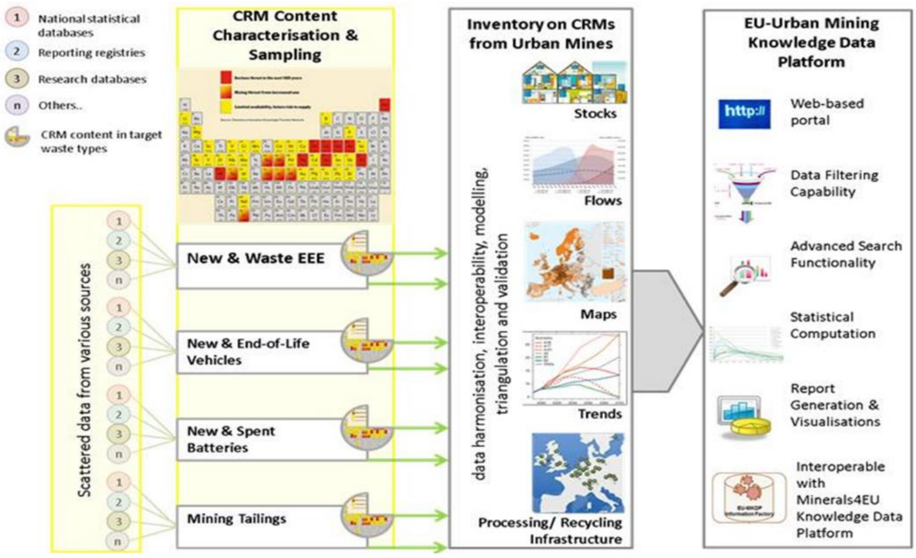
CRM assessment strategy for waste flows and deposits Deliverable 4.2



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Notice

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PURPOSE

This report, Deliverable 4.2, CRM assessment strategy for waste & tailings, documents the procedure for collecting and providing data on the waste flows related to Waste Electrical and Electronic Equipment (WEEE), waste batteries (BATT), End-of-life vehicles (ELV), and mining waste (MIN). This includes the selection of relevant waste flows and deposits, as well as the development of procedures for the statistical evaluation of the data and to handle data gaps. An overview of the produced datasets is provided in the chapter on results.

The datasets are available as annexes to the report. The datasets are also provided internally in the ProSUM project for use within WP5, e.g. to populate the ProSUM unified data model and to further develop the necessary programming.

EXECUTIVE SUMMARY

This Deliverable 4.2 aims to establish a strategy for the collection and provision of data on the content of CRM and other relevant characteristics in waste and tailings (mining wastes). For that, general methods aligned with the other work packages were developed for the four waste groups Waste Electrical and Electronic Equipment (WEEE), waste batteries (BATT), end-of-life vehicles (ELV), and mining wastes (MIN) to select the relevant waste flows, evaluate the data quality and handle data gaps. The methods were applied to the four waste groups to generate the datasets based on the raw data listed in the data inventory provided in D4.1.

For each waste group, the available data were assigned to the flows in the flow diagram and systematically described to get an overview of the coverage of the data in terms of flows, products (keys), countries and years. The overview revealed the redundancies and the data gaps. Availability of data of acceptable quality was the main criterion to select the most relevant flows. For WEEE, BATT and ELV, data on the total weight of waste flows and some data on p-f parameter (mass fraction of a product in a flow or stock) were available.

A joint "ProSUM Harmonisation paper" has been produced because developing methods for the statistical evaluation of the data and procedures to handle uncertainties is not only an objective of Task 4.2, but a core challenge of the entire ProSUM project. It defines four data quality levels, a common approach for judging data quality and measuring the uncertainty, and a procedure for cataloguing metadata descriptors to identify all data sources used. These methods were applied on the waste flow data. Several methods may be used to complete data gaps, like including no data in the database as a consequence of the missing data or making justified assumptions. The most adequate decision for handling a data gap is very case specific. For all waste flows, the description of data quality is far from uniform and the geographical and temporal coverage as well as sample size and representativeness leaves room for substantial improvements.

Despite dedicated approaches for describing waste flow data for BATT, EEE and ELV, the resulting datasets produced in Task 4.2 are according to templates aligned with the ProSUM unified data model developed in WP5. This includes the main and common structuring features (product key, year, country, description of the flow/stock). The data and information available enabled the quantifying of the weights of the waste flows for the four waste groups, but not the CRM content. Hardly any reliable data on CRM in waste flows are available. To gather these data, the use of data from the other work packages (e.g., on composition) is necessary. This was shown for microwaves in conjunction with Deliverable 2.5. For MIN, the data model and several necessary code lists for MIN are developed. To finalise the collection of data, the existing M4EU model is being adapted to cover MIN in the frame of Work Package 5.

The first quarter of 2017 will be devoted to presenting the data model and the code lists to the participants and pointing out the links and similarities with the Minerals4EU data base which the ProSUM-Mining Waste data base will form part of.

One next step concerns the finalisation of the data consolidation for the waste flows, to increase the level of detail related to p-f, in order to get information at e-f level (element in a flow or stock), because no reliable data on CRM in waste flows are directly available. This requires using the produced data on product composition (WP2) and the results of the stocks and flows modelling (WP3), and will enable the overall assessment and data reconciliation steps and cross-sectoral comparisons. The data will be used by WP5 for harvesting into the ProSUM database. One other next step is the formulation of recommendations to facilitate the data harvesting, which is the aim of Deliverable 4.4.

1 Introduction: aim and scope of the Deliverable

As outlined in the Description of Action, task 4.2 aims to establish a strategy for the collection and provision of data on the content of CRM and other relevant characteristics in waste and tailings (mining wastes). This includes the following subtasks:

1. Evaluate, filter and complement the data from T4.1 with regard to requirements from WP5. This includes the development of a procedure to select relevant waste flows and deposits and their material profiles to include in the database under specific CRM considerations. This includes a scheme to statistically evaluate data on the selected relevant waste flows and deposits and their CRM parameters and procedures to handle data gaps and uncertainties.
2. Consolidate datasets for CRM database. The procedures developed in T4.2.1 are applied to the data screened in Task 4.1 to configure datasets for inclusion in the databases and portrayals which feed the EU-UMKDP.

The data inventory and other outcomes of Task 4.1 served as a basis for Task 4.2. In Deliverable 4.1, the waste systems for all four waste groups, i.e. WEEE, BATT, ELV, and MIN, were described and illustrated with contribution of ProSUM team members, participants of the Information Network, surveys, and expert interviews. Also reporting requirements and procedures were analysed. The system distinguished waste generation, waste collection, different waste-specific treatment steps and recycling processes, resulting e.g. in recycling or disposal. Task 4.1 provided a data inventory with an overview of the general availability and lack of data. Taking into account the harmonisation and classification set in D5.3, all data sources were stored in one temporary ProSUM bibliographic overview in EndNote which is designed to feed the final knowledge base of the ProSUM portal. This provides the basis to harvest CRM parameter information in a harmonized template.

Prerequisites for providing datasets to the ProSUM harvesting and diffusion databases are 1) the harmonisation of all available data, 2) a transparent procedure for selection, evaluation and consolidation of data, and 3) to meet the database requirements set in WP5. Chapter 2 presents the methodological framework for the selection of relevant waste flows and deposits and the development of procedures for the statistical evaluation of the data and to handle data gaps, as well as its concrete applications to the four waste groups. An overview of the produced datasets is provided by chapter 3. Chapter 4 describes the next steps.

The positioning of D4.1 in WP4 and other work packages is illustrated by the Pert chart shown in Figure 1.

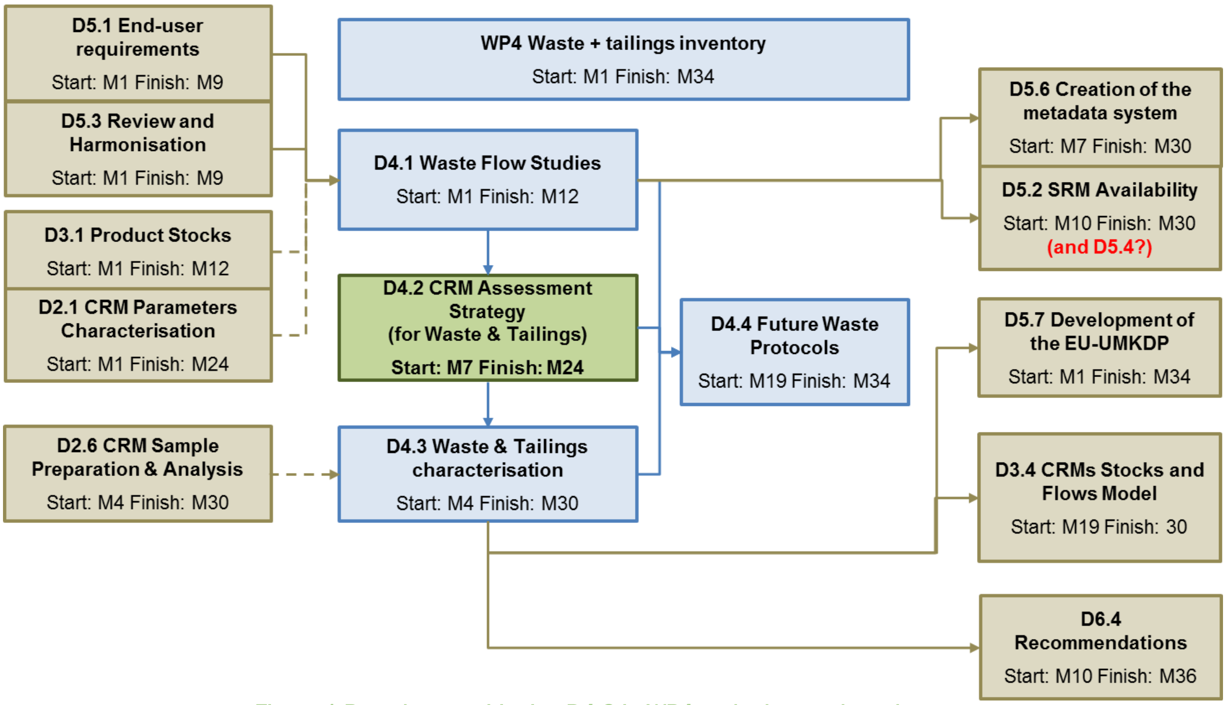


Figure 1 Pert chart positioning D4.2 in WP4 and other work packages

General linkages with the other work packages arise from the necessity to apply common methods for issues that are common to all work packages. This concerns, for example, the classification of products and flows and the evaluation of the data quality.

The following linkages to other work packages and deliverables are of importance:

1. Deliverable 2.5 (WP2) develops datasets on the composition of the individual products put on the market (POM). In many cases, these data will be used in WP4, because they are the only available or most reliable data with which to make assumptions and build estimates. The combination of information from WP2 with the findings of WP4 will provide a deeper understanding of the waste flow.
2. Deliverable 3.3 (WP3) compares measured product counts in the various collected and treated waste flows with the theoretical generated amounts delivered by the stocks and flows modelling. This data reconciliation process, to be completed by June 2017, will complement the data from Task 4.2 to provide further elaborated and consolidated data on volumes, composition and CRM content of the flows. Product characteristics such as average weight and lifespan resulting from the stocks and flows model will be compared against the information delivered by the measurements on waste flows. Also Deliverable 3.2, on complementary waste flows, provides information that can be used to compare the waste generated flows which have been modelled (WP3) with the measured waste flows (WP4).
3. The outcomes of WP5 regarding for instance the building of the unified data model, harmonisation issues and classifications provide guidance to conduct the tasks in WP4 (top-down approach), and the experience carried out by examining the waste flows provide practical input to develop and improve the outcomes of WP5 (bottom-up approach).

2 Evaluate, filter and complement the data from the data inventory

This chapter presents the methods used to evaluate, filter and complement the data from the data sources identified in Task 4.1. for each of the four wastes in scope, Waste Electrical and Electronic Equipment (WEEE), waste batteries (BATT), end-of-life vehicles (ELV), and mining wastes (MIN). The methodological developments address the selection of relevant waste flows and procedures to evaluate the data quality and deal with data gaps. A close cooperation enabled the development methods harmonised at project level because these issues are common to all work packages of ProSUM. This chapter presents the proposed methods and their specific applications to the four waste groups.

2.1 Selection of the relevant waste flows and deposits

In Task 4.2, a procedure has been developed to select relevant waste flows and deposits and their material profiles for specific CRM to include in the project databases and portrayals. This chapter describes the relevant information and explains why data will or will not be entered into project databases.

2.1.1 Selection methods

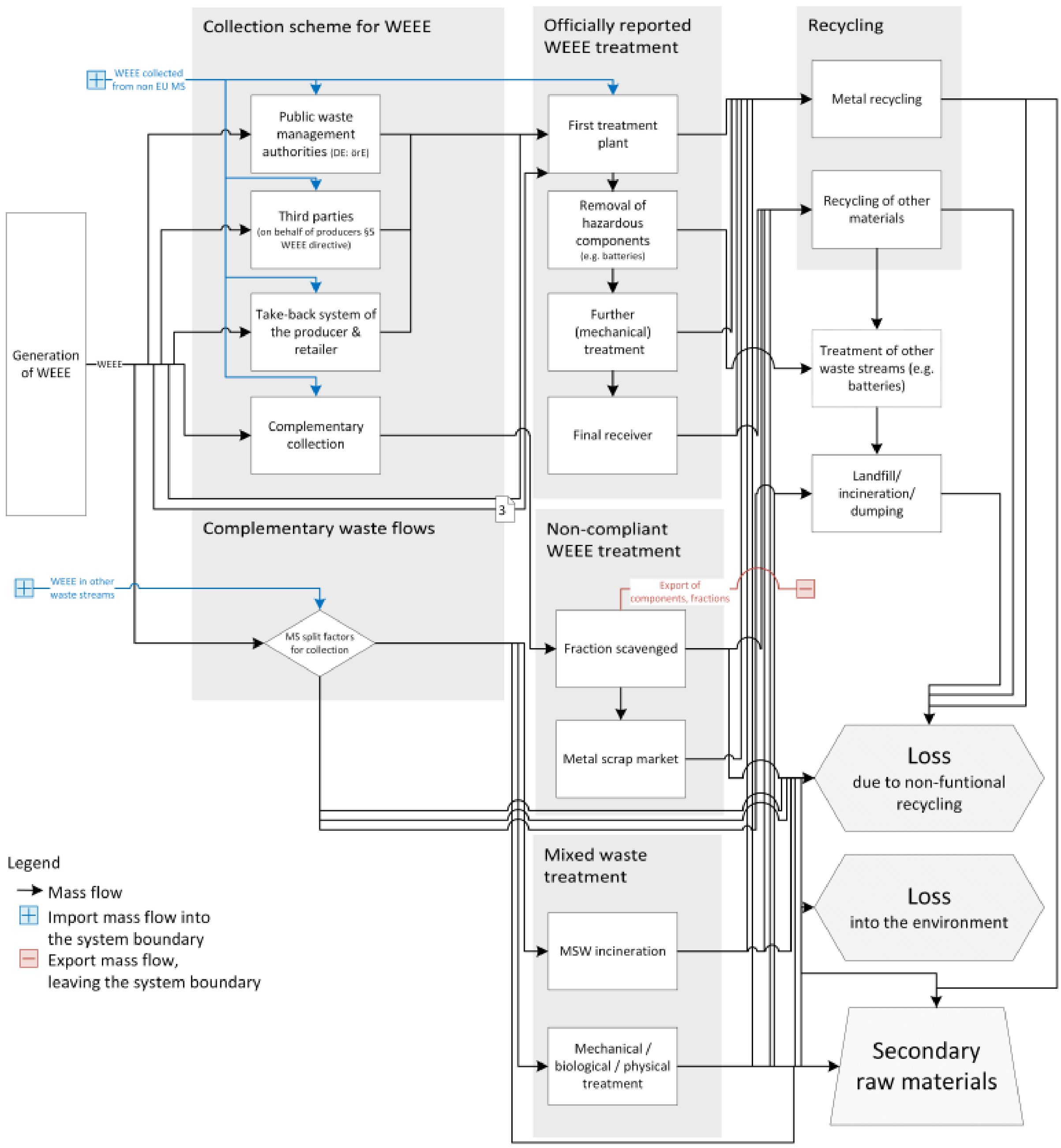
The basis for the selection was the flow diagrams first presented in D4.1, which were adapted to improve the flow depiction and to illustrate the selection of flows (Figure 2, Figure 3 and Figure 6).

The main criterion to select the most relevant flows was the availability of data of acceptable quality. The data on each selected flow address the flow volume, e.g. in tons per year, in pieces or in kg per inhabitant, and, if available, further information on the flow composition, which includes both data at product or component levels, e.g. which types of products are contained in the waste flows, and data on the CRM content of the waste flows. Based on the data inventory (D4.1), the available data were assigned to the flows in the flow diagram and systematically described to get an overview of the coverage of the data in terms of flows, products (keys), countries and years. The overview revealed the redundancy of data (where several data sources address the same flows) and the data gaps.

The generation of information on the composition of waste flows is a part of Task 4.2 where waste specific data are available. In many cases, depending on the product groups, the datasets on the composition of products POM produced in WP2 have to be used to quantify the composition of the waste flows, because it is the only reliable data available with which to make assumptions and estimates for the composition of wastes. This section explains the linking of compositional data and waste flow data for each product group and the availability data in terms of product-related, temporal and geographical granularity.

2.1.2 Selected flows and deposits for WEEE

A range of data sources and reports were reviewed in D3.2 in order to analyse the complementary flows for WEEE in the EU28 plus Switzerland and Norway. The different types of WEEE flows analysed include both reported WEEE treatment streams and non-compliant treatment of WEEE. The selected flows analysed and quantified for WEEE are shown in Figure 2. All definitions are referred to in Deliverable 5.3 and in Annex 1.



END-OF-LIFE		
COLLECTION	TREATMENT	RECYCLING

Figure 2 Flow diagram for Waste Electric and Electronic Equipment, including collection, treatment, recycling and exports

WEEE reported as collected is presented in the Eurostat database (Eurostat, 2016d) and covers the EU from 2005-2014 with the exception of Switzerland. Analysis and updating of all data sources showed that a number of data points are missing i.e. 2010 data for Croatia, 2013 data for Ireland, Greece, Italy, Cyprus and Romania, and additional 2014 collection data for a range of countries.

Usually this data is reported regularly to national registers by Producer Responsibility Organisations (PROs) and EEE producers. The WEEE Forum has collected and reported data for 2015 and made this available for ProSUM. However, due to the delay in Eurostat data reporting for all countries (incl. Switzerland) in respective years, the entire 2015 data cannot yet be consolidated.

Consequently, to complete the consolidation and the alignment of reporting into six collection categories, the 2015 data has not been used yet to analyse complementary flows.

As described in D3.2 all data from the different types of WEEE flows (collected, waste bin, exports, legitimate harvesting of parts for reuse and complementary flows) have been analysed and harmonised. For this deliverable, five additional third party collected flow datasets have been analysed and consolidated to improve the quality of the previous D3.2 WEEE datasets.

Obviously, the D3.2 data sets specifically cover the totals for the collection streams and not individual products. For this Deliverable, in cooperation with selected WEEE Forum Linked Parties, specific analysis has been undertaken for the presence of individual products in the return streams, i.e. the p-f parameter in the ProSUM harmonised approach, by means of frequency count of appliances in the six collection categories. The UNU keys 0114 for microwaves, 0303 for laptops and tablets and, 0408 for flat panel TVs have been used to calculate, from top to bottom, their components, materials and the presence of individual elements as a proof of concept for the ProSUM approach throughout. The UNU key 0114 for microwaves is used as a particular example, since identifying the data for this UNU key is complex because of the heterogeneous collection flow of small household appliances it belongs to.

As a result, the data from all available sources has been analysed and consolidated for both p-f and e-f flows which will be further described in section 3.1.

2.1.3 Selected flows and deposits for BATT

Figure 3 presents the flow diagram for waste BATT, and Table 1 shows an overview of the flows for which data are available.

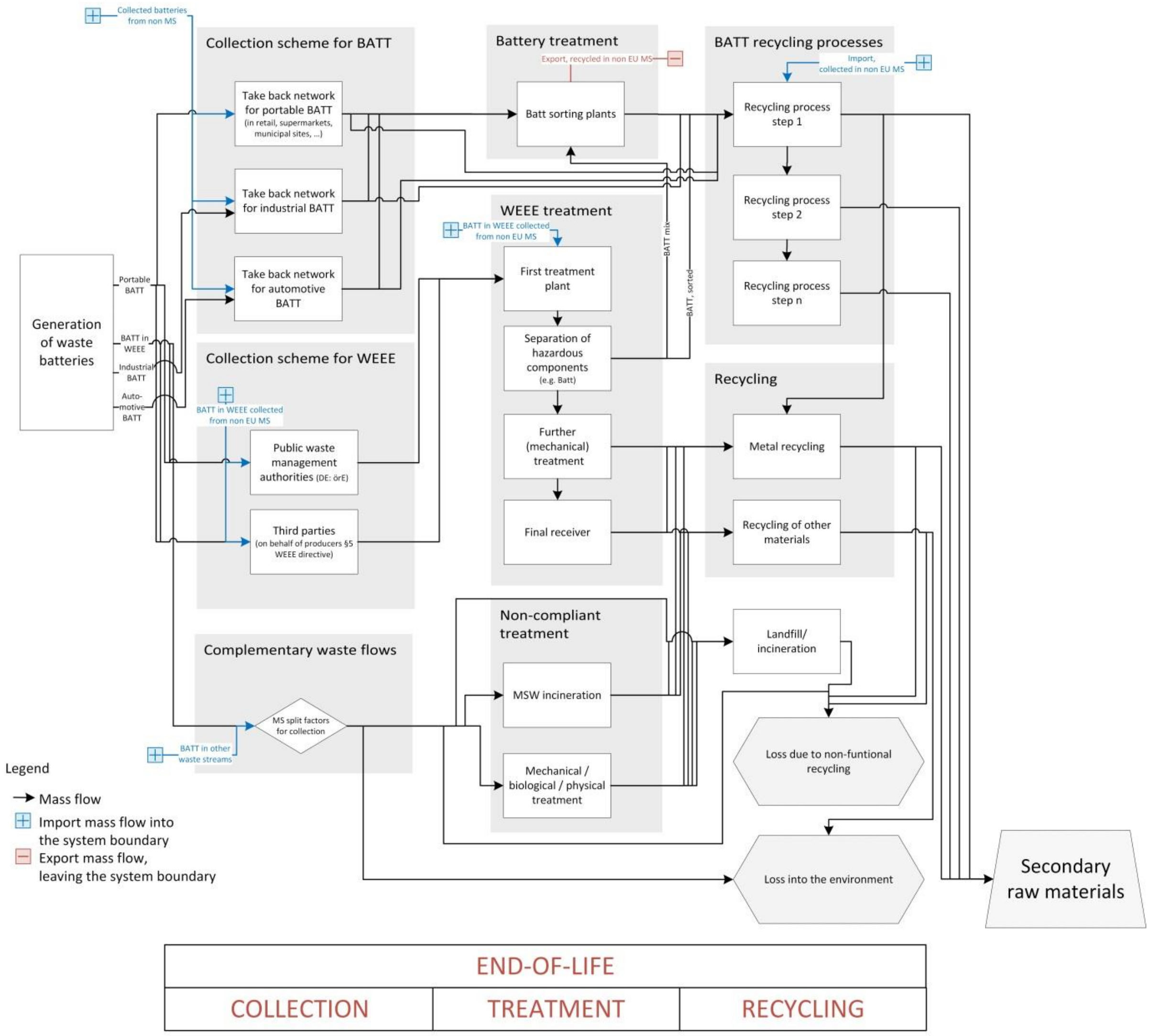


Figure 3 Flow diagram for waste BATT, including collection, treatment and recycling

Table 1 Overview of the available data for waste BATT

Flow from process	Flow to process	Data sources	Submission interval	Parameter*	Geographic precision
Take-back network for portable BATT	BATT recycling process	BATT collection organisations and compliance schemes, Eucobat, EPBA, reporting of national EPAs and Eurostat	1:year	f, p-f (Quantity of portable batteries collected on the market (in tons), by BATT keys	Country
Take-back network for industrial BATT	BATT recycling process	BATT collection organisations and compliance schemes, reporting of national EPAs	1:year	f, p-f (Quantity of industrial batteries collected on the market (in tons), by by BATT keys	Some countries
Take-back network for automotive BATT	BATT recycling process	BATT collection organisations and compliance schemes,	1: one to 3 years	f (Quantity of automotive batteries collected on the market (in tons))	Some countries

Flow from process	Flow to process	Data sources	Submission interval	Parameter*	Geographic precision
		reporting of national EPAs			
Separation of hazardous components in WEEE treatment	BATT sorting plants	WEEE Collection organisations reporting, Eucobat	1:year	f	Some countries
BATT sorting plants	Secondary raw materials produced by BATT recycling	Recycling companies, compliance schemes, national EPAs	1:year	f, p-f, e-f (data to calculate the recycling efficiency)	Country (but not yet published) Some data from Germany and France are published

* As defined in Table 12

2.1.3.1 Collection scheme for BATT

The available data on collected volumes (parameter f) are basically collected by the BATT collection organisations, which are in many countries the compliance schemes (PROs). Basically, possible collection point hosts are retailers, municipalities, schools, companies and WEEE dismantlers. The data on collected volumes are provided to the national authorities, who compile and forward them to Eurostat for publication (Eurostat, 2016a, 2016b). Also the European Portable Battery Association (EPBA, 2015) collect these national data for portable batteries. The overall goal of ProSUM is to provide an inventory of secondary raw materials, particularly CRM, arising in WEEE, ELVs, BATT and MIN. The distinction of portable, industrial and automotive batteries conducted in the Batteries Directive and reflected by the fact that the data reported by Eurostat (2016b) address only portable batteries does not serve the achievement of this objective. The focus was set on getting differentiated data on the electrochemical systems as classified by the BATT keys and sub-keys. The BATT keys were modified to differentiate primary and rechargeable lithium-based batteries. This differentiation is important to enable the quantification of the amounts of CRM contained in the waste batteries, since the composition of rechargeable waste BATT is very different from the composition of primary waste BATT, which for example contain no cobalt.

Data on “recycling of batteries and accumulators” are published by Eurostat (2016a) for three categories that are less detailed than the BATT keys: lead, nickel-cadmium and “other” batteries. Some countries report flows of collected batteries that are fed to recycling inside and outside the country, other countries report only the batteries recycled within the countries, which result in inconsistencies and possible double counting. In ProSUM, it has been:

1. Assumed that collected waste batteries may be exported within the EU for recycling, but not outside the EU.
2. Decided to quantify, for each BATT key, country and year, “only” the flows of collected batteries. Some national data on flows fed to recycling in one country may be available in the Eurostat data on “recycling of batteries and accumulators”, but this is not reliable enough for inclusion into the harvesting database. For most countries, the Eurostat data on “recycling of batteries and accumulators” reflect the collected volumes.

Information on the battery keys in the flows (parameter p-f) is presented in some publicly available reports from national authorities such as France (ADEME, 2016) and in England (Environment Agency, 2016), from compliance schemes such as the German GRS (GRS Batterien, 2015), and were provided by the industrial association Eucobat (2016), which collects the data from its members.

For the 28 member states of the European Union as well as Switzerland, Norway and Iceland, the following steps were applied:

- The data from Eurostat (2016a) on recycling of lead, nickel-cadmium and "other" batteries were collected for all countries. It was assumed that all "other" batteries are portable, because automotive batteries are only lead-based, and the collection of industrial batteries that are neither lead-based nor nickel-cadmium (i.e. mainly lithium-based batteries) is still very low. Based on the key figures of Eucobat (2016), the shares of zinc-based, lithium primary, NiMH, lithium rechargeable and other batteries were estimated. For some countries, national data are available on the shares of zinc-based, lithium primary, NiMH, lithium rechargeable and other batteries. For the other data, an EU average was used.

- The data on collection of portable batteries from Eurostat (2016b) was compared with the data of EPBA (2015). Even though in 2009, the data were not consistent in many countries (Figure 5), harmonisation efforts across the countries have achieved that the figures were well aligned in 2014 (Figure 4). Where Eurostat data do not match the EPBA data, usually Eurostat was selected, except if expert knowledge furnished evidence that the EPBA data were more valid. This selection is documented in the metadata.

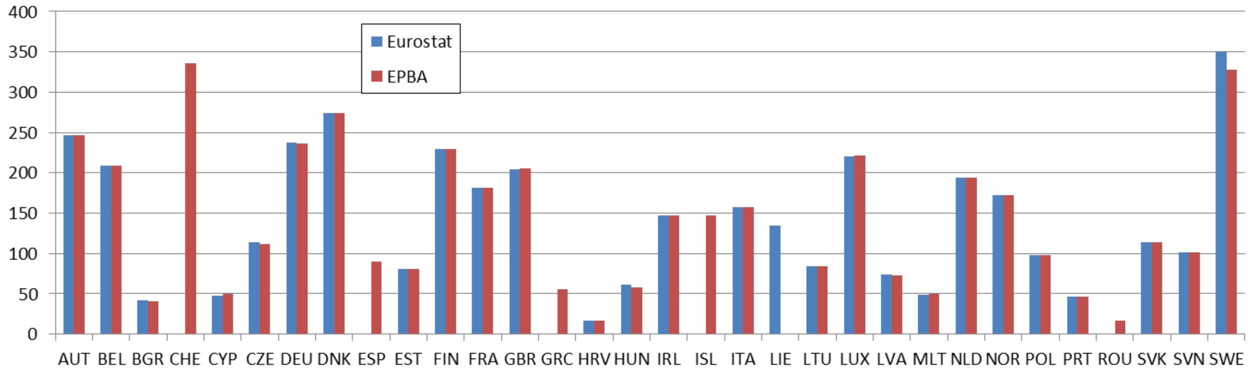


Figure 4 Comparison of the Eurostat and EPBA data on collected portable waste batteries, in g/inh in 2014

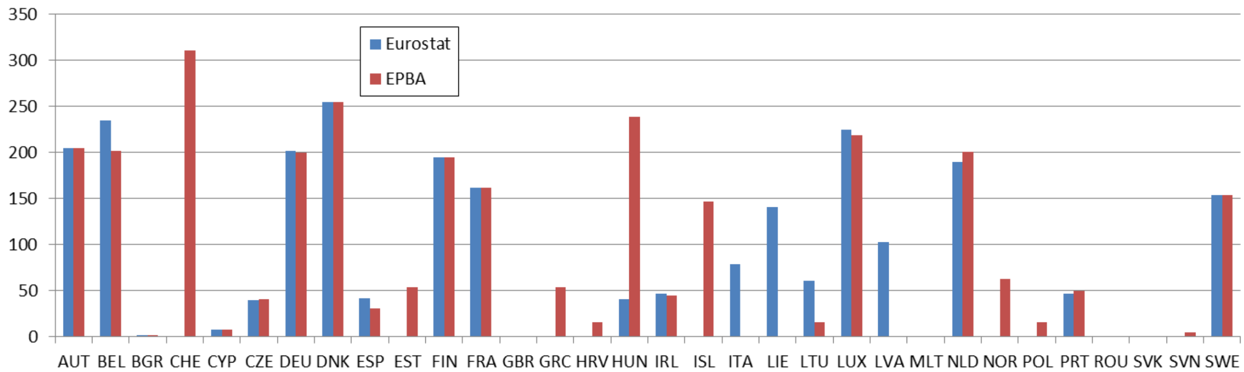


Figure 5 Comparison of the Eurostat and EPBA data on collected portable waste batteries, in g/inh in 2009

For the countries and years for which the Eurostat data (Eurostat, 2016a) on recycling of "other" batteries are not available or not realistic, the data on collection of portable batteries from Eurostat and/or EPBA were multiplied with estimated shares of Zinc-based, Lithium Primary, NiMH, Lithium Rechargeable and other batteries according to the Eucobat key figures. The data on collection of portable batteries were compared for every country with the data on recycling of "other" batteries. The best available data were selected. In most cases, the volumes reported as collection of portable batteries were higher than the volumes reported as recycling of "other" batteries, due to the fact that some portable batteries are NiCd and lead-based.

- The Eurostat data (Eurostat, 2016a) on recycling of lead and nickel-cadmium were checked for reliability by comparing with data from other sources (national authorities, reports from BATT compliance schemes, Eurobat figures, ACEA, JAMA, KAMA, & ILA (2014)) and using expert knowledge. Unrealistic data, which may indicate that a country includes waste batteries imported for recycling in its reporting, were removed. The shares of portable, automotive and industrial lead and nickel-cadmium batteries were estimated as a reliability check, but these estimates will not be integrated into the harvesting database. As explained in Deliverable 3.2, for industrial BATT and for automotive BATT the data are scarce and there is insufficient supporting evidence to assess whether the above potential flows are significant. Industrial BATT are often mixed with portable BATT due to challenges in distinguishing between industrial and portable battery at a collection stage.

The detailed origin of each dataset (differentiating the BATT key, the flow, the country and the year) is documented in its metadata.

The available data enable to quantify the flows of collected batteries at BATT key level, but not to go to e-f level. This can be done by using the composition data collected in WP2, because the average material composition of batteries with a specific electrochemical system does not significantly change over time.

2.1.3.2 BATT CRM flows and recycling efficiency

According to the Batteries Directive, battery recycling companies are required to collect data to calculate recycling efficiency: the quantity of input waste batteries sorted/treated, the output (sorted fractions and/or products) and the composition of the fractions. Some of these data are published (GRS Batterien, 2015; ADEME, 2016) and show the amount of secondary resources produced by BATT recyclers. Most data are unpublished and confidential. The available data will not be integrated into the harvesting database because:

1. The data do not address specifically CRM but focus on bulk materials, as well as hazardous substances like lead and cadmium. Some CRM are mentioned in the published data.
2. The geographical coverage is too limited for all resources except lead and cadmium (for which data can be found for 2014 and 2015 in Eurostat but not for CRM). The only available data come from France and Germany.

Those reporting data on CRM flows are expected to be expanded in the next years, due to the development of European and national legislation. A task for the future would be to check the data quality of the produced data and to integrate robust data into the harvesting database.

2.1.3.3 Link to WEEE - Collection of waste batteries by WEEE treatment facilities

Batteries in EEE contribute around 20% to 30% of portable batteries placed on the market (EPBA, 2015). D3.2 presented estimates for BATT in collected WEEE and indicated that the BATT extracted from WEEE are likely to be recycled through official treatment routes and that, given its possible illegality, it is impossible to get verifiable data quantifying the amount of BATT not extracted from WEEE. According to EPBA (2015), studies suggest up to 40% of WEEE and used EEE may be improperly treated in or outside the country in which the EEE was originally placed on the market.

The data on collected flows in tonnes introduced in the previous section include batteries from WEEE dismantlers. Organisations collecting batteries are often not able or willing to identify the share of waste batteries removed from WEEE in total collection volume (EPBA, 2015). Public and confidential data from organisations suggest the share of batteries removed from WEEE is on average 7% in the 19 countries investigated by EPBA (2015), and ranges from 1% to 20%. This range matches the Eucobat data (Eucobat, 2016) from compliance schemes on the share of batteries collected by WEEE dismantlers in 2015.

The available data on waste batteries extracted by WEEE dismantlers are not considered consistent and robust enough to be integrated into the harvesting database (when compared to the data coming from WEEE collection and treatment).

2.1.3.4 Link to ELV – Automotive lead batteries

The available data show that around 1.3 million tons of lead-based batteries were sent for recycling in 2013 in the EU (Eurostat, 2016a), from which, according to Eucobat (2016), around two thirds are automotive batteries. By assuming an average battery weight of 18.75 kg (Avicenne, 2016), that means around 55 million lead-acid automotive batteries were recycled in 2013.

For ELV, around 6 million end-of-life vehicles were dismantled (data source Eurostat) and around 45 million after-market batteries were sold (Eurobat, 2013), i.e. around 45 million end-of-life batteries were recycled after being replaced. In total, that would mean that around 51 million lead-acid automotive batteries were sent for recycling.

This rough verification shows that both estimates have the same order of magnitude (55 vs. 51 million lead-acid automotive batteries). The level of detail of the available data does not allow a more detailed consolidation of data coming from BATT collection and from ELV dismantling.

2.1.4 Selected flows and deposits for ELV

In D4.1, an inventory of potential data sources for ELV flows and deposits was reported. Few sources were found, and the most comprehensive and aligned was chosen as the single source of data on ELV generation and treated waste for ProSUM i.e. Member States' (MS) reports on the ELV directive as published by Eurostat (2016c). In ProSUM, Eurostat data has been retrieved and somewhat elaborated to describe all mass flows in the ELV waste treatment system illustrated in the flowchart in Figure 6. Process numbers indicate the Eurostat table from which the data was retrieved. Note that only formally treated and reported flows and processes are included. No data on CRM composition has been included since such data is scarce and highly variable in existing data sets, which is further explained in section 3.3.2 and in Annex 3.

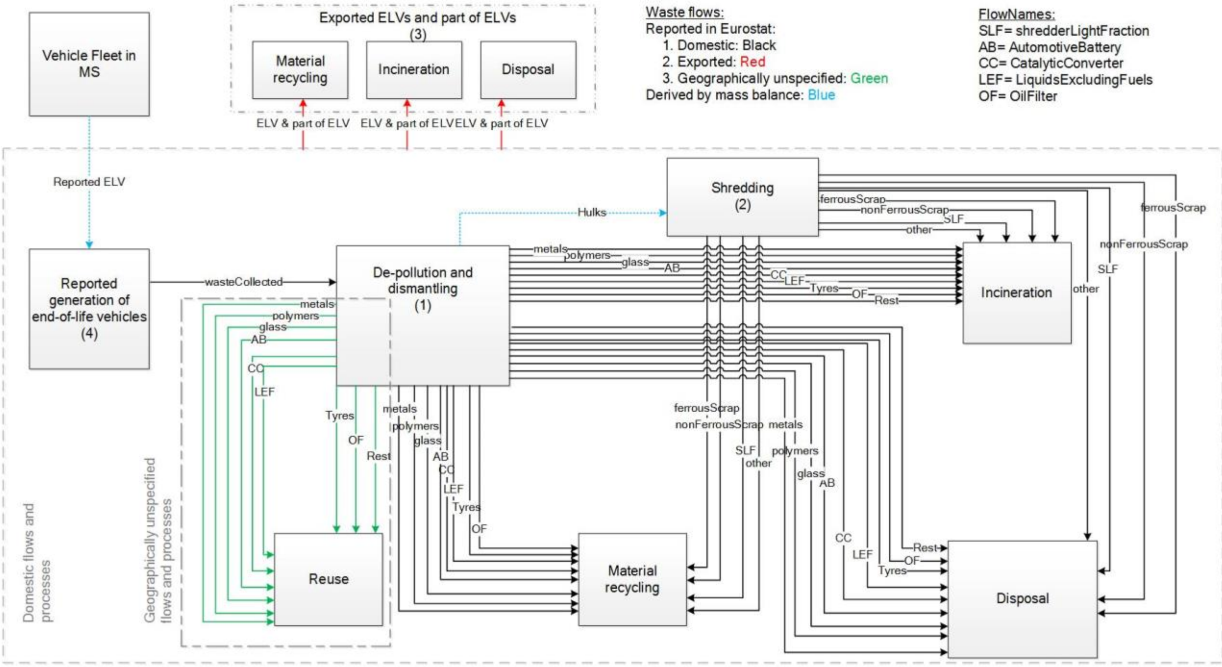


Figure 6 Flow diagram showing the data on ELV treatment flows in ProSUM. All data originate from Eurostat, either directly extracted (black, red and green lines) or derived from mass balances (blue dashed lines).

Eurostat data are published in four tables, all describing annual arisings in tonnes per country: (1) Treatment of materials from de-pollution and dismantling, (2) Treatment of materials from shredding, (3) Treatment of exported ELV, and (4) Generation, reuse, recycling and recovery of ELV (see Appendix).

The inflow to the system is the reported generation of end-of-life vehicles, “Generation of end-of-life vehicles”. The delimitation for reported vehicles means that vehicles discarded, exported or otherwise taken out of use without being reported are not included. The quantity of such unreported flows has been estimated to around 3.5 million vehicles per year in the EU during the last decade (Oeko institute, 2016). The quantification of complementary flows was a task of D3.2.

The reported generation of ELV is assumed to equal the inflow, “wasteCollected”, to the process of De-pollution and dismantling (further referred to as Dismantling). The nine outflows from Dismantling equal the ones reported by Eurostat except “Rest” which is the aggregation of the two flows “Other materials arising from de-pollution” and “Other arising from dismantling”. These flow types are not mandatory to report and are, for the MS that do not report them, treated as data gaps in ProSUM (flows were fully reported for 50% of MS in 2014).

The flow “Hulk” is not reported as output from Dismantling nor as inflow to Shredding by Eurostat, but has been derived through mass balances (see Section 4). The four output flow types from the shredder equal the ones available at Eurostat.

Exported flows are reported as total mass flows to material recycling, incineration or disposal and include ELV, part of ELV and ELV-related waste by Eurostat. There is no information on the split between the processes they originate from, nor the country to which they are exported. No separation is made between domestic and exported reuse flows reported by Eurostat (green flows in Figure 5), which is also how they are treated in ProSUM.
The data cover passenger cars with up to 9 seats and vehicles for transport of goods up to 3.5 tons (vehicle types M1 and N1 in international vehicle classification). The data reported by MS to Eurostat follows regulations and is designed for monitoring the targets on reuse and recovery as well as on reuse and recycling in the ELV Directive (EC 2005). Since all Europe Economic Area

(EEA) countries report, Liechtenstein, Norway and Iceland are included in addition to EU member states. Data, submitted to Eurostat 18 months after the end of a reporting year (Eurostat Statistics Explained, 2016), is available from 2005-2014 with increasing coverage in later years. The countries with the largest flows, such as Germany, Spain, France, Italy and UK, are well represented from 2006-2007. In ProSUM, data from 2008-2014 are included, due to lower coverage and some data irregularities in the first years. The reporting of Switzerland follows national regulations (Der Schweizerische Bundesrat, 2005) and differs significantly from that of the ELV directive. Although detailed data are reported by depollution- dismantling- and shredder facilities in Switzerland, these are generally not publicly available. Moreover, the Swiss ELV-related waste flows are not reported according to their treatment type (reuse, recycling, incineration, disposal). Thus, the inclusion of Swiss data has been limited to the input to dismantling and depollution (officially collected waste) and the mass flow of hulks from dismantling and depollution to shredding within Switzerland, for the year 2014.

The data cover passenger cars with up to 9 seats and vehicles for transport of goods up to 3.5 tons (vehicle types M1 and N1 in international vehicle classification, UNECE (2016)). No similar statistics exist for other vehicles such as heavy duty trucks, buses and construction equipment, which makes their inclusion impossible.

Note that the ELV Directive recycling and recovery rates are in fact defined in relation to the reported quantities of treated ELV (since "generation" is handled as equal to reported treatment). Thus, the rates describe the efficiency of the treatment of collected waste, disregarding any uncollected ELV, and are therefore measures of waste treatment efficiency. This differs from the recycling and recovery rates in the WEEE Directive which are set in relation to all WEEE generated and are therefore measures of the efficiency of collection and waste treatment combined. In the following sections, the ProSUM elaboration of the Eurostat data will be further explained.

2.1.4.1 Elaboration of data on exports and imports

Exports must be reported and imports must not be included in any data so that recycling and recovery rates can be assessed for each MS individually (Eurostat, 2013). Furthermore, it must not only cover entire end-of-life vehicles, but also depolluted and dismantled end-of-life vehicles (hulks) and waste from treatment such as material and components arising from dismantling and shredder output (Eurostat Statistics Explained, 2016). It is acknowledged that finding information that makes it possible to distinguish between exported and domestic flows is challenging (Eurostat Statistics Explained, 2016 and Oeko-Institut, 2016). Additionally, the data could be distorted by used vehicles exported for final disposal instead of for reuse, also referred to as illegal exports (Eurostat, 2013).

Each MS has to derive ratios for the distribution of exported flows over material recycling, recovery and disposal, see Figure 2. In practice, the ratios may vary with e.g. export destination, age and material composition of the vehicle, shredder technology and parts in consideration (Eurostat Statistics Explained, 2016). The ratios should be described in quality reports accompanying data sets (Eurostat, 2013). These reports can be made confidential and are not even required to be shared with Eurostat and so far no such reports are published by Eurostat.

Since imports should be excluded in reported data, MS should also state how the inclusion of imports is avoided and how unofficial exports and imports are corrected for (Eurostat, 2013). Imported ELV, de-polluted ELV, hulks, and parts of ELV could arrive at treatment facilities without information about being imported (Eurostat, 2013). Resulting outputs could hence be mistaken for domestic waste. Theoretically, imports could be part of all flows indicated by the blue lines in figure 2, due to illegal exports resulting in illegal imports and to lack of information about the share of treatment output arising from imports. The risk concerns flows from both dismantling and shredding, but is likely smaller for dismantling where the origin of the ELV could be monitored more easily.

Exports for reuse are reported together with the reported reuse in the MS. Consequently, the exported quantity is not known, only that it can be part of reported quantities to reuse from dismantling (Eurostat, 2013).

In summary, due to lack of information, it is impossible in ProSUM to capture exports and imports between MS and to detail from which treatment processes the flows originate.

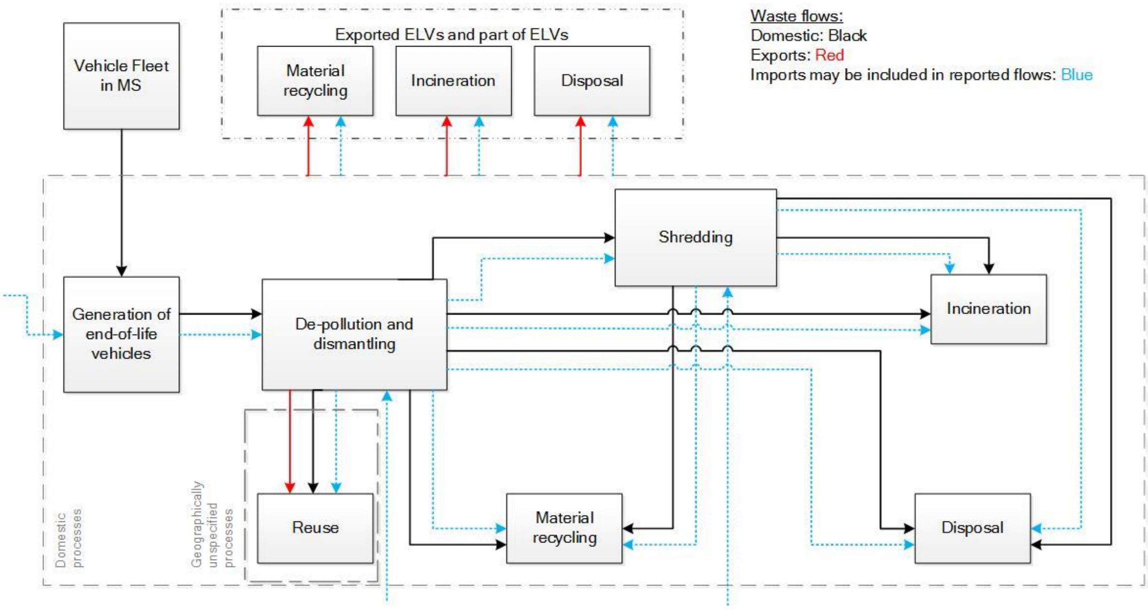


Figure 7 System overview of exports and imports. Domestic flows are black, exports red and flows where imports may be included in are blue if reporting guidelines have not been fully followed.

The challenges in reporting exports can be illustrated by, for example, Luxembourg in 2006, Sweden in 2006 and Cyprus in 2007. Reported total exports to recycling exceeds recovery, which leads to negative figures for incineration, since recovery should be the sum of recycling and incineration (for example, incineration in Luxembourg in 2006 would be 32-3872 = -3842). This suggests that incorrect values have been reported or that guidelines have been not been followed.

2.1.4.2 Eurostat reporting approaches

MS can choose between two reporting approaches: compiling data obtained from operators of authorised treatment facilities or calculating data using the “metal content assumption” (MCA) (Eurostat Statistics Explained, 2016). With the MCA approach, metals flow types are exclusively reported in the table for total recycling and reuse rate without accounting for from which processes they arise or if they are exported. UK and Ireland are among countries using the MCA approach, while Norway and Sweden are among countries reporting data derived from operators. The chosen approach also affects data quality, uncertainties (Eurostat Statistics Explained, 2016), and comparability between MS.

Data derived from operators is not likely to cover all active operators since the number is often large, in particular that of dismantlers. Dismantlers do not always report mass quantities, but instead the number of units or volumes, which are then converted to mass assuming unit or volume weights. Reports from shredder operators are often based on samples since inputs and outputs are not measured continuously. Also, it is influenced by the variability of the inflows of ELVs and other waste shredded.

The MCA approach balances "the risks of inaccuracies and the administrative efforts of achieving precise information… ", and works as "… a data-based assumption concerning the average percentage of reused, recycled and recovered metal of end-of-life vehicles…" (Eurostat, 2013).

1. MCA $= Metal\ content\ of\ ELV * Output\ factor$

The metal content of ELVs is the metal share of the weight of a given car. To derive it two additional equations are needed:

2. $Average\ metal\ content\ of\ all\ ELV\ of\ year\ (i) \approx$
   $Average\ metal\ content\ of\ all\ cars\ M1\ and\ N1\ registered\ in\ year\ (i-a)$

3. $Average\ metal\ content\ of\ all\ cars\ registered\ in\ year\ (i-a) =$
   $\sum_{k=1}^{n} Metalcontent(producerK) * \frac{number\ of\ registrations\ of\ producerK\ in\ year\ (i-a)}{total\ number\ of\ registrations\ in\ MS\ in\ year\ (i-a)}$

Equation 2 calculates the average metal content of all ELVs in a given year (i), where the average age of the ELV in year (i) is (a). Equation 3 determines the average metal content of the car models entering the market in a year weighted by their market shares (Eurostat, 2013). For instance, if the average lifetime of ELV is assumed to be 14 years, then the metal content assumption of ELV in 2016 should refer to metal content of vehicles entering the vehicle fleet in 2002. Equation 1 also includes the *output factor*, which is the share of metals that are reused, recovered or recycled. In conclusion, the MCA includes the total metal output of reuse, recovered and recycled metals of ELV treatment.

MS using MCA should not report any dismantled metal flows since these should be accounted for by the MCA. This is illustrated for example by UK in 2013, where the metal components from dismantling are not reported and the reported data is clearly linked to non-metallic components and materials such as tyres and liquids.

Furthermore, data on metals from the shredding process should be filled in as ferrous scrap and non-ferrous materials for recycling. Neither incineration nor disposal are applicable. Any metal losses in shredder light fractions (SLF) or other flows are not accounted for. This is illustrated by for instance Hungary in 2009, where the total mass going to disposal is the sum of SLF and other materials arising from shredding. What may look like reporting irregularities between countries, could in fact be due to the different procedures.

2.1.4.3 Overview of elaboration of Eurostat data

Some data used in ProSUM are derived through elaboration of data reported by Eurostat, see Table 2. Total shredding outputs were calculated by summarising disposal and recovery, based on the assumption that input equals output for the shredder process, and that recovery is the sum of recycling and incineration (Eurostat, 2013). In Eurostat, there is no data for exports to incineration, which was instead calculated assuming that recovery equals recycling minus incineration (Eurostat, 2013).

Table 2 Overview of data conversion

ProSUM excel sheet notation	Eurostat table number	Eurostat table name	Conversion description
A	1,2,3,4	1. Treatment of Materials from de-pollution and dismantling within the Member State, by waste category, treatment type country and year, in tonnes. 2,3,4: names as described below.	Data reported as described in the source
B	2	Treatment of Materials from shredding within the Member State, by waste category, treatment type, country and year, in tonnes	Total shredding = Disposal + Recovery
C	3	Treatment of Exported ELVs, by country, treatment type and year, in tonnes	Incineration = Recovery – recycling
D	4	Generation, reuse, recycling and recovery of ELVs, by treatment type, year and country, in number of cars, tonnes and percent (%)	wasteCollected in ProSUM = Waste Generated in Eurostat

The inflow to the process Generation of end-of-life vehicles is assumed to equal wasteCollected, given that there are only one inflow and one outflow:

1. $wasteCollected = generation\ of\ ELV$

The inflow to shredding, hulks, from dismantling can be calculated based on outflows from shredding reported by Eurostat:

2. $Hulks = ferrousScrap + nonFerrousScrap + SLF + other$

Inflows to shredding also equal one of the outflows from dismantling (since shredding should not include imported ELVs). This outflow from dismantling is not reported, but could be calculated as the difference between wasteCollected and the sum of all other outflows from dismantling.
Thus, there are two alternative ways of deriving the inflow to shredding: as the sum of outputs from shredding; or as the difference between inflows and outflows from dismantling. If the two are equal, the following relationship holds:

3. $wasteCollected = Total_{reuse,dismantling} + Total_{MaterialRecycling,dismantling} + Total_{Incineration,dismantling} + Total_{Disposal,dismantling} + Hulks = Total_{reuse,dismantling} + Total_{MaterialRecycling,dismantling} + Total_{Incineration,dismantling} + Total_{Disposal,dismantling} + ferrousScrap + nonFerrousScrap + SLF + other$

where, for example, total reuse from dismantling can be calculated as the sum of reused flows from dismantling:

$$Total_{reuse,dismantling} = metals + polymers + glass + AB + CC + LEF + Tyres + OF + Rest$$

For some countries, for instance Belgium and Spain, the relationship in equation 3 holds. It may be assumed that that such countries have derived data using the MCA. If it does not hold, or is far from holding, it is more likely that data derived from operators has been reported to Eurostat, without adjusting it. It is difficult to say which approach results in more reliable data, it may depend on country specific conditions. Additional plausible explanations for why some MS have unbalanced data could be: stockpiling over years, errors in reporting of data, errors in measuring input/output, mistakes in calculations, incorrect assumptions regarding data and missing data for imports/exports.

Some additional information on data is reported by Eurostat, such as missing values, estimates, or estimates done by Eurostat. This information has been included in ProSUM in the notes column.

Codes were added to ProSUM code lists in order to keep the level of detail and information of Eurostat data, see Table 3.

Table 3 New codes added to the ProSUM code lists

Process	Eurostat	ProSUM code	Code classification
De-pollution and dismantling	Liquids (excluding fuels)	LiquidsExcludingFuels	Component group
De-pollution and dismantling	Tyres	Tyres	Component
De-pollution and dismantling	Oil Filter	OilFilter	Component
De-pollution and dismantling	Other materials arising from de-pollution Other arising from dismantling	Rest	Material
Shredding	Ferrous scrap	ferrousScrap	Downstream waste flow fraction
Shredding	Non ferrous scrap	nonFerrousScrap	Downstream waste flow fraction
Shredding	Shredder light fraction	shredderLightFraction	Downstream waste flow fraction
Shredding	Other	Other	Downstream waste flow fraction

2.1.5 Selected flows and deposits for MIN

Every mining, quarrying and mineral processing operation generates MIN. A primitive way to estimate the amount of waste generated by mining is to use available databases on mines and their ore production and use average waste rock/ore factors for different mining methods. Figure 8 shows the location of more than 1600 mines for which the amount of waste rock have been calculated that way. Please note that preliminary data on MIN from mineral processing cannot be calculated in the same way since we do not have a common EU-database for mineral processing plants.

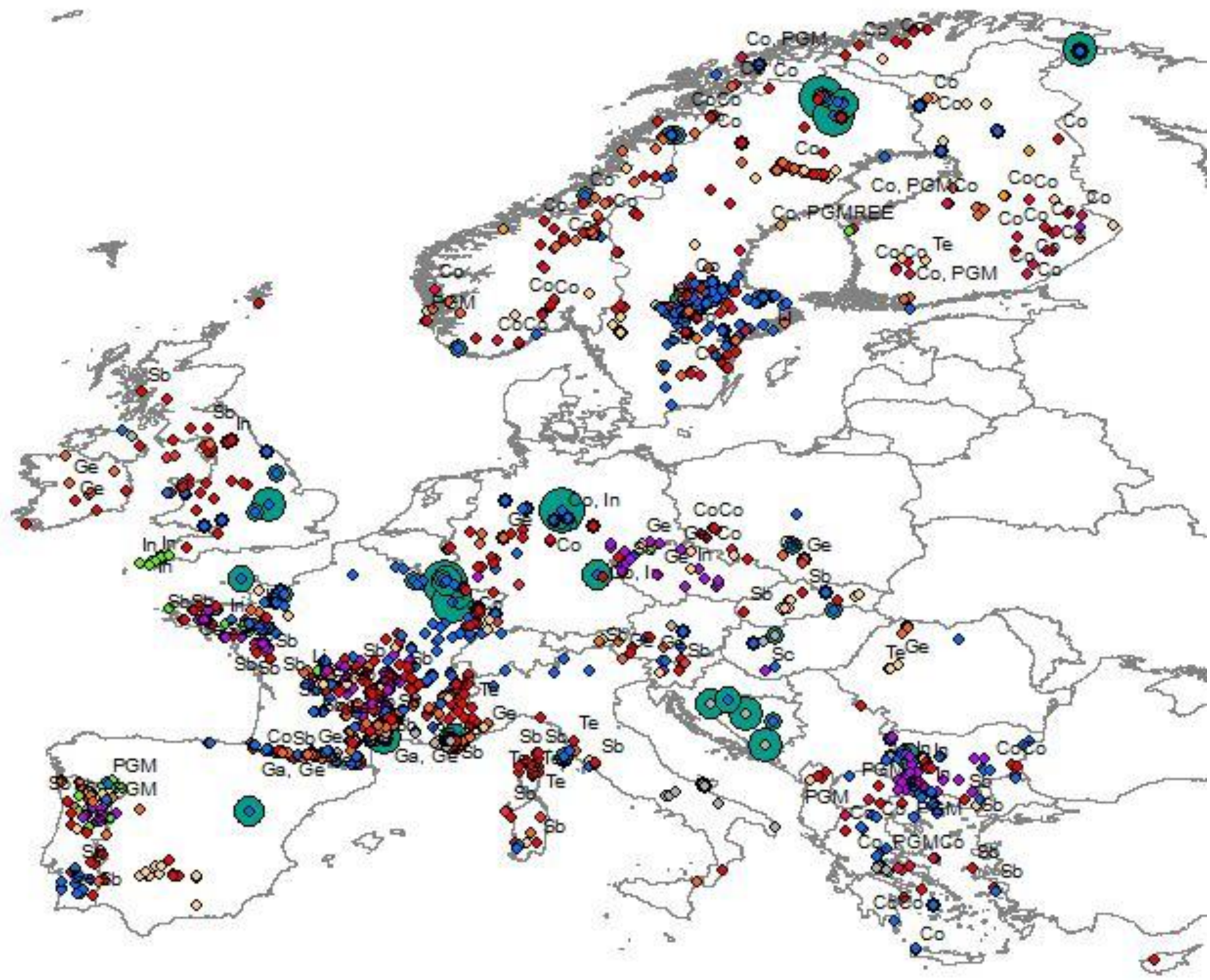


Figure 8 Map of Europe showing closed and operating mines. Green circles represent the calculated amount of waste rock where the largest circles represent more than 500 Mt of waste rock. Diamonds represent smaller mines and colors represent type of ore; blue for iron and iron-alloy metals, yellow for precious metals, red for base metals, grey for bauxite, violet for energy metals (U) and green for special metals. Data from ProMine (http://promine.gtk.fi/)and FODD (http://en.gtk.fi/informationservices/databases/fodd/).

One of the main goals for ProSUM is to create a common framework for the collection and storage of data on MIN including location, amount and composition. This will be achieved through an extension of the existing Minerals4EU framework including data on MIN. Collection of data on MIN from the participating countries will then take place through the existing harvesting system for Minerals4EU. The work so far has resulted in an improved data model for MIN completed in WP5 (Cassard et al., 2016) and a set of code lists completed in WP4 and WP5. To finalise the collection of data, the existing M4EU model has been modified accordingly to better handle MIN related data. The system will be fully operational early in 2017.

From this dataset a selection will be made in order to gather data on the most important waste deposits with respect to the CRM as well as the common commodities. The selection will be determined, in order of priority, by;

1. Size of waste deposit:
   The deposit must be large enough to justify investment in infrastructure, extraction facility and permitting processes. A very large MIN deposit can compensate for a low grade.

2. Metal and/or mineral content:
   The deposit must contain sufficient concentrations of metal or mineral, common commodities as well as new commodities (CRM), to enable future extraction.

3. CRMs:
   MIN deposit with sub-economic levels of CRM that must be extracted due to an acute shortage of supply. The reason why CRM are not given a top priority is that most of the data available are limited to those commodities that gave economic viability to the mine or processing plant, i.e., common commodities such as iron and alloy metals, base metals and precious ones. Since mining in Europe and in the world has been and remains focused on these commodities we have a lot of good quality data for those. More rare metals and minerals with lower economic or environmental importance, including several of the CRM, were seldom analysed and reported. Most of the CRM occur together with common commodities for which they have physical and/or chemical affinities (e.g., Verhoef et al., 2004) and there are methods to estimate the CRM content from knowledge of the get around these obstacles. See section 2.3.5 on data gaps for further discussions and methods to solve this dilemma.

4. Active mines and processing plants:
   An active industrial site with access to an industrial infrastructure, skilled work force and some of the necessary environmental and land use permits in place is of interest since the wastes have not reached the stock yet but are still in the process. It is highly probable that an emerging extraction of MIN will start or has already started at active mines and plants.

5. Small MIN deposits:
   Small but metal-rich waste deposits can be of scientific and academic interest but are, in most cases, too small to allow a profitable metal or mineral extraction. For those a combined metal and mineral recovery and a mine site restoration, co-funded by environmental authorities and extractive company is a more realistic case. These deposits will be considered but their small size give them a lower priority.

6. The unexpected:
   The efforts to collect data at the national level, including sampling and analysis, compilation of data from literature and otherwise, may result in the discovery of MIN deposits with grades of metals and minerals that were not expected. These deposits will also be considered but the search for them cannot be prioritised.

The work of gathering data is ongoing in several participating countries and has already been done in some. The search for the most interesting MIN deposits is in progress at national level and will, with a common database for the whole EU, be carried out at EU level. Results from Sweden are shown below in paragraph 2.3.5.

2.2 Statistical evaluation of the data and procedures to handle uncertainties

To develop methods for the statistical evaluation of the data and procedures to handle uncertainties is not only an objective of Task 4.2, but a core challenge of the entire ProSUM project. To address it globally, a common "ProSUM Harmonisation paper" was produced and published on the ProSUM webpage for external feedback and consultation (Huisman et al., 2016; Loevik et al., 2016). The Harmonisation paper presents the definitions, classifications of stocks and flows, products, components, materials and elements, and the harmonization of metadata descriptors, data quality (DQ), uncertainty and error propagation agreed at project level.

The main points relevant for the statistical evaluation of the data and procedures to handle uncertainties in Task 4.2 are:

- Three types of information are distinguished: i) sources containing actual **measured data**; ii) sources based on **coherent estimates** and substantiated extrapolations; and iii) sources with expert assumptions and extrapolations which are insufficiently substantiated. Data of this third type is included in the analysis and project files, but excluded from the portrayals and Knowledge Base. Comments related to the data quality assessment; the description of data consolidation steps where applicable; and the type of estimation used to produce a coherent estimate, e.g. extrapolation and/or interpolation, is also stored in a harmonised way.
- Four data quality levels are used :
    - A = Highly confident: This level is defined as estimates or values based on a large number of measurements made from a large number of sources that represent a large part of the population.
    - B = Confident: A value based on a number of measurements made at a small number of representative samples, or an engineering calculation/estimate based on a number of relevant facts and data points.
    - C = Less confident: A value based on a single measurement or an engineering judgement or estimate derived from a number of relevant facts and some assumptions.
    - D = Dubious: An estimate or value based on an engineering judgement derived from assumptions only, or from a very limited number of data points.
- The common approach for judging data quality is based on unambiguous criteria:
    - Is there a clear and consistent definition of the (product) scope and is temporal, geographic and demographic representativeness well specified?
    - Are the sample size, assumptions and limitations to the data well described?
    - Are there alternative sources (partly) confirming the data? Does the data fit into the time series, when available?
    - When the data points are derived from a model: what is the scale of the model and is the model validated?
    - How many assumptions, estimates and proxies are made and how far reaching are they?
- For quantitative sources with their statistical information, the ProSUM data model allows for various units of measurement for uncertainty. For sources without statistical information, the uncertainty ranges need to be estimated to allow an assessment of the total uncertainty ranges. A common qualitative judgement is used with distinct values for 'stocks and flows' (Table 4) versus 'composition' (Table 5).

Table 4 Uncertainty levels for qualitative sources for flows

Data Quality Types	Ranges for qualitative judgement (flows)	Mean
Highly confident	0-10%	5%
Confident	>10-20%	15%
Less confident	>20-50%	35%
Dubious	>50%	100%

Table 5 Uncertainty levels for qualitative sources for composition

Data Quality Types	Ranges for qualitative judgement (compositions)	Mean
Highly confident	0-20%	10%
Confident	>20-50%	30%
Less confident	>50-100%	75%
Dubious	>100%	200%

Metadata information will be catalogued using fields based on Dublin Core descriptors. These metadata descriptors are harmonised within the entire consortium to describe the consolidated data in the databases and to share and collate bibliographical files. Due to the expected multitude, variety and complexity of the data sources, additional fields were added to build, maintain and manage the ProSUM bibliography and Knowledge Base, and a more precise description and definition was developed for the descriptors used in the Dublin Core, which are in some cases open to interpretation. An interactive bibliography file was created, providing a unique metadata ID, which is used throughout all project databases. The so-called 'MICKA' catalogue (see Cassard et al., 2016) is used as a tool for structured data to allow for the description of consolidated sources. The use of meta data describing all used sources in this and the adjacent deliverables D2.5 and D3.3, as well as higher level summaries of the data consolidation process for completed datasets, are prepared and in an advanced stage for use in D5.6 Creation of the Metadata System which is due for June 2017.

2.2.1 Assessment of the data quality for WEEE

In general for the data sets used in this Deliverable, the answers to the criteria for judging the data quality for WEEE are as follows:

1. Is there a clear and consistent definition of the (product) scope and is temporal, geographic and demographic representativeness well specified?
   The product scope is clearly defined and it includes all types of WEEE and PV panels. Its temporal data description includes the years 2010-2014. In the case of the proof of concept example, p-f for microwaves, it was done for 2012-2014. The sample size used is taken into consideration when evaluating the quality of datasets. The average weight per product is generally not considered country dependent, the average weight in return stream is not country specific but depends on the age of the products.
   The five collection flow composition datasets from third parties differ substantially, therefore when an extrapolation or consolidation was done the size of the flow and its quality of its datasets are taken into consideration. The average weight for proof of concept example is taken from a highly confidential third parties source dataset.

2. Are the sample size, assumptions and limitations to the data well described?
   Where information is not available or not representative, further information is provided within this deliverable. Frequently, dubious or non-representative sources and data points are removed from the consolidated dataset. This is for example the case for p-f data, where it is known and obvious that the collection data is not representative for the country involved. This applies as well for certain countries with multiple compliance schemes in place with an uneven ratio for certain categories and/or individual products.

   For Average Weight, except some country dependent ones like fridges, it is assumed the Average weight distributions are not country dependent, meaning the product characteristics for instance for tablets are country independent. Depending on the sample size and the quality of the data found in the third parties datasets, the p-f consolidation step is done. The uncertainty levels used are the same used and described in D3.2 and D3.3 and shown in Table 5.

It is important to note that how representative the datasets are in respect to the differences for various countries is not always known in the case of p-f data. For composition with a sufficient sample size, this is generally more country and region independent. Therefore, the data quality approach will differ for analysing p-f data compared to compositional analysis as performed in D2.5.

3. Are there alternative sources (partly) confirming the data? Does the data fit into the time series, when available?
   All sources analysed are compared with alternative sources allowing us to have a higher quality of data. For the p-f microwave example, third party datasets were compared. Country studies done by UNU for quantifying amounts of WEEE in different EU member states (Huisman et al., 2013, Magalini et al., 2013, Wielenga et al., 2013, Monier et al., 2013, Magalini et al., 2015) WRAP, Eurostat and the CWIT project (Countering WEEE Illegal Trade) cover some of the main flows for 2010 and 2012 (Huisman et al., 2015) are used for the calculation of complementary flows.

4. When the data points are derived from a model: what is the scale (reach?) of the model and is the model validated?
   This is not applicable for Average Weight and p-f product frequency count for WEEE.

5. How many assumptions, estimates and proxies are made and how far reaching are they?
   The quality assessment done for p-f is weighted depending on the type of data source, year of the data source and sample size it represents. Datasets that were considered uncertain or based on too few data points could hamper a proper consolidation of the flow and therefore were done in the same way as described in D3.2: Sources are weighted with the stated factor for dubious, less confident, confident and highly confident. Non-representative and data points based on expert guesses are excluded. In the case of qualitative information, the statistical information is used as done for the Average Weight for POM data from details national market input data.

   It is important to note that in the case of p-f, the consolidation of data is more country specific and unfortunately it is not always known how representative the datasets are for a specific country in respect with those from various countries. On the contrary, for compositions data, with a sufficient sample size, this is generally less country and region independent. Therefore, the data quality approach differs for analysing p-f data compared to compositional analysis as performed in D2.5.

The aforementioned 5 data quality criteria are also applied to the individual data and the results are included in the consolidated data sets describing data quality. Following the uniform approach, for sources with only qualitative information on the data quality, the 4 uncertainty levels are applied in a similar way as for the other data model components.

It is important to maintain a uniform and standardised approach among all products BATT, ELV and WEEE for evaluating data quality and uncertainty levels in the case of absent information. Therefore, the same approach as the one described in D3.2 is maintained in the evaluation of the different datasets for WEEE flows.

2.2.2 Assessment of the data quality for BATT

The data on the selected BATT flows are, as described in section 2.1.3, reporting data. The BATT related answers to the criteria for judging the data quality are as follows:

1. Is there a clear and consistent definition of the (product) scope and is temporal, geographic and demographic representativeness well specified?

This question can be answered with a clear yes for some countries and keys, but not others. A consistent definition of the product scope is not given for the key "battOther", in which, in some countries, batteries may be accounted that should be allocated to the other BATT keys. Other inconsistencies affecting the produced datasets may result from the limits between portable, industrial and automotive industry. Limitations to the temporal representativeness are timing issues, because some collected waste batteries are stocked before being recycled, which can affect the year in which they are accounted in the reporting. Limitations to the geographic representativeness are exports issues, since waste batteries may be treated in another country. This is especially obvious for countries that do not have battery recycling plants like the Netherlands and Portugal. The reporting is not harmonised across the member states on this (see section 2.1.3.1).

2. Are the sample size, assumptions and limitations to the data well described?
   The legislation provides some guidance for the reporting, but there is room for interpretation which leads to differences in the data collection and reporting procedures of the member states. These procedures are not well documented in most countries, so that it can be concluded that the assumptions and limitations to the data are not well described. In other countries like France, Belgium and Germany, the reporting procedures are clear.

3. Are there alternative sources (partly) confirming the data? Does the data fit into the time series, when available?
   This was checked by comparing the Eurostat, EPBA, Eucobat, data from the national authorities and from compliance schemes, and strongly influenced the evaluation of the data quality. The data fit into time series was checked and influenced the evaluation of the data quality of some datasets. Some explanations of data not fitting into a time series were found, e.g. due to changes in the methods used for collecting the reporting data. Datasets were classified as "very confident" if data are published by different sources and all available data and time series are coherent.

4. When the data points are derived from a model: what is the scale (reach?) of the model and is the model validated?
   Not applicable here.

5. How many assumptions, estimates and proxies are made and how far reaching are they?
   The main limitations on that are the uncertainties on the shares of the different electrochemical systems in the collected waste batteries, which are mainly derived from the Eucobat key figures. For example, the use of European average figures when national figures are not available reduces the validity of the data.

Data that would be evaluated as dubious were excluded from the consolidated datasets and portrayals available for the EU-UMKDP.

Table 6 summarises, for each BATT key and each year, the number of datasets on collected waste batteries that were evaluated as confident or less confident.

Table 6 Number of data sets which were evaluated as highly confident, confident and less confident, per year and BATT key

	2008	2009	2010	2011	2012	2013	2014	2015
battLiPrimary								
Highly confident	1	2	3	4	4	4	5	5
Confident	10	17	17	19	18	18	22	13
Less confident	5	7	9	8	9	8	4	5
battLiRechargeable								
Highly confident	1	2	3	3	3	3	4	5
Confident	10	17	17	20	19	19	23	13
Less confident	5	7	9	8	9	8	4	5
battNiCd								
Highly confident		2	3	4	4	4	5	5
Confident		9	10	11	13	16	16	13
Less confident				3	1	3	3	2
battNiMH								
Highly confident	1	2	3	4	4	4	5	5
Confident	10	17	17	19	18	18	22	13
Less confident	5	7	9	8	9	8	4	5
battOther								
Highly confident		1	1	1	1	1	1	1
Confident	1	1	1	1	2	2	2	2
Less confident	15	24	27	29	28	27	28	20
battPb								
Highly confident		1	2	4	4	4	4	5
Confident		11	13	15	15	16	19	16
Less confident		1	2	3	4	4		1
battZn								
Highly confident	1	2	3	4	4	4	5	5
Confident	10	17	17	19	18	18	22	13
Less confident	5	7	9	8	9	8	4	5

2.2.3 Assessment of the data quality for ELV

One single source of ELV generation and treated waste is used in ProSUM: MS reports on the ELV Directive as published by Eurostat. The data have mostly been retrieved as is, but some data have been calculated by means of mass balances. In practice, this should mean that most data sets could rely on the quality assessments that Eurostat likely performs when compiling all MS data sets and which, in turn, is likely to make use of MS quality assessments of their individual data sets. However, no such information is available from Eurostat: meta data information for published data sets is missing and no quality reports of individual MS are available. However, we know that data has been controlled and processed, that it is based on extensive reporting to a common directive throughout the EU, that there are guidelines for the reporting, and that the first reporting was done more than 10 years ago. Based on this, quality could be assumed to be rather high, “confident”. At the same time, we know that there are data gaps e.g. due to partly voluntary reporting, that MS use different approaches when reporting, that there is a risk that not all concerned operators report data. Taking this into account, the data quality, despite the processing of Eurostat, may not be so high, i.e. “less confident” or “dubious”. Acknowledging the risk of assessing the quality without access to Eurostat’s meta data and quality assessment, we answer the ProSUM criteria for judging the data quality as follows:

1. Is there a clear and consistent definition of the (product) scope and is temporal, geographic and demographic representativeness well specified?

The product scope is clearly defined and includes M1 and N1 vehicles. Temporal representativeness is likely rather good, but as for batteries, there are probably timing issues due to stocking of vehicles before recycling which can affect the year in which they are accounted in the reporting. Limitations to the geographic representativeness concern exports and imports of ELV, since all reporting is allocated to the country in which the ELV was first generated and not in which it was first (or finally) treated. Countries which import for treatment should consequently not include flows in their reporting, but there is a risk that such flows still get accounted for in the importing country (see section 2.1.3.1). Furthermore, some flows are left unreported for some countries because they are not mandatory.

2. Are the sample size, assumptions and limitations to the data well described?
   Information is not available.

3. Are there alternative sources (partly) confirming the data? Does the data fit into the time series, when available?
   No other data sources are available for comparison.

4. When the data points are derived from a model: what is the scale (reach?) of the model and is the model validated?
   Not applicable here.

5. How many assumptions, estimates and proxies are made and how far reaching are they?
   Assumptions and estimates were made regarding the mass balance of flows reported. These could be said to be far reaching for certain data sets. No estimates were made in order to fill the gaps where MS had not reported data, e.g. if some year was missing or if MS only reported mandatory (aggregated) flows. As explained in section 2.1.4.2, some MS use the "metal content" assumption, while others rely more directly on data reported by processors. This information could potentially inform the data quality evaluation, but is not available due to the lack of access to MS quality reports associated with the reporting to Eurostat.

Table 7 summarises for each ELV data set the quality assessment. It should be noted that a revision will be considered in the coming data consolidation, if more information become available, e.g by Eurostat sharing data quality reports.

Table 7 Datasets provided for ELV evaluated as highly confident, confident and less confident

Flow or stock	Geographical coverage	Time coverage*	Data source	Description of the dataset	*Suggested data quality*
Flow	EU28 + IS, LI, NO, CH***	2008-2013	*Mass balance*	wasteCollected	*Less confident*
Flow	EU28 + IS, LI,NO	2008-2013	Eurostat	from dismantling to reuse: metals, polymers, glass, automotive battery, catalytic converter, liquid excluding fuels, tyres, oil filer, rest	*Dubious*
Flow	EU28 + IS, LI,NO	2008-2013	Eurostat	from dismantling to incineration: metals, polymers, glass, automotive battery, catalytic converter, liquid excluding fuels, tyres, oil filer, rest	*Dubious*
Flow	EU28 + IS, LI,NO	2008-2013	Eurostat	from dismantling to material recycling: metals, polymers, glass, automotive battery, catalytic converter, liquid excluding fuels, tyres, oil filer, rest	*Dubious*
Flow	EU28 + IS, LI,NO	2008-2013	Eurostat	from dismantling to disposal: metals, polymers, glass, automotive battery,	*Dubious*

Flow or stock	Geographical coverage	Time coverage*	Data source	Description of the dataset	*Suggested data quality*
				catalytic converter, liquid excluding fuels, tyres, oil filer, rest	
Flow	EU28 + IS, LI,NO, CH***	2008-2013	*Mass balance*	from dismantling to shredding: hulks	*Less confident*
Flow	EU28 + IS, LI,NO	2008-2013	Eurostat	From shredding to material recycling: ferrous scrap, non-ferrous scrap, SLF, other	*Less confident*
Flow	EU28 + IS, LI,NO	2008-2013	Eurostat	From shredding to incineration: ferrous scrap, non-ferrous scrap, SLF, other	*Less confident*
Flow	EU28 + IS, LI,NO	2008-2013	Eurostat	From shredding to disposal: ferrous scrap, non-ferrous scrap, SLF, other	*Less confident*
Flow	EU28 + IS, LI,NO	2008-2013	Eurostat	Export to material recycling	*Less confident*
Flow	EU28 + IS, LI,NO	2008-2013	Eurostat	Export to incineration	*Less confident*
Flow	EU28 + IS, LI,NO	2008-2013	Eurostat	Export to disposal	*Less confident*

* Time coverage 2008-2013 is not complete for all countries
** As defined in Table 12
*** Time coverage CH: 2014

2.2.4 Assessment of the data quality for MIN

The bulk of the available data on ore, mineral processing and MIN come from the extractive industry, and can be found in annual reports or environmental reports. Their data are based on several thousand of analyses taken during the operations and it is assumed that these data are correct and representative since a correct knowledge of amounts and grade of processed ore is essential and often a legal requirement for the companies. For other data sources, i.e. environmental investigations made by government authorities, research reports etc. the analytical methods are, in most cases, reported and can be used to evaluate the analytical quality.

For the quality assessment on data on the amount and composition of MIN, two code lists have been developed – see Table 8 and Table 9. These were originally means to make it possible to store low-quality data in cases where better data did not exist but serves well as quality indicators.

Table 8 Code list for the quality of information on amount of MIN

Code	Name	Description
highDensityDrillingOrTrenching	High density drilling or trenching	Sampling by drilling or trenching with a sample density sufficient for a reliable statistical calculation of the amount of MIN.
lowDensityDrillingOrTrenching	Low density drilling or trenching	Sampling by drilling or trenching with a sample density not sufficient for a reliable statistical calculation of the amount of MIN.
productionStatistics	Production statistics	Amount of MIN calculated from statistics on produced amount of waste rock, produced amount of tailings, ore input to concentrator minus quantity of produced concentrate or similar. For highest accuracy information on amount of recycled waste (backfill, reprocessed, as aggregates, etc.) is known.
oreProductionStatistics	Ore production statistics	Estimate from direct measurements of the area of landfill and estimates of depths.
fieldMeasurement	Field measurement	Seismic, GPR
geophysicsremoteSensing	Geophysics Remote sensing	Calculations from digital aerial photos, satellite images or similar
literatureData	Literature data	Data from the literature without any information of methods

Code	Name	Description
locationOfMine	Location of mine	The mere presence of a mine or mineral processing plant means that MIN is nearby. No information on amount though it can be estimated from knowledge of the mining activity.

Table 9 Code list for the quality of information on composition of MIN

Code	Name	Description
detailedSamplingAndAnalysis	Detailed sampling and analysis	Drilling or trenching: Sampling by drilling or trenching with a sample density and analytical quality sufficient for a statistical estimation to calculate the amount of material for a resource estimate acceptable for international reporting (i.e., the JORC code, NI 43-101, etc.)
sampling	Sampling	Drilling or trenching: Random drilling or trenching with a sample density and analytical quality not sufficient for a proper statistical analysis.
randomSampling	Random sampling	Drilling or trenching: One or very few locations sampled and analysed
productionStatistics	Production statistics	Production statistics: Calculations from known composition of produced waste rock, produced tailings, ore input to concentrator minus quantity of produced concentrate or similar.
oreProductionStatistics	Ore production statistics	Production statistics: Estimates from amount and composition of produced ore and estimates of recovery

2.3 Procedures to handle data gaps

2.3.1 Methods to handle data gaps

The first step to handle data gaps is their clear identification. This consists of comparing the actual data availability with the desired data situation to get a complete picture of the waste flows. Based on that, several methods may be used to complete data gaps:

- Include no data in the database as a consequence of the missing data;
- Take into account data from another geographical or temporal area; or
- Make justified assumptions for which the data quality is satisfying.

Decision making for data gaps is very case specific. This section describes the data gaps in the four product groups and the concrete strategies adopted to deal with them to produce the datasets.

2.3.2 Data gaps for WEEE

The quantification of complementary flows is quite challenging since there are only a few countries with substantiated information and literature available. Even for the available data related to analysing actual collection flows, the description of data quality is far from uniform and the geographical and temporal coverage as well as sample size and representativeness leaves room for substantial improvements. In addition, another main challenge encountered is obviously the lack of reporting for WEEE which is collected via informal routes or in other waste flows. This is especially the case for legitimate harvesting of parts for reuse and the scavenging of products as well as components. The relevance of these scavenging levels is not to be under-estimated as the cherry picking in many cases has a substantial impact on the presence of valuable CRM. Mathematically, the ProSUM data model is designed to cope with these missing values. However, often no direct statistical sources are available to quantify the different components and materials missing from products. A hotspot approach or assumption of which materials and elements are being harvested prior to further treatment can be made for future calculations, but with considerable uncertainty levels. In the case of metal scrap and export, the CWIT report and various country studies were harmonised by comparing each individual source according to its data quality. For the complementary recycling of WEEE products, the data is harmonised based on the detailed survey data of recyclers as addressed in D3.2.

Following the flow size information for all complementary flows which were harmonised and consolidated in D3.2, five different collection flow composition datasets from linked third parties were analysed and consolidated. In doing so, an in depth analysis and mapping of the product frequency, has been undertaken. This is illustrated with the p-f and e-f results for Microwaves as a proof of concept. The consolidation of data composition of microwave ovens is done in D2.5. This provides information for elements found in this specific product. In order to consolidate p-f ratios, the average disposal age, put on market data, average weight over time and mis-sorted products in sample batches are also considered and included in the overall evaluation and alignment of WP2, WP3 and WP4 research activities.

2.3.3 Data gaps for BATT

The data gaps concern different aspects of the collection of data on waste BATT.

2.3.3.1 Temporal and geographical coverage

Data were collected for the 28 MS of the EU as well as Norway, Iceland and Switzerland. No data are available before 2008, and for several countries, the availability of data starts in 2009 or 2010. Some countries did not publish yet data for 2015. A detailed overview of the temporal and geographical coverage is provided in section 3.3. Data gaps were not covered by assumptions, but left empty.

2.3.3.2 Coverage in terms of BATT keys

The available data enabled an estimation of the shares of the different BATT keys in the waste flows, but did not allow increasing the level of detail to the BATT sub-keys. No data on the composition of waste BATT were available, but this is not a data gap because, as explained in Deliverable 2.3, the composition of batteries with a specific electrochemical system did/does not change significantly over time. Decisive factors for the changes of the material composition of flows of waste batteries are not changes of the composition of batteries with a specific electrochemical system, but market shifts from an electrochemical system to another. The composition data for BATT put on the market collected in WP2 are assumed to be applicable to the waste BATT.

2.3.3.3 Differentiation collected/recycled

As explained in section 2.1.3.1, even though Eurostat officially publishes data both on collected volumes of portable batteries and on recycling, in practice the national authorities do not make a clear distinction between both, so that it will not be possible to get differentiated figures showing, for each country, on the one hand the volumes that are collected per key, and on the other hand the volumes treated.

2.3.3.4 Data for automotive and industrial batteries

Unlike for portable batteries, the legislation defines no reporting requirements regarding the collection of automotive and industrial batteries. D3.2 showed that for industrial BATT and for automotive BATT there is insufficient supporting evidence to quantify the waste flows. Industrial BATT are efficiently collected and recycled at the end of their life because they are also often sold with take back clauses in their contracts.

Some national authorities like France and the UK collect and publish data that were useful to check the credibility of the data to be integrated into the harvesting database. For the other countries, these cross-check was not feasible.

2.3.3.5 Data on complementary waste flows

The availability of data on complementary flows of waste batteries is described in D3.2. Whereas some data are available on waste batteries in municipal solid waste, the data availability is very limited for the other complementary flows.

2.3.4 Data gaps for ELV

The presentation of identified data gaps for ELV integrated in section 2.1, is summarized here:

Data was collected for all MS, Liechtenstein, Norway and Iceland from 2008-2014, but is not complete for the full period for all countries. Only two data points from the reporting of ELV flows and treatment in Switzerland in 2014 could be added, since public Swiss reporting is sparse and not harmonized with the ELV directive data format.

Data includes, but does not distinguish between, vehicles M1 and N1. Only ELV average mass is available. Vehicle properties, such as powertrain type and mass, reported in European vehicle fleet statistics, is not reported for ELV. This means that no distinction over the Vehicle keys defined in the ProSUM classification could be made. Further, it was not possible to produce data on the material and elemental composition of flows. The only way achieve this is by linking product composition data to ELV flows calculated by the stock and flow model (which are expressed in terms of vehicle keys).

Exported flows are reported as total mass flows to material recycling, incineration or disposal and include ELV, part of ELV and ELV-related waste. There is no information on the split between the processes they originate from, nor the country to which they are exported. No separation is made between domestic and exported reuse flows.

It is not mandatory to report disaggregated outflows dismantling. Such unreported flows are treated as data gaps (flows were fully reported for 50% of MS in 2014). But even when such flows are available, their usefulness is limited for the purposes of ProSUM since they do not represent CRM-relevant flows. For example, oil filters and liquids are available as separate flow types, but CRM-relevant flows such as specific metal alloys and electronics are likely only reported as "metals" and "rest".

2.3.5 Data gaps for MIN

Once the data harvesting has started, it will be possible to pinpoint the data gaps for MIN, especially regarding critical raw materials. It is, however, possible to forecast some data gaps already before the data harvesting.

2.3.5.1 Lack of data on the amount of MIN

MIN has mostly been regarded as an environmental problem; it is only in recent years that the economic potential has been recognised. The previous lack of economic interest means that there are limited data on the amounts of MIN (waste rock, tailings, waste sludge etc.) produced and accumulated in stocks (waste rock landfills, tailing and sludge dams). Alternative sources of information are:

- The national environmental protection agencies (EPA) who could have information gathered in accordance with the Mining Waste Directive 2006/21/EC (European Commission, 2006b).
- Computer-aided terrain model calculations using modern topographic models can be used to estimate volumes of MIN. This information together with knowledge of the density of the material will give estimates of the tonnage of the waste.
- The ratio of waste rock vs. ore (strip ratio or stripping ratio in mining terminology) depends on mining method and varies between near zero for room-and-pillar operations (Table 10),

0.7 for most other underground operations, 0.5-3 for open-pit mines and can be up to 5.5 for gold mines. For most mines a ratio of 0.7 for underground mines and 2 for open pit mines will give a good estimate on the amount of waste rock. The proportion of the ore to the concentrator that becomes waste is highly dependent on the type of ore and can thus be estimated from this knowledge. For gold ores and low-grade base metals ore almost all of the processed ore will become waste while around 30% of the iron ore will become waste. Table 11 shows some well-documented cases where the proportion of ore that becomes waste is given. Using these figures, it will be possible to estimate the amount of waste from knowledge of type of ore and amount of processed ore.

Table 10 Waste rock/ore ratio for different types of mines and ore types. The ratio makes it possible to estimate the amount of waste rock from knowledge of the amount of produced ore.

Waste rock/ore ratio	Room-and-pillar underground mining	open-pit mining	iron ore, underground	massive sulphide deposits, underground	gold deposits, open-pit
0	■				
0.5		early stages, small open-pit ■	■		
1		■	■		
1.5		■		■	
2		■			
2.5		■			■
3		late stages, large open-pit ■			■
3.5					■
4					■
4.5					■
5					■
5.5					■

Table 11 Proportion of the ore that becomes waste during mineral processing of different types of ore (preliminary data)

Type of deposit	Waste (%)	Examples (Sweden)
Low grade ore (porphyry copper, gold ore…)	99	Aitik, Björkdal, Åkerberg
Disseminated ore (skarn deposits, sandstone hosted…)	94	Laisvall, Yxsjöberg
Massive sulphides	75	Kristineberg, Boliden, Zinkgruvan
Iron ore	30	Kiruna, Grängesberg

2.3.5.2 Lack of data on the composition of MIN

Several of the CRM have never been extracted on a large scale in the EU and therefore the amount of available analytical data is limited, especially compared to the data on primary resources.

Alternative sources to MIN data include environmental reports and mine site remediation reports conducted by environmental authorities and mining companies, data from studies by national surveys in accordance with the Mining Waste Directive and scientific reports dealing with various aspects of MIN.

A more statistical approach to handle the lack of data is to use metal associations, sometimes illustrated as the Metal Wheel (see for example Verhoef et al., 2004). In nature, different elements can have physical and/or chemical affinities so that when a metal is deposited in a specific ore forming environment it is often followed by other, "chemically similar" elements. Well known examples are manganese together with iron, cadmium together with zinc, cobalt together with copper and PGM together with nickel-copper deposits. The metal associations vary from one deposit type to another but within a specific type of deposit formed in a specific way these metal associations are similar. By showing that such a metal association is valid for a group of elements in a certain type of deposit it becomes possible to use the large amount of data for the commodity (here called carrier metal) and correlate them with a few multi-element analyses to produce a reliable and referenced estimate of the total composition of the MIN deposit, including trace elements and CRM. These relations, established for a few deposits, can then be used to estimate the content of minor, trace and critical elements in a large number of similar deposits.

2.3.5.3 Filling the gaps with field work, sampling and analysis

The most expensive and time consuming, but at the same time most reliable way to handle data gaps on amount and composition is ordinary field work with measurements, sampling and chemical analysis. For budget reasons, this cannot be completed for the thousands of MIN deposits that can be found in EU but some targets, preferably large landfills at active or recently closed mines and plants and with a commodity that suggests the presence of CRM according to metal associations will be included in the end results.

3 Results

This chapter gives an overview of the datasets produced in Task 4.2, using templates aligned with the data models developed in WP5 that include the main structuring features (product key, year, country, description of the flow/stock).

The practical steps of T4.2 were similar to the steps of T2.2:

1. Describe and record *raw data* from original sources in a semi-structured format (spreadsheets) based on the data inventory provided in D4.1;
2. Evaluate the data quality of the raw data based on recorded information;
3. Select the waste flows that can be covered (section 2.1)
4. Select or calculate the best available data for all selected waste flows, product keys, countries and years
5. Evaluate data quality and estimate uncertainties (section 2.2) and
6. Consolidate the waste flow data in templates (*data portrayals*) for harvesting into the database

Table 12 presents the classification of the parameters defining the information content of data on waste stocks and flows. This classification is used in the product-specific overview tables of the produced datasets presented in sections 4.1 to 4.4.

Table 12 Parameters defining the information content of data

Code	Description
e-m	Mass or mass fraction of an element in a material
e-c	Mass or mass fraction of an element in a component
e-p	Mass or mass fraction of an element in a product
e-f	Mass fraction of an element in a flow or stock
m-c	Mass, mass fraction or volume of a material in a component
m-p	Mass, mass fraction or volume of a material in a product
m-f	Mass fraction of a material in a flow or stock
c-c	Mass, mass fraction, number, length, volume, area or other extensive property of a component in another component
c-p	Mass, mass fraction, number, length, volume, area or other extensive property of a component in a product
c-f	Mass fraction of a component in a flow or stock
p-p	Mass, mass fraction, number, length, volume, area or other extensive property of a product in another product
p-f	Mass fraction of a product in a flow or stock
f-f	Mass fraction of a flow or stock in a flow or stock
c	Mass, length, area, volume or other extensive property of a component
p	Mass, length, area, volume or other extensive property of a product
f	Mass, volume or other extensive property of a flow or stock

3.1 Overview of the consolidated datasets for WEEE

Table 12 provides an overview of the datasets produced for WEEE by proceeding in accordance with the explanations given in the previous chapters.

Table 13 Waste flows datasets provided and analysed for WEEE

Flow or stock	Geographical coverage	Time coverage	Parameter*	Data source	Description of the dataset
Flow	EU 28 and EU28+NOR AUT, BEL, CHE, DEU, DNK, FIN FRA, IRL, LUX, NLD NOR, SWE CYP, EST, HRV, HUN, LVA, MLT, NOR, POL, PRT, ITU	2010-2014	f f f	Eurostat (2005-2013) Eurostat (2005-2013) Eurostat (2005-2013)	EEE POM, WEEE Collection volumes cat. (1-10) Metal Scrap, UNU Keys (I – VI) Waste Bin, 1-10 (I – VI)
Flow		2010-2014	f	WF Key figures platform (2010, 2010-2012, 2013, 2014)	WEEE collected volumes Collection cat. (1-10) and (I-VI)
Flow	ITA FIN POL ESP AUT EU28+CHE, NRW	2012 2012 2013 2012 2010-2014 2010-2014	f, p-f p-f	Huisman, J. (2015).	Complementary Flows (waste bin), Collection cat. (I – VI) Scavenging , 1-10 (I – VI)
Flow	FRA SWE	2012	f f, p-f	Monier, V. (2013)	Complementary Flows (waste bin, Export), Collection cat. (I – VI) Waste Bin, 1-10 (I – VI)
Flow	NLD	2010- 2013	f, p-f	Huisman, J. (2012)	Complementary Flows (Waste bin, Export), Collection cat. (I – VI)
Flow	AUT	2010-2014	f	Kopacek, B., (2013)	Export, UNU Keys (I – VI)
Flow	BEL	2010-2014	f, p-f	Wielenga, K., Huisman, J., (2013)	Export, UNU Keys (I – VI), Waste Bin, 1-10 (I – VI)
Flow	DEU	2010-2014	p-f, f	Sander, K., et al.; (2010)	Waste Bin, Export, UNU Keys (I – VI)
Flow	CHE	2010-2014	f	BAFU (2007) BAFU (2012) BAFU (2014)	Waste Bin, 1-10 (I – VI)
Flow	CZE	2010-2014	f	Polák, M. (2012).	Waste Bin, 1-10 (I – VI)
Flow	DNK	2010-2014	f	Bigum, M. (2013).	Waste Bin, 1-10 (I – VI)
Flow	ESP	2010-2014	f	Montejo, C. (2011). Ministerio de Industria, Energía Y Turismo, (2015)	Waste Bin, 1-10 (I – VI)
Flow	EST	2010-2014	f	Skatteverket (2012).	Waste Bin, 1-10 (I – VI)

Flow or stock	Geographical coverage	Time coverage	Parameter*	Data source	Description of the dataset
Flow	FIN	2010-2014	f	Pannuzzo, B. (2014).	Waste Bin, 1-10 (I – VI)
Flow	GBR	2010-2014	f	WRAP. (2011)	Waste Bin, 1-10 (I – VI)
Flow	GRC	2010-2014	f	Charisios A. (2012). Dimitrakis et al (2009).	Waste Bin, 1-10 (I – VI)
Flow	IRL	2010-2014	f	WRAP. (2011)	Waste Bin, 1-10 (I – VI)
Flow	ITA	2010-2014	f	Magalini, F. (2012).	Waste Bin, 1-10 (I – VI)
Flow	LUX	2010-2014	f	Regeringskansliet, Regeringen och. Environment. (2014)	Waste Bin, 1-10 (I – VI)
Flow	BGR, ROU, SVK, SVN	2010-2014	f	Dvoršak, S. (2011).	Waste Bin, 1-10 (I – VI)
Flow		2013-2015	e-p p-f	Third parties	Collected Flow 1-10 (I-VI)

* As defined in Table 12

3.2 Example results for the consolidated datasets for WEEE

As previously described in section 2.2.1 for the frequency count of products in a flow, the product used as a proof of concept are microwaves corresponding to collection Cat. V and analysed for the years 2014 and 2015. Table 14 describes all products found in Cat V.

Table 14 WEEE products found in Cat V

UNU Keys found in Category V	Product Description
0114	SHA Microwaves ((combined) microwaves, excl. grills)
0201	SHA Other (small ventilators, irons, clocks, adapters, etc.)
0202	SHA Food (kitchen, food processing, frying pans, etc.)
0203	SHA Hot water (coffee, tea, hot water, etc.)
0204	SHA Vacuum cleaners (excl. professional ones)
0205	SHA Personal Care (tooth brushes, hair, razors, etc.)
0401	SHA CE (other, headphones, adapters, remote controls)
0402	SHA Portable Audio/ Video (MP3, e-readers, car nav., etc)
0403	SHA Radio & Hifi (audio sets, components, etc.)
0404	SHA Video (VCR, DVD(R), Blue Ray, decoders, etc.)
0405	SHA Speakers
0406	SHA Cameras (camcorders, photo &dig. still cameras)
0501	SHA Lamps (pocket, christmas, halogen, ex. LED & incand.)
0506	SHA Luminaires (incl HH incandescant fittings)
0507	PROF Luminaires (all lum. offices, public space, industry)
0601	SHA Tools (all HH saws, drills, cleaning, garden, etc.)
0701	SHA Toys (small toys, vehicles, small music)
0801	SHA Medical (small HH thermom., blood pressure meters)
0901	SHA Monitoring (alarm, heat, smoke, security, ex. screens)

Figure 9 illustrates the flow of all products in Cat V for the year 2014 for three countries 1, 2 and 3 compared to the average EU 28 WEEE Generated share per UNU key total collection category V for the corresponding year. The latter value is included for comparison reason to represent the share of UNU keys assuming an equal composition in the collection stream compared to the waste generation potential. The data from linked third parties covering countries 1, 2, and 3 is made available for ProSUM but cannot yet be released publicly due to their datasets being confidential and therefore cannot be named nor published until the providers permission is explicitly granted.

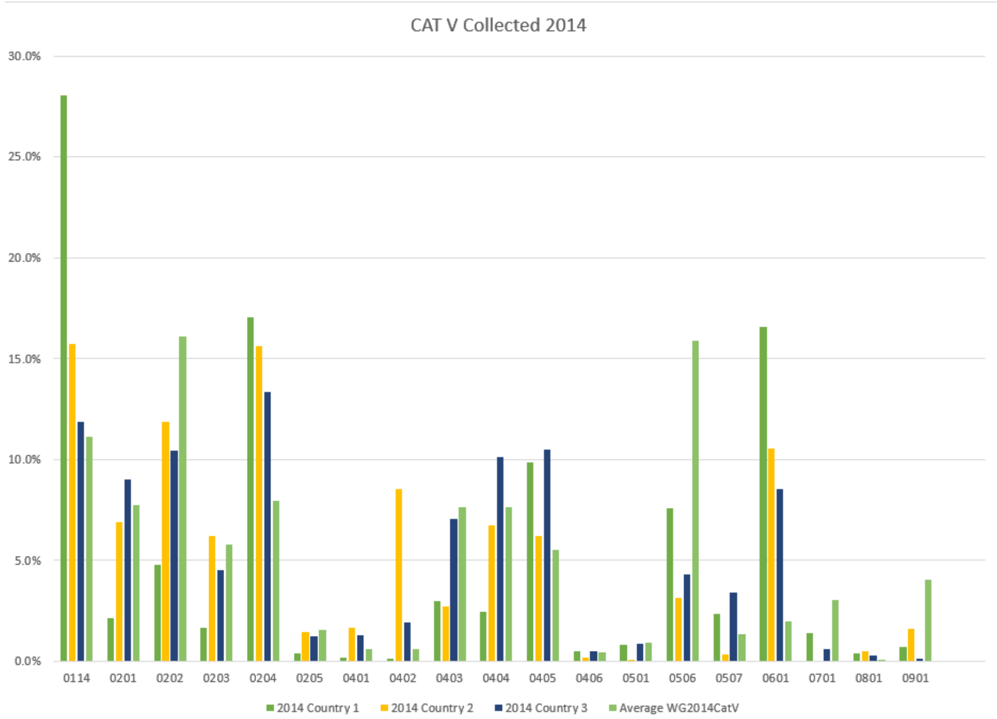


Figure 9 Flow of collected amounts of products in Cat V in 2014 for Country 1, 2 and 3.

In both cases, for the year 2014 and 2015, it can be seen that the microwaves, small household appliances for food and tools have the highest share in the flow of products for Country 1, 2 and 3. All Countries assessed in Figure 9 have a similar income level and therefore can be compared. The sample sizes for Countries 2 and 3 are larger than Country 1 and following the data quality criteria discussed in Section 2.2.1 are therefore considered to have a higher quality level.

All p-f flows analysed are compared with WEEE Generated shares to evaluate the collected amount of discarded product flows in a year prior to any type of subsequent recovery or treatment. By doing a comparison with the collected flow and WEEE generated we can measure and analyse the amount of 'missing' products that are ending up in one or more complementary flows such as the waste bin, export, scavenging and mixed metal scrap flows. In other words, how much of the concerned products are not treated or form part of the regulated and reported upon collection flows.

As a second example of collection Cat II, for screens, it is observed in Figure 10 that in country 2 newer LED TVs are clearly under represented. The 'missing products' effect is in below graph not related to the modelling of the product lifespan assuming a median residence time of 9 years and an average disposal age of 4 years. Due to the recent market introduction and related low saturation level for newer LED TVs means that they are relatively very attractive for reuse, trade and export. Hence, the amount of actually collected products is much lower than the modelled amount of waste being generated for this specific country.

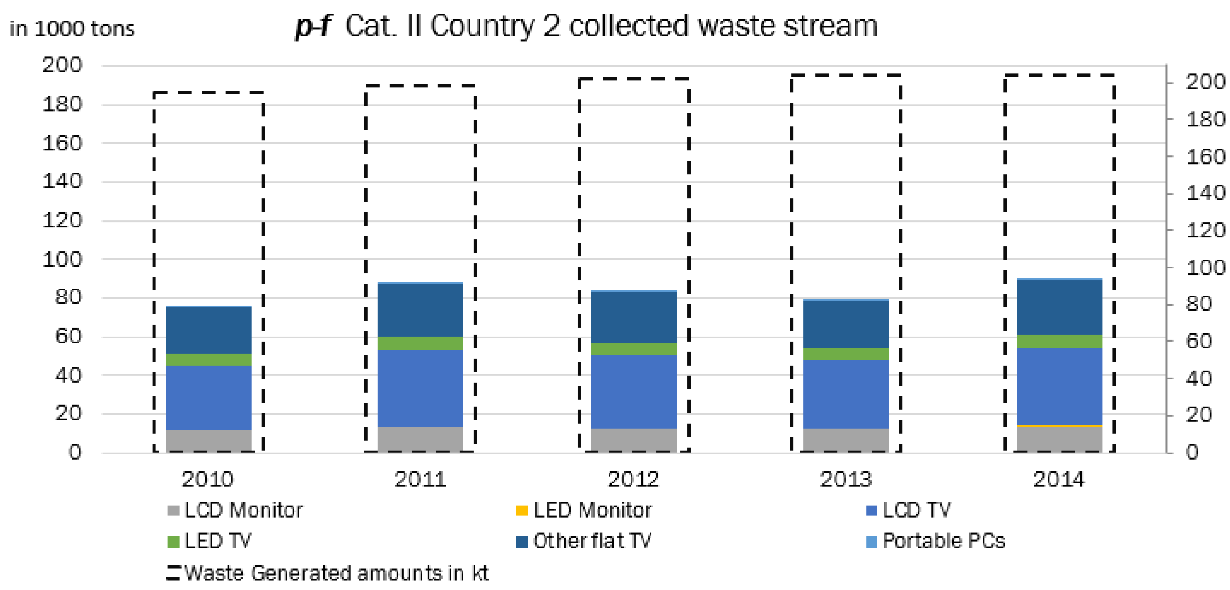


Figure 10 p-f Cat. II for Country 2 collected waste stream vs. Waste generated

Having a set of structured datasets from the collected flow makes it possible to connect those consolidated datasets found in D2.5 with those found for WEEE in D3.2. This can be done by multiplying the elements, materials and components found in specific products with amounts of those products present in the collected flows (calculated in D3.2). The important and novel result is the ability to determine the actual e-f amounts as displayed in Figure 11. In the case of the WEEE generated, the split factors for EU28+2 are generated from Cat VI to product level (UNU Key level). This allows a comparison of WEEE generated in the countries being analysed with the collected flow of its respective country. This is an important comparison and achievement because previous assessments where an equal and theoretical presence of valuable products in the return streams is often assumed, are actually proven to vary considerably.

As previously described, the sample sizes and the quality of the data for countries 1, 2 and 3 is considered when performing this proof of concept. Also when analysing and consolidating the datasets, certain assumptions and inevitable data corrections have been performed. For all countries analysed, the sorted products have been allocated when possible to their respective UNU key. However, there are always mismatches in allocation due to mis-sorted products, components and materials present in the collection stream that cannot be identified and linked to individual UNU keys or a grouped classification of counted products contributing to two or more UNU keys. For products that cannot be allocated at all, they are considered as unsorted products and included during the consolidation and quantification of e-f. Here average split factors have been applied to allocate these amounts to the related UNU keys assuming no mis-sorting takes place. Loose parts and materials are equally distributed to the related UNU keys. For products not specified with a corresponding product name, it is either assumed they have a similar share in the total compared to another measurement year or neighbouring country. All of these assumptions taken in this consolidation related to the average or recalculated share of those products are specified in the resulting harmonised datasets for these countries (Country 1, 2 and 3). For the rest of Europe, the average consolidated datasets derived for these three countries is used for determining the e-f levels. The influence of this latter rather rough assumption is to be tested in the coming months.

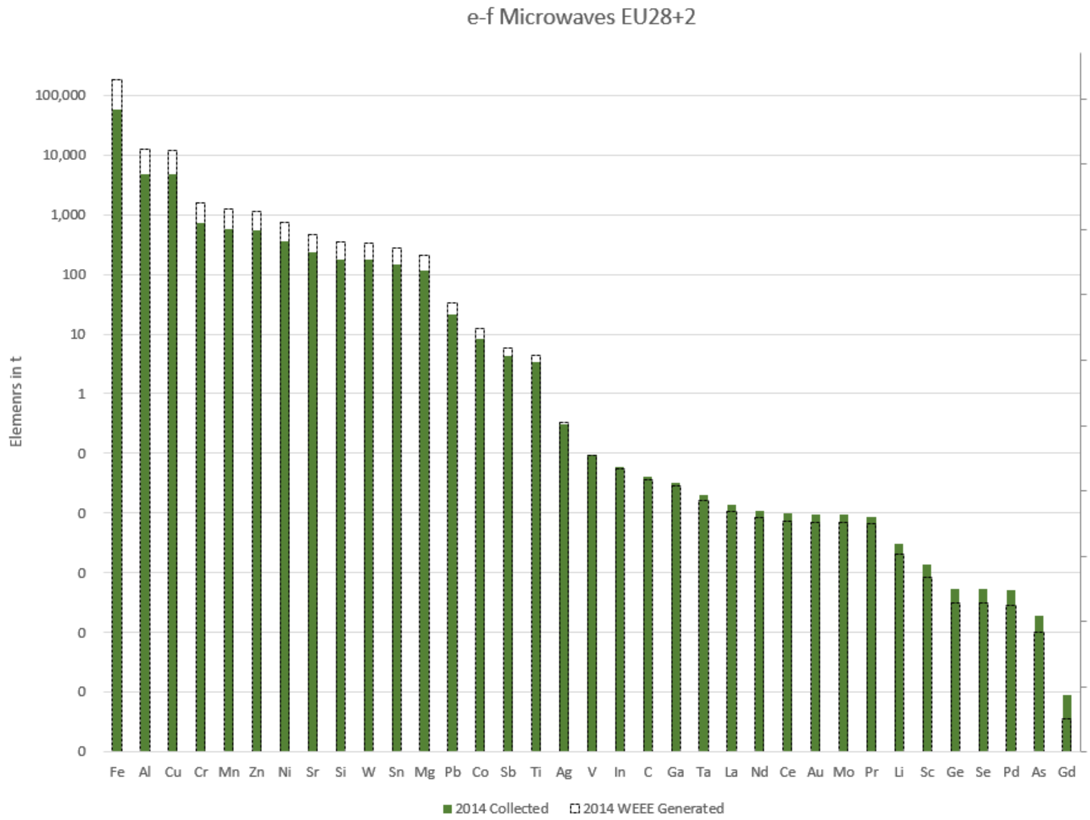


Figure 11 Element flow in EU28+2 vs WEEE generated in 2014

With the above consolidation and using the assumptions stated, Figure 11 displays the elemental composition of all CRM present in collected WEEE flows in the EU28+2 for microwaves in 2014. Obviously, the main elements are Iron, Copper, Aluminium and Chromium. The calculation approach not only allows to quantify the actual flow of products and elements in all EU 28+2, at the same time it enables comparison of what is supposed to be present in the reported and regulated return streams. Figure 13 also provides insights into how much of these elements should have been present in the collection of both products, components and materials at a theoretical 100% level. In that regard, Figure 13 represents the missing percentage of products that are supposed to be present and not yet the detailed scavenging levels of components. Although this c-f specification was not a requirement of deliverable, with the datasets currently available, this type of flow could mathematically be quantified and analysed for EU28+2 from 2010 until 2014. Unfortunately the scavenging information of components itself is quite challenging to determine quantitatively, since it is rarely available on dismantling and sampling trials and therefore should be measured, reviewed and described in future sampling protocols.

3.3 Overview of the datasets for BATT

Table 15 provides an overview of the datasets produced for BATT by proceeding in accordance with the explanations given in the previous chapters.

Table 15 Datasets provided for BATT

Flow or stock	Geographical coverage	Time coverage	Parameter*	Data source	Description of the dataset
Collected waste battLiPrimary	EU28 + IS, LI, NO	2008-2015	f, p-f	Eurostat, EPBA, Eucobat, national authorities	217 datasets
Collected waste battLiRechargeable	EU28 + IS, LI, NO	2008-2015	f, p-f	Eurostat, EPBA, Eucobat, national authorities	217 datasets
Collected waste battZn	EU28 + IS, LI, NO	2008-2015	f, p-f	Eurostat, EPBA, Eucobat, national authorities	217 datasets
Collected waste battNiMH	EU28 + IS, LI, NO	2008-2015	f, p-f	Eurostat, EPBA, Eucobat, national authorities	217 datasets
Collected waste battOther BATT	EU28 + IS, LI, NO	2008-2015	f, p-f	Eurostat, EPBA, Eucobat, national authorities	217 datasets
Collected waste battPb	EU28 + IS, LI, NO	2009-2015	f, p-f	Eurostat	144 datasets
Collected waste battNiCd	EU28 + IS, LI, NO	2009-2015	f, p-f	Eurostat	127 datasets
Recycled waste battPb	EU27/28 as a whole	2009-2015	f, p-f	Eurostat	7 datasets
Recycled waste battNiCd	EU27/28 as a whole	2009-2015	f, p-f	Eurostat	7 datasets

* As defined in Table 12

A detail of the data for collected waste BATT is given by Table 16. It shows that the data availability increases continuously for the years 2008 to 2011. The data availability is lower for 2015 than for 2014 because some countries had not made the data available yet in September 2016.

Table 16 Number of countries for which data on collected flows are available per year and BATT key (maximum is 31: the 28 EU member states, Norway, Iceland and Switzerland)

BATT key	2008	2009	2010	2011	2012	2013	2014	2015	Total
battLiPrimary	16	26	29	31	31	30	31	23	217
battLiRechargeable	16	26	29	31	31	30	31	23	217
battNiCd		11	13	18	18	23	24	20	127
battNiMH	16	26	29	31	31	30	31	23	217
battOther	16	26	29	31	31	30	31	23	217
battPb		13	17	22	23	24	23	22	144
battZn	16	26	29	31	31	30	31	23	217
Total	**80**	**154**	**175**	**195**	**196**	**197**	**202**	**157**	**1356**

3.4 Overview of the datasets for ELV

3.4.1 Datasets provided for ELV

The datasets provided for ELV only include mass flows, see table 14. No data on CRM composition is provided, which is further justified in section 3.2.2.

Table 17 Datasets provided for ELV

Flow or stock	Geographical coverage*	Time coverage*	Parameter**	Data source	Description of the dataset
Flow	EU28 + IS, LI, NO, CH***	2008-2013	f	Mass balance	wasteCollected
Flow	EU28 + IS, LI,NO	2008-2013	f	Eurostat	from dismantling to reuse: metals, polymers, glass, automotive battery, catalytic converter, liquid excluding fuels, tyres, oil filer, rest
Flow	EU28 + IS, LI,NO	2008-2013	f	Eurostat	from dismantling to incineration: metals, polymers, glass, automotive battery, catalytic converter, liquid excluding fuels, tyres, oil filer, rest
Flow	EU28 + IS, LI,NO	2008-2013	f	Eurostat	from dismantling to material recycling: metals, polymers, glass, automotive battery, catalytic converter, liquid excluding fuels, tyres, oil filer, rest
Flow	EU28 + IS, LI,NO	2008-2013	f	Eurostat	from dismantling to disposal: metals, polymers, glass, automotive battery, catalytic converter, liquid excluding fuels, tyres, oil filer, rest
Flow	EU28 + IS, LI,NO, CH***	2008-2013	f	Mass balance	from dismantling to shredding: hulks
Flow	EU28 + IS, LI,NO	2008-2013	f	Eurostat	From shredding to material recycling: ferrous scrap, non-ferrous scrap, SLF, other
Flow	EU28 + IS, LI,NO	2008-2013	f	Eurostat	From shredding to incineration: ferrous scrap, non-ferrous scrap, SLF, other
Flow	EU28 + IS, LI,NO	2008-2013	f	Eurostat	From shredding to disposal: ferrous scrap, non-ferrous scrap, SLF, other
Flow	EU28 + IS, LI,NO	2008-2013	f	Eurostat	Export to material recycling
Flow	EU28 + IS, LI,NO	2008-2013	f	Eurostat	Export to incineration
Flow	EU28 + IS, LI,NO	2008-2013	f	Eurostat	Export to disposal

* All countries do not report all flows in data set over the full time period 2008-2013
** As defined in Table 12
*** Time coverage CH: 2014

3.4.2 Other relevant ELV data not included in the harvesting database

No data on CRM composition for ELV flows is provided for several reasons, of which one is the lack of such published data. Furthermore, the composition of all ELV flows will depend on factors such as material composition of ELV and of other co-treated waste, dismantling approach, shredding and post-shredder treatment technology, as well as the local price and eligibility of landfilling. The fact that these factors differ between countries as well as over time increases the variability in composition.

Some studies of the composition of automotive shredder residues (ASR) exist and have been reviewed, as presented in Annex 3. However, as explained, elaborating this data to a representative data set for ASR was found impossible. The review makes it clear that the composition of ASR varies greatly and analytical sampling methods vary between studies. Furthermore, ASR composition cannot be unambiguously linked to the available and relevant mass flow data of SLF and Others. ASR is not a uniform flow. In some cases, ASR refers to all residual, non-metallic outflows from shredding, i.e. the sum of Others and SLF. In others, ASR refers to a mostly organic fraction with residual metal content resulting from several steps of post shredder treatment, i.e. SLF. In practice, "pure" automotive shredder residue rarely exist, since ELV are mostly co-shredded with other waste flows from both households and industry. However, research indicates that CRM may accumulate in ASR (Widmer et al., 2015). Their content as well as potential for their recovery are therefore relevant to further explore.

3.5 Overview of the datasets for MIN

3.5.1 National datasets

As explained in section 2.1.5, the work of gathering data is still ongoing in several participating countries and has already been performed in some, including:

- Several years ago, the Greece Geological Survey (IGME) presented datasets for "man made" deposits: (http://promine.gtk.fi/abstracts/promine_abstract_conference_20120612_bologna_arvanitidis_1.pdf).
- The ProMine project gathered data from several EU countries in their "Anthropogenic concentration" database: (http://ptrarc.gtk.fi/ProMine/default.aspx).
- The Irish geological survey (GSI) has re-analyzed archived waste rock and tailings in order to document the CRM content. (Gerry Stanley, pers. comm.) and the Swedish survey (SGU) recently got a mission from the government to improve the knowledge of CRM content in primary and secondary resources in Sweden, data that will be fed into the ProSUM database.

Data collections according to the Mining Waste Directive are published from several countries, including countries not participating in but informed of the ProSUM project:

- Hungary: http://www.mbfh.hu/home/html/index.asp?msid=1&sid=0&hkl=547&lng=2
- Slovakia: http://www.geology.sk/new/en/sub/ms/geof/skladky_en

3.5.2 Example of assessment of CRM content in MIN

In the Grängesberg mining district in Sweden, tailings from a century (c. 1890-1989) of large scale mining and mineral processing of apatite iron ore make up 14 Mt of waste sand according to mining statistics (260 annual summaries of ore to concentrator and produced concentrate). It has been known for a long time that the ores also contained REE, although the REE was never recovered and the REE grade was never documented. Modern analyses of apatite iron ore from drill cores and from tailings shows a positive correlations between phosphorous (P2O5) and total

REE (Figure 12) and this correlation, together with the calculated Fe and P-content from mining statistics, can be use to estimate the total amount and composition of the tailings;
14 Mt@23 % Fe, 0,74 %P, 0,02 % S and 336 g/t TREE
Thus, this example shows that – at least in some favorable cases - the REE content in tailings from processing of apatite iron ore can be estimated from few modern analyses of the ore and tailings.

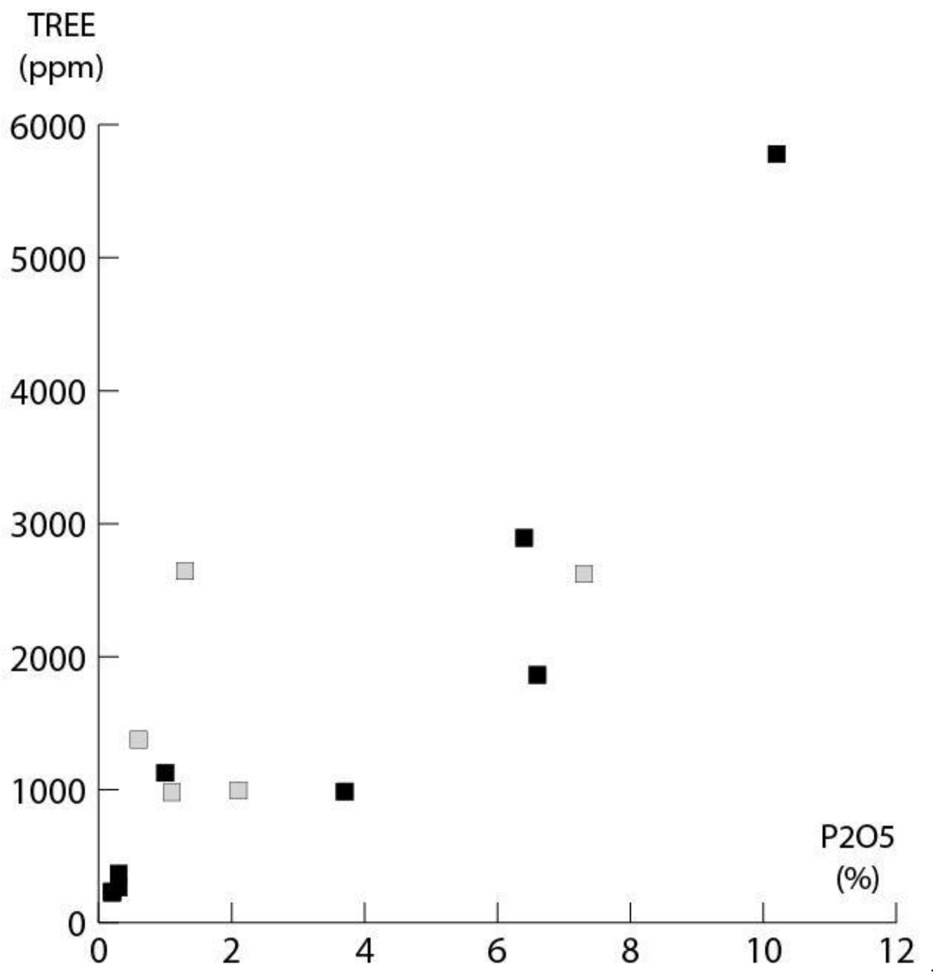


Figure 12 P_2O_5 vs. total REE (TREE) for iron ore samples from drill cores in the Grängesberg iron-apatite deposit (black boxes) and waste sand from three tailing dams (grey boxes). The limited sampling suggest that a few analyses of ore samples can be used to estimate the total content of REE in the tailing dams

An alternative, but less precise method to estimate the amount and REE content of the tailings when reliable statistics are not available is to use topographical data and sampling. Figure 13 shows a topographical model of the Grängesberg area with major mines and tailing sampling sites are marked. The area of the tailing dams can be measured using GIS tools and the volume by making a topographical model of the tailing dams and surroundings. Sampling is necessary to get the density and an estimate of the composition of the tailings.

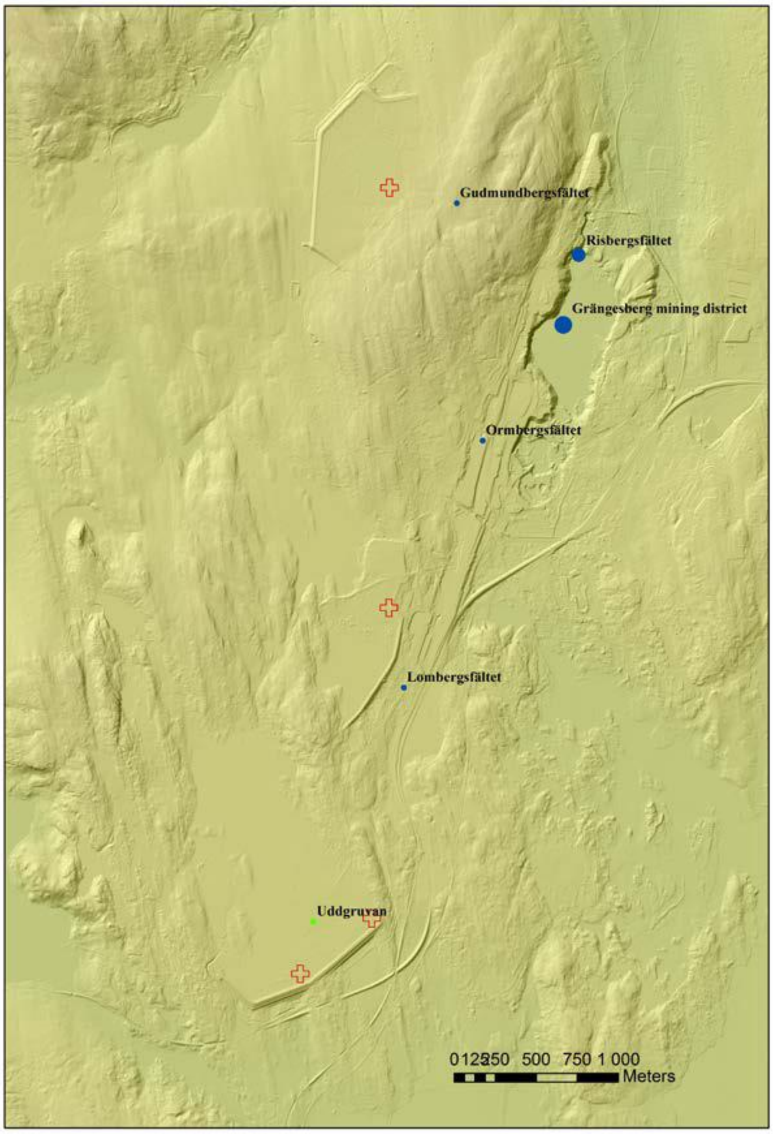


Figure 13 Topographical model of the Grängesberg iron ore district where three tailing dams and the large water filled open pit can be identified. Blue and green dots indicate mines, the red crosses show the sampling stations for tailing samples shown in Figure 12

4 Conclusions and Recommendations

The data and information available enabled quantifying the weights of the waste flows for the four waste groups, but not the CRM content. No reliable data on CRM in waste are available. To gather these data, the use of data from the other work packages is necessary. This was shown for microwaves.

The subsections of Chapter 4 present, for the four product groups, the main learnings associated with the production of the datasets, the barriers that were encountered, and the next steps.

4.1 WEEE

Following harmonisation efforts and inventory steps from D3.2, all WEEE flows data are well structured and considered as consolidated data to be used for further evaluations and calculations of complementary flows.

As a crucial calculation procedure outcome, as illustrated with the example of microwaves, the consolidated datasets for the collected flow can be connected to those found in D2.5 as well as to the stocks and flows of D3.3. This can be done since all three datasets are well structured allowing a direct multiplication with e-p, m-p and c-p values derived from D2.5 and p-f values from D4.2 in section 3.2.

With this important completed working procedure to harmonise and consolidate all calculation steps, from elements to materials to components in products, with the product frequency and (size of) various flows, a complete analysis can be done. As a next step, all efforts will concentrate on the finalisation of the data consolidation for the collection flows and other quantifiable flows like the waste bin p-f product count (assuming sufficient data is available) for all WEEE UNU Keys in EU28+2. This in turn enables the overall assessment and data reconciliation steps and cross-sectoral comparisons by the project by April 2017 for all EEE compositions and by June 2017 for final reconciliation as scheduled.

A summary of the current EEE Waste flows status is provided in Table 18.

Table 18 Summary of current EEE Waste flows status

What is present	What is missing/ Data gaps	Comments
WEEE product flows are available for 2000-2020 per UNU Key. WEEE product flows from 2015-2020 are considered as coherent estimates with the exception of some short lived products.	Data prior to the year 2000 and after 2020 is missing.	Product data prior to 2000 and after 2015 can also be extrapolated by using put on market trends per UNU Key.
WEEE product flow data for EU28+2 is available in Col. cat 6 for the years 2010-2014	There is currently no collected product flow on UNU Key level for datasets prior to the year 2000 and after 2015.	Most of p-f product count data is not available in all of the different types of WEEE flows, only for a few countries in the collected flow.
WEEE flow composition and legitimate harvesting of parts for reuse flow (scavenging) data is available for a few components for EU28+2 in Col.cat 6 for the years 2010-2014	WEEE flow composition data is not in UNU Key or product level. Information of all relevant components in the legitimate harvesting of parts for the reuse flow (scavenging) is missing.	The legitimate harvesting of parts for reuse flow (scavenging) for both \`p\` and \`c\` affect the composition flow severely since their trends differ greatly over time, recycling techniques used and in geographic space.

For future research, the comprehensive approach and data processing presented here, allows complementary flows to be evaluated in the context of the larger waste management system performance per country. It enables the amount of elements per flow currently out of sight to be addressed which is an essential step to derive a comprehensive 'Prospecting of Secondary Raw Materials' based on actual occurrences. The analysis of the types of elements found in the different flows can lead to an improvement in decision making by recyclers and local governments as well as more targeted interventions to close important material loops.

4.2 BATT

With regard to BATT, the production of datasets mainly relied on the reporting obligation defined in the Batteries Directive. The data available in Eurostat were completed with other data from the industrial associations Eucobat, EPBA and Eurobat, from BATT compliance schemes and from national authorities. The produced datasets cover the flows of collected waste batteries for all seven BATT keys defined in the ProSUM classification for the 28 member states of the European Union as well as Switzerland, Norway and Iceland and the years 2008-2015. A summary of the current BATT Waste flows status is provided in Table 19.

Table 19 Summary of current BATT Waste flows status

What is present	What is missing/ Data gaps	Comments
Collected waste batteries (2008-2015) per BATT key. Data sources: EPBA, Eucobat, Eurostat, national authorities, compliance schemes	Data are not available or of low quality before 2010 in many countries. Data limited for automotive and industrial batteries	Lack of harmonisation of the data collection limits the data quality
Treated waste batteries (2008-2015) for NiCd and lead-based batteries. Data sources: Eurostat, national authorities	Data for the other BATT keys not available	Lack of harmonisation of the data collection limits the data quality and even possibly causes double counting
Waste batteries in municipal solid waste for some countries	Data are not available for all countries, no differentiation of the BATT keys Data not available for most other complementary flows	-

The main barrier to the data collection was the lack of harmonisation of the reporting practice across the countries. That limited the comparability of the data, which impeded e.g. differentiating the flows of waste batteries collected within each country and the flows of collected batteries treated within one country, which would have enabled a better understanding of the flows from collection to treatment. The lack of harmonisation also concerns the definition of boundaries, like the criteria to differentiate "portable" and "industrial" batteries. Another barrier is linked to data gaps for some countries and years. The reporting of element-specific flows that has been mandatory for lead and cadmium since 2014 does not apply to CRM. This was a limitation for the production of the datasets, which could not cover the CRM flows.

To estimate the CRM flows, two steps are necessary:

1- Get estimates on the shares of the sub-keys, e.g. for the rechargeable lithium-ion batteries, for each key-specific waste flows. These data will be available through the modelling of the stocks and flows conducted in D3.3, since the input data on BATT put on the market have the sub-key level of detail (finalisation of the p-f count)
2- Calculate e-f by multiplying the waste flows at sub-key level with the composition data (share of CRM in a battery) collected in D2.5 (e-f count)

This exercise will be finalised by June 2016.

Another next step primarily concerns data consolidation between the work packages. For instance, the datasets produced in Task 4.2 will be compared to the outcomes of the stocks and flows modelling in WP3 to get a better understanding of the gaps between generation of waste batteries and measured collection.

Deliverable 4.4 of future waste protocols will contain recommendations for a better data gathering. The recommendations identified so far basically deal with the issues of harmonisation and expansion of the data reporting.

4.3 ELV

The production of datasets on ELV relied solely on the reporting obligation defined in the ELV Directive as published by Eurostat. The produced datasets cover formally reported flows of generated ELV and their subsequent treatment for the 28 member states of the European Union, Norway. Lichtenstein and Iceland. Data cover the years 2008-2013 although some years are missing for some countries. Furthermore, the same resolution is not available for all countries, since parts of the reporting is not mandatory. Exported flows are reported, but without information on the destination, which makes it impossible to state in which country dismantling and further treatment takes place. Only two data points from the reporting of ELV flows and treatment in Switzerland in 2014 could be added, since public Swiss reporting is sparse and not harmonized with the ELV directive data format.

Since no distinction in types of vehicles is made in the ELV Directive reporting, no distinction over the Vehicle keys defined in the ProSUM classification could be made. Further, it was not possible to produce data on the material and elemental composition of flows.

Next steps primarily concern data consolidation between the work packages. Based on the data collected in WP2, the flows of materials and elements contained in generated ELV could to some extent be estimated, although one must expect large uncertainties because of the variability and uncertainty in vehicle material composition. For this, generated ELV flows will be specified in terms of vehicle keys with the help of results of stock and flows modelling conducted in WP3. The datasets produced in the stock and flow modelling will also be compared with the dataset of Task 4.2 to estimate the gap between reported ELV flows and unreported flows (including unreported ELV, unreported hibernation and unreported trade of vehicles).

Current EU reporting is designed for monitoring the progress in relation to the targets of the ELV directive and is not sufficient for monitoring of flows and their CRM composition. Deliverable 4.4 on future waste protocols will contain data reporting recommendations in order to improve opportunities for such monitoring. The recommendations identified so far deal with detailing of data reporting on e.g. vehicle types collected, destination of exports and shredder output flows and mandatory reporting requirements of all flows. We also note that current knowledge on the material and elemental composition of ELV waste flows is highly insufficient.

For all three product groups, the use of meta data describing all used sources in this and the adjacent deliverables D2.5 and D3.3, as well as higher level summaries of the data consolidation process for completed datasets, are prepared and in an advanced stage for use in D5.6 Creation of the Meta Data System which is due for June 2017.

4.4 MIN

The existing M4EU data model for MIN has been extended/improved, all the necessary additional code lists have been developed and a set of recommendations has been set up on how to select best targets and to solve problems with data gaps on the amount and composition of MIN, with special reference to CRM.

Images of the UML updated data model (see Cassard et al., 2016), an overview of necessary code lists and an explanatory text have been mailed to the participating organizations. An Excel table with all the finalised code lists will be mailed very early in 2017 in order to prepare the data harvesting (in other words, the mapping of the provider’s data over the ProSUM data model, to make them interoperable). The following months will be devoted to data harvesting, identification of data gaps and intense work to fill these data gaps.

4.5 Summary of the next steps

In short, the next steps are:

- Finalisation of the data consolidation for the waste flows and other quantifiable flows at p-f and e-f level for all WEEE, BATT and ELV Keys in EU28+2, using the results of D2.5
- Data consolidation with WP3: comparison of the datasets on waste flows produced in Task 4.2 to the outcomes of the stocks and flows modelling in WP3 to get a better understanding of the gaps between generation of waste batteries and measured collection
- For MIN, completion of the existing M4EU model (WP5)
- Use of the produced datasets for harvesting into the ProSUM database (WP5)
- Formulation of recommendations to facilitate the data harvesting (Deliverable 4.4), including on reporting practices.

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Annex 1 – Definitions

Unless stated otherwise the definitions in this chapter are ProSUM working definitions and project terminology. Where they are available standard terms have been used e.g. those described in legislation.

Data Organisation

Classification
Organisation and arrangement of items into groups according to their similarities (Adapted from the Oxford English Dictionary, 2015).

Classification System
A system which organises the classes according to their common relationships or affinities (Adapted from the Oxford English Dictionary, 2015).

Code List
A type of controlled vocabulary containing a finite list of codes and meanings that represent the only allowed values for a particular data item. This list can be extended in certain conditions.

Correlation
The process of establishing a relationship or connection between two or more things (Oxford English Dictionary, 2015).

Data Consolidation
Data consolidation refers to the collection and integration of data from multiple sources into a single destination. During this process, different data-sources are put together, or consolidated, into a single data store (Techopedia, 2015).

Data Quality
Characteristics of data that relate to their ability to satisfy stated requirements, as defined by ISO 14044. Data quality evaluates whether the accompanying characteristics are in accordance with the objective: time-related, geographical and technology coverage, precision, completeness, consistency, reproducibility, sources of data and uncertainty (Biemann et al., 2013).

Data uncertainty
The range of possible values within which the true value of the measurement lies (Oxford English Dictionary, 2015).

Database
A collection of structured data held on a computer. Data is organised to allow for easy access, management and updating (Oxford English Dictionary, 2015).

Diffusion Database
Database optimised for diffusion. This central database contains all of the data retrieved (harvested) from the project databases and is used to provide services on top of the EU-UMKDP (search facilities, maps, statistics etc). The optimisation provides end-users with the best experience with the platform.

Dublin Core
The Dublin Core Metadata descriptors (http://dublincore.org/) are a set of vocabulary terms which can be used to describe resources for the purposes of discovery. The original set of 15 classic Metadata terms, known as the Dublin Core Metadata Element Set are endorsed in the following standards documents:

- IETF RFC 5013

- ISO Standard 15836-2009
- NISO Standard Z39.85

EU Member States/Countries
For spatial data, the ISO 3166 alpha-2 list is going to be used for reporting and the alpha-3 list in the databases.

EPA
Environmental Protection Agency interchangeable with Ministry of Environment or Government Department. Each Member State has their own arrangements for which of these organisations collects data concerning environmental Directives.

EU-MKDP
European Minerals Knowledge Data Platform, created by the Minerals4EU project to 'house' data on mineral and ore deposits.

EU-UMKDP
European Urban Mine Knowledge Data Platform, being created by the ProSUM project to 'house' data on secondary raw materials. Both platforms will be linked to allow for comparisons between primary and secondary resources.

Harmonisation
Adjustment of differences and inconsistencies among different measurements, methods, procedures, schedules, specifications, or systems to make them uniform or mutually compatible.

Harvesting Database
Database making the bridge between the project databases used to stored harmonised data and the Diffusion database. This database allows for the retrieval and consistent formatting of data from different sources before being sent to the Diffusion database.

Knowledge Base
Systematically organised or structured repository of indexed information (usually as a group of linked data files) that allows easy retrieval, updating, analysis, and output of data. Stored usually in a computer, this data could be in the form of graphics, reports, scripts, tables, text, etc., representing almost every kind of information, structured and unstructured (adapted from Wikipedia 2015).

Metadata
Metadata uses descriptors to describe other data-sources, and acts as label for cataloguing and indexing purposes.

Metadata Descriptors (see Annex 7)
Metadata descriptors are the elements of Metadata (ISO 16642).

NSI
National Statistical Institute

Output Query
A precise request for information retrieval from a database.

Project Database
Database coming from activity within the project used as raw data for feeding the Knowledge base.

Properties (Database Field)
Properties describe the value and format of a database field.

PropertyType
Code list that allows for further description of the (compositional) properties (of products and components).

Relations (and types)
An association or connection between objects.

Split-factors
Multipliers that are used to convert a value or number into various values that sum up to the original value.

Unified Data model
A unified data model is an abstract model that organizes elements of data and standardizes how they relate to one another (Len Silverstone & Paul Agnew 2008). In PROSUM, the Unified Data Model applies to the three product groups ELV, BAT, WEEE.

User defined output lists
Retrieval of information from a database in pre-defined format based on user demands, by means of using specific output queries.

General terms

BATT (BATT)
A 'battery' or 'accumulator' is any source of electrical energy generated by direct conversion of chemical energy and consisting of one or more primary battery cells (non-rechargeable) or consisting of one or more secondary battery cells (rechargeable) (Directive 2006/66/EC).

Best available techniques
Best available techniques as defined in Article 2(11) of Directive 96/61/EC (Directive 2008/98/EC).

Broker
Any undertaking arranging the recovery or disposal of waste on behalf of others, including such brokers who do not take physical possession of the waste (Directive 2008/98/EC).

Coherent estimates
A Coherent estimate describe the strength of association between two series of data where the possible dependence between them is not limited to simultaneous values but may include primary, covered and smoothed relationships (Everitt, B.S. 2002; The Cambridge Dictionary of Statistics, CUP. ISBN 0-521-81099-X).

Complementary flows
The term mainly refers to all waste flows that are not reported by the official compliance systems and others to a national level specified according to the ELV, BATT and WEEE Directives. A certain portion of these flows ends up being exported, incinerated or landfilled. The term also includes non-compliant treatment like recycling with other waste streams, for instance with mixed metal scrap. The amount of WEEE and BATT treated this way is very difficult to quantify.

For ELV the complementary flows are referred to as unknown whereabouts of ELV. These are vehicles which are not reported; they are neither registered as part of the European vehicle stock (also called "vehicle fleet" or "vehicle parc"), nor as vehicles exported from the EU (termed extra EU-Export in COMEXT), nor as ELVs (Eurostat) (Mehlhart, G. et.al, (2011).

Electrical and Electronic Equipment (EEE)
Equipment which is dependent on electric currents or electromagnetic fields in order to work properly and equipment for the generation, transfer and measurement of such currents and fields and designed for use with a voltage rating not exceeding 1 000 volts for alternating current and 1 500 volts for direct current (Directive 2012/19/EU).

End-of-life Vehicle (ELV)
A vehicle which is waste within the meaning of Article 1(a) of Directive 75/442/EEC (Directive 2000/53/EC).

Exported
WEEE, BATT or ELV products that are exported as defined by Regulation (EC) No 1013/2006 on shipments of waste.

Eurostat
Eurostat is the statistical office of the European Union. Its task is to provide the European Union with statistics at European level that enable comparisons between countries and regions. Eurostat is actually the only provider of statistics at European level and the data Eurostat issue are harmonised as far as possible (Eurostat, Eurostat - what we do, 2016). Eurostat contains reported data on flows on sold production, imports and exports of BATT and battery-containing items as well as information on separately collected BATT and battery containing items for the EU-28. All data is collected following standard definitions and criteria. This can be used to identify complementary flows.

Gap
The gap is non-accounted or the unknown whereabouts of the end of life vehicles (ELV), waste batteries (BATT) and Waste Electrical and Electronic Equipment (WEEE).

For this report, the WEEE Gap is defined as the difference between the WEEE generated, the WEEE officially reported, and sum of complementary flows as expressed in the following formula:

WEEE Gap= generated- officially reported- sum of complementary flows

Lifespan or Residence Time
The time equipment spends at a household, business or the public sector is called the lifespan or residence time. This timeframe includes the exchange of second hand equipment among households and businesses within the given territory usually being the country borders. This is to be distinguished from the commonly used lifespan that is reflecting first use by the first consumer or business (Baldé et al., 2015; Wang et al., 2013).

Placed on the market
Placing on the market (also commonly referred to as ‘put on the market’ or POM) means the first time a product is sold on the market within the territory of a Member State on a professional basis (Directive 2012/19/EU).

Preparing for re-use
Checking, cleaning or repairing recovery operations, by which products or components of products that have become waste are prepared so that they can be re-used without any other pre-processing (Directive 2008/98/EC).

Prevention measures taken before a substance, material or product has become waste, that reduce: (a) the quantity of waste, including through the re-use of products or the extension of the life span of products (b) the adverse impacts of the generated waste on the environment and human health; or (c) the content of harmful substances in materials and products (Directive 2008/98/EC).

(Product) Stocks
Material reservoirs (mass) within the system analysed that have the physical unit of kilogrammes and tonnes (per inhabitant or household). For the purpose of the project and the sales-stock-lifespan model, stocks are the total amount of products (EEE, BATT and vehicles) in households, businesses and public sector. This is destined to become waste in the future and is also often referred to as the "urban mine". The stocks can be differentiated between in-use stocks and hibernated stocks (functioning and non-functioning products).

Producer Compliance Scheme
A Producer Compliance Scheme is usually a limited company, through which producers will meet their obligations to register with the appropriate authority and finance the cost of collection, treatment, recovery and environmentally sound disposal.

Recovery
Any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy. Annex II sets out a non-exhaustive list of recovery operations (Directive 2008/98/EC).

Recycling
Any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations (Directive 2008/98/EC).

Removal
Manual, mechanical, chemical or metallurgic handling with the result that hazardous substances, mixtures and components are contained in an identifiable stream or are an identifiable part of a stream within the treatment process. A substance, mixture or component is identifiable if it can be monitored to verify environmentally safe treatment (Directive 2012/19/EC).

Reuse
Any operation by which products or components that are not waste are used again for the same purpose for which they were conceived (Directive 2008/98/EC and Directive 2000/53/EC).
Separate collection The collection where a waste stream is kept separately by type and nature so as to facilitate a specific treatment (Directive 2008/98/EC).

Scrap
Scrap consists of recyclable materials left over from product manufacturing and consumption, such as parts of vehicles, building supplies, and surplus materials. Unlike waste, scrap has monetary value, especially recovered metals, and non-metallic materials are also recovered for recycling (Oxford English Dictionary, 2016).

Split-factors
Multipliers that are used to convert a value or number into various values that sum up to the original value.

Treatment
Any activity after the end-of life vehicle [or any other product or good] has been handed over to a facility for [mechanical, chemical, thermal, biological pre-processing, such as] depollution, dismantling, shearing, shredding, [sorting], recovery or preparation for disposal of the shredder wastes, and any other operation carried out for the recovery and/or disposal of the end-of life vehicle and its components (Directive 2000/53/EC). It is not the recovery or disposal operation itself but rather the preparation prior to recovery or disposal (Directive 2008/98/EC).

Vehicle
Any vehicle designated as category M 1 or N 1 defined in Annex IIA to Directive 70/156/EEC, and three wheel motor vehicles but excluding motor tricycles (Directive 92/61/EEC).

Waste
Means any substance or object in the categories set out in Annex I of Directive 2006/12/EC which the holder discards or intends or is required to discard.

Waste battery
Waste battery or accumulator' means any battery or accumulator which is waste within the meaning of Article 1(1)(a) of Directive 2006/12/EC and Directive 2006/66/EC.

Waste Bin
WEEE or waste BATT put in the waste bin and not separately collected for recycling but typically landfilled or incinerated includes household waste and mixed bulky waste.

Waste electrical and electronic equipment (WEEE)
Electrical or electronic equipment which is waste within the meaning of Article 3(1) of Directive 2008/98/EC, including all components, sub-assemblies and consumables which are part of the product at the time of discarding (Directive 2012/19/EU). WEEE is grouped in categories outlined in Annexes I to IV of the WEEE Directive.

Waste flows
Waste flows are the amounts of waste from the point of being waste generated heading via collection to various recycling, recovery, disposal and export (for reuse) destinations.

Waste generation
WEEE Generated in a Member State corresponds to the total weight of discarded products (waste) as a result of consumption within the territory of that Member State in a given reporting year, prior to any activity (collection, preparation for reuse, treatment, recovery (including recycling) or export) after discarding. Waste arising from private, business and industrial sector. Waste generated is not the same as waste collected, since other non-compliant waste flows and processing exist. Moreover, a differentiation between excluding und including major mineral waste is made in Eurostat statistics.

Waste holder
The waste producer or the natural or legal person who is in possession of the waste (Directive 2008/98/EC).

Waste management
The collection, transport, recovery and disposal of waste, including the supervision of such operations and the after-care of disposal sites, and including actions taken as a dealer or broker (Directive 2008/98/EC).

Waste producer
Anyone whose activities produce waste (original waste producer) or anyone who carries out pre-processing, mixing or other operations resulting in a change in the nature or composition of this waste (Directive 2008/98/EC).

WEEE, BATT, ELV collected (and treated)
The WEEE that is collected, reported and regulated by national transposition of the WEEE, Battery or ELV Directive. This includes WEEE, BATT, and ELV that is collected, exported and treated and recorded in national and European statistics.

WEEE, BATT, ELV generated
The amount WEEE, BATT, ELV discarded after consumption within the member state in a given reporting year, prior to any collection, reuse, treatment or export, as defined in the WEEE, Battery, and ELV Directives. Generally WEEE and BATT generated is calculated using a sales-lifespan approach, according to internationally agreed statistical guidelines (Baldé et al., 2015) using the UNU keys for WEEE (Magalini et al., 2016) and the BATT keys for BATT.

WEEE officially collected and treated
The WEEE that is reported as collected and recycled under the producer compliance regime within the member state and recorded in national and European statistics.

BATT specific terms

Automotive BATT
Any battery or accumulator used for automotive starter, lighting or ignition power (Directive 2006/66/EC).

Battery recycling efficiency
The recycling efficiency of a recycling process means the ratio obtained by dividing the mass of output fractions accounting for recycling by the mass of the waste BATT and accumulators input fraction expressed as a percentage (Regulation (EU) No 493/2012).

Battery recycling process
Any reprocessing operation as referred to in Article 3(8) of Directive 2006/66/EC which is carried out on waste lead-acid, nickel-cadmium and other BATT and accumulators and results in the production of output fractions as defined in point 5 of this Article. The recycling process does not include sorting and/or preparation for recycling/disposal and may be carried out in a single facility or in several facilities (Regulation (EU) No 493/2012).

Industrial BATT
Any battery or accumulator designed for exclusively industrial or professional uses or used in any type of electric vehicle and also include BATT and accumulators used in electrical vehicles, such as electric cars, wheelchairs, bicycles, airport vehicles and automatic transport vehicle (Directive 2006/66/EC).

Input fraction
The mass of collected waste BATT and accumulators entering the recycling process as defined in Annex I (Regulation (EU) No 493/2012).

Output fraction
The mass of materials that are produced from the input fraction as a result of the recycling process, as defined in Annex I without undergoing further treatment, that have ceased to be waste or that will be used for their original purpose or for other purposes, but excluding energy recovery (Regulation (EU) No 493/2012).

Preparation for recycling
Treatment of waste BATT and/or accumulators prior to any recycling process, which shall, inter alia, include storage, handling, dismantling of battery packs or separation of fractions that are not part of the battery or accumulator itself (Regulation (EU) No 493/2012).

Registration bodies
National authorities or with national producer responsibility organisations authorised by Member States where the registration of producers of BATT and accumulators shall take place (Directive 2006/66/EC and 2013/56/EU).

ELV specific terms

Automotive shredder residue (ASR)
Residues from ELV treatment after de-pollution, dismantling and shredding of the hulk, with or without mechanical post-shredder metal separation (Vermeulen et al., 2011).

Certificate of Destruction
A Certificate of Destruction (CoD) is a document issued to a registered Authorised Treatment Facility (ATF). Legally, all cars recycled by an ATF must be issued with a CoD.

COMEXT
Statistical database on trade of goods managed by Eurostat

De-pollution
Removal or treatment of components listed in ANNEX I of Directive 2000/53/EC, such as BATT, liquefied gas tanks; removal or neutralization of potential explosive components (e.g. air bags), removal and separate collection and storage of fuel, motor oil, transmission oil, gearbox oil, hydraulic oil, cooling liquids, antifreeze, brake; fluids, air-conditioning system fluids and any other fluid contained in the end-of-life vehicle, unless they are necessary for the re-use of the parts concerned; removal, as far as feasible, of all components identified as containing mercury (Directive 2000/53/EC).

Dismantling
Treatment operations in order to promote recycling as listed in ANNEX I of Directive 2000/53/EC, including removal of catalysts, removal of metal components containing copper, aluminium, and magnesium if these metals are not segregated in the shredding processes, removal of tyres and large plastic components (bumpers, dashboard, fluid containers, etc.), if these materials are not segregated in the shredding process in such a way that they can be effectively recycled as materials, and removal of glass.

Economic operators
Producers, distributors, collectors, motor vehicle insurance companies, dismantlers, shredders, recoverees, recyclers and other treatment operators of end-of-life vehicles, including their components and materials (Directive 2000/53/EC).

ELV Guidance
Guidance How to report on end-of-life vehicles according to Commission Decision 2005/293/EC describes the scope of the ELV directive and provides guidance to compile a quality report covering the ELV rates for reuse/recovery and reuse/recycling.

Export/ Import of used vehicles
A vehicle running in a foreign country with registration plates from the country of origin is not considered as exported unless it is re-registered in the country of destination. Most MS apply the rule that all residents must register their vehicles in the country of their main residence.

Extra-EU trade
Refers to transactions with all countries outside of the EU: the rest of the world except for the EU.

Fleet of motor vehicles
A total number of vehicles on the roads. The 27 European Union (EU-27) member countries had a fleet of over 256 million in 2008, and passenger cars accounted for 87% of the union's fleet. The five largest markets, Germany (17.7%), Italy (15.4%), France (13.3%), the UK (12.5%), and Spain (9.5%), accounted for 68% of the region's total registered fleet in 2008. The EU-27 member countries had in 2009 an estimated ownership rate of 473 passenger cars per 1000 people.

Hulk
Car body after de-pollution and dismantling.

Intra-EU trade
Refers to transactions occurring within the EU.

POLK
Polk is now part of IHS Automotive. With the addition of Polk, IHS Automotive provides expertise and predictive insight across the entire automotive value chain from product inception-across design and production-to the sales and marketing efforts used to maximize potential in the marketplace. No other source provides a more complete picture of the automotive industry. For more information about IHS Automotive, please visit www.ihs.com/automotive.

Producer
A vehicle manufacturer or the professional importer of a vehicle into a Member State (Directive 2000/53/EC).

Registration/ de-registration/ re-registration
These terms are not applied in the same manner across the EU and within different domains (e.g. vehicle registration according to Article 3(1) of Directive 1999/37/EC and ELV treatment according to Article 5(3) of Directive 2000/53/EC). Definitions for the purpose of this project:

- *Registration* should be understood as the administrative authorisation for the entry into service in road traffic of a vehicle, involving the identification of the latter and the issuing to it of a serial number, to be known as the registration number. Registration is applied for the first registration of a vehicle;
- *Re-registration* is applied for two cases:
  - when a vehicle is temporarily de-registered (see below) and registered again in the same country;
  - when a vehicle is transferred to another country and re-registered in this new country.
- *De-registration* should be understood as a 'cancellation of a registration', which means the cancellation of a Member State's authorisation for a vehicle to be used in road traffic.
- *Temporary de-registration* means that a vehicle is temporarily (for certain limited time) either fully or in limited manner not permitted to be used in road traffic. 'Temporary de-registration' is typically applied by dealers when they keep used vehicles on private ground (in this case vehicles may obtain special dealer plates) but also can be applied by private person in order to avoid paying tax for a vehicle when the vehicle is not in use
- *Permanent cancellation of registration* occurs when a vehicle has been treated as an ELV. A Certificate of Destruction (CoD) is a condition for de-registration of the ELV. *Final de-registration* is used as a synonym term.

Shredder
Any device used for tearing into pieces or fragmenting end-of life vehicles, including for the purpose of obtaining directly reusable metal scrap (Directive 2000/53/EC).

Treatment
Any activity after the end-of life vehicle has been handed over to a facility for depollution, dismantling, shearing, shredding, recovery or preparation for disposal of the shredder wastes, and any other operation carried out for the recovery and/or disposal of the end-of life vehicle and its components;

Unknown whereabouts of ELV
The complementary flows are referred to as unknown whereabouts of ELV. These are vehicles which are not reported; they are neither registered as part of the European vehicle stock (also called "vehicle fleet" or "vehicle parc"), nor as vehicles exported from the EU (termed extra EU-Export in COMEXT), nor as ELVs (Eurostat). (Mehlhart, et.al., 2011).

Used Car
A used car, a pre-owned vehicle, or a secondhand car, is a vehicle that has previously had one or more retail owners. Used cars are sold through a variety of outlets, including franchise and independent car dealers, rental car companies, leasing offices, auctions, and private party sales.

Vehicle registration certificate
An official document providing proof of registration of a motor vehicle. It is used primarily by governments as a means of ensuring that all road vehicles are on the national vehicle register, but is also used as a form of law enforcement and to facilitate change of ownership when buying and selling a vehicle. In the European Economic Area vehicle registration certificates are govern by the European directive 1999/37/EC.The data on numbers of registered vehicles in Europe are available from official sources, i.e. Eurostat

Vehicle deregistration
Cancelling your vehicle's registration removes the vehicle from the Motor Vehicle Register, which means the vehicle owner can no longer lawfully use the vehicle on the roads. Vehicle deregistration may occur only at the request of the vehicle's registered person or an insurance company.

Vehicle park
European vehicle stock or vehicle fleet

WEEE specific terms

Clearing House
A central agency for the collection, classification, and distribution especially of information. Clearing houses may be of public or private nature. In the context of this report, their aim is to coordinate the activities of Compliance Schemes (for BATT and WEEEs) at national level.

Collection
The gathering of waste, including the preliminary sorting and preliminary storage of waste for the purposes of transport to a waste treatment facility (Directive 2008/98/EC).

Dealer
Any undertaking which acts in the role of principal to purchase and subsequently sell waste, including such dealers who do not take physical possession of the waste (Directive 2008/98/EC).

Disposal
Any operation which is not recovery even where the operation has as a secondary consequence the reclamation of substances or energy. Annex I sets out a non-exhaustive list of disposal operations (Directive 2008/98/EC).

Distributor
Any natural or legal person in the supply chain, who makes EEE available on the market. This definition does not prevent a distributor from being, at the same time, a producer within the meaning of point (f) (Directive 2012/19/EU).

Harvesting or Scavenging
Removal of valuable components, only considering reuse or material value in e.g. compressors from temperature exchange equipment, hard disks, memory and other small IT components. Harvesting implies pre-treatment in a regulated environment. Scavenging implies theft from whole units in storage.

Mono flows of WEEE (pure WEEE flow)
A mono-flow contains devices which are financially attractive to the market. Mono-flows of WEEE are scrap metals flows that (almost) exclusively contain WEEE products (Wielenga et al., 2011).

Non-treatment
The term non-compliant does not necessarily imply substandard treatment, but rather refers to these quantities not being declared to national/ EU levels. Other terms commonly used are complementary treatment or unreported treatment.

Registered (reported) Flows/Collection
The quantities of WEEE reported to national registers and Eurostat WEEE database are called registered flows (Wielenga et al., 2011).

Unreported flow
The unreported flows are declared to regional authorities under different reporting regimes.

WEEE in mixed metal scrap (WEEE in light iron fraction, pre-shredder material)
Mixed flows (pre-shedder material) can contain metals from all possible sources ad these mostly contains limited percentage of WEEE (Wielenga et al., 2011).

WEEE from private households
WEEE which comes from private households and WEEE which comes from commercial, industrial, institutional and other sources which, because of its nature and quantity, is similar to that from private households. Waste from EEE likely to be used by both private households and users other than private households shall in any event be considered to be WEEE from private households (Directive 2012/19/EC).

Mining wastes and minerals terms

Mining waste and minerals terms are those used commonly within the Geological Survey community, as defined in the Minerals4EU project and as defined within the INSPIRE Directive framework. See also the US Geological Survey (USGS) 2011.

CGI
Commission of the International Union of Geological Sciences (IUGS - http://www.iugs.org/) for the Management and Application of Geoscience Information.

Geologic Material
The rocks and sediments that make up the land where we live. The characteristics of geologic materials reflect the processes that form them and the environments in which they form. Geologists divide these materials into three basic rock types.

Industrial Minerals and Rocks
Minerals which are neither metallic nor used as fuels, but which are mined and processed for their economic use. A broader definition describes an industrial mineral as any rock, mineral, or naturally occurring substance of economic value, exclusive of metallic ores and mineral fuels, and gemstones. In essence, they are the raw materials used in many industrial, agricultural and construction products.

Material
The term material is used ambiguously in geological science and in engineering science. Materials in natural systems are distinctly different from engineered materials. The term ‘Materials’ as used

[1] http://geomaps.wr.usgs.gov/sfgeo/geologic/stories/geologic_materials.html

here refers to ‘engineered materials’ that are composed, manufactured and processed to achieve intended properties.

A Metal (Metallic) Ore

A type of rock (mineral raw material) from which metal can be extracted at a profit.
Metals may be present in ores in the native form (such as native copper), or as noble metals (not usually forming compounds, such as gold), but more commonly they occur combined as oxides, sulphides, sulphates, silicates, etc. The generic wording 'metals' covers 'true' metals (see Periodic Table of Elements https://en.wikipedia.org/wiki/Periodic_table) but also includes semi-metallic substances or metalloids such as As and Ge which are often intimately associated with metals.

Mineral Raw Material

A natural inorganic or organic substance, such as a metallic ore, industrial mineral, construction material or energy fuel, but excluding water.

Open Geospatial Consortium:

The Open Geospatial Consortium (OGC - http://www.opengeospatial.org/) is an international not for profit organisation committed to making quality open standards for the global geospatial community. These standards are made through a consensus process and are freely available for anyone to use to improve sharing of the world's geospatial data.

Ore

Any naturally occurring (raw) material from which a mineral or aggregate can be extracted at a profit. The term 'ore' originally applied only to metallic minerals but now includes such non-metallic substances as sulphur, calcium fluoride (fluorite), and barium sulphate (barite). Ore is always mixed with unwanted rocks and minerals, known collectively as gangue. The ore and the gangue are mined together and then separated. The desired element (often a metal which is usually contained in chemical combination with some other element in addition to various impurities) is then extracted from the ore. It may be still further refined (purified) or alloyed with other metals.

ProMine AC database

This database stores all the information related to Anthropogenic Concentrations of mining wastes and smelting residues (http://ptrarc.gtk.fi/promine/default.aspx).

Aggregates

Any of several hard, inert materials, such as sand, gravel, slag, or crushed stone, used for mixing with a cementing or bituminous material to form concrete, mortar, or plaster; or used alone, as in railroad ballast or graded fill (Neuendorf, Mehl, & Jackson, 2011).

Ballast

Gravel, broken stone, expanded slag or similar material used as a foundation for roads, esp. that laid in the roadbed of a railroad to provide a firm bed for the ties, distribute the load, and hold the track in line, as well as to facilitate drainage (Neuendorf, Mehl, & Jackson, 2011).

Back fill

Earth or other material used to replace material removed temporarily during construction or permanently during mining, such as stones and gravel used to fill pipeline trenches or placed behind structures such as bridge abutments, or waste rock used to support the roof after removal of ore from a stope. The process of refilling an excavation, a mine opening, or the space around a foundation (Neuendorf, Mehl, & Jackson, 2011).

Cobbing

The separation, generally with a hand-held hammer, of worthless minerals from desired minerals in a mining operation, e.g. quartz from feldspar (Neuendorf, Mehl, & Jackson, 2011).

Concentrate
Enriched ore material collected after a removal of waste in a mill or concentrator. The rejected waste material is known as tailings (Neuendorf, Mehl, & Jackson, 2011).

Concentrator / dressing plant
An industrial facility where mineral processing takes place.

Extractive industry
All establishments and undertakings engaged in surface or underground extraction of mineral resources for commercial purposes, including extraction by drilling boreholes, or treatment of the extracted material (Directive 2006/21/EC).

Gangue
The valueless rock or mineral aggregates in an ore; that part of an ore that is not economically desirable but cannot be avoided in mining. It is separated from the ore minerals during concentration (Neuendorf, Mehl, & Jackson, 2011).

Marginal ore
Ore which, at current market value of products from its excavation and processing, just repays the cost of its treatment (Science Dictionary, 2016).

Mineral processing
Treating crude ores and mineral products in order to separate the valuable minerals from the waste rock, or gangue (Encyclopedia Britannica, 2016).

Mine
(a) An underground excavation for the extraction of mineral deposits, in contrast to surficial excavations such as quarries. The term is also applied to various types of open-pit workings.
(b) The area or property of a mineral deposit that is being excavated; a mining claim (Neuendorf, Mehl, & Jackson, 2011).

Mining
The process of extracting metallic or non-metallic mineral deposits from the Earth. The term may also include preliminary treatment, e.g. cleaning or sizing (Neuendorf, Mehl, & Jackson, 2011).

Mining waste (MIN)
Waste from extraction and processing of mineral resources. It involves materials that must be removed to gain access to the mineral resource, such as topsoil, overburden and waste rock, as well as tailings remaining after minerals have been largely extracted from the ore (European Commission, Mining Waste, 2016).

Ore
The naturally occurring material from which a mineral or minerals of economic value can be extracted at a reasonable profit (Neuendorf, Mehl, & Jackson, 2011).

Overburden
Barren rock material, either loose or consolidated, overlying a mineral deposit, which must be removed prior to mining (Neuendorf, Mehl, & Jackson, 2011).

Recovery
The percentage of valuable constituent derived from an ore, a measure of mining or extraction efficiency (Neuendorf, Mehl, & Jackson, 2011).

Run-of-mine
Ore in its natural, unprocessed state; pertaining to ore just as it is mined (Neuendorf, Mehl, & Jackson, 2011).

Slag
A by-product of the fusion of ores, metals, flux, and fuel that contains noneconomic constituents of the furnace charge (Neuendorf, Mehl, & Jackson, 2011).

Sorting
Processes that operate on particulate material to concentrate a desired component and separate it from waste material.

Tailings
The waste solids or slurries that remain after the treatment of minerals by separation processes (e.g. crushing, grinding, size-sorting, flotation and other physico-chemical techniques) to remove the valuable minerals from the less valuable rock (Directive 2006/21/EC).

Tailings dam
An earth-fill embankment dam used to store by-products of mining operations after separating the valuable fraction from the uneconomic fraction of an ore (Wikipedia, 2016).

Waste
Any solid or liquid generated by human activity that has little or no economic value, usually the result of the manufacture, mining, or processing of a material to produce an economic product (Neuendorf, Mehl, & Jackson, 2011).

Waste facility
Any area designated for the accumulation or deposit of extractive waste, whether in a solid or liquid state or in solution or suspension, for the following time-periods (Directive 2006/21/EC).

Waste rock
Rock that must be broken and disposed of in order to gain access to and excavate the ore; valueless rock that must be removed or set aside in mining (Neuendorf, Mehl, & Jackson, 2011).

Composition

Component
Uniquely identifiable part or subunit of products. Components are usually mechanically removable in one piece and are considered indivisible for a particular function or use. A component can consist of other components, e.g. a printed circuit board may contain a capacitor which is also a component. Some products may contain other products as components, for instance, a car has a battery. Other terms include subsystem, part, cluster of parts, or assembly.

Component Group Type
The ComponentGroupType aggregates all components included on a 'ComponentList' to a higher level of component groups. The aggregation is based on characteristics, application purposes, and composition.

Component List
A comprehensive list of components contained with products.

Composite Material
A composite material or composite is a material made from two or more distinct constituent materials with significantly different physical or chemical properties that, when combined, produce

a material with characteristics different from the individual components, adapted from Wikipedia, 2015).

Engineered Materials
Refined and processed raw materials to achieve specific functions and specifications e.g. alloys.

Homogeneous material
One material of uniform composition throughout or a material, consisting of a combination of materials, that cannot be disjointed or separated into different materials by mechanical actions such as unscrewing, cutting, crushing, grinding and abrasive processes" (Council Directive EC 2011, RoHS Art. 3 (20)).

HREE
Heavy Rare Earth Elements: Y, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb and Lu.

LREE
Light Rare Earth Elements: (Sc[2]), La, Ce, Pr, Nd, Pm and Sm.

Material Group Type
Defines the main categories in which materials are clustered into lists.

Material Type
The specification of the above mentioned material groups into material types.

Material List
The list of constituent materials within the material types.

Substance (or commodity)
Any (chemical) element or compound composed of uniform units (Brunner and Rechberger, 2004). All substances are characterised by a unique and identical constitution and are thus homogeneous.

[2] Not included in EC, 2014

Annex 2 – Waste legislation and reporting requirements

The framework for data gathering and reporting was set with the waste framework directive 2008/98/EC referring to the regulation that define basic rules of data structuring.

Directive 2008/98/EC
Waste framework directive. It provides a general framework of waste management requirements and sets the basic waste management definitions for the EU. It lays down general rules for waste prevention, re-use, recycling, recovery, and disposal as well as e.g. lists disposal (D, ANNEX I) and recovery (R, ANNEX II) operations.

Commission Regulations 2150/2002 and 849/2010
Commission Regulation 2150/2002 on waste statistics and Commission Regulation 849/2010 amending 2150/2002 establish a framework to produce Community statistics on waste generation (according to ANNEX I of 2150/2002), recovery, and disposal (according to ANNEX II of 2150/2002), complying with the mainly substance-oriented statistical nomenclature in ANNEX III of 2150/2002. Additionally, the Commission has to put up a table of equivalence between the latter nomenclature and the list of waste (Commission Decision 2000/532/EC).

BATT legislation

Directive 2006/66/EC is laying down the legislative basis concerning waste batteries on EU level since main aspects, such as minimum treatment requirement, collection as well as recycling rates (refined in Regulation (EU) No 493/2012, and reporting procedures are defined. Limitations of material usage is regulated in Directive 2013/56/EU.

Directive 2006/66/EC
on batteries and accumulators and waste batteries and accumulators and repealing Directive 91/157/EEC. Also known as 'Battery Directive' that define prohibitions, rules and requirements concerning production, POM and at the end of a batteries life. The overarching objective (Article 7) is, inter alia, to reduce the environmental impact of batteries by ensuring separate collection, reducing disposal and increasing the recycling of batteries and accumulators.
Within this context, the battery directive requires an annual reporting of the MS bodies to the EC containing at least the following content: battery mass collected, collection rate, and recycling efficiency. However, this is only obliged for portable batteries!

Directive 2013/56/EU
Directive on batteries and accumulators and waste batteries and accumulators as regards the placing on the market of portable batteries and accumulators containing cadmium intended for use in cordless power tools, and of button cells with low mercury content, and repealing Commission Decision 2009/603/EC. This Directive amends paragraphs of Directive 2006/66/EC.

Regulation (EU) No 493/2012
Rules regarding the calculation of recycling efficiencies of the recycling processes of waste batteries and accumulators.
This regulation refers to Directive 2006/66/EC and lays down general rules of the calculation of recycling efficiencies. Recyclers are obliged to report, inter alia, the recycling efficiency, input fraction, and output fraction and process design. The recycling efficiency "shall cover all individual steps of recycling and all corresponding output fractions". The composition of input and output fractions shall itemize elemental or component/compound level.

ELV legislation

Legislation on end-of-life vehicles has the aim to prevent and diminish negative environmental consequences caused by ELV, define producer responsibility, and establish rules and regulations for a better recyclability and recycling of vehicles. In addition to this, legislation on vehicles sets a classification system for types of vehicles, some of which are covered by European and MS directives and laws on end-of-life vehicles.

Directive 2000/53/EC
Directive 2000/53/EC on end-of life vehicles (known as "ELV Directive") defines a legislative framework to minimise the impact of ELV on the environment, to harmonise requirements for collection and treatment, and to set reuse/recycling and reuse/recovery targets for end-of-life vehicles.

Commission Decision 2005/293/EC
Commission Decision 2005/293/EC lays down detailed rules on the monitoring of the reuse/recovery and reuse/recycling targets set out in Directive 2000/53/EC on end-of-life vehicles and the minimum data required for reporting.

Directive 2005/64/EC
Directive 2005/64/EC on the type-approval of motor vehicles with regard to their reusability, recyclability and recoverability and amending Council Directive 70/156/EEC applies to vehicles belonging to the categories M1 and N1, which are defined in Directive 70/156/EEC, ANNEX II, and to new or reused components of M1 and N1 vehicles. It establishes rules and provisions to make sure vehicles and vehicle components maintain the required safety standards when being reused.

ELV Guidance
Guidance How to report on end-of-life vehicles according to Commission Decision 2005/293/EC describes the scope of the ELV directive and provides guidance to compile a quality report covering the ELV rates for reuse/recovery and reuse/recycling.

WEEE legislation

Legislation concerning WEEE on Member state level is directly linked to the WEEE Directive which is completed by compositional specifications and Commission Decisions 2004/249/EC and 2005/369/EC which lay down a questionnaire for the implementation report that Member States have to submit to the EC.

Directive 2012/19/EU
on waste electrical and electronic equipment (WEEE); known as 'WEEE Directive'. The WEEE Directive sets minimum requirements for the first treatment facilities. Moreover, it defines collection categories according to which data have to be reported.

Directive 2011/65/EU
Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment
OJ L 174 of 1 July 2011 (Roh's Directive).

Commission Decision 2005/369/EC
Commission Decision of 3 May 2005 laying down rules for monitoring compliance of Member States and establishing data formats for the purposes of Directive 2002/96/EC of the European Parliament and of the Council on waste electrical and electronic equipment (notified under document number C(2005) 1355).

Commission Decision 2004/249/EC
Commission Decision of 11 March 2004 concerning a questionnaire for Member States reports on

the implementation of Directive 2002/96/EC of the European Parliament and of the Council on waste electrical and electronic equipment (WEEE) (notified under document number C(2004) 714).

MIN legislation

The EU legislation that deals with mining waste (waste from the extractive industry) mainly deals with security (i.e. dam security) and health aspects (pollution of air, soil and water) of the waste. There is no legislation (yet!) similar to those dealing with WEEE, ELV etc., concerning reusability, recyclability and recoverability. Nevertheless, code lists (lexicon tables) derived from the Mining waste Directive (2006/21/EC) will be used in the data model developed for the ProSUM project.

Directive 2006/21/EC
Directive on the management of waste from extractive industries. The directive introduces measures for safe management of waste resulting from the extraction, treatment and storage of mineral resources and the working of quarries.

Decision 2009/335/EC
Technical guidelines for the establishment of the financial guarantee in accordance with Directive 2006/21/EC concerning the management of waste from extractive industries.

Decision 2009/337/EC
Definition of the criteria for the classification of waste facilities in accordance with Annex III of Directive 2006/21/EC concerning the management of waste from extractive industries.

Decision 2009/358/EC
On the harmonization, the regular transmission of the information and the questionnaire referred to in Articles 22(1)(a) and 18 of Directive 2006/21/EC on the management of waste from extractive industries.

Decision 2009/359/EC
Completing the definition of inert waste in implementation of Article 22(1)(f) of Directive 2006/21/EC concerning the management of waste from extractive industries.

Decision 2009/360/EC
Completing the technical requirements for waste characterization laid down by Directive 2006/21/EC of the European Parliament and of the Council on the management of waste from extractive industries.

Annex 3 – Review of data on automotive shredder residues composition

In a review of data on composition of automotive shredder residues (ASR), a number of studies were examined that were published between 1995 and 2016, with data originating from Switzerland, Japan, Italy, Sweden, Korea, U.K., Canada, France, Australia, Spain and unspecified countries. The coverage of ProSUM raw materials in these studies is presented in Table 20. With respect to the ProSUM scope, data were reported for 35 out of the 44 raw materials that were considered as very relevant according to the selection and evaluation criteria presented in Annex 5 of Deliverable 5.3, 12 out of 25 raw materials for which consideration is optional and 3 out of 11 raw materials that were classified as not relevant. Seven metals dominate the reporting: Al, Cr, Cu, Fe, Hg, Ni and Pb. These represent metals that may be economically interesting to recover or need to be monitored because of their hazardousness.

Table 20 Data sources on ProSUM elements in ASR.

	Raw material	Element symbol	Number of sources
Mandatory consideration	Aluminum	Al	9
	Antimony	Sb	3
	Beryllium	Be	1
	Cerium	Ce	1
	Chromium	Cr	19
	Cobalt	Co	3
	Copper	Cu	26
	Dysprosium	Dy	2
	Erbium	Er	
	Europium	Eu	
	Gadolinium	Gd	1
	Gallium	Ga	2
	Germanium	Ge	2
	Gold	Au	3
	Holmium	Ho	
	Indium	In	2
	Iridium	Ir	
	Iron	Fe	10
	Lanthanum	La	1
	Lithium	Li	1
	Lutetium	Lu	
	Magnesium	Mg	2
	Natural graphite	C	2
	Neodymium	Nd	2
	Nickel	Ni	18
	Niobium	Nb	2
	Osmium	Os	
	Palladium	Pd	3
	Platinum	Pt	3
	Praseodymium	Pr	1
	Rhodium	Rh	1
	Ruthenium	Ru	1
	Samarium	Sm	2
	Scandium	Sc	
	Silicon (metal)	Si	3
	Silver	Ag	5
	Tantalum	Ta	2
	Terbium	Tb	2

	Thulium	Tm	
	Tin	Sn	5
	Tungsten	W	2
	Ytterbium	Yb	
	Yttrium	Y	1
	Zinc	Zn	21
Optional consideration	Argon	Ar	
	Arsenic	As	13
	Bismuth	Bi	
	Cadmium	Cd	18
	Hafnium	Hf	
	Helium	He	
	Krypton	Kr	
	Lead	Pb	24
	Manganese	Mn	4
	Mercury	Hg	16
	Molybdenum	Mo	2
	Neon	Ne	
	Rhenium	Re	1
	Selenium	Se	8
	Strontium	Sr	2
	Tellurium	Te	1
	Thallium	Th	
	Vanadium	V	1
	Xenon	Xe	
	Zirconium	Zr	3
	Cooling/freezing agents (CFC, HFCs, etc.)		
	Ceramics		
	Alloys (to be further specified: i.a. Al-,Cu-,Fe-,Mg-,Zn- alloys		
	Glass (to be further specified: CRT glass, LCD glass, ...)		
	Plastics (to be further specifed: ABS, ABS-PC, Epoxy family, HIPS, Nylon, PA, PBT, PC, PET, PMMA, PI, POM, PP, PPE, PS, PUR, PVC, EPDM (rubbers), SAN, TPE, TPU, silicon based plastics)		
Not to be considered	Barium	Ba	3
	Borate		
	Coking coal		
	Fluorspar		
	Magnesite		
	Phosphate rock		
	Promethium	Pm	
	Rubidium	Rb	1
	Titanium	Ti	1
	Cardboard paper		
	Wood		

Other raw materials are more sparsely reported. Nine of the raw materials considered mandatory in ProSUM were not reported at all in the 30 studies reviewed. It is clear that only a few studies focus specifically on the scarce and critical metals content in ASR. Also, the reviewed studies differ in objectives and study methods. Some use ASR samples with different sizes, collected in different countries, at different times, and apply different digestion methods as well as methods for measurement. Some studies do not state such information. Data for some raw materials are presented for illustrating both the variability and the sparsity of data for most raw materials.

Copper is the most commonly studied raw material with 47 recorded data points in 26 studies (Figure 14). The distribution and difference between sources is striking: the highest value is more than 30,000 times higher than the lowest one as presented.

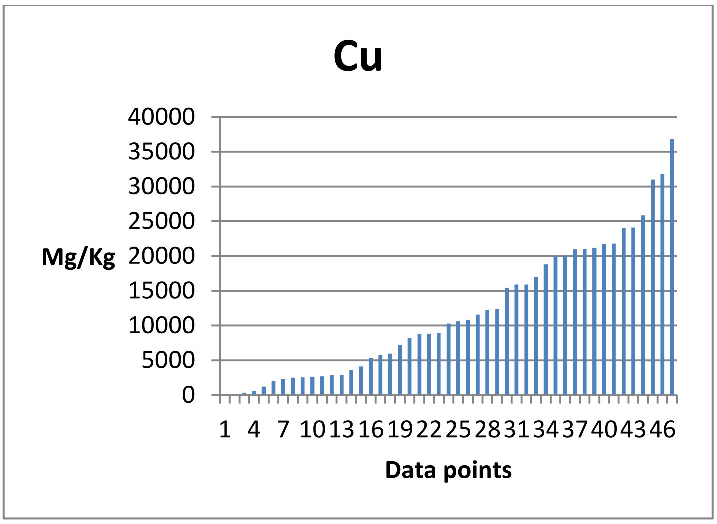

Figure 14 Reported mass fraction of Cu in ASR in reviewed studies

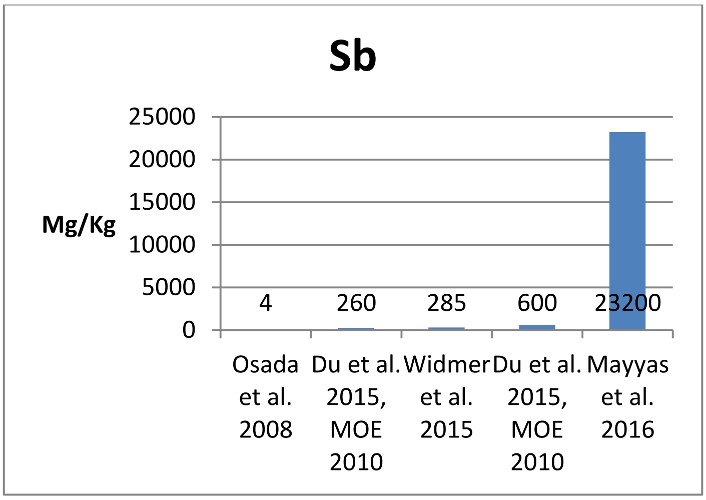

Figure 15 Reported mass fraction of Sb in ASR in reviewed studies

Figure 15 shows that the highest value on Sb (Mayyas et al., 2016) is significantly higher than the other four sources (Osada et al., 2008; MOE, 2010;, Du et al., 2015, Widmer et al., 2015 and Mayyas et al., 2016). Mayyas et al. (2016) is a pyrolysis study investigating environmental benefits and energy recovery from ASR, where only the mass fraction of the elemental analysis of the original ASR is included, not the ones treated under different temperatures for pyrolysis. If excluded, the remaining reported values of Sb would differ less.

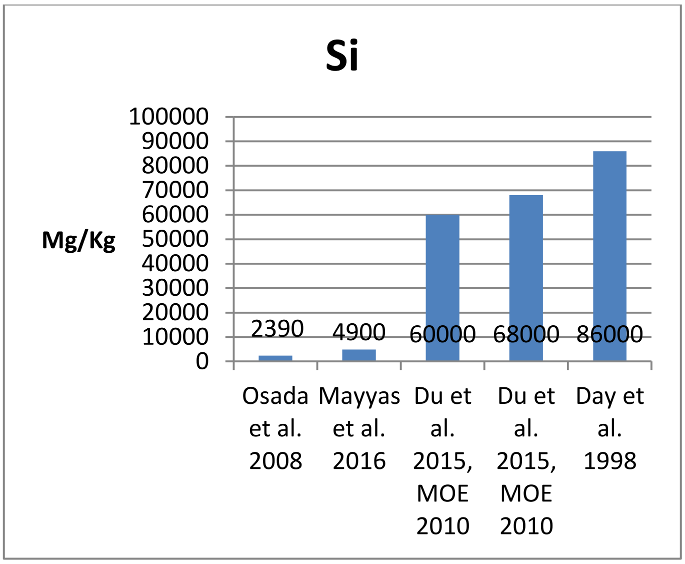

Figure 16 Reported mass fraction of Si in ASR in reviewed studies

Sources on Si also differ (Figure 16). But two studies are similar, Ministry of Environment Japan (2010) and Du et al. (2015), and use the same analytic methods, are conducted by the same researchers, and results are from a study of ASR of 70 ELV manufactured before 1996 and 70 ELV manufactured after 2000.

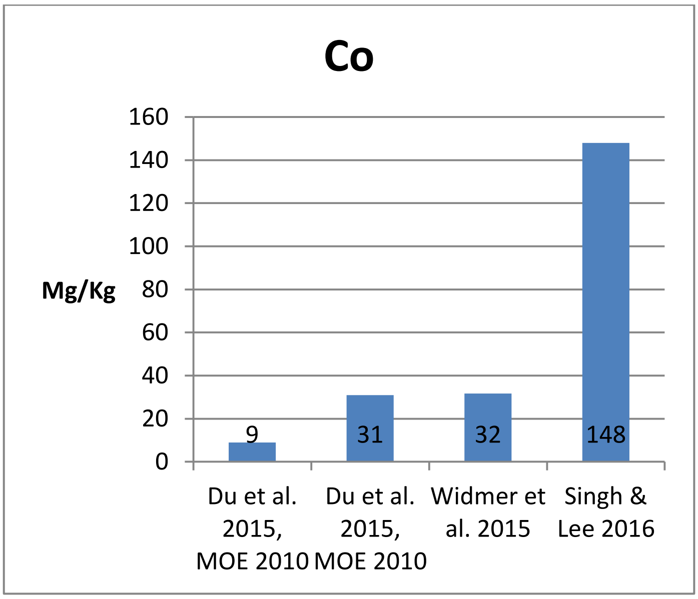

Figure 17 Reported mass fraction of Co in ASR in reviewed studies

The review also found large differences in recorded values of Co (Figure 17). The highest value was found in a study with the goal to maximize recovery of Cu, Ag, Mn and Co (Singh and Lee 2016).

The review makes it clear that the composition of ASR varies greatly. The variation is due to factors such as material composition of ELV and of other co-treated waste, dismantling approach, shredding and post-shredder treatment technology, as well as the local price and eligibility of ASR landfilling. The fact that these factors differ between countries as well as over time increases the variability of ASR composition. It is also clear that analytical sampling methods vary between studies. Moreover, ASR is not a uniform flow. In some cases, ASR refers to all residual, non-metallic outflows from shredding. In others, ASR refers to a mostly organic fraction with residual metal content resulting from several steps of post shredder treatment. Finally, in practice, "pure" *automotive* shredder residue rarely exist, since ELVs are mostly co-shredded with other waste flows from both households and industry. For these reasons, it was decided to not provide data on CRM composition of ASR in ProSUM. However, research indicates that CRM may accumulate in ASR (Widmer et al., 2015): their content as well as potential for their recovery should be further explored.

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