from the collection points are excluded from the boundaries

The phase corresponding to the travel by consumers (or by other stakeholders) to the collection point is excluded from the scope of the study. The conditions for the conduct of this phase (distance, loading of vehicle, reason for travel) can be extremely variable; moreover, they are outside the control of collective take-back schemes.

[Scope of study 13|Boundaries, exclusion] ► Infrastructures are excluded from the boundaries

The evaluation was conducted excluding infrastructures.

This choice was made due to a decision between the scale of the work required to incorporate this component reliably (the structural solutions can be diverse, the surface areas occupied by the infrastructures of the same activity category can vary significantly particularly based on property costs, the depreciation factors to be taken into consideration can be complex to determine particularly when a building has been used successively by various activities) and the added value of such information in relation to the foreground waste management system under evaluation as a priority.

F.5 ELECTRICITY PRODUCTION

[Scope of study 14|Boundaries, electricity production] ► The modelling of the electricity consumed by the foreground system phases is conducted as specifically as possible in view of the level of visibility in respect of the location of the various successive operations

The table below summarises, phase by phase, the electricity mix taken into consideration in respect of foreground system electricity production.

		Modelling of electricity consumed by foreground system phases
Collection/ massification		Not applicable as no foreground system electricity consumption
Rank 1 operator	Treatment	Electricity mix modelled specifically for the local country: all rank 1 treatment operators are located in France, except one T&L treatment operator located in Belgium The French electrical mix was applied to all operators whether located in mainland France or the French overseas departments and territories.
Op1-Op2 transport		Not applicable as no foreground system electricity consumption
Rank 2 operator	In case of treatment	Electricity mix modelled specifically for the local country: the location of the rank 2 treatment operators is known exactly for most of the WEEE streams studied. The vast majority of rank 2 treatment operators are located in France and in nearby European countries (Germany, Spain, Belgium, etc.) In the case of professional appliances cold for which a simplified working procedure was implemented, the approximation of the location of rank 2 operators in Europe was made, and therefore the use of the European electricity mix.
	In case of massification	Not applicable as no foreground system electricity consumption
	In case of final destinations	See final destinations
Op2-Op3 transport		Not applicable as no foreground system electricity consumption
Rank 3 operator	In case of rank 2 post-massification treatment	Electricity mix modelled specifically for the local country: subject to exceptions, the local country of rank 3 treatment operators was assimilated with the local country of rank 2 massification operators.
	In case of rank 2 post-treatment treatment	Electricity mix modelled in order to reflect the market assumptions taken into consideration. For example, for a rank 2 treatment operator located in France generating a "wire" fraction, 60% of the wires were considered to be mechanically treated in France and 40% in Asia; the electricity mix taken into consideration for these rank 3 operators is thus equivalent to 60% of a French electricity mix and 40% of a Chinese electricity mix.
	In case of final destinations	See final destinations
Op3-Final destination transport		Not applicable as no foreground system electricity consumption
Final destinations	In case of material and/or energy recovery with the exception of incineration with energy recovery	The behaviour of the materials studied in these different final destinations (steelworks, copper refinery, aluminium refinery, recovery in construction, glass manufacturer, etc.) are modelled on the basis of background data representative of the Europe region
	In case of storage or incineration with energy recovery	Electricity mix representative of France, Europe and China: in the specific case of storage and incineration with energy recovery, a distinction was made between the regions corresponding to France, Europe and China. The electricity mix

		of each of these regions was taken into account in the corresponding models. In the case of professional appliances cold for which a simplified working procedure was implemented, a location in France was chosen for the NHWSF and the HWIP, and a location in Europe for the MWIP.
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TABLE 2 – MODELLING OF ELECTRICITY PRODUCTION CONSUMED BY FOREGROUND SYSTEM PHASES

Modelling of electricity in France

When modelling the WEEE streams studied in 2017-2018 and updating the WEEE streams studied in 2015-2016, the decision was made to establish an average LCI for the period 2015 to 2017.

Because this was not directly available in the ecoinvent base, specific work was carried out based on:

- Annual production data published by RTE for mainland France;
- Annual import and export statistics of the physical electricity flows between France and the neighbouring countries (Germany, Italy, Belgium, Switzerland, Great Britain, Spain, Luxembourg);
- High-voltage electricity production LCIs available in ecoinvent according to production mode ("nuclear", "natural gas, conventional power plant", "hydro, run-of-river", etc.).

Loss assumptions considered by ecoinvent with regard to transformation into medium-voltage electricity and its transportation.

G. CUT-OFF CRITERIA

[Scope of study 15|Boundaries, cut-off criteria] ► No cut-off criterion was applied in the study of the foreground system phases of WEEE management. All the fractions produced following rank 1 WEEE treatment and the specific emissions and resources used at each of the WEEE management phases were particularly taken into account.

No cut-off criterion, whether in terms of mass, energy or the environment, was applied in the study of the foreground system phases of WEEE management, particularly in respect of:

- The study of the management of the fractions produced following the rank 1 treatment of the various WEEE categories studied: all the fractions, even when they represent a very minor percentage, were studied (see section M).
- Inclusion of the specific emissions and resources used at each of the phases of the end-of-life management of the various WEEE categories studied: all the emissions and resources used which could be identified have been taken into account; losses as well as consumptions of resources have also been taken into account for the massification phases.

This general consideration on cut-off criteria in the study of the foreground system phases of WEEE management does not rule out general imperfections:

- Material or energy inputs, specific emissions may have been omitted as they were not identified in spite of efforts to cover the impacts of the various operations involved as much as possible. In other words, applicable to all LCA work, the cut-off criterion concept is operative to represent that which has been taken into account with respect of the scope of known factors; on the other hand, the cut-off criterion cannot be deemed to represent that which has been taken into account with respect to the more general scope of known and unknown factors (by definition, the unknown phenomenon cannot be accounted in that which is not taken into account as it is unknown).

- The fact that known factors have been taken into account does not necessarily infer that this accounting method does not involve limitations with regard to certain impacts and that there is no room for improvement: by way of example, particle emissions by rank 1 treatment operators were taken into account; however, as no data are accessible in respect of the size of these particles, they were modelled generically (*Emissions to air - particulates, unspecified*): therefore, this represents a limitation of the model with regard to accounting for respiratory effects of particles. Further examples may be cited, more particularly in respect of the modelling of the behaviour of materials in the final destination: the reader may refer to the section relating to limitations for more details (see TABLE 24).

H. ENVIRONMENTAL IMPACTS

The aim of the work initiated is to provide modelling data for the management of the WEEE studied within the framework of the French take-back scheme. Accounting for the limitations repeated at the end of the summary (see TABLE 244), future users of these data will be able to calculate the environmental indicators that they are seeking on the basis of these data.

However, the aim of this section is to provide users with an initial review of the various impact categories within the scope of WEEE management.

High to very high relevance for WEEE management LCIs	
Climate change Acidification Photochemical ozone formation	<p>WEEE management within the framework of the take-back scheme brings into play various operations involving direct fossil fuel consumption: collection, transport phases as well as most final destinations (steelworks, copper refinery, glass manufacturer, etc.); management operations also involve inputs potentially having an impact in relation to these indicators (activated carbons, nitrogen, electricity, etc.).</p> <p>Material recovery from WEEE also involves the production of secondary materials substituting the production of raw materials which in turn consume various fossil fuels. Similarly, some of the constituent materials of WEEE may undergo energy recovery (e.g. in incineration or in cement works) which avoids the consumption of primary energy resources.</p> <p>The cooling gases used in the case of LHA cold and professional appliances cold and expansion gases used in LHA cold, certain professional appliances cold and LHA non cold are, according to the nature of these gases, potentially major contributors to the greenhouse effect in the case of direct emission: this applies for historically used gases and for certain gases still used in the design of professional appliances cold; however, it is no longer the case for gases used for household appliances currently placed on the market.</p>
Mineral, fossil & renewable resource depletion	<p>Electrical and electronic equipment make use of multiple resources (various common metals - steel, copper, magnetic and non-magnetic stainless steel, aluminium, etc. - and various precious metals, rare earths, petroleum resources used in the manufacture of plastic resins, etc.).</p> <p>Therefore, the end-of-life management of this equipment represents an opportunity to produce various secondary materials which avoid the use of primary resources.</p>
Particulate matter	Some WEEE treatment operations may generate dust. These dust particles have been taken into account with a limitation however due to the impossibility to

	distinguish between dust particles according to their particle size (see Table 244).
Human, toxicity, cancer effects Human, toxicity, non-cancer effects Freshwater ecotoxicity	<p>WEEE management within the framework of the take-back scheme offers guarantees in respect of the extraction and management in suitable chains of a large number of pollutant substances currently found in WEEE (see section C.1).</p> <p>However, toxic and ecotoxic aspects may nonetheless be involved relatively directly:</p> <p>Case of Hg: for a number of WEEE streams (T&L, Flat screens, SHA), direct Hg emissions may arise particularly due to the breakage liable to occur upstream from treatment operators or during the extraction of some components containing Hg. These emissions were taken into account.</p> <p>Case of other metals: emission of metal particles or compounds containing metals may occur at various stages of WEEE management (metal emissions in particulate form during treatment phases, emissions of trace metal compounds during final recovery operations or by leaching in the case of storage, etc.). These emissions were taken into account within the limitations applicable due to the availability of knowledge and the complexity of the phenomena involved.</p> <p>Other compounds: further substances, particularly organic, may potentially be involved within the scope of the various WEEE management operations within the framework of the take-back scheme. It was not possible to quantify these emissions, which may particularly be generated by varnishes, paints, additives associated with the main materials contained in WEEE within the scope of this project, subject to exceptions for trace dioxin emissions during combustion operations of chlorinated compounds, in view of the data required to conduct this evaluation and the complexity of the phenomena involved.</p> <p>As a general rule, users should refer to the limitations expressed in respect of the evaluation of toxic and ecotoxic impacts (see Table 244) so as to avoid any improper/incorrect interpretation of the results obtained.</p> <p>Some of these pollutant substance which are still currently found in WEEE have not been studied as they are no longer used, in the case of PCBs for example, in the manufacture of RoHS-compliant electrical and electronic equipment put on the market.</p>
(Ozone depletion)	<p>The case of ozone depletion is specific: this indicator has been found to be very relevant for some cooling or expansion gases historically used in LHA cold (CFC-12 and CFC-11) and still found in electrical and electronic equipment currently reaching the end-of-life phase.</p> <p>On the other hand, this indicator is of no relevance in the case of appliances currently placed on the market insofar as these gases are no longer used.</p>
Low or moderate relevance for WEEE management LCIs	
Water resource depletion	<p>WEEE management operations do not involve any foreground system water consumption issues. The impact on water consumption within the framework of the take-back scheme thus stems:</p> <ul style="list-style-type: none"> – Indirectly from inputs used by foreground system operations (e.g. electricity production or fuel consumption);

	<ul style="list-style-type: none">– From the profile associated with final destinations for energy or material recovery operations.
Terrestrial eutrophication	As for water consumption, WEEE management operations do not involve any foreground system risks in terms of contribution to eutrophication via direct emissions in sewage or in soils.
Marine eutrophication	The only direct impact of the various operations is linked with the nitrogen emissions (NO ₂ and NO _x) associated with the direct use of energy resources, these emissions being liable to affect terrestrial and marine eutrophication.
Freshwater eutrophication	As in the case of water consumption, an impact on these three indicators could further be linked with inputs used by foreground system operations or by the profile of final destinations for energy and material recovery operations
Ionising radiation HH	The WEEE streams studied within the scope of this work do not involve any direct imperatives in terms of ionising radiation. The impact on these indicators is thus exclusively associated with the background inventories used for modelling.
Ionising radiation E	
Not applicable for WEEE management LCIs	
Land Use	The land use associated with WEEE management cannot be evaluated via the LCIs provided.

TABLE 3 – EVALUATION OF THE RELEVANCE OF VARIOUS ENVIRONMENTAL IMPACT INDICATORS WITHIN THE SCOPE OF WEEE MANAGEMENT

I. SENSITIVITY ANALYSIS FOR REFINING OF SYSTEM BOUNDARIES

Insofar as the phases taken into account in the WEEE management description are considered to be exhaustive with regard to the entire treatment chain from the collection phase to the final destinations, no further investigation was carried out with respect to the refining of the system boundaries beyond those resulting in the inclusion of "upstream losses" in the case of:

- Mercury from T&L;
- Cooling gases and oil from LHA cold and professional appliances cold.

J. REQUIREMENTS WITH RESPECT TO DATA QUALITY

For this work, the quality requirements targeted are those defined for the ILCD "entry-level"; in other words, compliance with the requirements of ISO 14 044: 2006.

The criteria taken into consideration to define the requirements and to evaluate the data quality eventually achieved are as follows:

- **Geographic representation:** the data produced and released are intended to represent the end-of-life management of the material/WEEE stream pairs studied within the framework of the French WEEE take-back scheme, not ruling out that some operations downstream from the depollution and rank 1 treatment operations are carried out in other European countries or in Asia.

This involves representing an average national management for France. The data produced are not however intended to represent a specific local geographical context such as the management of the WEEE collected in a given department (e.g.: Loire), in a given community

(e.g., Mâcon), in the overseas departments and territories, etc. A local context is likely to differ significantly from the national average management.

Comments concerning collection and Rank 1 operations organised in the French overseas departments and territories:

With regard to the collection of WEEE, the streams collected in the overseas departments and territories were taken into account.

In the specific case of professional appliances cold, for which Rank 1 operators located in the overseas departments and territories can represent to date a significant proportion of the tonnages processed, the specific treatment details were taken into account only with regard to the management of expansion gases present in the polyurethane foams in these devices. For more details, the reader may refer to Section Q of this report.

For the other streams studied, Rank 1 operators located in the French overseas departments and territories process a limited proportion of the tonnages (less than 2%) and have not been counted in the context of this work.

- **Technological representation:** WEEE treatment/recovery technologies are likely to develop between now and the actual end-of-life of devices that go on the market now. This time horizon varies according to equipment family (from a few years to a few decades) and probably within a single equipment family.

However, it was deemed to be undesirable and unrealistic to represent forecasts of possible technological developments that could occur in the future. In fact:

- the processes that will be used and the recovery channels that will be mobilised 5, 10, 15 or 30 years or more from now are not definitely known (which is to be expected, and is not specific to the WEEE take-back scheme);
- the use of approaches that consist of choosing the Best Available Technologies, apart from the fact that these are not necessarily defined, could lead to an idealised vision of future performance.

That is why the professional WEEE management LCIs established in the framework of this project aim to be representative of the various current treatment/recovery technologies, which can apply in the context of this take-back scheme as it is organised by ESR, as well as the range of final destinations where the material/stream pairs of the WEEE being studied can end up. As a corollary, the duration of validity of the LCIs is determined with regard to the level of maturity of the treatment processes of the various WEEE streams concerned.

- **Temporal representation:** For the reasons mentioned above in the section concerning technological representativeness, the data produced and shared aim to reflect the current end-of-life management of the material/stream pairs of the WEEE being studied.

In view of the sequencing of the work, the period actually taken into account for all the streams studied is the period (2014-2017).

In the case of plastics, for which regulatory changes took place during the work period, ESR has drawn up projections of the known and foreseeable developments that will apply from mid-2018. The LCIs of the plastics from the various household and professional WEEE streams were thus established with these changes taken into account.

To define the validity period of the LCIs, the following elements were taken into account:

- *Possible technological changes by Rank 1 operators:* future calls for tender involving the choice of Rank 1 operators should be organised in 2020, for probable implementation the following year. In case of any significant change in technologies related to operator selection, the change(s) concerned will not apply until 2021 and the associated data collection will start in 2022 at the earliest;
- *Possible regulatory changes:* except for the case of plastics (see above), to date (i.e. in 2018) ESR does not have any visibility on possible regulatory changes likely to impose major changes in the management of WEEE. If such changes should arise, it will probably take several years for them to come into force;
- *Case of professional WEEE:* even though the data collected for professional WEEE concern more recent years than the data for household WEEE, it seems sensible to align their validity period with that of household streams because of: (i) expected changes in terms of an increase in the tonnages collected and adaptation of the treatment procedures; (ii) the use of household LCIs to establish the LCIs of professional appliances cold.

In view of the elements set forth above, the various LCIs produced are considered valid for the period 2014-2022. As specified with regard to the objective of long database life, their representative nature will be re-evaluated periodically, i.e. around 2021 (See § B.2)

- **Consistency:** the data produced and released are numerous and potentially based on values, parameters, assumptions, background data involved in an interdisciplinary manner: these interdisciplinary items should be conducted so as to ensure a very good level of consistency and prevent the introduction of bias.

The end-of-life management of a material/WEEE stream pair within the framework of the French take-back scheme involves a complex tree structure of different treatment and transport operations from collection to the final destinations (Figure 2). As such, the requirements were broken down phase by phase.

		Data quality requirements
Collection/massification		
Main process	Key parameters: Distances travelled, modes of transportation, load rates, HT gauges, methods of packaging, empty return rates	<u>Specific data by WEEE category:</u> Representative of 2014-2017 period Covering at least 90% of the tonnage collected for each WEEE stream.
	Other parameters: NA	NA
Other processes	Road vehicle / maritime transport combustion emissions	<u>Generic data:</u> Representative of HT fleet in France for road transport in 2014-2017 Representative of maritime transport on a global scale for the 2014-2017 period
Rank 1 treatment		
Main process	Key parameters: Nature and quantity of fractions generated by each operator Composition of fractions generated by each operator	<u>Recent specific data by operator:</u> Representative of 2014-2016 period <u>Case of professional appliances cold:</u> lower requirements in terms of LCI quality compared to household WEEE. A simplified approach based on household WEEE LCIs is being sought.

		Data quality requirements
	Other parameters: Energy and material inputs, specific emissions	<u>Specific data by operator:</u> Representative of 2014-2016 period <u>Case of professional appliances cold:</u> lower requirements in terms of LCI quality compared to household WEEE. A simplified approach based on household WEEE LCIs is being sought.
Other processes	Electricity profile, liquid nitrogen production, non-road diesel fuel, etc.	<u>Generic data:</u> Electricity: specific mix by country, representative of 2014-2017 period Other inputs: representative data of Europe for 2014-2017 period
Transport from Operator 1 – Operators 2*		
Main process	Key parameters: Distances travelled, modes of transportation	<u>Specific data by fraction and by operator:</u> Representative of 2014-2017 period Covering 100% of each fraction of each operator
	Other parameters: Load rates, HT gauges, methods of packaging, empty return rates	<u>Specific data by output fraction type:</u> Representative of 2014-2017 period
Other processes	Road vehicle / maritime transport combustion emissions	<u>Generic data:</u> Representative of European HT fleet for road transport in 2014-2017 Representative of maritime transport on a global scale for the 2014-2017 period A very marginal proportion of road distances are covered in Asia (Pakistan and China): the specific aspects of the transport models to be associated with this travel are not taken into account
Rank 2 and subsequent treatments*		
Main process	Key parameters: Nature of activity carried out by the rank 2 operator and country in which it is located	<u>Specific data for each rank 2 operator identified</u> Representative of 2014-2017 period
	Other parameters: Energy and material inputs, loss rates, extraction rates	<u>Generic data by type of activity</u> Representative of 2014-2017 period
Other processes	Electricity profile, non-road diesel fuel, etc.	<u>Generic data:</u> Electricity: specific mix by country, representative of 2014-2017 period Other inputs: representative data of Europe for 2014-2017 period
Downstream transport from rank 2 operators*		
Main process	Key parameters: Distances travelled, mode of transportation	<u>Generic market data by waste type</u> Representative of 2014-2017 period
	Other parameters: Load rates, HT gauges, methods of packaging, empty return rates	<u>Generic data by waste type</u> Representative of 2014-2017 period

		Data quality requirements
Other processes	Road vehicle / maritime transport combustion emissions	<p><u>Generic data:</u> Representative of European HT fleet for road transport in 2014-2017 Representative of maritime transport on a global scale for the 2014-2017 period</p> <p>A very marginal proportion of road distances are covered in China: the specific aspects of the transport models to be associated with this travel are not taken into account</p>
Final destinations		
Main process	<p>Key parameters: Nature of final destinations reached by material/WEEE stream pair</p>	<p><u>Specific data for each material/WEEE stream pair:</u> Representative of 2014-2017 period</p>
	<p>Key parameters/data: Specific modelling of the behaviour of materials for each final destination concerned on the basis of their key characteristics</p>	<p><u>Representative data of the materials studied for each final destination:</u> MWIP/NHWSF: representative of the specific France, Europe, China regions for the 2014-2017 period Other destinations: representative on a European scale and for the 2014-2017 period It also have been of interest for these other final destinations to be able to specify them by geographic regions: however, the scale of the work required and the data available did not allow such a process to be initiated</p>

TABLE 4 – DATA QUALITY REQUIREMENTS WITHIN THE SCOPE OF THE WORK

* For these stages, in the specific case of professional appliances cold, for which a lower level of quality is required, it is necessary to rely on average electricity and fuel consumption data previously established on the scale of all of these stages for LHA cold, SHA, and LHA non cold (these processes are mobilised for the treatment of this professional WEEE).

LIFE CYCLE INVENTORY

K. SECTION ORGANISATION

K.1 CONTENTS OF DETAILED OVERVIEW BY PHASE

This section details, phase by phase:

- The key modelling issue relating to the phase in question;
- Activity data: their nature, their source and if applicable the validation procedure, allocation rules and processing of these data;
- Background inventory data processed: the nature and source of the background inventory data processed;
- The quality of the data and their compliance with requirements.

K.2 FOCUS ON DATA VALIDATION PROCESS

[Data 1] Main activity data & Validation data ► Various data validation procedures making it possible to determine the final destinations of the materials and the successive phases to be taken into consideration between rank 1 and these final destinations were applied

Particular attention was focused on the validation of activity data.

This section highlights a few key points of the main validation procedures applied; further aspects relating to the validation procedures applied are also described in the sections relating to each of the phases.

Activity carried out by rank 2 operators:

The nature of the activity carried out by rank 2 operators along with their geographic location were the subject of a systematic check for plausibility on the basis of publicly available data in respect of the designated handlers. Besides harmonising the data to be taken into consideration for a single handler, this work made it possible to validate the data relating to:

- The transport distances to be taken into account between rank 1 and rank 2;
- The successive phases to be taken into account from rank 1 to the final destinations

Composition of fractions produced by rank 1 operators:

According to the methods for obtaining data in respect of the composition of the output fractions from rank 1 operators, validation work in respect of these data was undertaken based on:

- The expertise of the "treatment" specialists of ESR or external experts;
- The characterisation reports available for the various treatment operators, these reports particularly including photographs enabling a visual assessment of the materials contained in a fraction.

The average composition of each of the WEEE streams studied was calculated on the basis of the fraction composition data and the tonnages relating to each of the fractions. This composition was compared with other sources of information intended to describe the material composition of WEEE, in particular:

- The data drawn up by ESR through an analysis programme conducted for a number of years and aimed at determining the composition of the constituent products of household WEEE streams;
- Composition data based on the bibliography (e.g.: studies conducted within the scope of the implementation of the ErP directive, data from industrial federations, etc.).

This comparative work made it possible to refine the collection of fraction composition data or highlight any weaknesses in the data taken into account (case of some streams for which collection is still recent).

L. UPSTREAM LOGISTICS

[Key Modelling Imperative 2] Upstream logistics ► Prepare a quantified description of the upstream logistics procedure in terms of distances travelled, modes of transportation, HT gauges and their load rates in the case of road transport

For the household WEEE and professional appliances cold, the upstream logistics are entirely organised by ESR.

For the other professional WEEE streams, the collection and consolidation phases are, to a greater or lesser extent, directly organised by Rank 1 operators or other waste management operators. Note that the upstream logistics of industrial motors and professional inverters is mainly organised by waste management operators working with ESR.

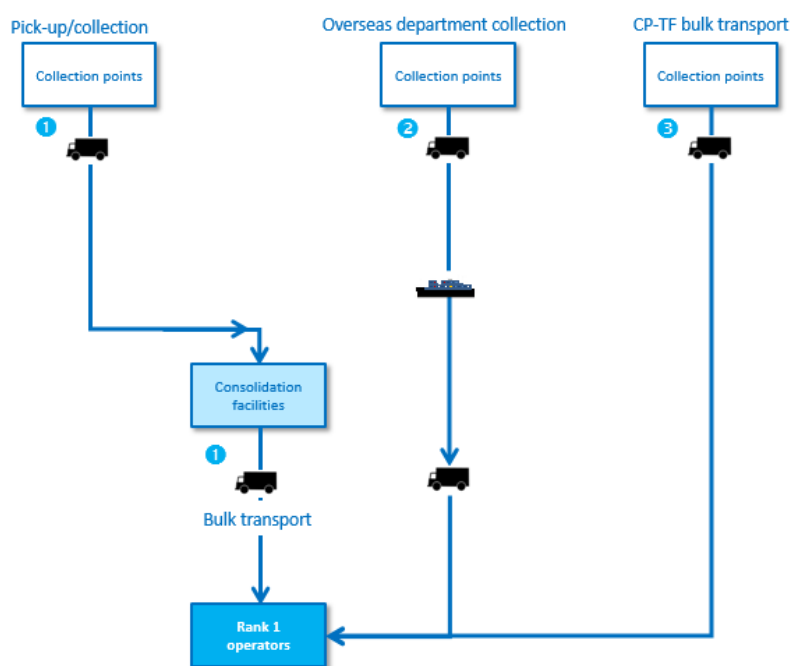


FIGURE 5 – SCHEMATIC DIAGRAM OF WEEE UPSTREAM LOGISTICS ORGANISED BY ESR

The figure above shows the general structure of the upstream logistics with respect to the WEEE studied in the case of the logistics organised by ESR:

- **Branch 1 – pick-up/collection followed by bulk transport between massification facilities (MF) and treatment facilities (TF):** this two-phase logistics firstly consists of non-bulk multi-

stream collection followed by a single-stream bulk transport phase: non-bulk collection makes it possible to collect WEEE from collection points and route it to massification centres; the bulk transport following this first phase makes it possible to route the various WEEE streams to treatment facilities.

- **Branch 2 - collection in French overseas departments from collection points (CP) followed by transport to treatment facilities (TF) in mainland France:** this logistics is broken down into three main phases: a non-bulk collection phase used to collect WEEE from collection points; this phase is followed by a maritime transport phase and a further road transport phase in order to route the various WEEE streams from the arrival ports to treatment facilities.
- **Branch 3 - direct bulk collection/transport between collection points (CP) and treatment facilities (TF):** a portion of the streams may be collected in a bulk, single-stream fashion and transported directly to treatment facilities without passing via massification facilities.

The general schematic diagram is applicable to each WEEE stream studied. Its characterisation data (tonnage involved, distances, HT gauge, etc.) were broken down specifically accounting for the specific activity data to each of the streams studied.

In a similar way to the logistics organised by ESR, the upstream logistics are directly organised by the waste management operators. This can be based on: (i) Direct transportation from the pick-up points to the Rank 1 operators; (ii) Collection and then massification at a consolidation centre before conveying them to Rank 1 operators.

L.1 ACTIVITY DATA

[Data 2] Upstream logistics & Nature of activity data ► Tonnage involved, distances, HT gauge, load rate, empty return rate, methods of packaging

For each of the three main branches of upstream logistics and specifically for each of the WEEE streams studied, the following activity data were established:

- **Tonnage involved for each of the three branches:** as a general rule, the majority of the tonnage of each of the WEEE streams is collected according to the methods of branch 1 (Pick-up massification and bulk transport to rank 1 treatment operators);
- **Gauge of road vehicles used on each of the branches:** a number of HT gauges may be used for each of the sub-phases; the HT gauges are generally lower for the pick-up phase than for the other phases;
- **Load rate:** the load rate – representing the ratio between the effective HT load and the payload – was taken into account; this factor has an influence on transport performances in terms of fuel consumption per tonne transported (section L.2.1);
- **Road vehicle empty return rate:** the road vehicle empty return rate was also taken into account; as for the load rate, this factor has an influence on transport performances in terms of fuel consumption per tonne transported (section L.2.1);
- **Methods of packaging:** some of the WEEE streams studied are transported without containers (e.g. motors, LPA&Mobiles building & medical, etc.). For other WEEE streams studied, various methods of packaging may be involved: PE containers, PP containers, cardboard containers, pallet box, etc. Where appropriate, these packaging solutions were taken into account, making a distinction between disposable solutions and reusable solutions for which the number of rotations on their service life was estimated.

[Data 3 | Upstream logistics & Assumptions] ► In the case of household WEEE, some rare assumptions were required to make up for the lack of some activity data; these assumptions relate to non-critical aspects

For professional WEEE for which some of the consolidation is organised by the waste management operators, it was necessary to use some assumptions or approximations for key parameters

The completeness and precision of the activity data compiled and processed with respect to the upstream logistics description is considered to be excellent for flows mainly collected by ESR. For household WEEE, some rare assumptions were required to fill in a few gaps; furthermore, these assumptions related to less critical aspects, e.g.:

- for some WEEE categories, as the pick-up phase in overseas departments/territories was not available, it was deemed to be comparable to the pick-up phase in mainland France: as this description related to a marginal percentage (< 3%) of the tonnage collected, it is considered to have a low impact;
- the empty return rate was not always specifically documented: in this case, the empty return values representative of the national average for the HT gauge in question were taken into account; these data are based on the Emission factor guide version 6.1 dated 2010 from the Ademe Carbon Accounting method.

For professional WEEE for which a significant share of the logistics is organised by waste management operators, it was necessary to establish the approximations and assumptions with support from certain operators. These applied in particular to:

- the truck size(s) most frequently used during the various stages as well as the average loads transported;
- the average distances covered, when they are not systematically tracked by the operators (e.g. collection subcontracted to external service providers).
- Finally, because the empty return rates are never specifically known, empty return values representative of the national value for the HT size concerned have been used.

[Data 4 | Upstream logistics & Source and representation of activity data] ► Internal ESR data and data collected by interviews with waste management operators: the data processed cover almost 100% of the tonnage collected by ESR or by the waste management operators; the data are representative of 2014, 2015, 2016 or 2017 according to the WEEE streams studied.

WEEE stream	Reference year
LHA cold	2014
T&L	2014
SHA	2014
LHA non cold	2014
Flat Screens	2015
SCEL	2015
SPA Building & Medical	2015
LPA&Mobiles Building & Medical	2016
Professional lighting equipment	2016
Professional inverters	2016
Electrical motors for industrial applications	2017
Professional appliances cold	2017

TABLE 5 – REFERENCE YEAR OF UPSTREAM LOGISTICS ACTIVITY DATA

LHA cold, T&L, SHA and LHA non cold WEEE represent streams in which collection is considered to be relatively mature; the data collected in respect of upstream logistics should not vary considerably in the coming years.

Flat Screens and the various professional WEEE studied are subject to more recent collection with a rise in tonnages in the coming years; for this reason, the need to update the upstream logistics data in respect of these streams could arise at a shorter interval than for the household streams mentioned above.

L.2 DATA PROCESSING/METHOD COMPONENTS

L.2.1 DATA PROCESSING

[Data 5|Upstream logistics & Data processing] ► The calculation of the HT fuel consumption, over a given distance, is modulated according to their load rate and their empty return rate

The formula applied for calculating the consumption of a heavy truck according to its load rate, the empty return rate and the distance travelled is as follows⁴:

$$\text{Consumption} = \text{distance} \times \text{consumption (full load)} \times \left[\frac{2}{3} \times (1 + R) + \frac{1}{3} \times \frac{C_r}{C_u} \right]$$

Where:

Consumption: effective truck consumption over the distance travelled and accounting for its load rate; this consumption is in litres.

Distance: distance travelled by the truck; this distance is in km.

Consumption (full load): consumption of truck at full load; this consumption is in litres/km.

R: empty return rate.

C_r: actual load transported by truck.

C_u: payload transported by truck.

The data relating to the estimation of the consumption at full load for the various HT gauges are based on Ademe research [10].

L.2.2 ALLOCATION

Allocation between different WEEE streams

[Data 6|Upstream logistics & Mass allocation] ► For common phases to multiple WEEE streams, a mass allocation of impacts is applied between the streams

During upstream logistics, pick-up from collection points may involve different WEEE categories collected mixed together – e.g. flat screens are collected mixed together with CRT screens: in this case, the impacts of the pick-up phases are allocated in mass between flat screens and CRT screens.

Allocation between different materials of the same WEEE stream

⁴ This formula is based on NF P01-010 on Environmental quality of construction materials; it is very similar to the formula used within the scope of Copert III and recommended by Ademe within the scope of the Carbon Accounting method.

[Data 7 | Upstream logistics & Mass allocation] ► The impacts associated with the upstream logistics of a given WEEE category are allocated in mass between the constituent materials of this WEEE category

A given WEEE category is made up of several materials. Insofar as the object granularity of the work is situated at a material/WEEE stream scale, all the logistic phases are affected by an allocation issue between the various constituent materials of a given WEEE category: the impacts associated with the upstream logistics of a given WEEE category were allocated in mass between the various constituent materials of this category.

L.3 BACKGROUND INVENTORY DATA

[Data 8 | Upstream logistics & Source of background inventory data] ► The background inventory data are based on ecoinvent V3.4 – allocation, cut-off.

The various inventory data processed to model the upstream logistics (transport and packaging solutions) are inventory data from *ecoinvent V3.4 – allocation, cut-off* as provided in Simapro.

In the case of road transport, an *ad hoc* inventory, covering the production and combustion of a litre of diesel fuel, was constructed based on ecoinvent inventory data so as to account for the breakdown in 2015 of the average HT fleet in France as per the various Euro standards.

This ad hoc inventory was used to model the upstream logistics of all the WEEE streams studied.

L.4 DATA QUALITY AND COMPLIANCE WITH REQUIREMENTS

The table below shows a qualitative evaluation of the data quality and specifies whether the quality requirements defined above were met.

		Reminder of requirements	Attainment of requirements / comments
Upstream logistics (collection/massification)			
Main process	Key parameters: Distances travelled, modes of transportation, load rates, HT gauges, methods of packaging, empty return rates	<u>Specific data by WEEE category:</u> Representative of 2014-2017 period Covering at least 90% of the tonnage collected for each WEEE stream	The requirements were fulfilled, using approximations, however, for the streams collected by the waste management operators and generic data for occasional parameters (e.g. empty return rates).
	Other parameters: NA	NA	NA
Other processes	Road vehicle / maritime transport combustion emissions	<u>Generic data:</u> Representative of HT fleet in France for road transport in 2014-2017 Representative of maritime transport on a global scale for the 2014-2017 period	The requirements were met.

TABLE 6 – UPSTREAM LOGISTICS: EVALUATION OF DATA QUALITY AND ATTAINMENT OF REQUIREMENTS

M. TREATMENT BY RANK 1 OPERATORS:

[Key Modelling Imperative 3 | Rank 1 treatment] ► The two key imperatives of this phase are: **1/**quantifying energy and material inputs as well as specific environmental emissions associated with rank 1 treatment ; **2/**quantifying the manner in which each of the materials studied is distributed between the various fractions output from rank 1 treatment

Rank 1 treatment operators have priority responsibility for WEEE depollution operations; in the case of household streams and part of professional streams, they also conduct a sequence of operations consisting of disassembly, shredding and the application of various sorting techniques (screening, aerodynamic screening, densimetric sorting, overband sorting or magnetic pulley, Eddy current sorting, etc.) making it possible to achieve a certain degree of sorting between materials. These treatment processes are specific to each WEEE stream; they may also vary, for the same WEEE stream, according to the operators.

For certain professional WEEE such as LPA&Mobiles MED&BUILD, professional inverters and professional lighting equipment, the operations carried out by all or some of the operators following depollution consist of manual disassembly.

Concerning the specific case of industrial motors, Rank 1 operators perform massification of streams only.

As such, following this rank 1 treatment, various fractions are produced, varying in quantity according to the WEEE categories and for the same WEEE category according to the organisation of treatment at each of the operators, consisting, without exception, of more or less complex mixtures of different materials and components.

WEEE stream	Number of fractions studied	% by mass of fractions	
		Max	Min
LHA cold	11 fractions	≈ 43%	≈ 0.2%
T&L	9 fractions	≈ 75%	≈ 1%
SHA	20 fractions	≈ 31%	≈ 0.003%
LHA non cold	21 fractions	≈ 47%	≈ 0.01%
Flat SCREENS	16 fractions	≈ 25%	≈ 0.2%
SCEL	11 fractions	≈ 37%	≈ 0.03%
SPA Med & Build & Ind & Research	13 fractions	≈ 31%	≈ 0.6%
LPA&Mobiles Building & Medical	11 fractions	≈ 59%	≈ 0.2%
Professional lighting equipment	10 fractions	≈ 27%	≈ 0.05%
Professional inverters	7 fractions	≈ 24%	≈ 0.3%
Electrical motors for industrial applications	Rank 1 massification only		
Professional appliances cold	Fractions not studied specifically, simplified modelling procedure, see section Q		

TABLE 7 – FRACTIONS FROM RANK 1 TREATMENT OF WEEE STUDIED

The table above summarises the number of fractions that it was necessary to study for each of the WEEE categories. This table also shows that the mass proportion of the various fractions is extremely variable: for example, for lamps, the largest fraction represents approximately 75% of the output tonnage and the smallest fraction approximately 1% of the tonnage.

Professional appliances cold constitute a special case because a simplified modelling approach was implemented for these streams (see section Q).

[Scope of study 16] Cut-off criteria \neq Studies of fractions ► No cut-off criterion was applied in respect of accounting for the fractions produced by rank 1 operators; the composition and management of the fractions, even the most minimal, were studied

It is important to note that, in view of the diverse nature of the materials studied, it was not possible – unless otherwise risking a bias in the results which is not quantifiable in principle – to disregard the study of fractions, even those representing a very small minority in terms of mass.

Indeed, a fraction, even a very minority fraction, may play an important role for a given material; for example, for each of the WEEE streams, the printed circuit board fraction is frequently a relatively minority output fraction in mass; however, at the scale of the precious metals studied (gold and silver in particular), this fraction is liable to play a key role. Furthermore, it was found to be very important to quantify the materials present in the form of mixtures or even impurities in major fractions: indeed, a material present at a level of 1% in the form of impurities in a fraction accounting for 50% ultimately represents 0.5% of the tonnage, i.e. a greater proportion by mass than a number of minority fractions.

The issue in respect of information collection and the work conducted at rank 1 operators is thus:

- Conventionally in LCA, that of quantifying energy and material inputs as well as specific environmental inputs associated with the operations conducted by rank 1 operators;
- Less conventionally in LCA, but according to an MFA (Material Flow Analysis) approach, that of quantifying the manner in which each of the materials studied is distributed between the various output fractions from the rank 1 operators; this involves being able to obtain composition data on each of the fractions as well as to the mass proportion between the various fractions.

M.1 ACTIVITY DATA

M.1.1 ENERGY AND MATERIAL INPUTS, SPECIFIC EMISSIONS

[Data 9] Rank 1 treatment \neq Nature of activity data ► Nature and quantity of energy inputs, nature and quantity of other material inputs, specific emissions

Other than in the case of fugitive emissions of cooling gases and expansion gases from polyurethane foams within the scope of LHA cold and professional appliances cold treatment and fugitive emissions of mercury within the scope of T&L treatment, all the activity data representing the nature and quantity of the various energy and material inputs as well as specific emissions were compiled using questionnaires from rank 1 treatment operators.

The treatment operators were queried on:

- their energy consumptions: electricity, fuel oil, non-road diesel fuel, propane
- their other material inputs: oil, nitrogen and activated carbon consumption
- their fugitive emissions: i/dust in the case of streams for which treatment is carried out in a non-confined manner, i.e. LHA cold, SHA, SCEL and SPA; ii/mercury in the case of T&L

In the specific case of fugitive emissions of gas during LHA cold and professional appliances cold treatment – which is carried out in a confined atmosphere inerted in nitrogen, tests, referred to as

phase 1 performance tests & phase 2 tests, are carried out regularly on the operators at the request of ESR. These tests which are subject to a CENELEC standard⁵ are used to measure

- **Phase 1 test:**
 - a) the quantity of CFCs (HFCs, HCFCs) captured with respect to the quantity of CFCs (HFCs, HCFCs) expected: this should be greater than 90% to comply with the requirements of the CENELEC standard;
 - b) the residual quantity of halogenated organic compounds (R12) in oils: this should be less than 0.2% to comply with CENELEC standard requirements
- **Phase 2 test:**
 - a) the quantity of CFCs (HFCs, HCFCs)/HCs separated and captured with respect to the quantity of CFCs (HFCs, HCFCs)/HCs expected: this should be greater than 90% to comply with CENELEC standard requirements;
 - b) the residual quantity of CFCs in the PUR foam fraction at treatment output: this should be less than or equal to 0.2% to comply with CENELEC standard requirements; iii/the residual quantity of PUR foam in the fractions:
 - plastics: should be less than 0.5% to comply with CENELEC requirements
 - ferrous metals: should be less than 0.3% to comply with CENELEC requirements
 - non-ferrous metals: should be less than 0.3% to comply with CENELEC requirements

For each of the treatment operators studied in the case of LHA cold, phase 1 and phase 2 performance tests were thus processed in order to quantify the fugitive emissions of cooling gas and expansion gas.

In the specific case of mercury emissions during the rank 1 treatment of T&L, the mercury emission monitoring reports for each of the T&L treatment operators were processed in order to quantify the fugitive atmospheric emissions of mercury.

[Data 10 | Rank 1 treatment ✕ Source and representation of activity data] ► The data in respect of energy and material inputs as well as emissions – with the exception of cooling gases and expansion gases emitted by LHA cold treatment operators and Hg emitted by T&L treatment operators – were compiled using questionnaires from operators; according to the WEEE stream, the data processed cover between 45% and 100% of the tonnages handled by the operators working for ESR and reflect the diverse range of the main treatment technologies used in Europe; according to the WEEE stream, the data are representative of 2014, 2015 or 2016.

The table below shows, for each of the streams studied, the number of rank 1 treatment operators involved, the number of treatment operators from whom the data were compiled (rank 1 operators covered) and the mass coverage rate represented by the latter with respect to the tonnage handled by ESR.

WEEE stream	Number of rank 1 operators	Number of rank 1 operators covered	Mass coverage rate
LHA cold	9 operators	9 operators	100% of tonnage 2014
T&L	4 operators	4 operators	100% of tonnage 2014
SHA	15 operators	13 operators	≈ 95% of tonnage 2014

⁵ Collection, logistics & treatment requirements for end-of-life household appliances containing volatile fluorocarbons or volatile hydrocarbons (CENELEC Standard EN 50574:2012 (TC111X/WG4))

LHA non cold	19 operators	14 operators	≈ 90 % of tonnage 2014
Flat SCREENS	7 operators	4 operators	≈ 93 % of tonnage 2015
SCEL	10 operators	2 operators	≈ 46% of tonnage 2015
SPA Med & Build	13 operators	3 operators	≈ 48 % of tonnage 2015
LPA&Mobiles Building & Medical	12 operators (95% of the tonnages)	3 operators	≈ 60 % of tonnage 2016
Professional lighting equipment	12 operators	3 operators	≈ 65 % of tonnage 2016
Professional inverters	12 operators	2 operators + simplified approach	≈ 74 % of tonnage 2016
Electrical motors for industrial applications	31 operators	4 operators	≈ 60 % of tonnage 2016
Professional appliances cold	8 operators	Simplified modelling approach, streams (see § Q)	

TABLE 8 – MASS COVERAGE RATE OF RANK 1 OPERATORS INCLUDED
WITH RESPECT TO TONNAGE HANDLED BY ESR FOR THE YEAR CONSIDERED

In the case of professional WEEE, the mass coverage rate is more limited than in the case of the household streams: the characterisation data, quantifying the proportion of each of the fractions produced at rank 1 output for each operator, and the data relating to the composition of these fractions were not available for all the operators due to the recent growth in collection of these professional WEEE categories. As these data were essential for the application of the approach, only the treatment operators for whom they were available were taken into account, which necessarily limits the coverage rate achieved.

With regard to inverters, data were available for two operators performing manual treatment, bearing in mind that 25% of inverter tonnages in 2016 were processed by operators performing mechanical treatment similar to that of SPA MED&BUILD. To avoid neglecting the proportion of mechanised treatment, we have directly used the LCIs according to material established for the SPA MED&BUILD stream.

The operators selected for this data collection cover, for each WEEE category, the diverse range of the main treatment technologies observed in Europe.

WEEE stream	Technological variants covered
LHA cold	<p>The rank 1 treatment technologies for LHA cold are very similar between different operators. The main variants covered relate to:</p> <ul style="list-style-type: none"> ▪ The shredding technology: cutter or chain shredder ▪ Nitrogen production: internal or external ▪ Oil degassing: heating or stirring by sonication ▪ The gas condensation technology: cryogenics or activated carbon
T&L	<p>Two main T&L rank 1 treatment technologies are covered:</p> <ul style="list-style-type: none"> ▪ End Cut Air Push: this technology is only applicable to tubes; it consists of cutting the ends and "blowing out" the luminophore mixture contained in the tubes. ▪ Shredding/rolling with subsequent sorting of the various materials
SHA	<p>There are no major technological variants per se in SHA treatment. However, the processes are differentiated by the shredding/disintegration techniques used and by the organisation and nature of the sorting techniques.</p>
LHA non cold	<p>As for SHA, there are no major technological variants in LHA non cold treatment. However, the processes are differentiated by the shredding/disintegration techniques used and by the organisation and nature of the sorting techniques.</p>
Flat SCREENS	<p>Three main Flat Screen rank 1 treatment technologies are covered:</p> <ul style="list-style-type: none"> ▪ Manual disassembly; ▪ Robotic disassembly;

WEEE stream	Technological variants covered
	<ul style="list-style-type: none"> Shredding of entire screens in a confined atmosphere.
SCEL	SCEL is treated in mixed streams, on the same type of line as SHA.
SPA Med & Build & Ind & Research	SPA Med & Build are treated on the same type of line as SHA, in a specific operation, or, depending on the operators, mixed with SHA
LPA&Mobiles Building & Medical	The main Rank 1 treatment technology for this equipment, i.e. manual treatment (80% of tonnage) is covered. On the other hand, a process combining manual disassembly and mechanical treatment of certain subassemblies could not be taken into account.
Professional lighting equipment	Three main Rank 1 professional lighting equipment treatment technologies are covered: <ul style="list-style-type: none"> Manual disassembly; Mechanical treatment Manual disassembly with mechanical treatment of plastics.
Professional inverters	Both technologies used in Rank 1, i.e. manual dismantling and mechanical treatment (simplified approach using the material LCIs of SPA MED&BUILD) are covered.
Electrical motors for industrial applications	Only a massification is performed in Rank 1 for motors, which was taken into account.
Professional appliances cold	Four equipment families are studied: <ul style="list-style-type: none"> Professional cold cabinets are exclusively processed by LHA cold operators because the technological variants are similar to those described for LHA cold. Rooftop air conditioning unit are processed by LHA non cold operators. Water fountains and small air conditioning devices are first depolluted by LHA cold operators and can then be processed by LHA cold, LHA non cold, or SHA operators. See FIGURE 12 in section Q for more details.

TABLE 9 – TECHNOLOGIES COVERED BY THE RANK 1 OPERATORS TAKEN INTO ACCOUNT

[Data 11 | Rank 1 treatment ✕ Assumptions] ► In the case of oil consumption and fugitive dust emissions, the arithmetic mean of the data compiled was applied to make up for any gaps created due to a lack of responses. For professional lighting equipment directed to mechanical treatment, in the absence of any available specific data, the data were approximated by using data from SPA MED&BUILD

The compilation of data relating to energy and material input consumptions and emissions was satisfactory, with the exception of the case of oil consumption and dust emissions where responses were not always given by the operators. For these two aspects, the arithmetic mean of the responses given by the respondents was applied in order to make up for any gaps in the data compiled.

Operators were also queried on the power and hourly output of the machines installed on their treatment chain. The analysis of this feedback and its comparison with the energy consumption data demonstrate that quantifying the energy consumption (excluding handling machinery) would lead to an overestimation of the energy consumption in particular (this approach was thus ruled out); this is explained by the fact that the rated power of a machine, particular for tearing machines or shredders, is only solicited in a limited manner.

In the case of professional lighting equipment, which are partially processed mechanically, oil consumption and transient dust emissions per tonne of equipment have been considered similar to those of SPA MED&BUILD.

No dust emissions, however, have been considered in Rank 1 for equipment subject to manual disassembly only. Note that the diffuse emissions related to manual treatment are assumed to be very

small. Any possible diffuse emissions in case of leaching of stored fractions, which are likely to have toxic and ecotoxic effects, have not been considered because of a lack of quantified information with which to evaluate whether they are negligible or significant. Note, however, that the uncertainties concerning these diffuse emissions are secondary compared to other limits that must be considered when evaluating the toxic and ecotoxic effects of WEEE management (see Table 24).

[Scope of study 17 | Rank 1 treatment ✕ Exclusion] ► Water consumption for sanitary purposes by rank 1 treatment operators was excluded from the system boundaries

With the exception of some LHA non cold treatment processes, when they reduce dust by sprinkling and/or separation by flotation, the treatment processes of the WEEE streams studied consume no water. The water consumption specified by operators in the questionnaires corresponds to:

- process water and sanitary water consumption in the case of LHA non cold;
- sanitary water consumption in the case of the other WEEE categories studied.

Water consumption for sanitary purposes, as well as the associated emissions and their WWTP treatment, were not taken into account except in the case of LHA non cold treatment where it was not possible to separate the consumption generated by the process from the consumption for sanitary purposes (the impact of the latter being minimal in relation to the former).

[Data 12 | Rank 1 treatment ✕ Source and representation of activity data] ► The results of standardised performance tests conducted in 2012 or 2013 on LHA cold treatment operators were used to determine the fugitive cooling gas and expansion gas emissions generated.

In the specific case of fugitive cooling gas and expansion gas emissions from PUR foams during rank 1 treatment of LHA cold, the data processed are based on the phase 1 performance tests and the phase 2 performance tests within the framework of the CENELEC standard EN 50574-1 [7].

The data processed cover 100% of Eco-systèmes' LHA cold operators who treated LHA cold on behalf of ESR in 2014 ; depending on the operators, the data are based on tests conducted in 2012 or in 2013.

[Data 13 | Rank 1 treatment ✕ Source and representation of activity data] ► The results of reports in respect of monitoring conducted in 2012 or in 2014 were used to estimate fugitive mercury emissions from T&L treatment operators.

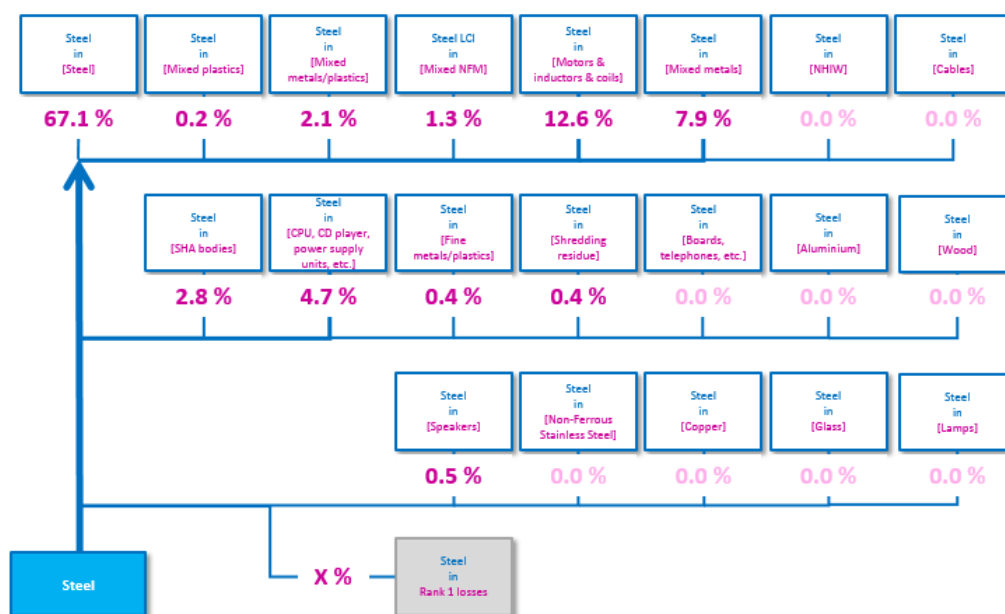
In the specific case of fugitive mercury emissions (Hg) during the rank 1 treatment of T&L, the data processed are based on reports in respect of external monitoring of mercury emissions from each of the T&L treatment operators. Depending on the operators, the data are based on tests conducted in 2012 or in 2014.

M.1.2 DISTRIBUTION OF MATERIALS IN THE VARIOUS FRACTIONS

[Data 14 | Rank 1 treatment ✕ Type of activity data] ► For each WEEE stream, tonnage and composition of the fractions produced following treatment by rank 1 operators

For each WEEE stream studied, except professional appliances cold, for which a simplified approach was applied, a quantitative description was prepared of fractions produced following its treatment by rank 1 operators. By combining the quantitative description of the composition of the fractions with the tonnage of each of the fractions, a map of the manner in which each material studied is distributed between the various fractions is obtained (Figure 6).

The figure below illustrates the type of results obtained following this work in the case of steel from SHA: as such, it is observed that, apart from any consideration of losses between the process input and output, the constituent steel in SHA is distributed following rank 1 treatment as follows: 67.1% in the [Steel] fraction⁶, 0.2% in the [Mixed plastics] fraction, 2.1% in the [Mixed metals/plastics] fraction, etc.



The values specified in this figure are given by way of illustration. They vary according to the WEEE stream in question, the treatment operator, the processes used and are liable to change over time.

FIGURE 6 – DISTRIBUTION OF MATERIALS BETWEEN THE VARIOUS FRACTIONS PRODUCED FOLLOWING RANK 1 TREATMENT X ILLUSTRATION OF PRINCIPLE WITH STEEL FROM SHA

This figure demonstrates that, if seeking to determine the end-of-life management LCI of a given material in a given stream (in this instance, steel from SHA), it is necessary to study the outcome - in terms of process, transport and final destinations - of the material (steel) via each of the fractions in which it is found at the rank 1 treatment output: [Steel], [Mixed plastics]... [Motors & Inductors & Coils], etc.

[Data 15] Rank 1 treatment X Source and representation of activity data ► For each WEEE stream studied, the annual tonnage of each fraction produced following rank 1 treatment is characterised and known for each of the operators included. Depending on the streams studied, the data are representative of 2014, 2015 or 2016.

The annual tonnage of each of the fractions is known precisely by ESR, for each of the operators studied; these data are produced within the scope of the characterisation operations conducted by outside contractors at the request of ESR or directly by ESR itself. Furthermore, these data are used to

⁶ [Fraction]: the symbolism [...] has been used in the various internal documents and reports in order to describe fractions, corresponding to mixtures of materials, and avoid any ambiguity with materials, particularly in the case where the usual description of a fraction and a material could be identical (e.g. in the case of steel)

calculate the recycling rate and recovery rate achieved within the framework of the WEEE take-back scheme; more generally, they are processed under:

- the European reporting tool WF RepTool (for example scope of Eco-systèmes);
- an internal reporting tool (for example scope of Récylum).

[Data 16 | Rank 1 treatment \propto Source and representation of activity data] ► For each WEEE stream studied, the composition of the fractions was determined via internal analysis data from ESR and data compiled using questionnaires from operators, the latter possibly corresponding to analyses or expert opinions from the operator. These data are considered to be representative of the period studied, i.e. 2014, 2015, 2016 or 2017 according to the streams.

It should be noted that, under the same fraction name, e.g. [Mixed metals/plastics], the actual composition may prove to be different:

- according to the input WEEE category treated;
- for the same input WEEE category treated according to the rank 1 treatment operators: indeed, the actual composition of the fractions is dependent on the nature and organisation of the processes installed (tearing machine or shredder, types and sequence of other machines) along with choices in the conduct of these processes (e.g. residence time in the tearing machine or distance between belt and overband).

The fraction description work was conducted so as to resemble reality as closely as possible and with the aim of obtaining in an optimal fashion the specific data for each stream and each operator in view of the information available.

It was necessary to use a number of information categories in order to describe the composition of fractions:

- internal ESR data corresponding to i/rank 2 treatment characterisation results (e.g. for [mixed metals/plastics] or ii/ results of the analysis of fractions or the analysis of complex components present in the fractions (for example, composition of motors & coils) or iii/ results of the phase 1 and phase 2 performance tests in the case of LHA cold (% of PUR foam in fractions, % of CFCs in PUR foam, etc.);
- data compiled using questionnaires from operators on the composition of certain fractions: these data were produced using different methods (manual count analyses, compositions forwarded by rank 2 operators handling the fractions from rank 1 operators or expert opinion from the operator).

M.2 DATA PROCESSING/METHOD COMPONENTS

M.2.1 DATA PROCESSING

The data relating to specific emissions and consumptions of resources compiled from rank 1 treatment operators are processed operator by operator in the model developed in Simapro: no prior data massification for all the treatment operators from the same stream was conducted in order to ensure satisfactory model traceability and facilitate subsequent updates.

However, an average energy consumption value per tonne of WEEE treated was also calculated for each WEEE category studied; this calculation was conducted in the context of a critical analysis in order to observe whether the overall trends were found to be plausible and relevant with regard to the type and operations of the various treatment processes.

[Data 17 | Rank 1 treatment ✕ Data processing] ► On the basis of detailed data relating to the tonnage of the fractions produced by each operator at the rank 1 output and the composition of these fractions, the calculation of the distribution of each of the materials studied was consolidated at the scale of each WEEE category; this consolidated distribution is processed in the model developed in Simapro

For a given WEEE stream, the distribution of each of the materials studied was consolidated at the scale of these WEEE stream, as illustrated in Figure 6, by combining:

- the tonnage of each of the fractions produced by each of the treatment operators of this stream;
- the composition of each of the fractions produced by each of the treatment operators of this stream.

Only this consolidated distribution for all the rank 1 treatment operators of the WEEE category studied is processed in the modelling in Simapro.

[Data 18 | Rank 1 treatment ✕ Critical analysis of data] ► For each household WEEE stream, a critical analysis of the plausibility of the data relating to the fractions was conducted by comparing the composition of this stream as calculated on the basis of the tonnage and the composition of the fractions and the composition of this stream as known from other sources.

The previous data (tonnage and composition of fractions) were also processed so as to obtain a typical composition of each WEEE stream studied. This typical composition calculated on the basis of the data relating to the fractions obtained from rank 1 treatment was compared to a typical composition determined by other sources:

- data based on DT9⁷ programmes in the case of SHA, LHA non cold and Flat Screens;
- data based on the bibliography in the case of other streams (e.g. EUP⁸ data in the case of LHA cold).

This comparison firstly made it possible to ensure that the analysis of the composition of the fractions produced consistent results in terms of composition of each of the WEEE categories and that it did not give rise to a noteworthy "disappearance" of a given material or, on the other hand, the noteworthy "creation" of a given material between the rank 1 treatment input and output. It also allowed a critical distance with regard to the results obtained and made it possible to identify the material/WEEE stream pairs for which the dispersion profile obtained is liable to display a lesser degree of robustness.

Note however that this type of approximation could not be made for professional WEEE streams, for which there are few available data on the characteristics of the supply. This means that the confidence level is lower for data on the average composition of professional WEEE streams compared to household WEEE.

⁷ DT9 is an annual programme conducted by ESR (for example Eco-systèmes scope) consisting of a detailed analysis of the composition of input WEEE streams of rank 1 treatment operators. This work was conducted systematically for SHA, LHA and Flat Screens. By way of example, the SHA DT9 in 2014 consisted of disassembling and analysing the composition of 1875 appliances, distributed into 285 sub-categories (cameras, telephones, ink-jet printers, laser printers, coffee-maker, etc.) representing a total of 6.5 tonnes

⁸ European Commission (DG ENTR) - Methodology Study Eco-design of Energy-using Products. Final Report MEEUP. Product Cases Report. 2005, 466 p.

M.2.2 ALLOCATION

▪ Allocation between different WEEE streams

[Data 19|Rank 1 treatment ✕ Allocation] ► In the case of facilities treating multiple WEEE categories, the inputs, other than nitrogen and activated carbons, associated with rank 1 treatment are allocated in mass between the various WEEE categories; in the particular case of nitrogen and activated carbons, these inputs were specifically allocated to the WEEE categories involving these inputs.

Some rank 1 treatment facilities treat multiple WEEE categories with, in some cases, manual treatment (particularly facilities performing CRT screen disassembly). In this case, the various material and energy inputs were provided by the operators for their entire facility; however, dust emissions were provided specifically for the treatment lines of each WEEE category.

The energy consumption of the process was allocated in mass between the various WEEE streams treated mechanically by the operators. The energy and oil consumptions for handling machinery were allocated in mass between all the WEEE streams treated by the operators.

The nitrogen consumption and activated carbon consumption were specifically allocated to the WEEE streams using this type of inputs: for example, for a facility treating SHA and LHA cold, the nitrogen consumption is entirely allocated to LHA cold as only this WEEE category requires work in an inert atmosphere.

Dust emissions did not require allocation.

▪ Allocation between different materials of the same WEEE stream

[Data 20|Rank 1 treatment ✕ Allocation] ► The inputs associated with the rank 1 treatment of a given WEEE category are allocated in mass between the various constituent materials of that category. Dust emissions are allocated in mass between the various materials except in the case of concrete and glass from LHA non cold to which the average differential observed between LHA non cold and SHA dust emissions is specifically allocated.

As a general rule, the activity quantified at the scale of a WEEE category are allocated in mass between the various constituent materials of this category.

In the case of fugitive dust emissions, a noteworthy difference was observed between LHA non cold operators and operators treating SHA, SCEL, and SPA Med & Build & Ind & Research. As LHA non cold operators tend to produce more dust; the average differential observed between these different sets of values was allocated to the concrete and glass contained in LHA non cold (essentially ballast concrete and washing machine door windows).

M.3 BACKGROUND INVENTORY DATA

[Data 21|Rank 1 treatment ✕ Source of background inventory data] ► The background inventory data are based on ecoinvent V3.4 – allocation, cut-off, except the electricity inventory for France. The electricity mix is specific to the country in which each of the operators is located.

The various inventory data processed to model the rank 1 treatment are inventory data from ecoinvent V3.4 – allocation, cut-off as provided in Simapro.

In the case of electricity consumption, the inventory model in question is that corresponding to the country in which each of the operators is located; it should be noted that, for rank 1 operators, the operators are all located in France with the exception of one treatment operator in the case of T&L.

For the electricity mix in France, as described in section F.5, specific work was conducted in the context of this project in order to obtain an inventory representative of the period 2015-2017 (the most recent data compiled by *ecoinvent* gives an LCI concerning the year 2014 only).

[Data 22 | Rank 1 treatment & Source of background inventory data] ► In the case of metals, dust emissions are modelled using particulate emissions of the metal studied; in other cases, the emissions are modelled in the form of unspecified particulates

In respect of dust emissions, these were modelled using:

- the elementary stream corresponding to unspecified particulates (*Emissions to air - particulates, unspecified*) for all materials such as plastics, glass, concrete, wood, etc.
- the elementary stream corresponding to the target metal in the case of the different metals studied (for example, in the case of the construction of the LCI for aluminium from LHA non cold, the associated dust emissions were modelled using *Emissions to air – Aluminium*; the choice to model them in the form of metal emissions, rather than unspecified particulates, was made as it was presumed to maximise the environmental impacts potentially associated with these emissions.

M.4 DATA QUALITY AND COMPLIANCE WITH REQUIREMENTS

The table below shows a qualitative evaluation of the data quality and specifies whether the quality requirements defined above were met.

		Reminder of requirements	Attainment of requirements / comments
Treatment by rank 1 operators:			
Main process	Key parameters: Nature and quantity of fractions generated by each operator Composition of fractions generated by each operator	<u>Recent specific data by operator:</u> Representative of 2014-2017 period	The requirements were met for most WEEE categories. However, these data are considered to be somewhat less robust for recent streams and those undergoing rapid development (professional WEEE and flat screens).
	Other parameters: Energy and material inputs, specific emissions	<u>Specific data by operator:</u> Representative of 2014-2017 period	The requirements were met for the vast majority of operations and the majority of inputs/emissions: some isolated missing data on dust/oil consumption required completion
Other processes	Electricity profile, liquid nitrogen production, non-road diesel fuel, etc.	<u>Generic data:</u> Electricity: specific mix by country, representative of 2014-2017 period Other inputs: representative data of Europe for 2014-2017 period	The requirements were met.

TABLE 10 – RANK 1 TREATMENT OPERATORS: EVALUATION OF DATA QUALITY AND ATTAINMENT OF REQUIREMENTS

N. TRANSPORT BETWEEN RANK 1 AND RANK 2 OPERATORS

[Key Modelling Imperative 4] Transport between rank 1 and rank 2 operators ► Establish a quantified description accounting for the key modelling points relating to transport (e.g. distances travelled, modes of transportation, HT load rates in the case of road transport)

For this phase, it was necessary to establish a quantified description of the transport of the fractions between rank 1 treatment operators and rank 2 operators in terms of distances travelled, modes of transportation, and HT load rates in the case of road transport

N.1 ACTIVITY DATA

[Data 23] Transport between rank 1 and rank 2 operators ✕ Nature of activity data ► Tonnage involved, distances, HT gauge, load rate, empty return rate, methods of packaging

In the questionnaires sent to the various operators, or during the interviews conducted with operators, the following questions were asked for each of the fractions:

- the identity and location of the various rank 2 operators and the breakdown of the tonnage sent to each of these handlers;
- the packaging methods in respect of the fractions (bulk in containers, big-bags, etc.) and their density.

All these data were processed in their entirety in order to model the transport between rank 1 treatment operators and rank 2 operators for each fraction. By way of example, the description of the transport of the fractions produced following SHA treatment includes the distances calculated for 291 journeys of which 281 are exclusively road journeys and of which 10 combine an upstream road journey, a maritime journey and a downstream road journey.

[Data 24] Transport between rank 1 and rank 2 operators ✕ Assumptions ► The HT gauge and empty return rates are based on assumptions

The rank 2 treatment operators were not queried on the HT gauge used to transport the fractions to the handlers; they were also not queried on the HT empty return rate. Therefore, these two factors are based on assumptions:

- the HT gauge was modelled as corresponding to the largest gauges authorised for circulation in France, i.e. HTs with a payload of 25 t; the choice of such a gauge is justified in that the fractions are transported in mass as much as possible.
- the empty return rate was modelled as corresponding to the empty return rate representative of the French average for this HT gauge, i.e. 27%.

[Data 25] Transport between rank 1 and rank 2 operators ✕ Source and representation of activity data ► The activity data were compiled using questionnaires from rank 1 operators. This information is representative of the years 2014, 2015, 2016 or 2017 depending on the WEEE categories

The rank 1 treatment operators provided in response to the questionnaire the identity, location and breakdown of the tonnages between the various handlers of each of the fractions produced; they also provided information on the packaging and density of the fractions. Depending on the WEEE categories, the information compiled is representative of the years 2014, 2015, 2016 or 2017 (in the case of electrical motors).

N.2 DATA PROCESSING/METHOD COMPONENTS

N.2.1 DATA PROCESSING

[Data 26] Transport between rank 1 and rank 2 operators ✕ Data processing ► The detailed data relating to the identity, location and breakdown of the tonnages between the various handlers, were processed and consolidated so as to obtain for each WEEE category a road distance and a maritime distance representative of the transport of each of the fractions.

The data provided by the rank 1 treatment operators relate to the identity, location and breakdown of the tonnages between the various handlers of each of the fractions produced. This information was processed with on-line mapping and maritime navigation tools to determine the road and maritime distances corresponding to all the journeys identified.

For a given WEEE stream, all these distances were then consolidated at the scale of each of the fractions in question so as to obtain a road distance and a maritime distance representative of the transport of this fraction between the rank 1 treatment operators producing the fraction and rank 2 handlers; the packaging methods were consolidated at the scale of the fractions. Finally, only these data consolidated at the scale of each of the fractions of each WEEE stream are processed in the model developed in Simapro.

[Data 27] Transport between rank 1 and rank 2 operators ✕ Data processing ► The calculation of the HT fuel consumption, over a given distance, is modulated according to their load rate and their empty return rate

As for upstream logistics, the calculation of the HT fuel consumption, over a given distance, is modulated according to their load rate and their empty return rate (section M.2.1)

N.2.2 ALLOCATION

- Allocation between different materials of the same fraction

[Data 28] Transport between rank 1 and rank 2 operators ✕ Mass allocation ► For each WEEE category, the impacts associated with the transport of a given fraction between rank 1 treatment operators and the rank 2 handlers of this fraction are allocated in mass between the constituent materials of that fraction.

As a fraction is a more or less complex mixture of several materials, the impacts of the transport of a given fraction between the rank 1 treatment operators producing the fraction and the handlers of this fraction are allocated in mass between the constituent materials of these fraction.

N.3 BACKGROUND INVENTORY DATA

[Data 29] Transport between rank 1 and rank 2 operators ✕ Source of background inventory data ► The background inventory data are based on ecoinvent V3.4 – allocation, cut-off.

The various inventory data processed to model the transport between rank 1 treatment operators and rank 2 operators are inventory data from *ecoinvent V3.4 – allocation, cut-off* as provided in Simapro.

In the case of road transport, an *ad hoc* inventory, covering the production and combustion of a litre of diesel fuel, was constructed based on ecoinvent inventory data so as to account for the breakdown in 2015 of the HT fleet in France as per the various Euro standards. This inventory is applied to the various road transport phases, whether they actually took place in France, in another European country or in Asia:

- the breakdown of HTs between the various Euro standard is probably relatively similar for France and other European countries;
- on the other hand, in the case of Asia, this inventory is considered to represent a proxy in that neither the applicable regulations or the actual status of the HT fleet were studied for this geographic region; however, the proportion of the volume of transport taking place in Asia is very secondary compared to the volume of transport taking place in France and in other European countries.

N.4 DATA QUALITY AND COMPLIANCE WITH REQUIREMENTS

The table below shows a qualitative evaluation of the data quality and specifies whether the quality requirements defined above were met.

		Reminder of requirements	Attainment of requirements / comments
Transport: rank 1 - rank 2 operators			
Main process	Key parameters: Distances travelled, modes of transportation	<u>Specific data by fraction and by operator:</u> Representative of 2014-2017 period Covering 100% of each fraction of each operator	The requirements were met*.
	Other parameters: Load rates, HT gauges, methods of packaging, empty return rates	<u>Specific data by output fraction type:</u> Representative of 2014-2017 period	The requirements were met overall: for packaging methods, only non-reusable packaging methods (big-bags) were taken into account; the load rates display some uncertainty as the data compiled could display non-negligible variability according to operator feedback
Other processes	Road vehicle / maritime transport combustion emissions	<u>Generic data:</u> Representative of European HT fleet for road transport in 2014-2017 Representative of maritime transport on a global scale for the 2014-2017 period	The requirements are considered to have been met: the profile of the French HT fleet was used to represent the European HT fleet.

TABLE 11 – TRANSPORT BETWEEN RANK 1 AND RANK 2 OPERATORS: EVALUATION OF DATA QUALITY AND ATTAINMENT OF REQUIREMENTS

* For professional WEEE, the requirements are attained for the various streams studied except professional appliances cold, for which a simplified work approach was applied (see section Q).

O. RANK 2 AND SUBSEQUENT OPERATIONS AND TRANSPORT OPERATIONS TO FINAL DESTINATIONS

Based on the nature of the fractions and based on the choices specific to rank 1 operators with respect to their handlers, rank 2 operators may be:

- operators corresponding to final destinations (material recovery, energy recovery, thermal destruction, landfilling).
- treatment operators (sorting of complex fractions, mechanical treatment of wires, mechanical treatment of motors, shredding/sorting of x-ray tube bodies, SRF preparation);
- trading/massification operators.

In the case where the rank 2 operators do not correspond to final destinations, it is then necessary to describe the sequence of treatment and transport operations enabling the various constituent materials of the fractions to reach final destinations.

[Key Modelling Imperative 5] Other treatment and transport operations prior to final destinations ► The sequence of any intermediate treatment and transport operations between rank 1 and the final destinations of the fractions should be determined. For each intermediate treatment operation, it is as such necessary to quantify its specific inputs and emissions and account for the outcome of the materials following the treatment.

If the rank 2 operators to which the fractions produced by rank 1 operators have been delivered do not correspond to final destinations, it is necessary to describe the sequence of treatment and transport operations enabling the various constituent materials of the fractions to reach final destinations.

On the basis of this description, it is then necessary to:

- quantify the energy and material inputs and the environmental emissions associated with these treatment and transport operations;
- quantify the manner in which each of the materials studied is distributed between the various sub-fractions produced following each of these intermediate treatment operations.

O.1 ACTIVITY DATA

Rank 2 operations and subsequent operations until the final destinations are conducted by several hundred operators on the scale of all the WEEE categories studied. Unlike rank 1 operators, the vast majority of these operators are not in direct contact with ESR.

For work volume and data access difficulty reasons, it could not be envisaged to compile the activity data relating these operations via questionnaires. As such, alternative strategies for obtaining data - described in the sections below - were applied.

O.1.1 DESCRIPTION OF RANK 2 AND SUBSEQUENT OPERATIONS UNTIL FINAL DESTINATIONS

[Data 30] Rank 2 and subsequent operations until final destinations ✕ **Nature of activity data** ► The identification of the sequence of treatment operations enabling the constituent materials of the fractions produced by the rank 1 treatment operators to reach final destinations is an essential preliminary requirement with a view to the qualification and quantification of the activity data relating to these phases

Rank 1 treatment operators were queried on the identity, locations and breakdown of the tonnages between the various handlers of each of the fractions produced; similarly, within the scope of the questionnaires, they were also requested to specify the nature of the operations conducted by their handlers (rank 2 operators) and in some cases by rank 3 operators.

The information provided by the rank 1 operators on the roles of the handlers were, wherever possible, consolidated by research and analysis of publicly available information.

As such, the processing of this set of data made it possible to demonstrate that the rank 2 operators, handling the fractions produced following the rank 1 treatment of a WEEE category, may consist of:

- a) final destination operators (material recovery, energy recovery, thermal destruction, landfilling);
- b) treatment operators (sorting of complex fractions, mechanical treatment of wires, mechanical treatment of motors, shredding/sorting of x-ray tube bodies, SRF preparation);
- c) trading/massification operators.

As such, for the fractions produced following the rank 1 treatment of a WEEE category, it was possible to establish a representation of the manner in which this fraction is handled in terms of:

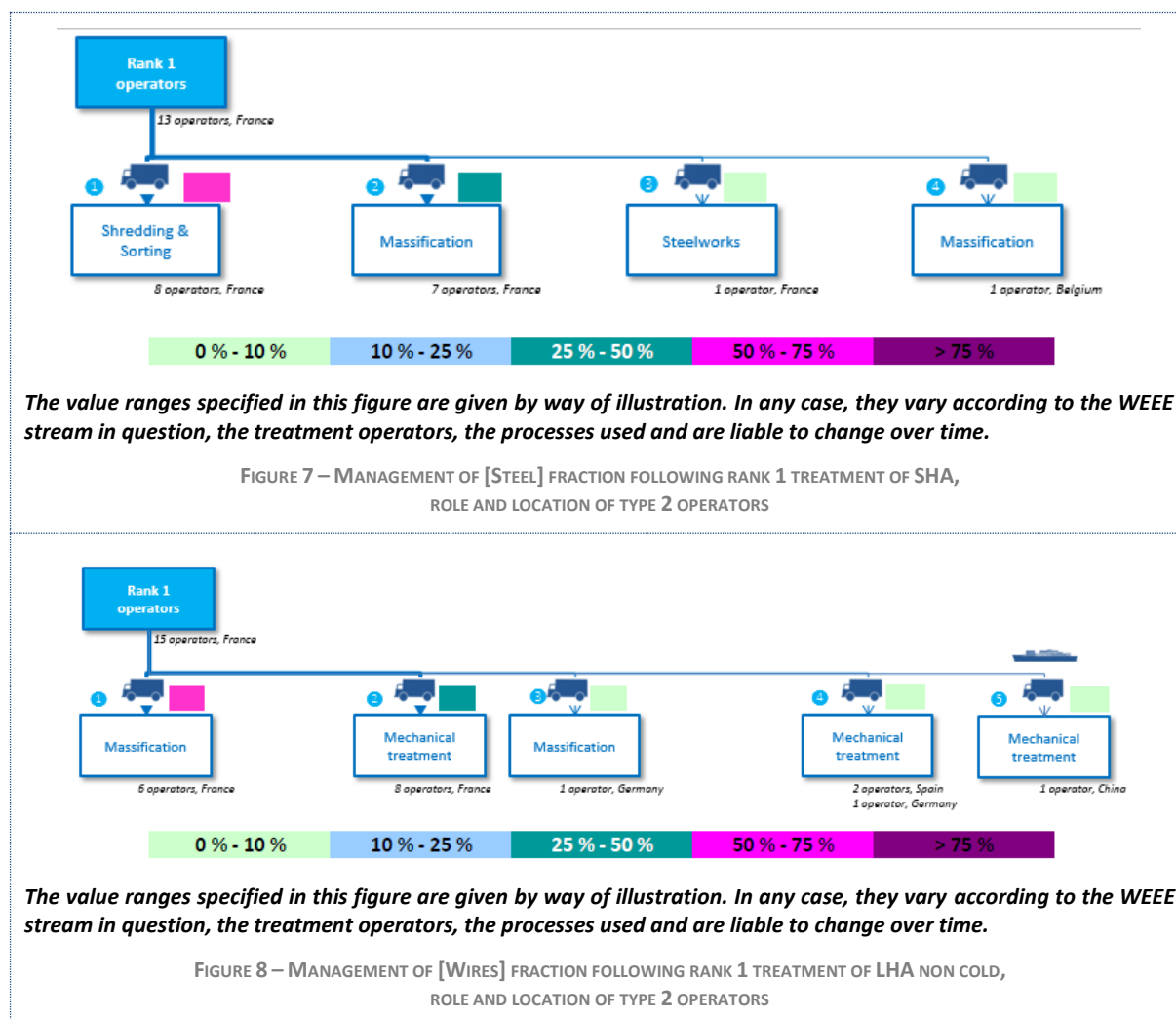
- type of operations carried out by rank 2 operators;

- geographical location.

The figure below illustrates the type of results determined within the scope of this analysis:

- for the [Steel] fraction from rank 1 treatment of SHA (Figure 7);
- for the [Wire] fraction from rank 1 treatment of LHA non cold (Figure 8);

For confidentiality reasons, the breakdown between the various rank 2 operator categories is not specified exactly in the figures but merely in terms of value ranges.



When rank 2 operators do not correspond to final destination but to treatment (sorting of complex fractions, mechanical treatment of wires, SRF preparation, etc.) or trading/massification operators, it was then necessary to complete the management synopsis of the fractions until the final destinations.

[Data 31] Rank 2 and subsequent operations until final destinations ✕ Assumptions ► Besides rank 2 operators, it was necessary to formulate assumptions on the nature of the operations conducted downstream from these rank 2 operators and until the final destinations. The fraction management diagrams presented in the reports for each WEEE category – confidential reports – ensure traceability between the factual information and the assumptions.

In the case of rank 2 operators corresponding to massification operators, the nature of the operations conducted by rank 3 operators was determined, either via the information provided by the rank 1 operators, or by analogy with the main rank 2 operators not corresponding to trade/massification

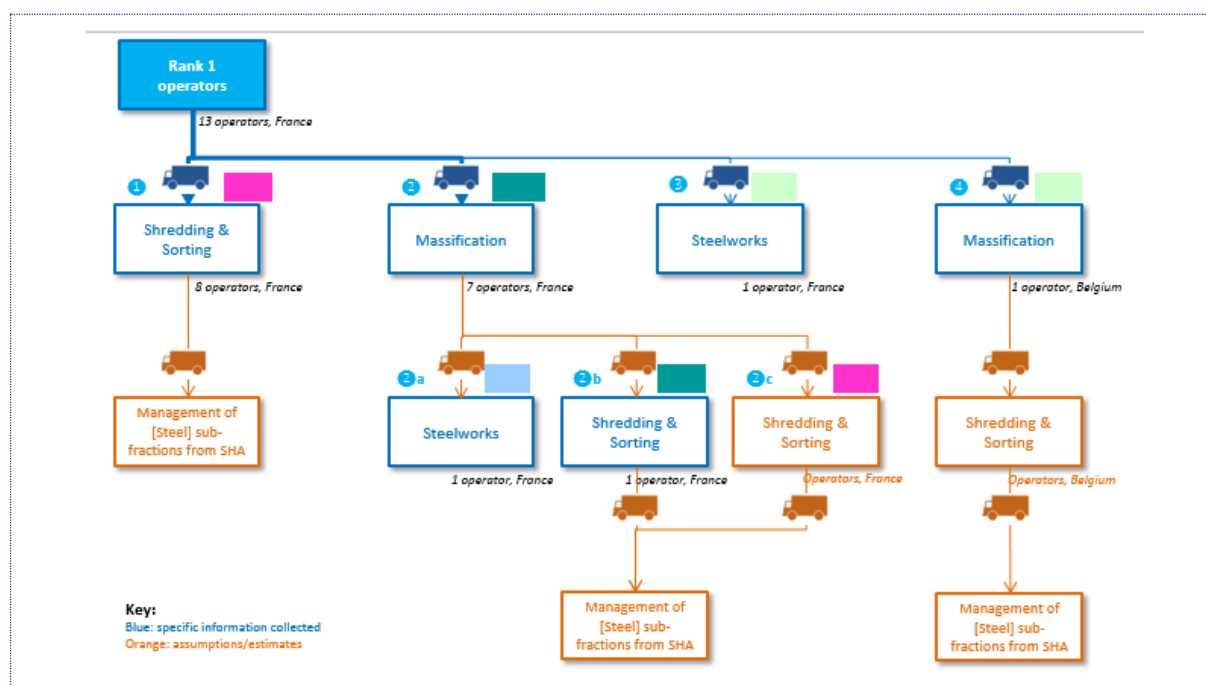
operators. As such, in the case of the [Steel] fraction produced following the rank 1 treatment of SHA (Figure 7), it was assumed that the rank 3 operators following the rank 2 trading/massification operators are shredding and sorting operators; similarly, in the case of the [Wires] fraction produced following the rank 1 treatment of LHA non cold (Figure 8), it was assumed that the rank 3 operators following the rank 2 trading/massification operations are mechanical wire treatment operators.

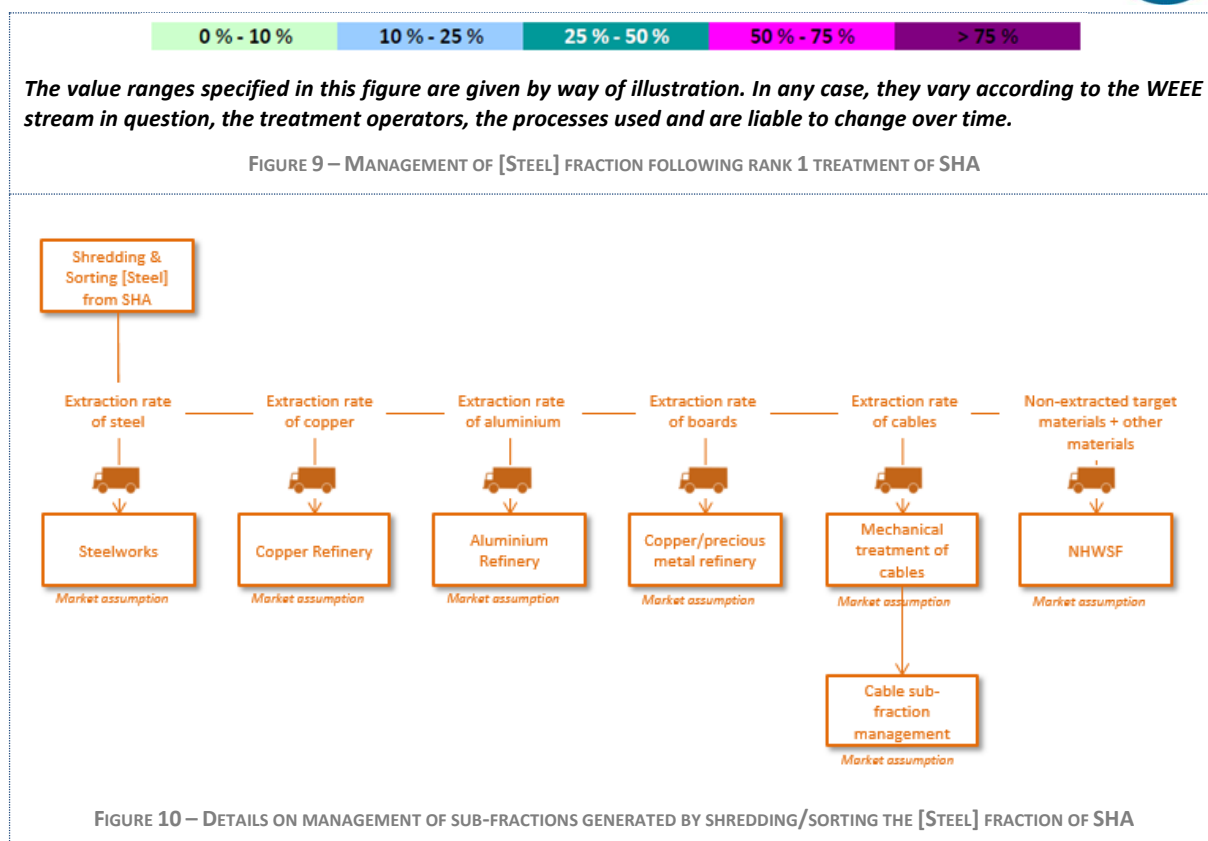
In the case of rank 2 operators corresponding to treatment operators, the nature of the operations conducted by the rank 3 operators was determined on the basis of the general information at our disposal on the nature of the operations conducted by these operators and on the various sub-fractions produced following these operations. As such, in the case of the [Wires] fraction, the information at our disposal made it possible to consider that the mechanical wire treatment operators carry out shredding/separation giving rise to the production of two sub-fractions, one consisting of copper of a very high purity and the other consisting of plastics from wires with some copper impurities; as such, the operators following the wire treatment operators were assimilated with final destination operators: direct reuse of copper in foundry for the copper sub-fraction and treatment of the plastic sub-fraction partially in incineration with energy recovery and partially in non-hazardous waste storage.

The accompanying reports, which are confidential for each WEEE category (LHA cold report, T&L report, SHA report, etc. see Table 1) particularly include a complete overview of the management of each of the fractions produced following the rank 1 treatment of the WEEE category in question. The traceability between the aspects based on information compiled from operators and the aspects based on assumptions supported by analogies or more generic information relating to the treatment process was ensured in these reports by the use of a colour code.

An illustration is provided in the case of the management of the [Steel] fraction following the rank 1 treatment of SHA (Figure 9):

- the blue-coloured items refer to specifically compiled information;
- the orange-coloured items refer to assumptions based on analogies and/or more generic information acquired in relation to the processes.





[Data 32] Rank 2 and subsequent treatment operations ▫ Source and representation of activity data ►

The data were compiled using questionnaires from rank 1 operations and related to all rank 2 operators involved for each of the fractions; depending on the WEEE category, the data are representative of 2014, 2015, 2016 or 2017 (in the case of electrical motors).

The nature of the operations conducted by the rank 2 operators, who may be final destination operators, treatment operators or trading/massification operators was compiled using questionnaires from rank 1 operators. The data cover all rank 2 operators for each of the fractions.

Depending on the WEEE category, the data are representative of 2014, 2015, 2016 or 2017 (in the case of electrical motors).

O.1.2 DISTRIBUTION OF MATERIALS IN THE VARIOUS SUB-FRACTIONS PRODUCED BY RANK 2 AND SUBSEQUENT TREATMENT OPERATORS

[Data 33] Rank 2 and subsequent treatment operations ▫ Nature of activity data ► The modelling of the treatment operations conducted by rank 2 and subsequent treatment operators is based on the identification of target materials to be recovered and accounting for extraction rates of these target materials

As for rank 1 treatment operators, the rank 2 or subsequent treatment operators conducting treatment operations, i.e. rank 2 or subsequent operators who are neither final destination operators nor massification/trading operators, produce sub-fractions from the fractions that they receive.

In terms of principle, the study of these downstream treatment levels thus raises the same question of material distribution between the output sub-fractions as that raised for rank 1 treatment operators.

The number of rank 2 and subsequent treatment operators involved would not make it possible to adopt a similar approach to that conducted in terms of rank 1 treatment operators, i.e. a quantified description of the distribution of the materials between the output fractions based on knowledge of the tonnage and composition of each fraction.

As a general rule, this question was resolved by determining for each case:

- target and non-target materials: target materials correspond to materials that the operators seek to extract from the input fractions in order to direct them to suitable recovery processes; non-target materials in turn tend to be directed towards standard NHSWF and/or MWIP treatment processes.
- extraction rate values relative to target materials: the extraction rates represent the ratio between the quantity of target material directed towards the sub-fraction intended for the targeted recovery processes and the quantity of target material at the treatment input.

[Data 34] Rank 2 and subsequent treatment operations \bowtie **Source and representation of activity data** ► According to the nature of the fractions and the WEEE stream in question, the identification of the target materials and the extraction rates in question are based either on data produced following characterisation work, or on expert opinions.

In the case of the complex fractions of household WEEE, frequently involving significant tonnage, such as the [Mixed plastics], [Mixed metals/plastics] and [Mixed fine metals/plastics] fractions, the extraction rates were determined on the basis of characterisation data conducted on rank 2 operators.

In the specific case of the [Mixed plastics] fraction containing BFR – this fraction concerning SHA, Flat Screens, SCEL and SPA Med & Build & Ind & Research – the modelling of the sorting process between plastics with BFR and plastics without BFR also accounts for the proportions of:

- plastics containing BFR directed towards the sub-fraction considered to be "without BFR";
- plastics without BFR directed towards the sub-fraction considered to be "with BFR".

The extraction rates and the proportions of plastics with BFR, on one hand, and without BFR, on the other, which are directed towards the fractions intended to concentrate BFRs (fraction "with BFR") and the fractions intended to be free from BFRs (fraction "without BFR") were determined on the basis of the results of the national programme conducted in 2014 by OCAD3E on the sorting performances between plastics containing BFRs and plastics not containing BFRs.

For other fractions (e.g. [mixed NFM]) subject to a treatment conducted by a rank 2 or subsequent rank treatment operator, the target materials and the extraction rates were determined on the basis of expert opinions compiled by ESR treatment experts from some operators. The extraction rates taken into consideration for these other fractions are generally situated in a range of values between 95% and 98%. A similar approach, established by experts, was implemented for the complex fractions obtained from the treatment of professional WEEE studied when Rank 2 characterisations were not available.

O.1.3 ENERGY AND MATERIAL INPUTS, SPECIFIC EMISSIONS OF RANK 2 AND SUBSEQUENT TREATMENT OPERATORS

[Data 35] Rank 2 and subsequent treatment operators \bowtie **Nature of activity data** ► Nature and quantity of energy inputs, nature and quantity of other material inputs, specific emissions

In the case of rank 2 and subsequent operators, activity data suitable for representing the nature and quantity of the energy inputs and other material inputs as well as specific emissions were taken into consideration.

[Data 36] Rank 2 and subsequent treatment operations ▫ Source and representation of activity data] ►

The activity data for operations conducted at rank 2 and later are based on analogies with some aspects of the operations conducted at rank 1, on bibliographic data or on in-house data acquired during prior studies; their temporal representation is deemed to be suitable with respect to an objective of representation of the 2014-2016 period.

The data taken into consideration is based on analogies with some aspects of the rank 1 treatment operations, on bibliographic data or in-house data from other studies.

In the case of trading/massification operators, the activity data taken into account relates to handling machinery energy consumption; this was determined on the basis of the consolidated value of handling machinery consumption in terms of rank 1 operators.

In the case of rank 2 and subsequent operators, performing a mechanical wire treatment operation, the activity data relate to:

- handling machinery energy consumptions;
- process energy consumptions.

The handling machinery energy consumption was determined on the basis of a consolidated value of handling machinery consumption in terms of rank 1 operators. The process energy consumption was determined on the basis of two bibliographic data displaying satisfactory mutual consistency.

In the case of rank 2 and subsequent operators, performing shredding/sorting operations of other complex fractions such as wires, the activity data taken into account relate to:

- handling machinery energy consumptions;
- process energy consumptions;
- dust emissions.

The data taken into account were determined by analogy with the rank 1 treatment process of SHA; the order of magnitude of the energy consumption of these processes are further consolidated by comparison with an isolated value compiled entered by a rank 2 operator conducting a plastics sorting process.

In the case of operators, Rank 2 and subsequent, performing shredding/sorting operations on industrial motors or x-ray tube bodies, data similar to those drawn up for the shredding/sorting of complex fractions were taken into account, but considering higher electricity consumption per tonne because the motors and bodies arriving for shredding are whole and of sturdy design.

In the case of rank 2 and subsequent operators, performing SRF preparation operations, the activity data taken into account relate to:

- handling machinery energy consumptions;
- process energy consumptions;
- dust emissions.

The handling machinery energy consumption was determined on the basis of a consolidated value of handling machinery consumption in terms of rank 1 operators. The process energy consumption was determined on the basis of data available in-house and compiled from an SRF preparation operator within the scope of another study. The dust emissions for their part were estimated by analogy with the rank 1 treatment dust emissions of SHA.

O.1.4 ENERGY AND MATERIAL INPUTS, SPECIFIC EMISSIONS OF TRANSPORT OPERATIONS DOWNSTREAM FROM RANK 2 OPERATORS

[Data 37] Transport downstream from rank 2 operators & Nature of activity data ► Tonnage involved, distances, HT gauge, load rate, empty return rate

The visibility in respect of the actual modes of transportation of the sub-fractions generated by rank 2 operators and, if applicable, by operators downstream from rank 2, is practically non-existent. However, these transport phases were modelled taking into consideration all the descriptive parameters previously used for the transport phases (tonnage, distances, HT gauge, load rate and empty return rate); on the other hand, no specific packaging was taken into consideration.

[Data 38] Transport downstream from rank 2 operators & Source and representation of activity data ► Typical scenarios for each geographic region or each market were defined. For market-based scenarios, the distances determined are based on statistics relating to the regions of use (domestic national market, European market, Asian market) of various waste categories (e.g. ferrous metals, copper, etc.). For typical scenarios, the PEP Ecopassport™ handbooks and the French environmental labelling handbook were used as points of reference to determine the distances travelled.

The transport phases downstream from the rank 2 operators are modelled using typical scenarios: i/ for each geographic region; ii/ for each market.

The table below shows the five scenarios per geographic region used.

	Road distance	Maritime distance	Examples of use of scenario
Local	50 km	0 km	Transport between operator and NHWSF
Regional	150 km	0 km	Transport between cullet preparation operators and glass manufacturers
National	500 km	0 km	Transport between trading/massification operator and subsequent treatment operator
Continental	1500 km	0 km	Transport of certain sub-fractions produced following the sorting process of plastic resins
Overseas Export	750 km + 750 km	18,000 km	Transport of certain sub-fractions produced following the sorting process of plastic resins

TABLE 12 – TRANSPORT DOWNSTREAM FROM RANK 2 OPERATORS & TRANSPORT SCENARIOS BY GEOGRAPHIC REGION

In the case of the road transport involved in these various scenarios for each geographic region, the HT are considered to correspond to the largest gauges generally authorised in Europe (40 t PTAC); their load rate was determined to be 100%: this is justified by the massification principles governing these phases; an empty return rate of 27% was also allocated to these phases.

The market-based transport scenarios are involved in the final transport phase whenever this phase is not known specifically. Therefore, they represent the transport operations between the final intermediate handlers and the final destinations.

A number of market profiles have thus been defined for the sub-fractions in question:

- "France" profile: when the intermediate operation is carried out in France, a market profile representative of the geographic destinations of the secondary materials collected in France is applied;
- "default" profile when the intermediate operation is carried out in Europe but outside France: this profile is applied when the intermediate operations are carried out in Belgium, Germany, Luxembourg, Italy, Spain, for example.

- in the case of intermediate operations carried out in Asia (China, Pakistan, etc.), the assumption has been made that the secondary materials obtained were all used in Asia.

Failing market statistics for the single fractions obtained from WEEE treatment, statistical data representative of the secondary materials - all sources combined - were sought and identified for the following materials:

- waste ferrous metal waste and stainless steels;
- waste aluminium;
- waste copper;
- waste brass, bronze and zinc;
- waste electrical wires;
- waste printed circuit boards;
- cullet;

With the exception of cullet, all the market-based scenarios are combinations of three scenarios per geographic regions:

- national;
- continental;
- overseas export.

In the case of cullet, the market is modelled by the regional transport scenario.

O.2 DATA PROCESSING/METHOD COMPONENTS

O.2.1 DATA PROCESSING

In respect of the modelling of the operations conducted by rank 2 and subsequent operators, no data processing was applied.

[Data 39] Downstream transport from rank 2 operators \bowtie Data processing] ► The calculation of the HT fuel consumption, over a given distance, is modulated according to their load rate and their empty return rate

As for the road transport modelling for previous transport operations, the calculation of the HT fuel consumption, over a given distance, is modulated according to their load rate and their empty return rate.

O.2.2 METHOD COMPONENTS

- Allocation between the various materials of the same fraction or the same sub-fraction

[Data 40] Rank 2 and subsequent treatment operations \bowtie Allocation] ► Applying the same logic as that applied for rank 1 treatment operators, the inputs associated with the treatment of a fraction/sub-fraction by a rank 2 operator or by an operator of a subsequent rank, are allocated in mass between the various consistent materials of that fraction/sub-fraction

[Data 41] Downstream transport from rank 2 operators \bowtie Allocation] ► Applying the same logic as that applied for transport between rank 1 and rank 2 operators, the impacts associated with the downstream transport from rank 2 operators, of a fraction/sub-fraction, are allocated in mass between the various constituent materials of that fraction/sub-fraction

O.3 BACKGROUND INVENTORY DATA

[Data 42] Rank 2 and subsequent treatment operations & Source of inventory data ► Applying the same logic as that applied for rank 1 treatment operators, the inventory data are based on ecoinvent V3.4 – allocation, cut-off; the electricity mix is specific to the country in which each of the operators is located; in respect of dust emissions, they are modelled using particulate emissions of the metal studied in the case of metals and they are modelled in the form of unspecified particulates in the case of other materials.

[Data 43] Downstream transport from rank 2 operators & Source of inventory data ► Applying the same logic as that applied for transport between rank 1 and rank 2 operators, the inventory data are based on ecoinvent V3.4 – allocation, cut-off.

O.4 DATA QUALITY AND COMPLIANCE WITH REQUIREMENTS

The table below shows a qualitative evaluation of the data quality and specifies whether the quality requirements defined above were met.

		Reminder of requirements	Attainment of requirements/comments
Rank 2 and subsequent treatments			
Main process	Key parameters: Nature of activity carried out by the rank 2 operator and country in which it is located	<u>Specific data for each rank 2 operator identified</u> Representative of 2014-2017 period	The requirements were met overall with some very isolated areas of uncertainty for operators who may, according to the circumstances, carry out massification only or treatment operations
	Other parameters: Energy and material inputs, loss rates, extraction rates	<u>Generic data by type of activity</u> Representative of 2014-2017 period	The requirements were met overall: some isolated data could be consolidated in the future such as the extraction rate of certain target materials (printed circuit boards) from complex fractions (mixed metals/plastics or fine metals/plastics)
Other processes	Electricity profile, non-road diesel fuel, etc.	<u>Generic data:</u> Electricity: specific mix by country, representative of 2014-2017 period Other inputs: representative data of Europe for 2014-2017 period	The requirements have been met.
Downstream transport from rank 2 operators			
Main process	Key parameters: Distances travelled, mode of transportation	<u>Generic market data by waste type</u> Representative of 2014-2017 period	The requirements were met. The market scenarios for each waste type were defined specifically, making a distinction between the markets from France and the markets from another European country

		Reminder of requirements	Attainment of requirements/comments
	Other parameters: Load rates, HT gauges, methods of packaging, empty return rates	<u>Generic data by waste type</u> Representative of 2014-2017 period	The requirements were partially met: all the parameters cited with the exception of the packaging method were taken into account but with generic values applied in a similar manner to all waste. No packaging method was taken into account.
Other processes	Road vehicle / maritime transport combustion emissions	<u>Generic data:</u> Representative of European HT fleet for road transport in 2014-2017 Representative of maritime transport on a global scale for the 2014-2017 period	The requirements have been met.

TABLE 13 – RANK 2 AND SUBSEQUENT TRANSPORT OPERATIONS UNTIL FINAL DESTINATIONS: EVALUATION OF DATA QUALITY AND ATTAINMENT OF REQUIREMENTS

P. FINAL DESTINATIONS

P.1 KEY MODELLING IMPERATIVES

[Key Modelling Imperative 6] Final destinations ► Two key imperatives were identified for this phase: **1/** modelling the behaviour of the materials/components studied in the various final destinations reached as specifically as possible; **2/** developing the modelling of the behaviour of the materials/components studied in the various final destinations with and without accounting of the benefits provided by substitution effects

P.1.1 SPECIFIC MODELLING OF THE BEHAVIOUR OF MATERIALS/COMPONENTS STUDIED IN VARIOUS FINAL DESTINATIONS

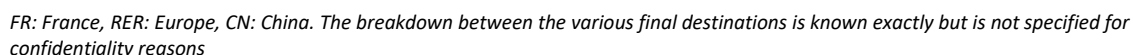
P.1.1.1 Note on impurities

The end-of-life management of a constituent material of WEEE – this comment being applicable for most waste – involves a large number of operations intended ultimately to i/preferentially direct this material to the most suitable final destination(s) (steel to steelworks, glass to glass manufacturer, cooling gas to HWIP, copper from wires to copper foundry, etc.) and ii/prevent this material from being directed to an unsuitable final destination (copper to steelworks, mercury to glass manufacturer, PVC to cement works, etc.).

However, in practice, this operational objective is not completely met: each of the materials initially present in the waste is still found dispersed – albeit to a lesser or greater extent – between various fractions or sub-fractions and thus reaches – in variable proportions – the most suitable final destination(s) which are its target destinations but also undesirable destinations in which it is found in the form of impurities.

The figure below illustrates by way of example the range of final destinations reached by steel in SHA accounting for its dispersion in each of the fractions produced following rank 1 treatment (see Figure 6) and accounting for the subsequent management of each of these fractions and losses at each of the phases:

- Most of the steel from SHA is directed to steelworks (> 90%);
- The remainder is distributed between copper/precious metal refineries, aluminium refineries, non-hazardous waste storage facilities (with over 90% based in France) as well as losses generated throughout the management operations.



are, on the other hand, undesirable impurities in the inputs of steelworks (plastics, copper, miscellaneous infusible materials, etc.)

- b) **specific modelling of the behaviour of each material in each destination involved:** unlike the previous option, this option involves seeking to understand the phenomena involved when a material reaches a final destination and constructing the modelling accordingly. By way of example, the behaviour of wood and copper in NHWSF is characterised in that the former contributes to biogas production, which is not the case of the latter; the leached substances are also different between these two materials. In the case of steelworks, steel will essentially remain in the steel bath whereas aluminium should normally be removed from the steel bath to be added to the slag; slag does not replace steel but is nonetheless used in other applications providing benefits by substitution.

Based on the most extreme cases, the cases for example of materials the presence of which is considered to be critical by certain recycling or recovery chains, we were of the view that it would have been particularly problematic to assign these materials with the impacts and benefits generated by the systems in which they represent disruptive elements.

Hence, the only guideline that seemed controllable for us, and that we sought to apply, is that consisting of seeking to qualify and quantify the impacts of a given material in a final destination by seeking to understand and describe the actual behaviour of that material in that destination.

P.1.1.3 Implications of specific modelling

The choice made – that of a specific approach to material behaviour in final destinations – is not without impact:

- **on the work volume:** while constructing one LCI per final destination would have been sufficient in the approach consisting of a mere mass allocation, it is necessary to envisage constructing the same number of LCIs as the number of material/final destination pairs in the case of a specific approach.
- **on the fineness of the analysis:** the characterisation of the behaviour of a material in a given final destination cannot be processed as a black box; it was thus found to be essential to acquire visibility in respect of the various operations/reactions/phenomena arising in the destination in question and elucidate, in the light of this understanding, what happens to the material within the framework of this destination.

In view of the complexity of the industrial systems involved and the complexity of the phenomena liable to arise, also in view of the restriction of easily and publicly accessible data, and finally in view of the time constraints that could be assigned to each of the cases, a number of the LCIs produced following this work are necessarily imperfect.

The degree of uncertainty of the LCI representing the impacts of a given material in a given final destination – e.g. the impacts of steel in NHWSF – was however put into perspective with regard to the contribution of this particular LCI in building the end-of-life management LCI of the material – *i.e.*, the contribution of the LCI of steel in NHWSF in the final LCI in respect of the end-of-life management of steel from LHA non cold or end-of-life management of steel from SHA.

P.1.2 BREAKDOWN OF LCIs WITH AND WITHOUT ACCOUNTING OF THE BENEFITS PROVIDED BY SUBSTITUTION EFFECTS

[Scope of study 18] Boundaries & Final destinations ► Where relevant, the end-of-life management LCIs of the constituent materials/components of electrical and electronic equipment are broken down according to two final destination accounting methods: **1/ With benefits:** the impacts associated with the behaviour of the material/component in the final destinations reached and the benefits provided by material and/or

energy substitution effects are taken into account; **2/ Without benefits** :only the impacts associated with the behaviour of the material/component in the final destinations reached are taken into account; the benefits provided by material and/or energy substitution effects are not taken into account.

In order to meet the needs of future users optimally, it was chosen to break down, where relevant, the end-of-life management LCIs of the constituent materials of electrical and electronic equipment according to two methods:

- method with accounting of the benefits provided by material and/or energy substitution effects;
- method without accounting of the benefits provided by material and/or energy substitution effects.

In this respect, the reader may also refer to the section of this document relating to the positioning of the work with respect to the CFF [6] of the PEF [5] (see section T).

P.2 INVENTORY DATA

The range of various final destinations involved for the entire LCI construction work is extensive. Furthermore, each of these destinations may be located in various geographic regions:

- the majority of the final destinations are located: in France and other European countries (Germany, Spain, Italy, Belgium, etc.);
- a minority are located: in Asia (China and Pakistan).

[Data 45] Final destinations & Geographic representation of inventory data ► The inventory data in respect of the behaviour of the materials/components in the final destinations reached were constructed: **1/** At the scale of the Europe region (RER) for all destinations corresponding to material and/or recovery operations except for incineration with energy recovery ; **2/** At the scale of the France (FR), Europe (RER) and China (CN) regions for destinations corresponding to storage or incineration operations with energy recovery.

The data accessible for carrying out the modelling of the behaviour of materials in the various final destinations, along with the volume of work required, meant it was not possible to break down the inventory data specifically for each of the geographic regions in question. It was thus chosen to construct and process inventory data:

- representative of the Europe region (RER) for all the final destinations corresponding to material and/or energy recovery operations with the exception of incineration with energy recovery;
- broken down according to the France, Europe and China regions for final destinations corresponding to storage or incineration operations with or without energy recovery; in the particular case of hazard waste storage and incineration, only the France region is concerned.

Final destinations studied	Geographic representation of data processed
Steelworks	RER
Aluminium refinery	RER
Copper/precious metal refinery	RER
Copper foundry	RER
Glass manufacturer	RER
Bright oil regeneration	RER
CL plastic regeneration	RER
OL plastic regeneration	RER
Recovery in construction sector	RER
Recovery as industrial absorbent	RER

Recovery as incinerator furnace protection	RER
Wood recovery in board manufacture	RER
SRF recovery in cement works	RER
Incineration with energy recovery	FR
Incineration with energy recovery	RER
Incineration with energy recovery	CN
Non-hazardous waste storage	FR
Non-hazardous waste storage	RER
Non-hazardous waste storage	CN
Hazardous waste incineration	FR
Hazardous waste storage	FR

TABLE 14 – FINAL DESTINATIONS & LIST AND GEOGRAPHIC REPRESENTATION OF FINAL DESTINATIONS MODELLED

[Data 46] Final destinations & Source of inventory data ► The inventory data in respect of the behaviour of materials/components in the final destinations reached were constructed by processing the data and information obtained from various data sources: existing databases (ecoinvent V3.4 and V3.2), specific software for the environmental evaluation of household waste management (Wisard™), data and information published by Material Federations (European Aluminium Association, WorldSteel, European Copper Institute, etc.), technical and scientific literature.

In view of the range of final destinations to be covered and in view of the range of materials/components liable to reach each of the final destinations, the data sources used for modelling the behaviour of materials in the final destinations reached are numerous and have a variety of origins; the various data source categories are as follows:

- **existing databases:** some LCIs contained in ecoinvent V3.4 and in ecoinvent V3.2⁹ were used, in part or in whole, for constructing the modelling of the behaviour of materials in final destinations;
- **household waste management environmental evaluation tool:** some calculation components that can be conducted with Wisard™ were processed in constructing the modelling of the behaviour of materials in final destinations;
- **data and documents published by Material Federations:** data and information published by Material Federations (European Aluminium Association, WorldSteel, European Copper Institute, etc.) were processed in constructing the modelling of the behaviour of materials in final destinations;
- **scientific articles, theses and technical literature:** if the above data and documents was not found to be sufficient for constructing the modelling of the behaviour of a material in a given final destination, bibliographic searches were conducted with the scope of technical and scientific literature; a number of Briefs (Ferrous metal industry, Non-ferrous metal industry, Glass manufacture, Incineration, etc.) were thus used along with theses and scientific articles.

The set of data and information used for modelling the behaviour of materials/components in the final destinations reached was logged and explained in the confidential internal report on background data dated August 2016 and its supplement from June 2018 (see Table 1).

⁹ Where applicable, the inventories concerning electricity consumption and/or fossil energy combustion come from the ecoinvent V3.4 database. Other inventories, whose contribution is secondary in modelling the behaviour of materials in the final destinations concerned, were not updated in 2018 and come from the ecoinvent v3.2 database.

P.3 DATA QUALITY AND COMPLIANCE WITH REQUIREMENTS

The table below shows a qualitative evaluation of the data quality and specifies whether the quality requirements defined above were met.

		Reminder of requirements	Attainment of requirements/comments
Final destinations			
Main process	Key parameters: Nature of final destinations reached by material/WEEE stream pair	<u>Specific data for each material/WEEE stream pair:</u> Representative of 2014-2017 period	The requirements were met: the model defined makes it possible to quantify, for each material/WEEE pair, the nature of the final destinations reached and the breakdown between these destinations
	Key parameters/data: Specific modelling of the behaviour of materials for each final destination concerned on the basis of their key characteristics	<u>Representative data of the materials studied for each final destination:</u> MWIP/NHWSF: representative of the specific France, Europe, China regions for the 2014-2017 period Other destinations: representative on a European scale and for the 2014-2017 period	The requirements have been met. However, the final data determined vary in quality according to the materials/final destinations in question; this assessment of the quality should be put into perspective according to the proportion of the material used in the final destination of a WEEE category (see below).

TABLE 15 – FINAL DESTINATIONS: EVALUATION OF DATA QUALITY AND ATTAINMENT OF REQUIREMENTS

The end-of-life management data within the framework of the WEEE take-back scheme of a material/WEEE stream pair involves various final destination data for modelling the final phase: the data processed contribute proportionally to the proportion of the material ultimately reaching each of the final destinations.

Some modelling data of the behaviour of a material in a final destination are considered to be of good quality and others are considered to be of relatively poor quality: the evaluation of the overall quality in respect of modelling of final destinations is dependent on the proportion of high-quality data and poor-quality data ultimately processed; the evaluation of the overall quality in respect of modelling of final destinations is, as such, specific to each material/WEEE stream pair.

In the modelling conducted in Simapro, a system for monitoring the quality in respect of modelling the final destinations has been specifically implemented. The system makes it possible, following the calculation of the LCI of a material/WEEE stream pair, to determine:

- the mass proportion of the material for which the modelling data of the behaviour in final destinations are of good quality;
- the mass proportion of the material for which the modelling data of the behaviour in final destinations are of adequate quality;
- the mass proportion of the material for which the modelling data of the behaviour in final destinations are of poor quality.

For the majority of material/WEEE stream pairs, the modelling data of the main final destinations are of good quality or of adequate quality. However, there are some cases in which the modelling data of the main destinations are weaker.

For each of the data items built, the documentation accompanying the data item specifies the final quality obtained particularly accounting for the modelling quality of the final destinations.

Q. SPECIAL CASE OF PROFESSIONAL APPLIANCES COLD: APPLYING A SIMPLIFIED APPROACH

[Key Modelling Imperative 7 | General approach implemented for professional WEEE] ► For professional cold WEEE, a simplified approach was applied, taking advantage of the work carried out for household WEEE. The data for household streams were therefore used as a basis for the work.

In view of the fact that the stream formerly organised by Eco-systèmes on the professional cold WEEE is relatively young, the data available for these streams are more limited, whether there are characterisation campaigns performed by Rank 1 operators handling depollution and treatment or knowledge of the material compositions of these devices (no equivalent of the DT9 programme deployed on household WEEE).

Nevertheless, similarities exist between the professional WEEE targeted by this work (water fountains, professional cold cabinets, rooftop air conditioners and small heat pumps & air-conditioners) and household WEEE such as LHA cold and LHA non cold:

- some of the materials that contribute to the composition of the professional WEEE targeted by this work are similar to those of household WEEE;
- professional WEEE are processed by Rank 1 operators who also process household WEEE (LHA cold, LHA non cold, or SHA).

To enable it to offer appropriate LCIs for professional WEEE to ESR members whilst optimising the volume of work to devote to it, ESR wanted to take a simplified working approach by capitalising on the work carried out for household WEEE.

[Key Modelling Imperative 8 | Final destinations of the materials studied] ► For professional appliances cold, application of the simplified approach first of all required identifying the treatment lines used by the operators for these appliances. It also involved taking into account certain specific features of the treatment of professional WEEE compared to the treatment of household streams.

The treatment procedures for professional WEEE containing refrigerant gases depend above all on the quantity of refrigerant fluid present in the device. Accordingly:

- Appliances containing **more than 2 kg** of refrigerant fluid must be depolluted **on site**. This depollution is handled by the owner/user of the appliance, and ESR is responsible for collecting and treating the depolluted appliance.
- Appliances containing **less than 2 kg** of refrigerant fluid are taken into ESR's care and are **depolluted by specialist LHA cold treatment operators**.

The subsequent treatment procedures will depend on whether or not insulating foam is present (expansion gas) in the appliances, as well as process decisions made by the Rank 1 treatment operators.

The following chart shows the various types of process likely to be mobilised by Rank 1 operators to treat the professional appliances cold being studied.

End-of-life management LCI of constituent materials of electrical and electronic equipment within the framework of the French WEEE take-back scheme

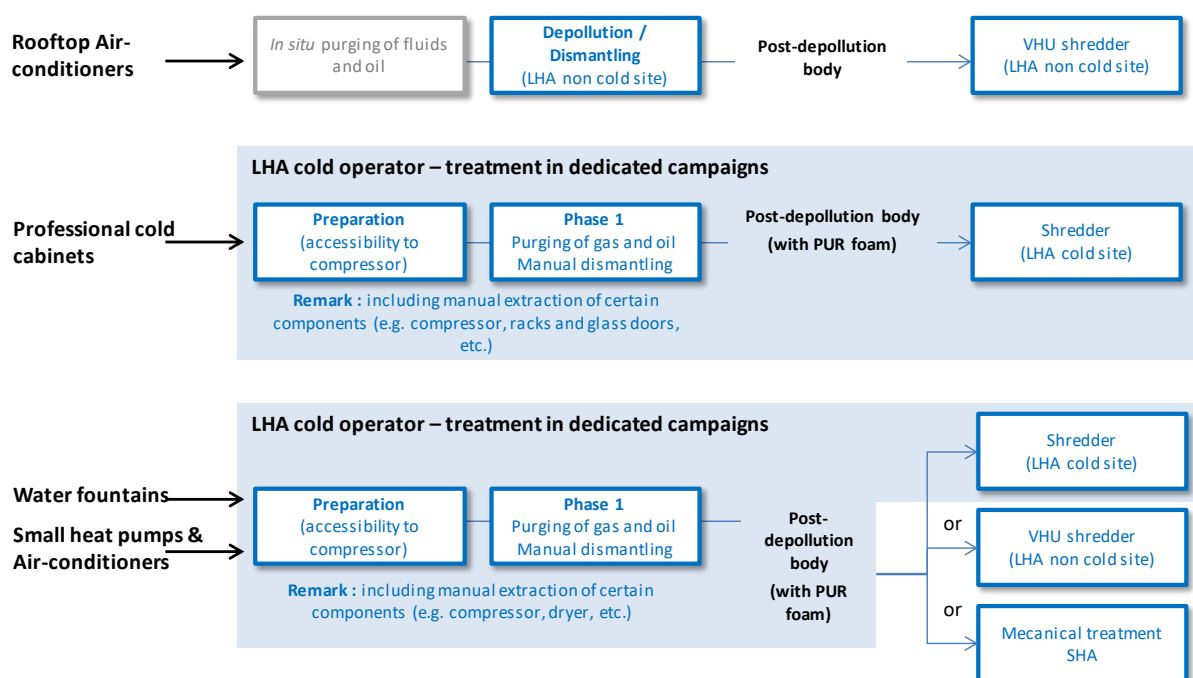


FIGURE 12 – TREATMENT PROCEDURES FOR THE STUDIED PROFESSIONAL APPLIANCES COLD

Eleven operators located in France – including two operators located in the French overseas departments and territories – have received and processed tonnages belonging to the four families selected for the year 2017 (year counted for the distribution of tonnages between Rank 1 operators).

It was also necessary to identify the similarities with household WEEE as well as the specific characteristics of professional WEEE with regard to their treatment and the final destinations of the materials.

[Data 47 | Data processing to establish the final destinations of materials] ► The construction of end-of-life LCIs of materials requires a quantified analysis of the final destinations to which these materials are headed. To establish these distributions, a calculation procedure has been implemented, based on: (i) The knowledge of the processes mobilised by each operator, (ii) The distribution of the tonnages of professional appliances cold according to operator, (iii) The material distribution profile previously established for LHA cold, LHA non cold, and SHA.

The distribution profiles of the materials to their various final destinations are the result of the efficiencies of the process lines and the decisions made by operators concerning the procedures for management of fractions by their handlers.

Because professional appliances cold are processed by the same operators as those who process household appliances for ESR, it was possible to optimise the work approach by relying as far as possible on the distribution profiles established for household streams.

The calculation process described below was therefore deployed for the four professional appliances cold sub-categories studied.

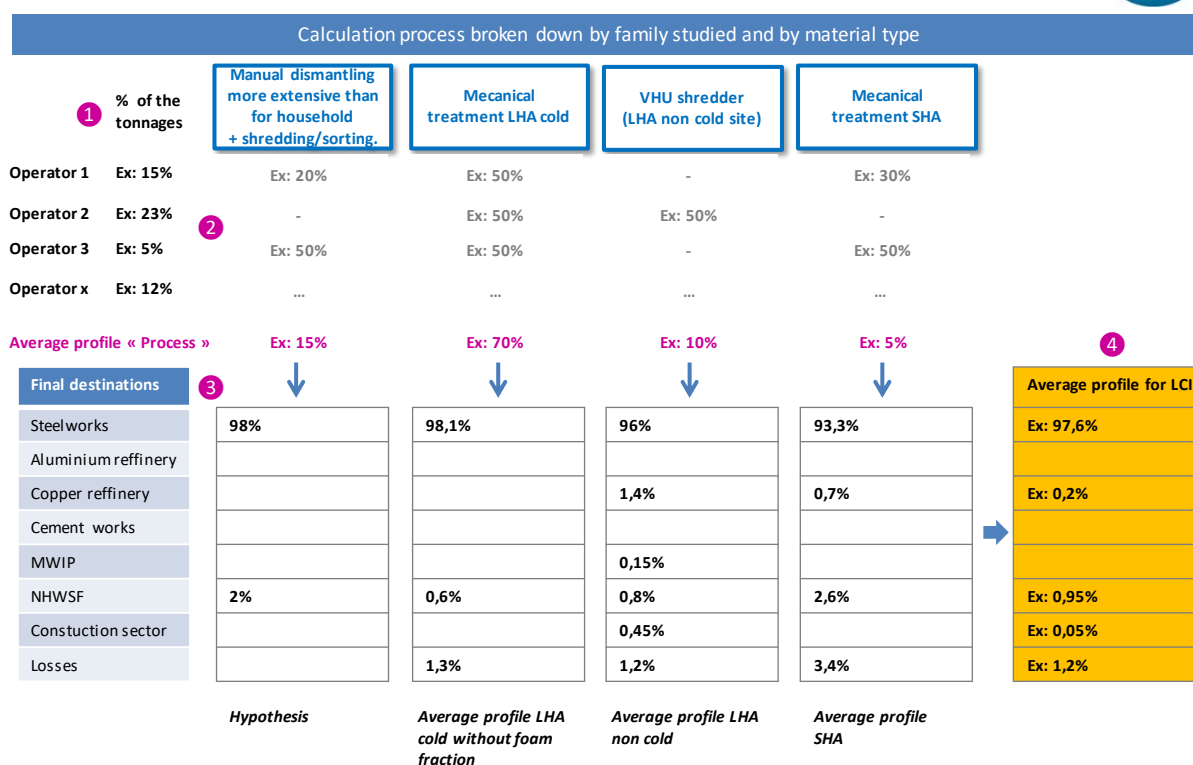


FIGURE 13 – CALCULATION PROCESS TO DETERMINE FINAL DESTINATIONS FOR MATERIALS FROM WATER FOUNTAINS AND SMALL HEAT PUMPS AND AIR-CONDITIONERS

To establish this profile of the distribution of materials to their final destinations, the calculation process described above was applied:

- 1: The Rank 1 operators who processed tonnages of professional appliances cold belonging to the four families studied in 2017 were identified, as well as the % of tonnages processed by each operator in that year.
- 2: For each of the operators, work was carried out to establish to which types of process the constituent materials of the appliances are directed. This was done by material, considering the following categories: gas, oil, ferrous metals, aluminium, copper, boards, cables, plastics. Certain operators have a unique mechanical treatment line, whereas other operators can mobilise several types of process to process the depolluted bodies of the appliances. To be able to reuse the data established for household streams, it was therefore necessary to use the following categorisation:
 - Manual disassembly, when it is more extensive than what is taken into account in the existing LCIs for LHA cold;
 - An LHA cold type process line (including manual disassembly and shredding);
 - An LHA non cold type process line (VHU shredder)
 - An SHA type process line.

On completion of this work, an average profile of orientation to the treatment processes characterises each of the materials studied.

- 3: The existing modelling work for LHA cold, LHA non cold, and SHA was then used to obtain a profile for the distribution of the material to the final destinations for the various material/process line combinations.

Some adaptations were necessary, however, to allow for the specific characteristics of professional appliances cold compared to household refrigeration appliances.

- 4: by consolidation of the data already established, it was possible to establish the average profile of distribution to final destinations of each of the constituent materials of the families studied.

[Data 47 | Adaptation of existing data to the specific treatment characteristics of professional WEEE] ► Situations for which direct reuse of the data established for household streams was not possible or relevant were identified and led to modifying the final destination profiles of certain constituent materials of professional appliances cold.

Situations for which direct reuse of the data established for household streams was not possible or relevant were identified. The main adaptations applied in this way are listed below:

- Adaptation of rates of upstream loss of refrigerant gases and oil in the case of professional appliances;
- Modification of the profiles of the final destinations of materials in the case of appliances containing no insulating foam with inflating agent (case of water fountains and small heat pumps & air-conditioners) and processed in dedicated campaigns in LHA cold treatment facilities;
- Management procedures and final destinations of plastics from professional refrigerated WEEE containing BFR and processed on an LHA cold line or an LHA non cold line;
- Adaptation of rates of capture of inflation agents present in professional cold cabinets foams;
- Management procedures and final destinations of the glass present in professional cold cabinets.

[Data 49 | Final destinations & Geographical location of inventory data] ► Simplified assumptions concerning the geographical location of the final destinations were established for professional appliances cold.

Modelling of the end-of-life environmental balance of materials requires the geographical location of the final destinations to be established. Because an optimised approach was implemented for professional appliances cold, simplified geographical location assumptions concerning final destinations were established for these appliances:

Final destinations	Simplified geographical location assumption
Recycling type destinations <i>Steelworks, copper refinery, aluminium refinery, copper foundry, plastic recycling, absorbent recycling, glass manufacturer, oil regeneration</i>	Europe
Cement works	Europe
HWIP	France
MWIP	Europe*
NHWSF	France

*In the case of LHA cold plastics sent for incineration with energy recovery, the MWIP are not located in France.

TABLE 16 – FINAL DESTINATIONS: SIMPLIFIED GEOGRAPHICAL LOCATION ASSUMPTIONS

[Data 50] Rank 1 and later treatment operations & Assumptions considered for the activity data ► The utility needs and emissions of these Rank 1, Rank 2 and later treatment stages and the transport stages to final destination were not taken into account based on the data already established for LHA cold, LHA non cold and SHA household streams.

The activities of Rank 1 and later operators require various forms of energy and utilities to run their treatment lines and handling vehicles and loaders. In addition, the transportation stages take the materials from the Rank 1 operators to the downstream operators and to their final destinations.

In the context of the simplified work approach implemented for professional appliances cold, the utility requirements and emissions of these stages were modelled as follows:

- **For Rank 1 operators**, the calculations are based on:
 - (i) the distribution of materials between process lines;
 - (ii) the average profiles established in Simapro for Rank 1 LHA cold, LHA non cold, and SHA operators with regard to utilities (electricity, fuel, and nitrogen consumption) and dust emissions.
 - (iii) The electrical production mix in France.
- **For Rank 2 operators and beyond as well as the transportation stages to final destination:** the consumption of electricity and fuel on the scale of all these stages were established considering:
 - (i) the distribution of materials between process lines;
 - (ii) average throughput indicators calculated in Simapro per material and per WEEE stream (LHA cold, LHA non cold and SHA);
- The electrical production mix in Europe (simplifying assumption).

R. DATA QUALITY ASSESSMENT REGARDING EXPECTATIONS OF PEF METHODOLOGY

In addition to above considerations, this section provides, for information, a quality assessment of the data used within the framework of this study with regard to expectations of PEF (Product Environmental Footprint) methodology.

Version 6 of the European Guidance Document on PEFCR development (Product Environmental Footprint Category Rules)¹⁰, at the time of writing of this section, specifies the procedures for evaluating the quality of the data as well as levels required.

Regarding processes that are not directly handled by firms using Product Environmental Footprint Category Rules (PEFCR) and for which these firms cannot dispose of specific data (case 3 of the Data Needs Matrix), expectations of the Guidance document are the following:

- Concerning the main processes: use of secondary data in aggregated format. Default inventories used must obtain a Data Quality Rating (DQR) ≤ 3 ;
- Concerning other processes: use of secondary data in aggregated format. Default inventories used must obtain a DQR ≤ 4 .

¹⁰ European Commission, 2016, *Environmental Footprint Guidance document, - Guidance for the development of Product Environmental Footprint Category Rules (PEFCRs)*, version 6.0, November 2016

Data considered in the modelling of the different steps of EEE end-of-life were thus assessed – by expert judgment – considering four data quality indicators of PEF methodology and a rating scale of 5 quality values:

- Data quality indicators:
 - Geographical representativeness (GR);
 - Time representativeness (TiR);
 - Technological representativeness (TeR);
 - Precision (P).
- Quality values:
 - 1 : Very good;
 - 2 : Good;
 - 3 : Fair;
 - 4 : Poor;
 - 5 : Very poor.
- DQR calculation: $DQR = (GR + TiR + TeR + P) / 4$

For each assessed step, a substantial set of data from different sources and involving material or environmental input/output have been gathered.

Table below presents a medium assessment, which can be completed by an alternative assessment – using the value in brackets, e.g. (3) – for some identified specific cases:

Steps (cf. Table 4)	DQR	Criteria assessed				Comments
		GR	TiR	TeR	P	
Collection/massification						
	1	1	1	1	2	
Rank 1 treatment						
	1 - 1,5	1	1	1-2	1-2 (4)	TeR and P = 2: Flat screens (panels) and SPA Med&Build TeR and P = 3: Professional appliances cold (except if 4), LPA&Mobiles, professional lighting equipment and professional inverters P=(4): special case of dust emissions (unknown particle size) and the distribution profile in outgoing fractions of certain materials from professional appliances cold.
Transport from Operator 1 to Operators 2						
	1 - 1,5	1-2	1	1	1-2	
Rank 2 and subsequent treatments						
	2	2	2	2	2	
Downstream transport from rank 2 operators and following						
	2,5	3	2	2	3	

Final destinations						
Type of destinations	1 - 2,5	1-3	1-2	1-3 (4)	1-2	GR and/or TeR = 3: all professional WEEE streams, Flat screens (panels) and more generally plastic resins from the various streams being studied. TeR = (4): case of certain materials from professional appliances cold.
Main destinations modelling	1 - 3	1-3	1-3	1-3	1-3 (4)	Assessment may vary depending on the couple material/destination
Secondary and marginal destinations modelling	2 - 4	2-3 (4)	2-3 (4)	2-3 (4)	2-3 (4)	P= (4) : specific case of flow contributing to toxic and ecotoxic impacts

TABLE 17 – SYNTHESIS OF DATA QUALITY, STEP BY STEP

Generally, data meet requirements of PEF methodology ($DQR \leq 3$ for the main processes and $DQR \leq 4$ for more marginal processes), with however vigilance needed regarding toxic and ecotoxic impact indicators, as well as impact indicators associated to dust (including respiratory effects).

POSITIONING OF WORK WITH RESPECT TO CIRCULAR FOOTPRINT FORMULA

This section describes the positioning of the work conducted with respect to the "end-of-life" formula selected [6] within the framework of the PEF.

The initial aim of the WEEE management LCI construction work is not that of meeting the requirements stated within the framework of the PEF and more particularly the requirements applicable to the end-of-life formula adopted in this context.

The issue of the positioning of this work with respect to European methodology – the Circular Footprint Formula – has thus been handled for explanatory purposes, with the aim that this explanation with respect to a reference system which should be shared extensively contributes to the transparency of the WEEE management LCI construction work. This positioning is also accompanied by some teachings intended, to a degree, to contribute to the reflections of the community of LCI professionals on end-of-life management evaluation.

S. NOTE ON CFF

The formula defined in replacement of the "end-of-life" formula presented in Annex V of the Product Environmental Footprint Guide (PEF Guide [5]), now referred to as the "Circular Footprint Formula" [6], is given below:

Material

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

Energy

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

Disposal

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

A	Impact and benefit allocation factor between supplier and user of recycled materials
B	Allocation factor for energy recovery; this factor applies to both impacts and benefits
Q_{sin}	Quality at point of substitution of recycled material included in production
Q_{sout}	Quality at point of substitution of recycled material at end of life
Q_p	Quality of primary material
R_1	Proportion of recycled material used in production inputs
R_2	Proportion of material of product to be recycled (reused) in a subsequent system. R_2 should account for deficiencies in respect of collection efficiency and the recycling (or reuse) process. R_2 should be measured at the output of the recycling facility.
R_3	Proportion of material of product used for energy recovery at end-of-life
$E_{recycled}$	Specific emissions and use of resources (per unit of analysis) generated by the material recycling (reuse) process, including collection, sorting and transport
$E_{recyclingEoL}$	Specific emissions and use of resources (per unit of analysis) generated by the end-of-life material recycling (reuse) process, including collection, sorting and transport
E_v	Specific emissions and use of resources (per unit of analysis) generated by virgin material acquisition and production

E_v^*	Specific emissions and use of resources (per unit of analysis) generated by acquisition and production of the virgin material substituted by the recycled material
E_{ER}	Specific emissions and use of resources (per unit of analysis) generated by energy recovery (e.g. incineration with energy recovery, storage with energy recovery, etc.)
$E_{SE,heat}$	Specific emissions and use of resources (per unit of analysis) that would have been generated by the heat substituted by the recovered energy
$E_{SE,elec}$	Specific emissions and use of resources (per unit of analysis) that would have been generated by the electricity substituted by the recovered energy
E_D	Specific emissions and use of resources (per unit of analysis) generated by end-of-life waste disposal, without energy recovery
$X_{ER,heat}$	Energy recovery efficiency for heat
$X_{ER,elec}$	Energy recovery efficiency for electricity
LHV	Lower heating value of the material subject to energy recovery

In the case of finished products, default values of A and B are applied.

Recyclable materials with:	Examples	Value of A	Value of B
Low supply and high demand	Glass, metals, papers	0.2	0
High supply and low demand	Textiles	0.8	0
Balanced supply and demand	Plastics	0.5	0

TABLE 18 – POSITION WITH RESPECT TO CFF & DEFAULT VALUES OF A AND B FOR FINISHED PRODUCTS IN CFF

T. POSITIONING OF WORK WITH RESPECT TO CFF

T.1 SCOPE

[Position with respect to CFF 1|Scope]► The scope studied within the scope of the work excludes terms referring to the production phase which are covered within the framework of the CFF

The scope studied within the scope of WEEE management LCI creation applies to the end-of-life portion of the CFF and excludes terms referring to the production phase.

Component not concerned by LCI scope

Material (production)

$$(1 - R_1)E_v + \left(AE_{recycled} + (1 - 1)E_v \times \frac{Q_{sin}}{Q_p} \right) +$$

Material (end-of-life)

$$(1 - A)R_2 \times \left(E_{recyclingEoL} - E_v^* \times \frac{Q_{Sout}}{Q_p} \right)$$

Energy

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

Disposal

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

[Position with respect to CFF 2|Scope]► The scope studied within the framework of the work only applies to a portion of the end-of-life covered within the framework of the CFF: management of WEEE not collected within the framework of the take-back scheme is excluded from the work

The figure below (Figure 14) shows a schematic diagram of the streams involved for the target material as defined by the JRC within the framework of the CFF.

It is particularly observed in this diagram that the quantity of a material put on the market (1) is broken down at end-of-life between:

- the quantity collected (2)
- the quantity not collected (3) which is assimilated with waste.

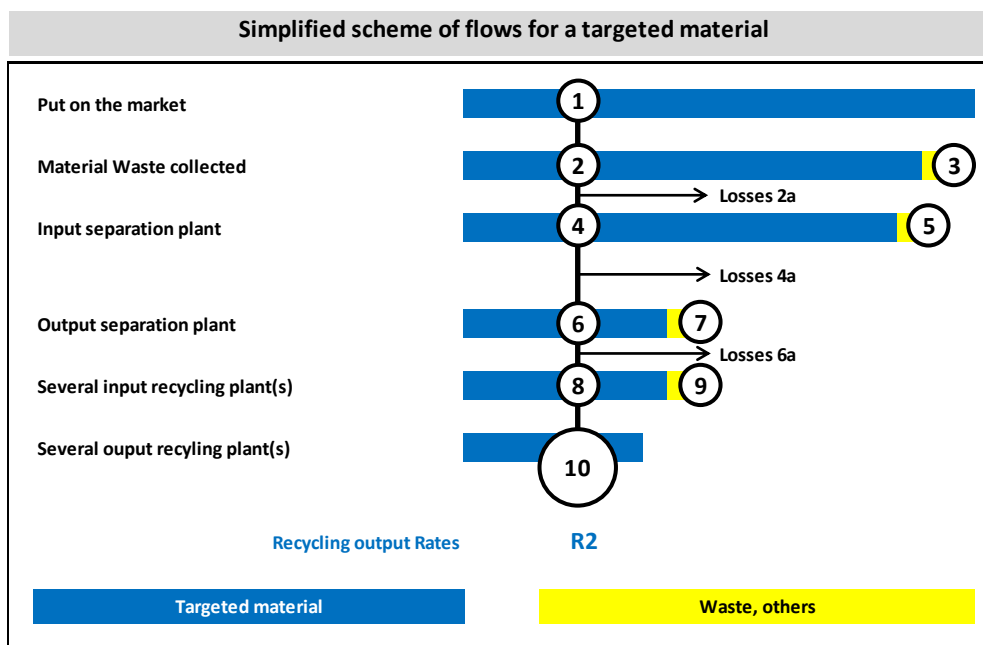


FIGURE 14 – POSITION WITH RESPECT TO CFF X SIMPLIFIED REPRESENTATION OF MATERIAL COLLECTION FOR RECYCLING (JRC)

In fact and depending on the product category, the quantities that are not collected within the framework of EPR take-back schemes may be greater than the scenario suggests: this is particularly the case for relatively recent take-back schemes such as those for WEEE.

Moreover, the end-of-life management of the materials which are not collected within the framework of the take-back scheme is more complex than conventional disposal operations:

- **recycling operations may be conducted within the scope "outside take-back schemes"**: some material recovered "outside the EPR take-back scheme" may undergo preferential material recovery within the framework of an informal economy, this particularly applies for some standard metals and components containing precious metals;
- **depollution and management operations in suitable take-back schemes of substances the removal of which is required by regulations are probably not conducted suitably within the scope "outside take-back schemes"**: as the operations conducted "outside take-back schemes" were not studied, it is difficult to be categorical on the outcome of these substances, the removal of which is normally required by regulations; however, there is a strong presumption, particularly due to lack of knowledge or for economical reasons, in favour of a lack of depollution and management of pollutants extracted in suitable take-back schemes. In any case, a shortcoming in depollution or unsuitable management of the pollutants extracted may give rise to significant impacts.

The figure below (Figure 15) offers an alternative version to the figure drawn up by the JRC and highlighting the following:

- the scope of end-of-life management within the framework of the EPR take-back scheme, this scope corresponding to the scope covered in the context of the work;
- the scope of end-of-life management outside the EPR take-back scheme, this scope being excluded from the scope covered in the context of this work and this scope being, as a general rule, poorly elucidated.

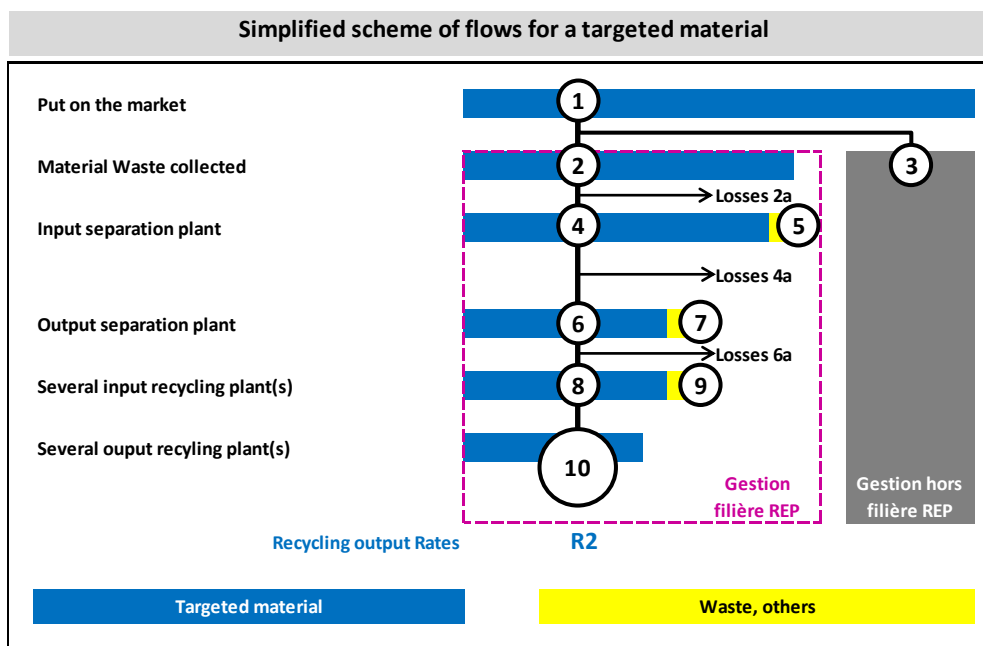


FIGURE 15 – POSITION WITH RESPECT TO CFF & SIMPLIFIED REPRESENTATION OF MATERIAL COLLECTION FOR RECYCLING (JRC)
& INTRODUCTION OF A DISTINCTION BETWEEN MANAGEMENT WITHIN AND OUTSIDE TAKE-BACK SCHEME

T.2 PARAMETERS

T.2.1 ALLOCATION PARAMETERS A AND B

[Position with respect to CFF 3 | Allocation parameters A and B] ► The allocation parameter of the benefits provided by material recovery and the allocation parameter provided by energy recovery are 0 for all the material/WEEE stream pairs studied.

For finished products such as electrical and electronic equipment, the CFF applies default values for allocation factors A and B.

	Value A CFF	Value A in work	Value B CFF	Value B in work
Glass, metals	0.2	0	0	0
Plastics	0.8	0	0	0
Wood, concrete	Not listed	0	0	0

TABLE 19 – POSITION WITH RESPECT TO CFF & ALLOCATION PARAMETERS A AND B TAKEN INTO CONSIDERATION IN WORK

Besides the fact that it was not within the objectives of the project to produce data complying with the CFF methodology, it should be taken into consideration that the final version of the CFF was drafted at a late stage with respect to this work. The allocation value in respect to the benefits provided by material recovery is different from the CFF values: the allocation parameter A of the benefits of recycling was considered to be equal to 0 for all the material/WEEE pairs studied.

It should be noted that aligning the value of A with CFF guidelines could give rise to a potentially significant or even major change in the LCI results.

T.2.2 RECYCLING RATE R2

[Position with respect to CFF 4 | Recycling rate R2]► Each of the recycling rates R2 processed in the project was calculated in compliance with CFF requirements: the calculation was conducted taking into consideration, along the entire chain between the collection points of the take-back scheme and the recycling process output, the various potential losses and the proportion of materials directed to non-recovered fractions

In respect of the recycling rate R2, the CFF particularly emphasises that this rate should account for deficiencies in terms of efficiency arising in the collection and recycling chain; the CFF stipulates that this rate is determined **at the output** of the recycling process.

The simplified diagram proposed by the JRC (Figure 14) proposes a form of framework of the calculation of the recycling rate R2 by indicating the possible gaps in the efficiency of the collection/treatment chain: indeed, this figure highlights i/the various losses (losses 2a, losses 4a, losses 6a) , ii/ possible direction of a portion of the target material to "waste" fractions which are not subject to recycling (stream 3, stream 5, stream 7, and stream 9) and iii/ the issue of efficiency of the recycling process (difference between stream 8 and stream 10).

Losses and waste streams*	Positioning of work	Comments
Stream 3	Outside scope of work	This stream consists of the proportion of WEEE managed outside the take-back scheme. It is outside the scope of the work. Its study potentially involves more complex operations than mere disposal: the management of this stream may include material and/or energy recovery operations; it should also incorporate a quantification of the deficiencies in terms of depollution and/or adequate management of pollutants (see T.1)
Losses 2a	Included	"Upstream" losses were taken into account for the material/WEEE stream pairs for which this was found to be relevant; this particularly applies to cooling gases and clear oils from LHA cold and Hg from lamps. (see F.2)
Stream 5	Included but equal to 0	Undesirable substances are removed from operators at the input of the treatment process: these undesirable substances consist of objects not belonging to WEEE. In the case of the material/WEEE pairs studied, no material was removed from the treatment process at the operator input phase.
Losses 4a	Included	Losses were systematically included for all the treatment phases. The loss rate was determined specifically on the basis of measurements for cooling gases and expansion gases from LHA cold and for Hg from lamps. The loss rate was determined by means of a generic estimation for each WEEE category for all the other material/WEEE pairs. For solid materials, these losses consist essentially of fine particles which are mostly captured (or which remain in the facilities between two cleaning phases) which are also emitted to the atmosphere in small proportions.
Stream 7	Included	The quantification of the dispersion of each of the materials studied between the various fractions produced at the rank 1 treatment output followed by the analysis of the subsequent management of each of these fractions until the final destinations made it possible to accurately identify the range of final destinations reached for each of the materials studied. The work thus makes it possible to obtain a

Losses and waste streams*	Positioning of work	Comments
		sound quantification of the quantities used in recycling processes, energy recovery processes and disposal processes. (see 0)
Losses 6a	Included	Losses were systematically taken into account for massification/trading operators liable to operate between transport operators and recycling operators (as well as between successive treatment operators)
Recycling efficiency	Included	The modelling of the final destinations was conducted by taking into consideration, whenever possible, on the basis of the inventoried knowledge, the specific behaviour of the materials in each of the final destinations reached. For the target materials of recycling processes, this approach involves taking into consideration the efficiency of these processes; for materials which do not constitute target materials of the processes but which arise in the form of impurities, their behaviour was modelled on the basis of the understanding of the phenomena involved in these processes (see P.1.1.2)

* the description of the streams and losses refers to that used for Figure 14 and Figure 15

TABLE 20 – POSITION WITH RESPECT TO CFF 5 CALCULATION OF RECYCLING RATE R2 IN THE WORK AND INCLUSION OF GAPS IN EFFICIENCY THROUGHOUT THE CHAIN

The table above describes the positioning of the work with regard to each of the causes liable to degrade the efficiency of the collection/treatment chain in relation to a material recovery target.

T.2.3 QUALITY RATIO Q_{sout}/Q_p

[Position with respect to CFF 5|Quality ratio Q_{sout}/Q_p]► The quality ratio Q_{sout}/Q_p which compares the quality of the end-of-life recycled material and the quality of the virgin material substituted by the recycled material was systematically determined on the basis of physical considerations.

The ratio Q_{sout}/Q_p represents the ratio between the quality of the recycled material (at end-of-life) and the quality of the virgin material substituted by the recycled material. This ratio represents the substitution rate between recycled material and virgin material.

The CFF stipulates that the ratio Q_{sout}/Q_p must be determined at the point of substitution with specific values for each application or for each material (where the values of Q_{sout}/Q_p are to be determined within the framework of the PEFCR). The CFF requires that the ratio Q_{sout}/Q_p be determined:

- In priority using economic considerations, for example by comparison between the sales price of the recycled material and the sales price of the virgin material, these prices being considered at the point of substitution;
- Possibly using physical considerations, if the economic approach appears to be less relevant than the physical approach.

Within the scope of the work, the quality ratio Q_{sout}/Q_p which compares the quality of the end-of-life recycled material and the quality of the virgin material substituted by the recycled material was systematically determined on the basis of physical considerations: this choice was made voluntarily as it was considered to be the most relevant rationale, particularly in comparison to a rationale involving a comparison of the sales prices between recycled and virgin material¹¹. This ratio is equal to 1 for all

¹¹ The limitations applied by a rationale involving the comparison of sales prices between virgin and recycled material are not developed within the scope of this summary; however, several points can quickly be listed: effect of price volatility, influence of oil barrel price on this assessment, influence of policy in some major countries in

cases in which the recycled material substitutes a virgin material of the same type; it can differ from 1 in other cases, which has been explained within the scope of the interdisciplinary report on background data.

T.2.4 POINT OF SUBSTITUTION

[Position with respect to CFF 6 | Point of substitution] Within the scope of the work, the point of substitution is systematically determined in line with the point of calculation of the recycling rate and that of the quality ratio Q_{sout}/Q_p ; this point is situated at the output of the recycling process and thus corresponds to the most downstream point possible of the waste management value chain.

The point of substitution represents the point of the value chain where the recycled material can be considered to substitute the virgin material

The CFF places particular emphasis on the fact that this point should, in principle, be identified by taking into consideration that it corresponds to the location where a stream consisting of 100% recycled material replaces a stream consisting of 100% virgin material. This CFF guideline can particularly be interpreted as the drive to prohibit evaluation practices where the point of substitution was sometimes taken into consideration considerably upstream from the waste management value chain, for example following collection or the first sorting phase while the streams still contain large quantities of materials not sorted or not targeted by recycling processes.

However, two configurations are envisaged by the CFF according to access options to detailed recycling process data:

- Access to detailed recycling process activity data: the point of substitution corresponds to the point where a stream consisting of 100% recycled material replaces a stream consisting of 100% virgin material;
- Limited access or lack of access to detailed recycling process activity data: the point of substitution corresponds to the point of output of the recycling process; the calculation of the differential can then be conducted by processing the profiles E_v and E_{rec} corresponding to mixes between recycled materials and virgin materials.

Within the scope of the work, the point of substitution is systematically determined in line with the point of calculation of the recycling rate and that of the quality ratio Q_{sout}/Q_p ; this point is situated at the output of the recycling process and thus corresponds to the most downstream point possible of the waste management value chain (e.g.: recycled plastic at regenerator output, steel at electrical steelworks output, etc.).

T.2.5 CALCULATION OF SPECIFIC EMISSIONS AND RESOURCES USED BY THE RECYCLING PROCESS $E_{\text{RECYCLINGEOL}}$ (ENERGY RECOVERY E_{ER} AND DISPOSAL E_{D})

[Position with respect to CFF 7 | Calculation of terms $E_{\text{recyclingEoL}}$, E_{ER} , E_{D}] Within the scope of the work, the specific emissions and resources used by the recycling ($E_{\text{recyclingEoL}}$), energy recovery (E_{ER}) and disposal (E_{D}) processes were accounted at all the treatment, massification and transport phases from the collection points to the final destinations reached by the materials.

The CFF specifies that the term $E_{\text{recyclingEoL}}$ which represents the specific emissions and resources used by the recycling process should cover all stages from the collection phase to the point of substitution.

relation to the marketing of basic materials, possibility to access sales price information with regard to competition rules, validity of this rationale with respect to the requirements of ISO 14044:2006, etc.

The CFF does not rule on the operations to be covered by the terms representing:

- the specific emissions and resources used by energy recovery processes E_{ER} ;
- the specific emissions and resources used by disposal processes E_D .

Within the scope of the work, the specific emissions and resources by the recycling, energy recovery and disposal processes were accounted at all the treatment, massification and transport phases from the collection points to the final destinations.

	Accounting of specific emissions and resources used		
	$E_{recyclingEoL}$	E_{ER}	E_D
Collection/massification	Yes see section L	Yes see section L	Yes see section L
Rank 1 treatment	Yes see section M	Yes see section M	Yes see section M
Transport: Rank 1 Op. - Rank 2 Op.	Yes see section Erreur ! Source du renvoi introuvable.	Yes see section Erreur ! Source du renvoi introuvable.	Yes see section Erreur ! Source du renvoi introuvable.
Massification or rank 2 treatment	Yes, if applicable see section O	Yes, if applicable see section O	Yes, if applicable see section O
Transport: Rank 2 Op. - Rank 3 Op.	Yes, if applicable see section O	Yes, if applicable see section O	Yes, if applicable see section O
Rank 3 treatment	Yes, if applicable see section O	Yes, if applicable see section O	Yes, if applicable see section O
Transport: Rank 3 Op. - Rank 4 Op.	Yes, if applicable see section O	Yes, if applicable see section O	Yes, if applicable see section O
Final destination (= rank 2, rank 3 or rank 4 operator)	Yes see section O	Yes see section O	Yes see section O

TABLE 21 – POSITION WITH RESPECT TO CFF & CALCULATION OF $E_{recyclingEoL}$, E_{ER} , E_D IN WORK

T.3 BREAKDOWN OF LCIs WITH AND WITHOUT ACCOUNTING OF THE BENEFITS PROVIDED BY SUBSTITUTION EFFECTS

As explained above (section P.1.2), and to respond better to users' various needs, the LCIs constructed within the scope of the work were broken down according to two final destination accounting methods:

- **With benefits:** the impacts associated with the behaviour of the material/component in the final destinations reached and the benefits provided by the material and/or energy substitution effects are taken into account;
- **Without benefits:** only the impacts associated with the behaviour of the material/component in the final destinations reached are taken into account; the benefits provided by the material and/or energy substitution effects are not taken into account.

A formal reading of this breakdown is provided in the table below via CFF formalisation.

LCI with **benefits**

Component not concerned by LCI scope

Material (production)

$$(1 - R_1)E_v + \left(AE_{recycled} + (1 - 1)E_v \times \frac{Q_{sin}}{Q_p} \right) +$$

Energy

Material (end-of-life)

$$(1 - A)R_2 \times \left(E_{recyclingEoL} - E_v^* \times \frac{Q_{Sout}}{Q_p} \right)$$

End-of-life management LCI of constituent materials of electrical and electronic equipment within the framework of the French WEEE take-back scheme

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

Disposal

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

LCI without benefits

Component not concerned by LCI scope

Material (production)

$$(1 - R_1)E_v + \left(AE_{recycled} + (1 - 1)E_v \times \frac{Q_{sin}}{Q_p} \right) +$$

Material (end-of-life)

$$(1 - A)R_2 \times (E_{recyclingEoL} - 0)$$

Energy

$$(1 - B)R_3 \times (E_{ER} - 0)$$

Disposal

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

TABLE 22 – POSITION WITH RESPECT TO CFF & CFF READING OF LCIs WITH AND WITHOUT INCLUSION OF BENEFITS

U. APPLICATION OF CFF FOR COMPLEX PRODUCTS – TEACHINGS OF WORK

The analysis of the positioning of this work with respect to CFF requirements and guidelines demonstrates that it is possible, using some adaptations, to apply the CFF in order to model the end-of-life management of waste from complex products such as WEEE.

The application in the case of WEEE makes it possible to formulate some observations which we deem useful to be reporting in this methodological document. These observations essentially relate to the limitations of the current CFF format in the case of complex products.

U.1 VARIETY OF RECYCLING PROCESSES, VARIETY OF ENERGY RECOVERY PROCESSES AND VARIETY OF DISPOSAL PROCESSES

[Position with respect to CFF 8|Teachings from work on WEEE LCI]► Without calling into question the various requirements stated within the scope of the CFF, the CFF should not close the possibility of accounting for, in the case of the end-of-life of a given material: i/several recycling processes; ii/several energy recovery processes; iii/several disposal processes.

The current format adopted in the CFF applies to materials for which the following are observed in relation to their end-of-life management:

- a **single recycling process**, which is governed by the rate R_2 and the benefits of which are represented by $\left(E_{recyclingEoL} - E_v^* \times \frac{Q_{Sout}}{Q_p} \right)$
- a **single energy recovery process**, which is governed by the rate R_3 and the benefits of which are represented by $(E_{ER} - LHV \times X_{ER,heat} \times E_{SE,heat} - LHV \times X_{ER,elec} \times E_{SE,elec})$
- a **single disposal process**, which is governed by the remainder which is not recycled or recovered in terms of energy $(1 - R_2 - R_3)$ and the impacts of which are expressed by E_D

The work conducted in the case of WEEE management within the framework of the take-back scheme demonstrated that this scenario, which consists of a simple combination of three processes, practically never corresponds to what happens in reality.

The table below gives various examples, encountered in the work relating to WEEE, which illustrate cases of co-existence between various recycling, energy recovery and disposal processes.

Illustrations	
Recycling	<ul style="list-style-type: none"> a plastic (e.g. PP) can be recycled in part so as to substitute the same virgin resin (PP) and in part so as to substitute other materials (wood, concrete, etc.) in applications with a lower added value steel can be recycled mainly in steelworks so as to substitute virgin steel but can also be found in lesser proportions in copper refineries where it will be included in drosses which are processed for recovery in the construction industry; it can also be recovered from clinker output from incinerators prior to subsequent introduction in steelworks copper can be recycled in part by processing in copper refineries but also, for very high-purity coppers, by direct reuse in foundry
Energy recovery	<ul style="list-style-type: none"> a combustible material (wood, plastic, etc.) can be recovered in part in the form of SRF in cement works as a substitute for coke/coal and in part in incinerators with energy recovery; furthermore, the incinerators with energy recovery can be located in various European countries with different performances and with a different substitute electricity profile
Disposal	<ul style="list-style-type: none"> In view of the trajectory followed via the various fractions, many materials are disposed both in storage facilities, potentially situated in different geographic regions, and by thermal destruction, also potentially situated in different geographic regions. In addition, some of the materials may be found to be emitted directly into the environment (particularly in particulate or gas form).

TABLE 23 – POSITION WITH RESPECT TO CFF X ILLUSTRATIVE SCENARIO ON THE CO-EXISTENCE OF VARIOUS RECYCLING PROCESSES, VARIOUS ENERGY RECOVERY PROCESSES AND VARIOUS DISPOSAL PROCESSES

On the basis of the format adopted in the CFF, the possibility of accounting for, in the case of the end-of-life management of a given material, various recycling processes, various energy recovery processes and various recovery process could for example be expressed as follows:

Component not concerned by LCI scope

Material (production)

$$(1 - R_1)E_v + \left(AE_{recycled} + (1 - 1)E_v \times \frac{Q_{sin}}{Q_p} \right) +$$

Material (end-of-life)

$$\sum_{i=1}^m (1 - A)R_{2i} \times \left(E_{recyclingEoLi} - E_{vi}^* \times \frac{Q_{Souti}}{Q_{pi}} \right)$$

Energy

$$\sum_{j=1}^n (1 - B)R_{3j} \times (E_{ERj} - LHV \times X_{ER,heatj} \times E_{SE,heatj} - LHV \times X_{ER,elecj} \times E_{SE,elecj})$$

Disposal

$$(1 - \sum_{i=1}^m R_{2i} - \sum_{j=1}^n R_{3j}) \times (\sum_{k=1}^p D_k E_{Dk})$$

The expression of the various factors involved in the formula is similar to that used for the CFF (see section S)

$i = 1 \text{ à } m$

The formula leaves the possibility of combining m different recycling processes

$j = 1 \text{ à } n$

The formula leaves the possibility of combining n different energy recovery processes

$k = 1 \text{ à } p$

The formula leaves the possibility of combining p different recycling processes

U.2 TREE STRUCTURE OF VARIOUS TREATMENT/SORTING AND INTERMEDIATE TRANSPORT OPERATORS

[Position with respect to CFF 9] Teachings from work on WEEE LCI ► The end-of-life management of complex products is based, not on a single level of treatment/sorting, but on a tree structure of various treatment/sorting and intermediate transport operators; CFF requirements should be broken down at the scale of this tree structure.

Within the scope of the CFF, the question of the waste treatment/sorting process between the collection phase and the arrival of the materials at the final destinations (recycling, energy recovery, disposal) is not formally elucidated. However, the simplified diagram proposed by the JRC in respect of collection for recycling, used to frame the calculation of the recycling rate R_2 , indicates the treatment/sorting consists of a phase conducted in terms of single operators (see Figure 14).

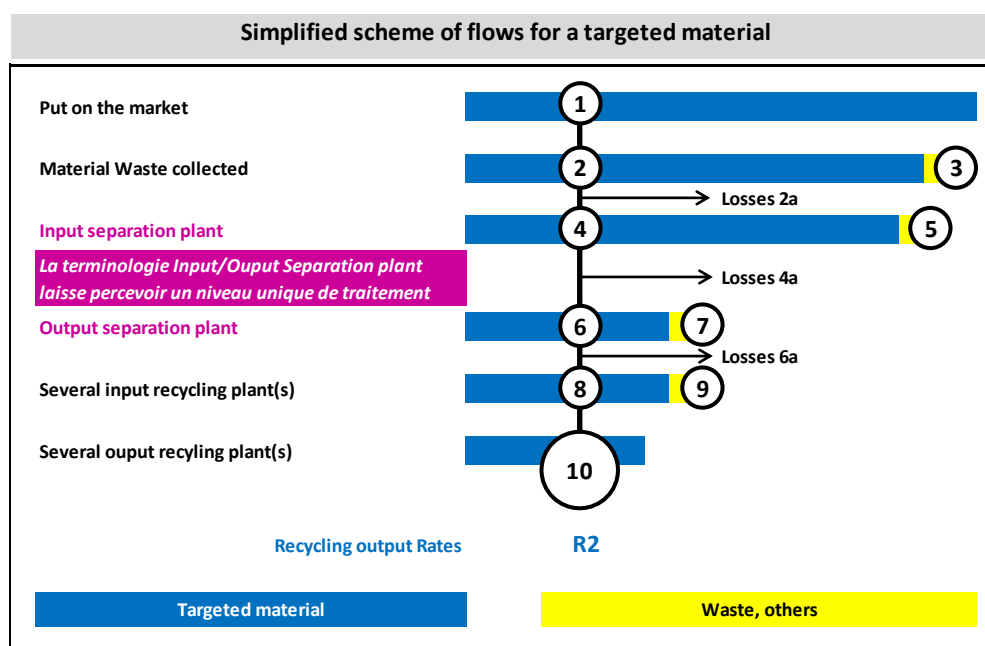


FIGURE 16 – POSITION WITH RESPECT TO CFF ✕ SIMPLIFIED REPRESENTATION OF MATERIAL COLLECTION FOR RECYCLING (JRC)
✕ CONSIDERATION OF A SINGLE TREATMENT/SORTING LEVEL

The organisation illustrated in this diagram is applicable to relatively simple waste such as packaging materials; after collection, packaging materials are generally sorted by materials in sorting facilities; the various material streams produced following this sorting are then directed to recycling operators.

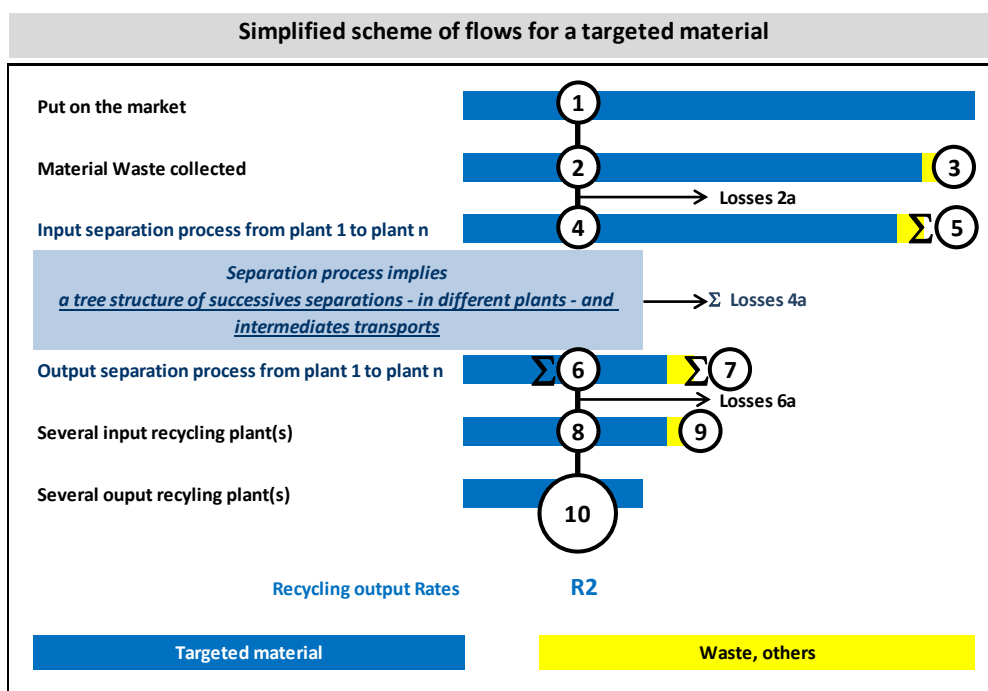


FIGURE 17 – POSITION WITH RESPECT TO CFF ✕ SIMPLIFIED REPRESENTATION OF MATERIAL COLLECTION FOR RECYCLING (JRC)
✕ CONSIDERATION OF A SUCCESSIVE TREATMENT/SORTING TREE STRUCTURE FOR COMPLEX WASTE

In the case of complex waste such as WEEE, it was on the other hand observed that the organisation of its end-of-life management within the framework of the take-back scheme is based on a tree structure of various treatment/sorting operators with intermediate transport operations in order to route the fractions from one operator level to the next operator level.

In our view, it is necessary to underline the distinction between the use of a single sorting/treatment level, applicable to the case of simple waste, and the use of a tree structure of various sorting/treatment operators with intermediate transport operations; it particularly implies that:

- the calculation of the term ($E_{\text{recyclingEoL}}$) – this also applies to the terms (E_{ER}) and (E_{D}) – which accounts for specific emissions and use of resources between the collection points and the output of the recycling process should include the specific emissions and use of resources of the tree structure of the various sorting/treatment operators and intermediate transport operators; the work required to conduct such an evaluation is necessarily more complex and more difficult than in the case of single sorting/treatment level.
- the losses (losses 4a) and routing of a portion of the materials to a waste fraction (streams 5 and 7) which are indicated in terms of a single treatment/sorting operator in the case of the diagram drafted by the JRC (see Figure 16) should be broken down and taken into account at each of the levels of the tree structure (see Figure 17); as for the previous point, the work required to conduct such an evaluation is necessarily more complex and more difficult than in the case of single sorting/treatment level.

LIMITATIONS OF THE WORK

The study of the end-of-life management of the various WEEE categories studied within the framework of the WEEE take-back scheme quickly demonstrated that this management is not based on a single treatment/sorting level followed by routing of the fractions to final destinations. The complexity of waste electrical and electronic equipment necessarily involves a complex tree structure of various levels of treatment operators and intermediate transport operations to the final destinations.

For each of the material/WEEE stream pairs subject to LCI production, this tree structure was understood in its complexity so as to:

- account for specific emissions and use of resources for all the treatment and transport operations involved in the trajectory of the material from collection in the WEEE category to which it belongs to the final destinations;
- determine the nature of the various final destinations including those corresponding to losses at each of the phases, as well as the breakdown between these destinations, included in the material studied following multiple trajectories followed within the tree structure.

The coverage rate of the specific activity data taken into account is moreover very high for the first phases: upstream logistics, treatment by rank 1 operators, treatment between rank 1 operators and rank 2 operators. Furthermore, the rank 1 treatment operators taken into account make it possible to cover the variety of treatment technologies of each of the WEEE streams at a French level, which is moreover considered to also be representative of practices on a European scale within the scope of the requirements of management within the framework of the take-back scheme.

The modelling of the environmental impacts and benefits generated by the materials in the various final destinations reached was further conducted as specifically as possible - in view of the current knowledge compiled within the scope of the work - while trying to characterise the actual behaviour of the materials in each of these final destinations. Besides the necessarily perfectible nature of the modelling work conducted on these aspects, it is important to note that this work was primarily intended:

- To avoid any form of overestimation of the recovered quantities and the benefits potentially associated with recovery operations;
- Not to neglect in principle the environmental impacts produced by the proportion of material reaching, in the form of impurities, non-target final destinations.

On this basis, and as a general rule, the data produced following this work are considered to be of very good quality both in the version with accounting of benefits and in the version without accounting of benefits.

However, some limitations should be pointed out to the user of these data.

■ Reminder of exclusions

[Limitations of work 1|Exclusions] ► The aspects excluded from the scope of the study should be taken into account by users in order to check whether they represent a limitation or not in respect of the envisaged use of the data

The definition of the scope of the study led to a number of exclusions which may represent limitations according to the use of the data envisaged by a user. These exclusions are summarised below:

- the end-of-life of EEE outside the take-back scheme was excluded from the scope of the work;
- WEEE streams, materials and components which are not currently put on the market were excluded from the scope of the work;
- the transport carried out between the location of use of the electrical and electronic equipment and the collection points set up by the take-back scheme was not taken into account;
- infrastructures were not taken into account.

▪ **End-of-life LCIs not possible for certain materials of professional WEEE**

[Limitations of work 2] LCIs that cannot be performed for certain materials ► The aspects excluded from the scope of the study should be taken into account by users in order to check whether they represent a limitation or not in respect of the envisaged use of the data

As a general rule, for each WEEE stream, the list of materials/components studied was selected with the aim of covering at least 95% (by mass) of the average composition of the stream as well as the materials/components whose proportion by mass in the appliances might be very small but which present special environmental challenges (e.g. gold from PCBs, mercury from lamps, etc.).

However, for the following materials, and even though they might make a significant contribution to the composition of certain appliances, limitations to the available data and strong uncertainties about the future of these materials have led to not providing an end-of-life LCI for:

- **Non-ferrous stainless steel** usable in industrial motors as well as professional appliances cold (e.g. agri-food applications, specific markets for oil rigs and naval applications);
- **Constituent materials of x-ray tube bulbs** used in certain medical applications;
- **Constituent materials of lead-acid batteries** that may be present in industrial inverters.

▪ **Points requiring attention with regard to impacts**

It is useful to express the most important limitations and points requiring attention in relation to the published data via a reading grid according to impact type.

Impact categories	Overall assessment
Climate change	In view of geographic representation, technological representation, temporal representation, method aspects, completeness and precision of the set of data processed, the quality of the data produced with regard to the quantification of these impact categories is, except for some material/WEEE stream pairs, considered to be good to very good.
Ozone depletion	
Acidification	
Photochemical ozone formation	
Mineral, fossil & renewable resource depletion	The user may refer directly to the documentation accompanying the published data in order to obtain a precise evaluation at the scale of each data item released.
Water resource depletion	
Terrestrial eutrophication	
Marine eutrophication	

Freshwater eutrophication	
Particulate matter	See Limitation 1 ► a sensitivity analysis is essential
Human, toxicity, cancer effects	See Limitation 2 ► as a precaution, a significant to very high uncertainty should be taken into consideration according to the data
Human, toxicity, non-cancer effects	
Freshwater ecotoxicity	
Land Use	See Limitation 3 ► the data produced and released does not allow the quantification of this impact
Ionising radiation HH	See Limitation 4 ► the elementary streams contributing to these impacts are exclusively controlled by background data taken into account
Ionising radiation E	

TABLE 24 – OVERALL QUALITY OF DATA PRODUCED AND RELEASED WITH REGARD TO VARIOUS IMPACT CATEGORIES

[Limitations of work 3 | Impacts] ► The data produced and released exhibit limitations in their ability to account for impacts relating to particulate emissions, toxicity, ecotoxicity, land use and ionising radiation. Users should account for these limits in terms of data use and interpretation

Limitation 1 with regard to particulate emissions

Particulate emissions were taken into account in terms of all foreground system activities involved in the WEEE management tree structure within the framework of the take-back scheme. However, the data processed did not allow a differentiation between particulates according to their particle size distribution even though this potentially has a significant impact on their impact category.

In respect of this impact category, the data released can be processed by performing sensitivity analyses in relation to the various particle sizes.

Limitation 2 with regard to toxic and ecotoxic impacts

The limitation highlighted here is not specific to this work but has a more general scope in respect of the possibility of accounting reliably for toxic and ecotoxic impacts within the framework of Life Cycle Analyses.

In respect of the quantification of the potential toxic and ecotoxic impacts associated with metal emissions, firstly, problems in quantifying the elementary streams liable to be involved in these impacts are encountered:

- The chemical speciation in which an element is found in the anthropic system is frequently poorly elucidated even though this speciation may be a decisive factor in terms of the environmental emissions of this element: by way of example, the stability and the leaching potential and evaporation potential between elemental Hg⁰ and mercury from red mercuric sulphide HgS have no common measurement (HgS offering a stable form).
- The bio-physico-chemical context in which an element is found in the anthropic system is frequently poorly elucidated even though this context may be a decisive factor in terms of the environmental emissions of this element. Multiple synergistic or antagonistic reactions may particularly arise to the advantage or disadvantage of some phenomena: injecting bromine into a wet fume purification system will promote mercury capture (and thus reduce its emission to the atmosphere); the acid-basic context, which particularly varies over the various

phases of the lifetime of a discharge, has a significant impact on the leaching potential of metals. Similarly, the form of the matrix in which a given element is found may prove to be a decisive factor: in the case of environmental emissions associated with a leaching phenomenon, the contact time and area between the solid and water are key parameters; in this context, the physical form - particle size distribution and porosity - of the solid in which a given element is inserted plays a very important role with regard to emissions.

- The chemical speciation of an element during its emission or the substance specifically emitted are frequently poorly elucidated even though these aspects are decisive factors in assessing the toxic/ecotoxic nature of this element or substance. By way of example, the toxic nature of H_2S , SO_2 or sulphur mercaptans are in no way comparable even though it is difficult to predict the form in which the sulphur compounds present in a storage facility can be emitted in biogas; similarly, the toxic/ecotoxic nature of mercury Hg^0 is less significant than that of some organic mercury compounds (e.g. methylmercury and ethylmercury); finally, another example with dioxin which can also exhibit a very different toxic/ecotoxic nature depending on the dioxin whereas the data generally available do not allow a differentiation between the molecules specifically involved.

All other things being equal, the toxic/ecotoxic impacts, for metals and also for other substances, which are associated with a given elementary stream can then be modified significantly according to:

- the manner in which this stream is emitted in spatial terms,
- the manner in which this stream is emitted in temporal terms (emission kinetics),
- various factors liable to affect its dispersion (temperature, wind rose, rainfall, etc.) and/or the formation of degradation by-products, which may be more or less toxic than the original molecule.

Within the specific scope of this work, significant endeavours were made to cover as much as possible the emissions of various pollutants liable to be generated in respect of the various operations involved in WEEE management and more particularly in respect of final destinations involving combustion and/or storage phenomena.

However, besides the general limits in respect of the possibility to account reliably for potential toxic and ecotoxic impacts within the framework of Life Cycle Assessment, and which are fully applicable within the scope of the production of these end-of-life data, the quantification work of pollutant emissions in respect of final destinations exhibit, according to our assessment, the following more specific limitations:

- **Emissions of complex organic pollutants of anthropic origin in NHSWF:** emissions into the atmosphere and in leachates, of organic pollutants (BTEX in particular) were taken into account in the case of the storage of materials considered to be biodegradable. On the other hand, emissions of complex organic pollutants liable to be generated by the organic molecules which may be associated with the materials studied as they were initially present in the form of additives, adhesive, paints, etc. could not be quantified within the scope of this work. The nature and quantity of the various organic molecules associated with the various materials included in the composition of waste electrical and electronic equipment are not known, the range of these molecules may moreover be potentially be extensive; furthermore, even if these characteristics were known, the actual modelling of their behaviour in a storage facility, particularly of the leaching behaviour, is a potentially difficult exercise.
- **Emissions of BFRs in NHSWF:** a portion of the plastic resins containing BFRs studied may be found in non-hazardous waste storage facilities. The potential leaching of BFRs, and of POP-BFRs in particular, is a subject on which scientific literature has already been made available.

The studies on this subject which were consulted appear to agree on the fact that a portion of the BFRs introduced into storage facilities are leached; however, apart from this general observation, it was not possible to extricate a general trend in relation to a quantification exercise from this literature. The potential emission of BFRs induced by storage in non-hazardous waste facilities of plastics containing BFRs was not quantified: the documentation associated with the data released underlines this limitation for the material/WEEE pairs in question.

- **Speciation of metal emissions:** the elementary streams quantifying metal emissions, in storage facilities or in other final destinations, were always expressed with the elemental metal. This represents a simplification of the actual situation insofar as metals can be emitted to the environment in other speciations, which may be mineral or organic and more or less toxic than the elemental form.
- **Specific case of Hg emissions:** mercury, in trace form at levels of a few ppm, may still be present in some fractions obtained from the treatment of some WEEE categories (T&L and to a lesser degree Flat Screens). Insofar as the intermediate storage time and conditions between the production of these fractions and their arrival at final destinations (storage, steelworks, incineration, etc.) is not known, the major assumption was made that all of these traces of mercury were emitted to the atmosphere.

Limitation 3 with regard to land use

Infrastructures and land occupancy issues were excluded from the work. The data developed and released are not suitable with a view to a quantification of land use.

Limitation 4 with regard to ionising radiation

The foreground system activities involved in the WEEE management tree structure within the framework of the take-back scheme are not affected by ionising radiation issues. As such, no foreground system activity data were taken into consideration in this respect.

The elementary streams contributing to ionising radiation arising in the data produced and released are obtained solely from the background data processing in the modelling.

PEER REVIEW

Final Review Report
of the Project
*“End-of-life management LCI of constituent
materials of electrical and electronic
equipment within the framework of the French
WEEE take-back scheme – Methodological
summary – V2.0 June 2018”*

*ISO 14040 & ISO 14044
ISO/TS 14071
ILCD entry level*

SOL 16-028.2

12th June 2018

for

ESR

1 Introduction

ESR (commissioner) and Blen Safran (practitioner) have prepared a report "End-of-life management LCI of constituent materials of electrical and electronic equipment within the framework of the French WEEE take-back scheme – Methodological summary – V2.0" dated June 2018, updating the previous report titled "End-of-life management LCI of constituent materials of electrical and electronic equipment within the framework of the French WEEE take-back scheme – Methodological summary – V0.1" dated January 2017.

This report represents the CR report and is the public deliverable of a wider LCI project, which has taken place in two phases:

- a first phase from 2015 to January 2017, covering 7 types of household and professional electrical and electronic equipment;
- a second phase, from 2017 to June 2018, covering 8 types of professional electrical and electronic equipment.

The goal of this wider project was to generate the LCI of materials coming out from the end of life of Electric and Electronic Equipment when following the approved waste treatment path. In total, 258 LCI have been generated for household equipment and 684 LCI for professional equipment.

This report states that ISO 14040:2006 and ISO 14044:2006 requirements have been applied. In that scope, ESR have requested a Critical Review (CR in the rest of the document) panel to make a critical review of the report.

Note: the CR panel has been involved all along the wider project, and has reviewed all deliverables, including the data gathering process and the related documentation, the LCI calculation process and the upstream databases used, the way the database which allows to calculate the LCI is built and the LCI themselves. One internal report has been generated for each

The present report is the "Final CR report", prepared by the CR panel under the direction of Philippe Osset (Solinnen). This CR report is dedicated to be integrated as a whole within the final report of ESR and Blen Safran. Additionally, it can be communicated separately.

2 Composition of the panel: reviewers names and institutions

The CR panel consisted of the following "external" experts, independent from the overall study content and external to Eco-systèmes, Récyclum and Blen Safran and the related business interests:

- Philippe Osset, Solinnen, dipl. eng. ECP ; Philippe has acted as the chair of the Critical Review panel,
- Ueli Kasser, Büro für Umweltchemie, lic. phil.nat./dipl. chem. Universität Bern, especially in charge of the final LCI review.
- Delphine Bauchot, Solinnen, dipl. eng. EMSE (first phase only),
- Guillaume Andard, Solinnen, PhD MINES ParisTech – PSL Research University (second phase only),

The following "internal" experts joined the CR panel during the first phase. They were independent from the overall study content, and are, as employees of ESR, experienced and familiar with the issue:

- Alice Bizouard, Eco-systèmes, WEEE treatment expert,
- Fabienne Van Assche, Récyclum, recycling manager.

The following "internal" experts joined the CR panel during the second phase:

- Alice Bizouard, ESR, WEEE treatment expert,
- Laure Morice, ESR, WEEE treatment expert,
- Romain Lesage, ESR, WEEE expert.

The intention of the panel set up was to make available competencies which cover the studied topic, including those brought by the internal experts. The reviewers were not engaged or contracted to represent officially their organization, but acted as independent expert reviewer.

Note: the wider study is not a comparative LCA. The CR review has been set up in order to prepare the communication to the public of a third party LCA report, and to answer the requirements of the ILCD entry level.

3 Nature of the CR work, CR process and limitations

The CR panel has worked according to the requirements of ISO 14040:2006 and 14044:2006 concerning CR. They have taken into account ISO/TS 14071 requirements too.

Critical Review Panel

for ESR

According to ISO 14044, the critical review process has worked in order to check if:

- the methods used to carry out the LCA are consistent with ISO 14044 requirements,
- the methods used to carry out the LCA are scientifically and technically valid,
- the data used are appropriate and reasonable in relation to the goal of the study,
- the interpretations (LCI here) reflect the limitations identified and the goal of the study,
- the study report is transparent and consistent.

The first task of the CR was *to provide ESR* with detailed comments in order to allow ESR and Bleu Safran to improve their work. These comments have covered methodology choice, results and reporting. The panel has checked the plausibility of the data used, including sample tests in the database. Additionally, the present final critical review report *provides the future reader* of the ESR and Bleu Safran reports and LCI data user with information that will help understanding the report and the LCI data.

The Critical Review report was prepared at the end of the production of the French version of the final project report. The English version of the report has not been reviewed by the CR panel. A plausibility check of the software model was performed.

The first phase of the CR work on the report started in November 2016 and ended up in January 2017: The CR set of 177 comments regarding the report covered general, methodological, technical and editorials aspects.

The second phase of the CR work on the report started in September 2017 and ended up in June 2018: During this period, the CR panel reviewed the methodology application to new electrical and electronic equipment categories from the professional area (154 comments), and reviewed the additions to the methodological report (10 new comments) and a report with LCI background information.

During these two periods, different oral and written exchanges have been held between the CR panel and Bleu Safran, including clarification exchanges regarding the CR comments, and the production of one set of detailed comments by the CR panel, and one new version of the report by ESR and Bleu Safran. The LCI calculations have been done based on the final version of the report.

Previous exchanges, during the wider project, have already covered some key methodology points. According to that process, the review may be considered as having been done "all along the project". The synthesis which is covered by the present CR statement is the result of these on-going exchanges between the CR panel and the practitioners.

ESR and Bleu Safran have taken into account most of the comments and modified and improved their report.

An efficient work has been done by ESR and Bleu Safran to provide a final report integrating answers to all the CR points, and the final result has improved as compared to the first one, towards the requirement of the reference standards.

The present final CR report is the synthesis of the final comments by the reviewers. The remaining detailed comments are provided within this final CR report, together with the full detailed exchanges as appendices.

The present CR report is delivered by the CR panel to ESR. The CR panel cannot be held responsible of the use of its work by any third party. The conclusions of the CR panel cover the full report from ESR and no other report, extract or publication which may eventually be done. The CR panel conclusions are based on the current state of the art and the information which has been received.

4 Conclusions of the review – Critical Review Statement – Review Details

As a whole, the panel considers that the requirements of the reference standards have been applied.

The final report and database reflect the goal which has been set up, within the scope of the limitations that are mentioned in the report, and the detailed panel comments which are provided in the next chapter.

5 Detailed comments

The following lines bring some highlights that a reader of the final LCA report may use to assist his reading and understanding of the report. They recap some critical comments which were not addressed (in fact none!), or which were addressed in a way which is different from what the CR panel expected. The comments which have been addressed no longer appear in the following lines. The reading of the detailed comments and answers (see the table in appendices of Chapter 6) is recommended to get all comments (except editorial ones which were removed).

5.1 Consistency of methods used with ISO 14044 requirements

The methods used are in line with ISO 14044 requirements. The final structure of the report reflects the ISO standard requirements. The methods that have been selected for calculations are clearly presented.

As a reminder for readers, and as written in the report, the current study was not a comparative assertion, even if the resulting LCI data sets are foreseen to be made available to third parties in order to assist them with Eco-design... which will lead them to make comparisons based on the resulting LCI. Therefore, additional ISO 14044 CR work shall be done when communicating on comparisons based on LCA studies, even if these studies use the LCI which have been calculated and reviewed in the scope of the present work!

5.2 Scientific and technical validity

The scientific and technical validity of the report and the overall study, including the underlying science used to calculate the LCI, is high. The models of the end of life routes are highly detailed, and allow being specific to each waste flow.

The way of modelling the end of life routes reflects the complexity of these routes. Then, few cut-off rules have been applied at that stage. The CR panel underlines that this first study is a good basis to simplify further studies in that field, which would allow to save time for data gathering and modelling.

ESR have provided initial data regarding the operators (e.g logistics data, material flows analysis through regular batches assessments and sampling programs, as well as downstream traceability). These data were completed with data and information collection which were based on interviews and questionnaires of a large panel of operators involved. Although plausibility checks have been made by the practitioner, the commissioners and the CR panel, the CR panel highlights that data from operators are not always reliable, as in most LCA, due to the fact that:

- Sometimes, the assessment of data quality, collected by operators is difficult; the tests to collect data are challenging, needs a lot of experience and time to stop the daily routine. Additionally, the methods to take representative waste samples and to analyze them are neither approved nor standardized,
- Sometimes, data collection methods applied by the data providers are not at the state of the art, and simply deficient.

However, it has to be stated that it is about a pioneer project in field of end of life treatment. Never before such a detailed modelling and data collection, representing a major part of the recycling technology of e-waste in France and the relevant chains abroad, was carried out.

5.3 Appropriateness of data used in relation to the goal of the study

According to the substantial amount of information which has been communicated to the CR panel, and reviewed, the data used are appropriated to the goal of the study.

Sometimes, the representativeness of selected operators can be discussed due to the fact that some waste management technologies are emerging and show differences among the operators. This information is clearly stated, when relevant, in the confidential individual reports which have been redacted and reviewed for each waste flow.

There is some discrepancy in the data quality between household and professional EoL inventories. The amount of EoL material collected is less important compared to the household sector. The take back scheme has only few experience and the treatment technologies are not much developed. There is a lot of manual treatment with first treatment operators and second and third treatment operators often are not known or do not provide data. Therefore the lack of information about treatment of professional appliances was compensated with plausible assumptions and analogies to the household sector.

The CR panel have to underline that the data collected represent the technology and the composition of appliances of 2014/15 for the LCI developed in the first phase, and 2016/17 for LCI developed in the second phase. If End-of-Life (EoL) Life Cycle Inventories (LCI) are applied to new appliances in order to evaluate their end of life performance, the user shall be aware of this limitation. The composition of the different waste flows, and the way how different materials are compounded in new appliances, may change in the future. Additionally, in the period between putting new appliances on the market and end-of-life, separation technology can change marginally, or significantly, and may not be represented by the current end-of-life route. It is an inherent challenge of this kind of project! It is not possible to anticipate future technologies and product design, taking into account that regulations promote improvements in the treatment of waste. This is why a significant number of material based EoL LCI have been produced within waste flows (instead of providing EEE based EoL LCI), which limits this bias at a second order of variability.

5.4 Validity of the calculated LCI in the scope of the limitations of the study

The validity of the calculated LCI is high regarding the expected use of these LCI.

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The user of the LCI should be careful about which LCI he selects, since two main methodology choices were selected for the LCI calculations. The selection should be made to avoid double counting all along the Life Cycle of the product he is designing, and shall also be consistent (between materials) to ensure fair interpretations.

It is an inherent necessity that LCI modelling has to be limited. The main limitations of the present project are:

- Some fugitive emissions, such as emissions from incidents and accidents, contamination of infrastructure and the surface (incl. soil) of the operation and storage site have not been considered, although it is a well-known problem of mechanical e-waste treatment and separation. It may be a workplace exposure problem as well as an environmental issue. Fugitive emissions are not quantifiable, but probably influence EoL LCI only to a small extent. It is a general limitations in LCI projects.
- Specific emissions from the landfill disposal site for some materials are not considered. In particular, polymers and its additives are considered as inert materials in the landfill while the emissions from incineration are included in the LCI. Due to this deficiency, interpretations of results based on toxicological or eco-toxicological indicators should be done with care. It is a general limitation in LCI projects, due to the lack of research on long-term emissions from landfill disposal sites. It is an important deficiency of the LCA practice, especially in EoL inventories.
- The infrastructure of operators is neglected. No specific data were available and default values would only enhance all the LCI in a small amount without any benefit. Differentiation between the LCI would become smaller at the end. This limitation is not important in the scope of EoL inventories.

5.5 Transparency and consistency

The overall level of transparency and consistency of the report is high and in line with the ISO 14044:2006 expectations. The CR panel has had access to all information in a very transparent manner.

So far, ESR has decided not to communicate to the public the individual reports which have been redacted and reviewed for each waste flow. The CR panel considers that a public access to these reports would be highly welcomed to enable future readers to understand better the sources which have been used and compiled during the project. It is a limitation to the transparency of the overall study. Whatsoever, this limitation is the result of an appropriated confidential information management, quite common during LCA studies.

6 Quality assessment tables

The following tables describe the CR work that has been done in terms of review actions, and an evaluation of the level of quality which is reached by the LCI which were produced.

Method of evaluation	Validation of data sources	Sample tests on calculations	Energy balance	Element balance	Cross-check with other source	Cross-check with other data set	Expert judgement	Mass balance	Compliance with legal limits	Compliance with ISO 14044 to 14044	Documentation	Evidence collection by means of plant visits and/or interviews
Raw data	YES	Not relevant	Not relevant	Not relevant	No other source	Not relevant	YES	Not relevant	Internal	YES	YES	Internal
Unit process(es): single operation	YES	Internal	Internal	Internal	Not relevant	Very few other sources	YES	Internal	Internal	YES	YES	Internal
Unit process(es): black box	No unit process under the form of black boxes has been submitted for review, just single operation											
Life cycle inventory methods	Not relevant						YES	Not relevant		YES		Not relevant
LCI results or partly terminated system	Not relevant	YES	YES	YES	No other source	No other source	YES	YES	Not relevant	YES	YES	Not relevant
LCA results calculation	Not relevant						YES	Not relevant		YES	YES	Not relevant
LCA results	Not relevant						YES	Not relevant		YES		Not relevant
Documentation	Not relevant						YES	Not relevant		YES		Not relevant

Table 1: Detailed Review Actions

Method of evaluation	Validation of data sources	Sample tests on calculations	Energy balance	Element balance	Cross-check with other source	Cross-check with other data set	Expert judgement	Mass balance	Compliance with legal limits	Compliance with ISO 14044 to 14044	Documentation	Evidence collection by means of plant visits and/or interviews
Raw data	X						X		X	X	X	X
Unit process(es): single operation	X	X	X	X		X	X	X	X	X	X	X
Unit process(es): black box												
Life cycle inventory methods							X			X		
LCI results or partly terminated system		X	X	X			X	X		X	X	
LCA results calculation							X			X	X	
LCA results							X			X		
Documentation							X			X		

Table 2: Simplified Table Gathering Review Actions

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		Technological representativeness	Time representativeness	Geographical representativeness	Completeness	Precision	Methodological appropriateness and consistency	Overall quality
Phase 1	SHA	Very good	Very good	Good	Good	Very good	Very good	Very good
	UHA cold	Very good	Very good	Good	Good	Very good	Very good	Very good
	UHA non-cold	Good	Very good	Good	Good	Very good	Very good	Very good
	Rat screens	Good	Fair	Good	Good	Very good	Very good	Good
	Tubes & Lamps	Very good	Very good	Good	Good	Very good	Very good	Very good
	Self-contained emergency lighting	Good	Good	Good	Good	Very good	Very good	Good
	SPA Build & Med & Ind & Research	Fair	Good	Good	Good	Very good	Very good	Good
Phase 2	UHA Build & Med & Ind & Research	Fair	Very good	Good	Good	Good	Very good	Good
	Professional Lighting Equipment	Fair	Good	Good	Good	Very good	Very good	Good
	Professional Inverters	Fair	Good	Good	Fair	Very good	Very good	Good
	Electrical Motors for industrial applications	Fair	Good	Fair	Good	Good	Very good	Good
	Water Fountain (tank and network)	Good	Good	Good	Good	Fair	Very good	Good
	Professional cold cabinet (with compressor)	Very good	Good	Good	Good	Good	Very good	Good
	Rooftop Air-conditioners	Good	Good	Good	Good	Fair	Very good	Good
	Heat Pumps & Air-conditioners (fluid filler < 2kg)	Good	Good	Fair	Good	Fair	Very good	Good

Table 3: Data Quality Assessment

7 Appendices

The detailed critical review tables exchanged during the work are the appendices of the present CR report. They recap the detailed exchanges between the CR panel, ESR and Bleu Safran.

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