FINAL REPORT - ProSUM Project

Prospecting Secondary raw materials in the Urban mine and Mining wastes

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ProSUM

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This document summarises the key recommendations resulting from the ProSUM project. Individual project deliverable reports provide more detail and can be found at www.prosumproject.eu. See Annex 1 for a complete list.

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Batteries, credit to FEE (p. 11)
Cars disposal, credit to EMPA (p. 14)
Scavenging of TV, credit Lucía Herreras (p. 31)

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Executive Summary

Introduction

Batteries, electrical and electronic equipment, vehicles and mining waste contain both significant amounts and a large variety of raw materials, ranging from base metals to plastics, as well as precious metals and critical raw materials (CRMs). The EU is reliant on imports for many of these raw materials and aims to realise a Circular Economy. Securing responsible sourcing of those materials as well as increasing recycling rates is a complex societal challenge, partly because of the lack of structured data on the quantities, concentrations, trends and final whereabouts in different waste flows of these secondary raw materials in the Urban Mine in Europe. Currently, data on primary and secondary raw materials are available in Europe, but scattered amongst a variety of institutions including government agencies, universities, NGOs and industry. The aim of the ProSUM project was to provide a state of the art knowledge base, using best available data in a harmonised and updateable format, which allows the recycling industry and policymakers to make more informed investment and policy decisions to increase the supply and recycling of secondary raw materials.

The Urban Mine Platform

The ProSUM project developed the very first EU-wide and open-access Urban Mine Platform (UMP) located at www.urbanmineplatform.eu. This dedicated web portal is populated by a centralised database containing all readily available data on market inputs, stocks in use and hibernated, compositions and waste flows of electrical and electronic equipment (EEE), vehicles and batteries (BATT) for all EU 28 Member States plus Switzerland and Norway. The UMP's user-friendly design features dedicated applications, allowing the user to select and produce charts and to download resulting data 'on-demand' in a quick manner. The knowledge base is complemented with an extensive library of more than 800 source documents and databases. With the ability to view the metadata, methodologies, calculation steps and data constraints and limitations are made explicit, allowing the user to review key information and to get an idea of the data quality of the sources used for this massive prospecting effort.

This work has been innovative in that it has taken available data from a very unstructured and wide range of published documents and unpublished data and created a system for harmonising and structuring this data. This is done by means of a new classification system and harmonisation code lists for all elements, materials and components in products which are feeding the carefully designed ProSUM Unified Data Model. This provides the ability to easily update, maintain and expand the data behind the platform in the future.

The centralised database built on the Unified Data Model includes data for products put on the market, in use or hibernated in-stocks within the Urban Mine, the waste generated at end of life, and the flows of waste generated. The data includes those elements and materials found to be of high abundance in these waste products. This includes mainly base metals, precious metals and those also listed as CRM. Some glass and plastics data is also recorded and provided although this was not a focus of the project.

A number of dynamic charts allow the user to access detailed data and market intelligence on:

1. The **Urban Mine** representing the number and type of products placed on the market, in-stock (in use and hibernated) and generated as waste.
2. The **Compositions** specified for key components, materials and elements, such as aluminium, copper, gold or neodymium, **contained in batteries, EEE and vehicle products.**
3. The **Waste Flows**, including reported collection amounts, estimates for small batteries and EEE products in unsorted municipal solid waste, certain complementary batteries and EEE recycling flows, exported used vehicles and unknown whereabouts of vehicles, batteries and electronics.

The products in the Urban Mine

If all of the EEE in stock in households, businesses and public space was shared out between each EU28+2 inhabitant, each person would own close to 44 EEE products plus another 12 (energy saving) lamps and 33 light fittings, which are counted separately. In addition, there are 0.50 vehicles per person in the fleet. In vehicles, EEE and other applications, there are another 40 batteries in stock on average per person. **Figure 1** illustrates these total quantities with the pieces per average person on the left and the average weight per person on the right.

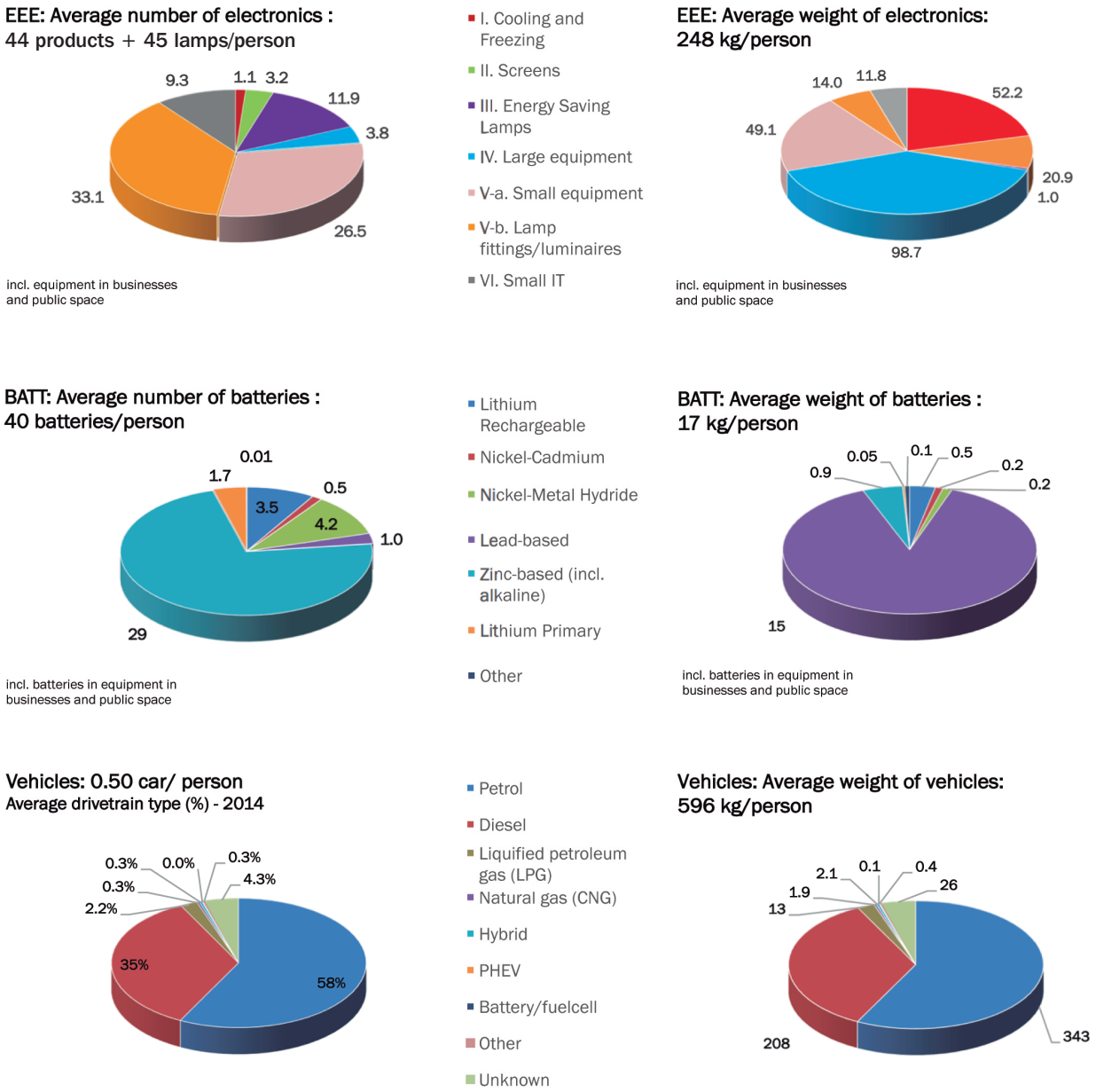


***Figure 1**. Total number of EEE, batteries and vehicles in-stocks in the Urban Mine in average number of pieces (left) and weight (right) per person, EU28+2, 2015 (2014 for vehicles).*

The above values per EU inhabitant are averages:

- For EEE, dependent on the country and the income levels, these averages per person range from 220 kg per inhabitant in Latvia up to 350 kg per person in Norway.
- For batteries, the averages range from 6 kg batteries per person in Greece up to around 25 kg in Austria, Belgium, Germany, Denmark and Sweden, and over 40 kg in Luxembourg.
- For vehicles the averages typically range in between 450 to 750 kg per person with lower amounts in Eastern Europe with for example 260 kg in Romania and a 1000 kg per person in the case of Luxembourg. Differences are mainly due to the number of vehicles per capita and not vehicle mass.

Specific data is available in the UMP for all EEE collection categories individually, for the 7 battery keys and for vehicles as well as for the whole of the EU28, including Norway and Switzerland and, for vehicles, also Iceland. Information is provided in tonnes, kilogrammes per inhabitant and in number of pieces. The charts contain actual and estimated data generally from 2000 until 2014 (vehicles) or 2015 (batteries and EEE) and projected data up until 2020 based on extrapolated market trends of the past years.

The components, materials and elements in the Urban Mine

The entire stock of products constitutes a considerable and growing Urban Mine as exemplified for the years 2000 to 2020 in **Figure 2** for EEE (last years projected). The left axis (coloured stacked bars) displays precious metals and indium in tonnes, the right axis (lines) illustrates the base metals aluminium and copper, the plastics materials and circuit boards as components. It is interesting to see that despite increasing numbers of products, the printed circuit board weights are decreasing due to rapid miniaturisation, the gold content is stabilising and the aluminium and in particular plastics content is drastically increasing.

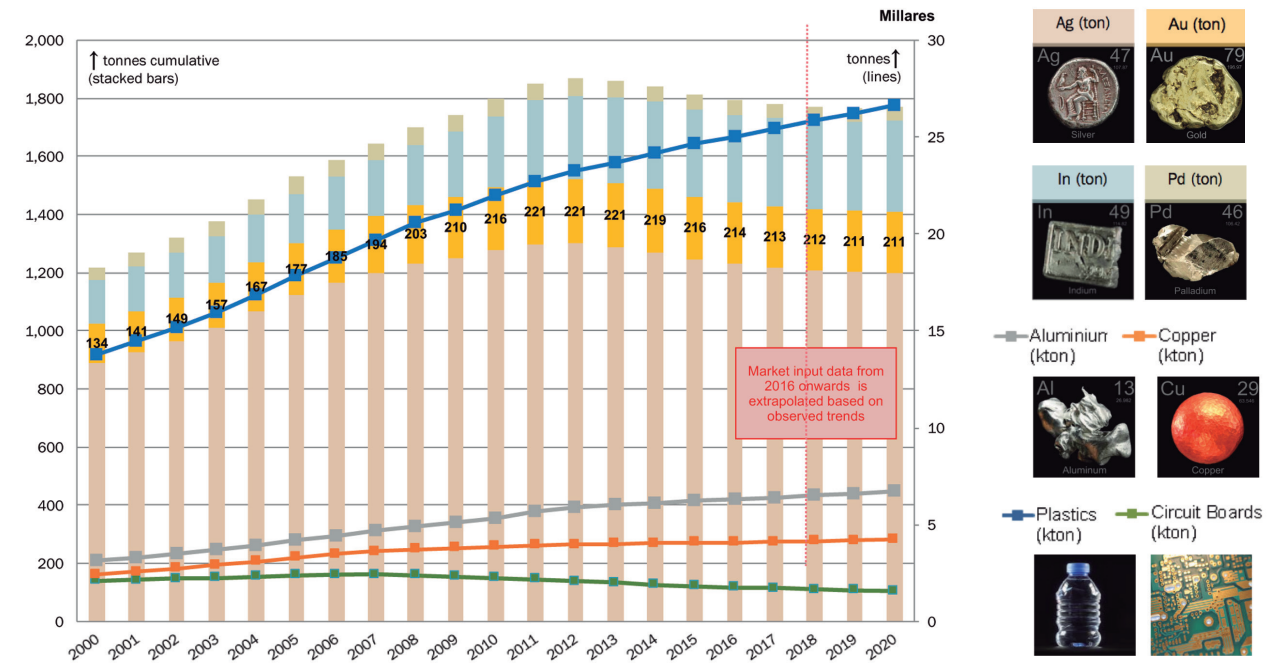


Figure 2. The Urban Mine development for selected elements, materials and components from EEE in-stock, 2000-2020, EU28+2.

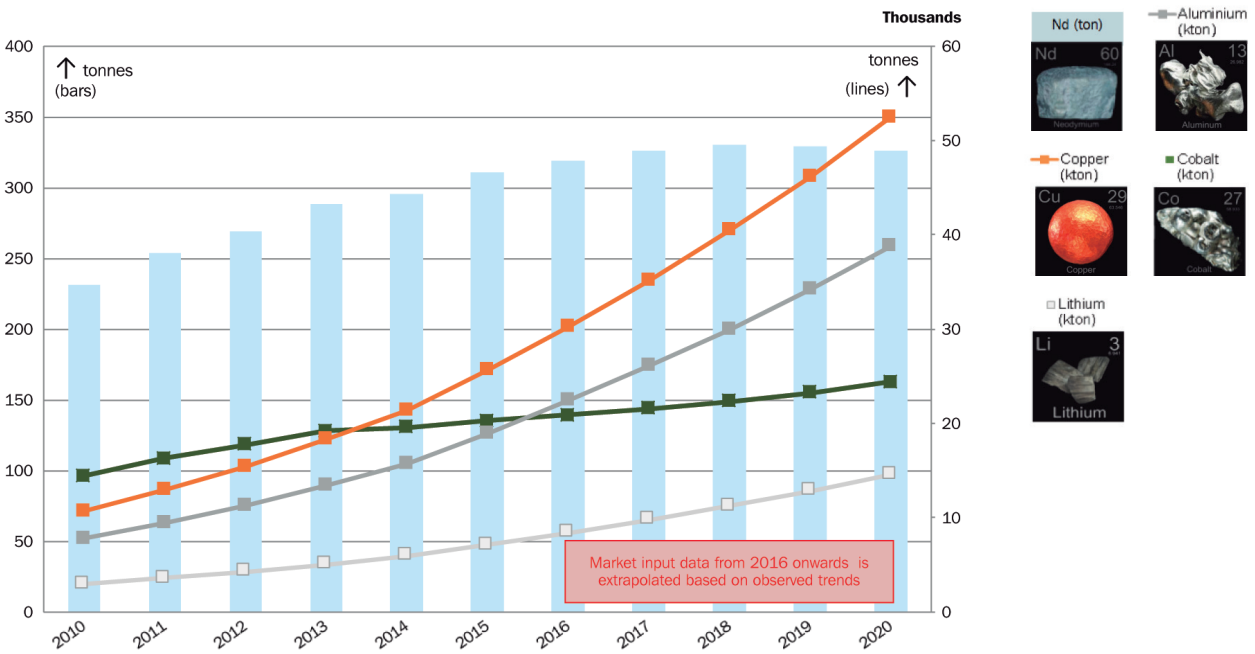


Figure 3. The Urban Mine development for selected elements from Batteries in-stock, 2010 – 2020, EU28+2.

Table 1 shows summary data for tonnes placed on the market (POM) and stocks as well as waste generated and estimates provided for some selected base metals, precious metals and CRMs, typically found in relatively high occurrences in these products and selected components. Interestingly, the amounts of gold and silver placed on the market seem somewhat higher for vehicles than for EEE, while in the stock the amounts are around twice as high in vehicles as in EEE. This is due to the longer lifetime of vehicles compared to EEE.

Table 1. *Overall results for the Urban Mine for elements in-stock in EEE and BATT (2015) and vehicles (2014).*

Product	POM (tonnes)	Uncertainty	Stock (tonnes)	Uncertainty	Waste generated (tonnes)	Uncertainty
Batteries	**2.7 million**	-25%/+25%	**9 million**	-30%/+30%	**2 million**	-40%/+40%
Selected elements	Cobalt: 3,500 Lithium: 2,100 Manganese: 37,000	-30%/+30% -50%/+50% -30%/+30%	Cobalt: 21,000 Lithium: 7,800 Manganese: 114,000	-30%/+30% -50%/+50% -30%/+30%	Cobalt: 2,700 Lithium: 720 Manganese: 32,000	-40%/+40% -60%/+60% -40%/+40%
EEE	**11.6 million**	-10%/+10%	**129 million**	-10%/+10%	**10.3 million**	-15%/+15%
Selected elements	Plastics: 2,900,000 Copper: 270,000 Gold: 26 Neodymium: 1,200 Indium: 30 Silver: 130	-15%/+20% -20%/+20% -15%/+15% -65%/+65% -35%/+35% -15%/+15%	Plastics: 26,500,000 Copper: 4,100,000 Gold: 230 Neodymium: 12,000 Indium: 300 Silver: 1,350	-15%/+20% -20%/+20% -15%/+15% -65%/+65% -35%/+35% -15%/+15%	Plastics: 2,400,000 Copper: 330,000 Gold: 31 Neodymium: 1,000 Indium: 30 Silver: 170	-20%/+25% -25%/+25% -20%/+20% -70%/+70% -40%/+40% -20%/+20%
Vehicles	**18 million**	-10%/+10%	**310 million**	-5%/+5%	**14 million**	-10%/-10%
Selected elements	Aluminium: 1,800,000 Copper: 410,000 Iron: 13,300,000 Silver: 210 Gold: 31 Palladium: 50 Platinum: 50 Neodymium: 1,700	-9%/+10% -17%/+20% -5%/+5% -50/+100% -50/+100% -33%/+50% -33%/+50% -33%/+50%	Aluminium: 24,000,000 Copper: 7,300,000 Iron: 213,000,000 Silver: 3,100 Gold: 440 Palladium: 850 Platinum: 530 Neodymium: 12,500	-9%/+10% -17%/+20% -5%/+5% -50/+100% -50/+100% -33%/+50% -33%/+50% -33%/+50%	Aluminium: 1,200,000 Copper: 360,000 Iron: 10,400,000 Silver: 160 Gold: 23 Palladium: 47 Platinum: 26 Neodymium: 500	-9%/+10% -17%/+20% -5%/+5% -50/+100% -50/+100% -33%/+50% -33%/+50% -33%/+50%

The above can also be visualised by means of a so-called Sankey diagram representing the fate of CRMs for example in collection and 'unknown whereabouts'. **Figure 4** shows the relative size of the flows for selected elements. The large middle section in the diagram shows a significant amount in-stock in the Urban Mine, representing what will be potentially available for future recycling.

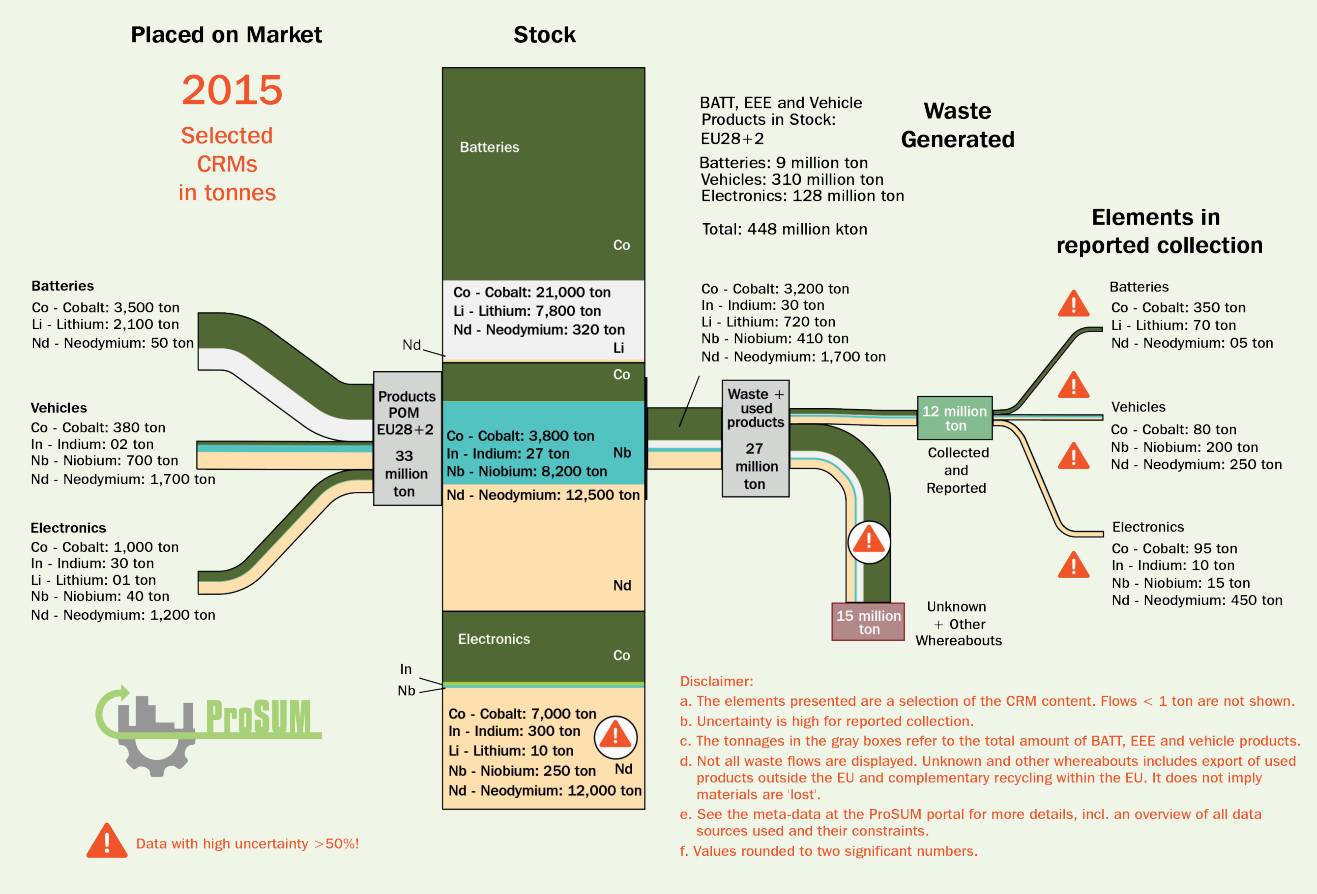


Figure 4. *Sankey diagram for market input, stocks, waste generation and waste flows for selected CRMs, 2015, EU28+2.*

At the right hand side of the chart, the actual reported collection is relatively low, due to significant trade and complementary recycling. These ratios are 'commonly' in between 40 to 70% as diverted waste flows for all three product groups, representing a significant amount of valuable materials and components remaining unaccounted for.

How reliable is the data? Data quality, limitations and constraints

As with any data gathering exercise and due to the scattered and incomplete nature of compositions data specifically here, some data presented are of lower confidence, as also illustrated in **Table 1**. For certain elements in certain products, the data should hence be considered the result of a first round of 'prospecting'. This is the reason why in the above **Table 1** and **Figure 4**, some elements are highlighted in red respectively with a warning sign on the total quantities computed where the uncertainty is larger than 50%. The reason is that for instance for some minor elements, no complete composition time series are available and thus significant uncertainty remains inevitable. Here, further 'exploitation' sampling efforts are recommended when CRM recovery investments are considered in the future.

In order to allow the user to better understand the background on this as well as all caveats and limitations, the listing of all source data, and the methodologies applied, any choices and assumptions are made available via the so-called metadata catalogue. This can be accessed via the 'Sources' part at the bottom of the left hand menu or via the 'More Information' button of each chart on the bottom right. Alternatively, this information is also available via http://prosum.geology.cz where one can directly navigate through a tree mirroring the main menu of the platform, down to the descriptions of all individual datasets for batteries, ELV and WEEE.

Mining Wastes and Minerals4EU database

The project scope also included mining wastes. During the project data on amount and composition of stocks of mining waste was collected with the purpose to create a dataset from which deposits with high levels of CRM could be identified and explored for. These data, which also contain other information about the mining waste such as location, type of waste and origin, will be stored in an extension of the database for primary raw materials, the Minerals4EU database. This database, accessible via http://minerals4eu.brgm-rec.fr, makes up an important part of the European Minerals Knowledge Data Platform (MKDP). In the Minerals4EU extension for mining waste it is possible to store information about generated waste rocks from mines, generated tailings from mineral processing plants but also data on waste from metal producing plants, i.e. smelters and blast furnaces. Data gathering on metal producing plants

was, however, not included in the project. The database extension also required new code lists though several of the code lists from Minerals4EU could be re-used in the ProSUM project. The MKDP lies within the ownership and development work of the Minerals4EU Foundation. The not for profit Minerals4EU Foundation overall scope is, on the one hand, to provide a one-stop-shop to official and verified data, information and knowledge on mineral resources, and, on the other, to act as contact point through which stakeholders can easily and transparently access its products and expertise. Among its main services, the Foundation will coordinate the development of the European Union Mineral Resources Knowledge Base infrastructure. Both the UMP and MKDP are linked and accessed through the ProSUM Portal where it will be possible to view data related to both primary and secondary resources, making the ProSUM Portal a unique site for combining data sources on both primary and secondary raw materials.

What is next?

All of this work was funded through the Horizon 2020 research and innovation programme, this three-year research project brought together a unique group of experienced professionals. The project commenced in January 2015 and concluded in December 2017. An Information Network was also created to engage end users and stakeholders in the development of the platform and expansion of the knowledge base. The project addressed a wide range of end users, including the recycling industry, producers and producer compliance schemes, and policy makers.

In the coming years, the project consortium will focus on delivering a minimum viable product for the most promising customer segments and servicing others with automated services. To that effect, the partners will seek to understand better the (potential) end-users' needs (market analysis and market testing) and, on that basis, develop (new) services and applications. A network of data providers will be set up. The aim is to maintain, update and expand www.urbanmineplatform.eu. Options are being sought to fund maintenance, reduce data gaps with more and newer information and to expand the Urban Mine Platform to other relevant waste streams. In 2018 specifically, the project consortium will investigate dedicated applications and services, dependent on the demand from industry, policy makers and academia. Users are kindly invited to provide feedback to the project coordinator or send inquiries for bespoke services and reports to info@weee-forum.org allowing this valuable work to continue in the coming years. From this contact, any information requests will be forwarded to the lead project partners specialised in the individual waste sectors, being Chalmers and EMPA for vehicles, TU Berlin for batteries and UNU for EEE.

After the end of the project, the Information Network is expected to remain the forum where professionals involved in prospecting the secondary raw materials in the urban mine meet, where both the future UMP managers and data providers meet customers. The current members of this exceptional network of professionals will be invited to monitor developments of the Urban Mine Platform and actively engage with the activities of the UMP through membership of a group on LinkedIn. An outreach will be made to expand the network. The WEEE Forum will explain to potential customers the advantages of the UMP, whilst the customers will inquire about the latest changes to data and protocols, or applications and services.

Finally, a detailed series of recommendations has been developed with focus on further improving the knowledge base for secondary raw materials. Some of these recommendations will form the starting point for new and ongoing Horizon 2020 projects.

A separate detailed recommendation report accompanies this final report and is available via **www.prosumproject.eu** in Deliverable 6.4 - Recommendations.

The range of data, charts and information which can be produced from UMP and MKDP is extensive. The reader is encouraged to visit **www.urbanmineplatform.eu** to further explore the data.
Notice that all battery data content is shown separately from the EEE and vehicles from which they came.

Table 2. Key terms used in this report to describe the Urban Mine.

Term	Definition
POM	Number of products Placed On the Market (POM) or sold to consumers, businesses and organisations each year.
Stock	The products which are in use or stored in households, businesses, and organisations before being thrown away.
Reported collection / deregistered vehicles	The amount reported as collected and recycled inside the extended producer responsibility system.
Waste generated	The estimated amount of waste (may include used products) leaving the stock once discarded (BATT and EEE) or deregistered (vehicles). For vehicles, this term refers to the total for waste and used products leaving the stock (vehicles recycled, exported for use and of unknown whereabouts).
Waste flows **1. Reported collection** **2. Complementary flows** **3. Unknown whereabouts**	1. Reported collection and recycling and an estimation of the fate of unknown whereabouts which includes complementary recycling (not managed through the formal extended producer responsibility system), exported, disposed of with residual waste, and unknown. 2. The term complementary flows mainly refers to all waste flows that are not reported at a national level by the official compliance systems, and others, according to the ELV, BATT and WEEE Directives. A certain portion of these flows are exported, and for BATT and WEEE incinerated or landfilled. 3. For vehicles, the complementary flows are referred to as unknown whereabouts. These are vehicles which are not reported, nor registered as part of the European vehicle stock ("vehicle fleet"), nor as vehicles exported from the EU (termed extra EU-Export in COMEXT), nor as ELVs reported to undergo treatment (Eurostat).

A more precise and elaborate description of all definitions used in the ProSUM project is available via www.prosumproject.eu in the ProSUM Deliverable 5.3 – Review and the Harmonisation for external feedback and consultation – Annex 1 – Definitions.

1. Introduction - A new knowledge base

The EU is reliant on imports of many raw materials, some of which are critical raw materials (CRM). Securing access to these materials is a societal challenge. The aim of the ProSUM project was to provide a state of the art knowledge base, using best available data in a harmonised and updateable format, which allows the recycling industry and policymakers to make more informed investment and policy decisions to increase the supply of secondary raw materials. Simply put, ProSUM Latin for 'I am useful', has sought to provide data which improves knowledge on the amount of secondary raw materials in the Urban Mine. It provides no technical or economic assessment of whether these materials can be recovered but is an initial 'prospecting' for potential sources, allowing for future 'exploitation' of the most abundant locations of secondary raw materials.

In ProSUM, the Urban Mine includes spent batteries, waste electrical and electronic equipment (WEEE), end-of-life vehicles (ELV) and mining wastes. These product groups are relatively rich in CRM. Historic mine deposits and wastes from active mining also contain untapped reserves of CRMs. Every year, over 10 million tonnes of WEEE, 14 million tonnes of ELV and over 2 million tonnes of batteries are estimated to reach their end of life. In addition, 650-700 million tonnes of waste from mining and quarrying (Eurostat, data for 2014) is generated annually.

Whilst this project was driven by the Strategic Implementation Plan of the European Innovation Partnership on Raw Materials and an aspiration to reduce material supply risks, particularly for CRM, there are additional environmental benefits from recycling materials and economic benefits from retaining materials in the economy for longer. This also supports the European Commission's Circular Economy Action Plan.

For the three product groups in the Urban Mine, a detailed inventory of available data has been created which describes products placed on the market (POM), the stock of them in use or hibernated at homes or businesses, and the waste generated when discarded. A stock and flow model provides the temporal dimension to this inventory. The inventory consists of available data, gathered from published and unpublished reports, data and national statistics, which characterise product content, product residence time, waste generated, waste composition, and waste flows. As the data was gathered from many different usually unstructured sources, produced for different objectives, using different techniques and stored in various formats, a new classification system was developed to provide a harmonised data structure.

Mining waste differs in many aspects from the other product groups in ProSUM in that there is no EU legislation that requires recycling, there is no major recycling industry, and there is sparse Eurostat statistics on mining waste and only at country level. The Mining Waste part in the ProSUM projected is therefore discussed separately in Chapter 8.

The results of the project provide the foundation for improving Europe's position on raw material supply, with the ability to accommodate more wastes and resources in the future. ProSUM provides an important fact based starting point for improving the collection and management of these wastes enabling enhanced resource efficiency via improved collection, treatment and recycling.

2. Describing and quantifying the Urban Mine

2.1 Collecting and harmonising data

The available data on secondary raw materials was generated by a large number of different institutions, including government agencies, universities, NGOs and industry. ProSUM has collected, harmonised, evaluated and consolidated this data, embodying the current state of knowledge, to produce the best possible estimate of the size and composition of the European Urban Mine of batteries, EEE and vehicles.

This was achieved through the development and use of a classification system for stocks and flows of products, wastes and their compositions. At the core of this system lies the representation of products as the sum of their constituent components, materials and elements (**Figure 5**). For each of the levels, a set of "code lists" was created, providing a library of clearly defined terms referring to specific types of products (e.g. mobile phone), components (e.g. printed circuit board), materials (e.g. stainless steel) and elements (e.g. chromium). The classification system allows for recording all data in a structured and harmonised way and also corresponds to possible measures for increased recovery: components containing larger amounts of CRM (hot-spots) may be identified, dismantled and separately recycled, different materials may be separated by mechanical treatment, and the composition of materials influences the recoverability of specific chemical elements in metallurgical processes.

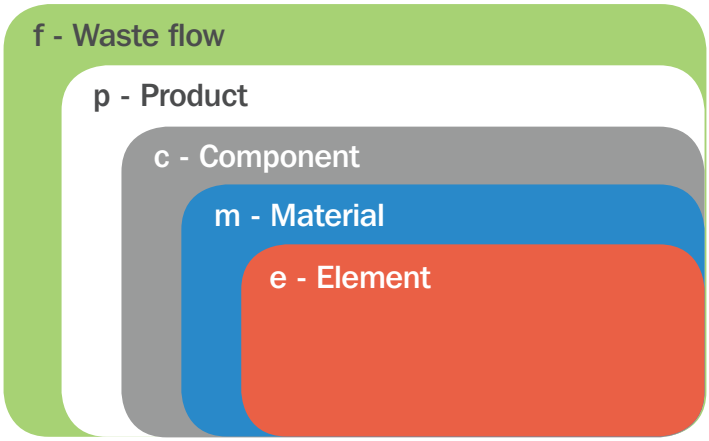


Figure 5. *Simplified ProSUM calculation sequence.*

2.2 Evaluating the quality of data

In an ideal world, reliable data would be available to describe the composition of every product for all of the levels shown in **Figure 5**. In practice, this is rarely, let alone completely, the case. The original data has often been generated for other purposes than quantifying secondary raw materials, in particular CRMs in the Urban Mine, influencing its reliability, scope, representativeness and ultimately its usefulness. ProSUM evaluated the quality of all original data using a pre-defined procedure that takes into account incomplete specifications as well as important aspects such as sample size, measurement method and temporal representativeness. Data was classified as "highly confident", "confident", "less confident" or "dubious" as illustrated in **Figure 6**. Later, when estimating representative values at the member state or European level, the assigned data quality was used to determine how much weight to place on different data sources.

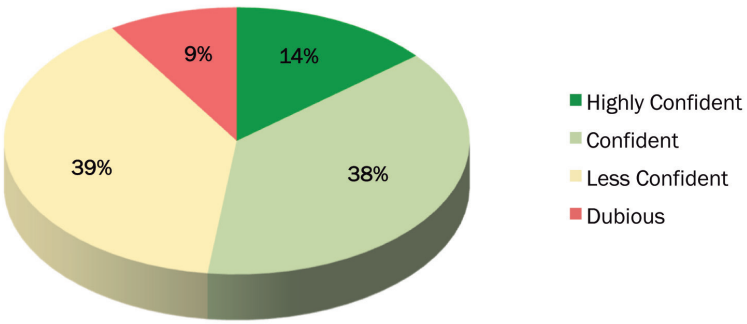


Figure 6*. Data quality levels assigned to product composition raw data in ProSUM.*

2.3 Data produced to describe the Urban Mine

The main difficulty with bringing together product composition data from different sources lies in the fact that they refer to different lists of components and materials and use different levels of detail to describe products. The consolidation of data was therefore handled separately for each product (or product group) and involved a careful trade-off between utilising as much of the available data as possible and simultaneously retaining and harmonising to a useful level of detail.

More than 800 sources containing data on the stocks, flows and composition of products and waste were processed during the project. The table below provides an overview of the data points created from these sources using a traffic light system to denote coverage. Data availability is relatively good for the amounts of products placed on the market, in-stock and generated waste as well as lifetimes, while there are significant gaps in the data for product weights and compositions, collected waste and other whereabouts of generated waste. Important to note is also that this coverage is not the same for each sector.

Table 3. *Data availability and coverage per waste sector.*

Data type	BATT	ELV	EEE
Products placed on market (POM)	19,364 records: 29% of data points are considered original. Gaps related to national data and years before 2011.	9,702 reported records plus 4,158 computed projected records.	43,507 records: 33% of data points are considered original. Plus external sources.
Product Average Weight	819 records based on market statistics and sampling.	26,460 actual records (stock information) and 11,340 computed records.	2,750 records: compared with product register data based on millions of data points.
Lifespan information	1,248 records, 51% based on age determination of collected waste batteries.	26,460 actual records (stock information) and 11340 computed records.	108 records: based on extensive multi-variate stock and flow modelling.
Composition	272 records Data for 17 electrochemical systems (subkeys), not differentiating time and regions.	1,764 records Data for 28 elements over 63 vehicle keys.	Cat. I, C&F: 4,680 records Cat. II, Screens: 5,460 records Cat. III, Lamps: 3,016 records Cat. IV, LHA: 10,868 records Cat. V, SHA: 14,820 records Cat. VI, IT: 4,662 records
Stock/ Waste Generation	2x 26,000 computed records, plus measured data for some countries and years on stocks of batteries in pieces per household.	23,000 of which 11,000 are computed.	2x 54 million records: computed.
Waste collected and reported	1,356 records in tonnes per country, year and battery family (key).	450 records (28+2 countries and 15 years).	1,080 records (2010-2015, 6 collection categories, 30 countries).
'Other' whereabouts Theft and parts harvesting	Some data on percentage of batteries in residual household waste (%), no data on other whereabouts.	600 records (28+2 countries and 20 years).	6,630 records: Based on 665 original data points/ sampling.

2.4 Unified data model

To be able to store the consolidated data produced within ProSUM in a single database, a unified data model, called the 'ProSUM-UDM', for WEEE, ELV and BATT and their stocks, flows and composition was developed. The UDM allows for storing and working with all the different types of data used to describe the Urban Mine, and ensures that applications and visualisations can be smoothly implemented in the Urban Mine Platform.

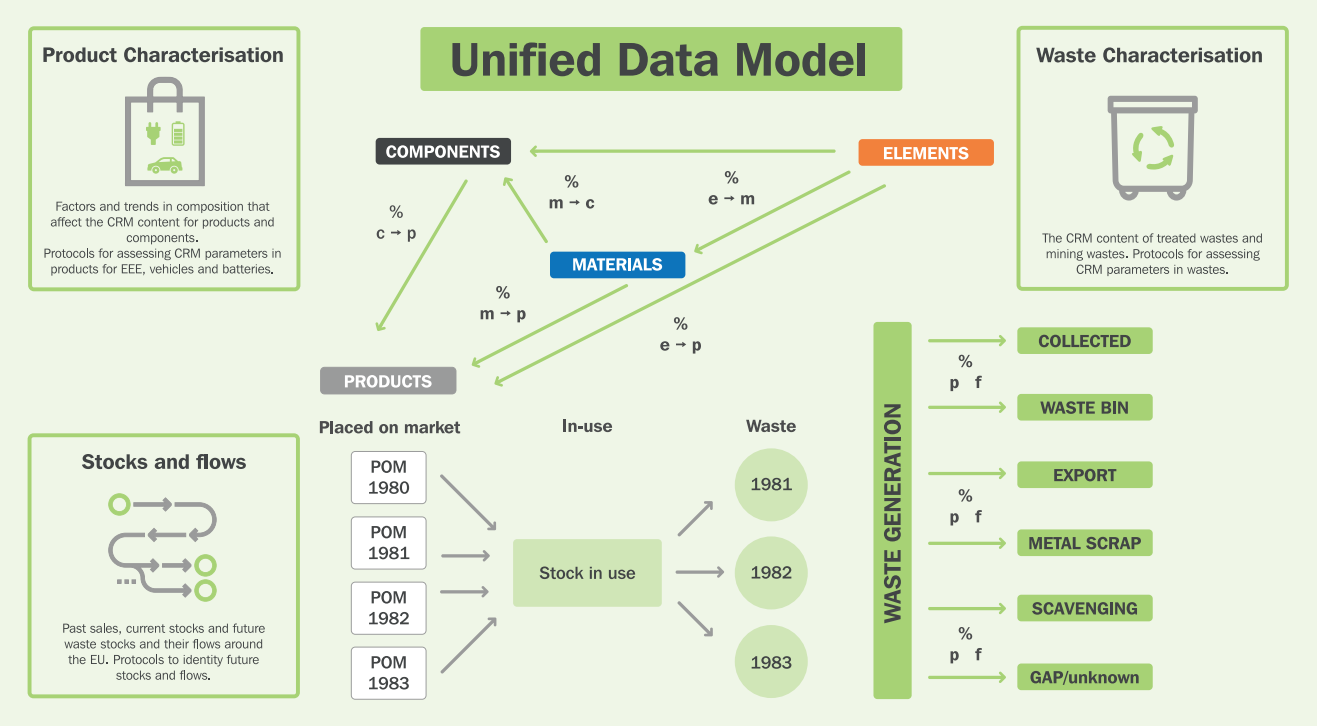


Figure 7. Schema showing a simplified interpretation of the ProSUM classification system for WEEE.

3. The Data Platforms created

3.1 Rationale

The ProSUM project is not designed to be stand-alone, but to be embedded and linked to a wider set of initiatives and portals aimed to jointly provide a comprehensive knowledge base on various types of primary and secondary raw materials. The ProSUM project has focused on rich sources of CRM: waste electrical and electronic equipment (WEEE), end-of-life vehicles (ELV), batteries (BATT) and mining wastes. In undertaking this work, data has also been collated on other secondary raw materials, primarily as base metals, precious metals and even gathered but not analysed for plastics, glass and other materials. The results are also shown by components, materials and elements where the data allows. The project consortium has constructed a comprehensive inventory based on harmonised data so that secondary raw material stocks and flows at national levels across Europe can be identified, quantified and mapped.

The availability of secondary raw materials data, easily accessible in one platform, aims to support Europe's position on raw material supply, with the ability to accommodate more wastes and resources in the future. This project's genesis was the Strategic Implementation Plan of the European Innovation Partnership on Raw Materials. Action II.8, in particular, was a call to action to develop a knowledge base on secondary raw materials to enhance the ability of the EU to use secondary raw materials and reduce reliance on imports.

An EU Raw Materials Knowledge Base Action II.8

A EURMKB on raw materials will serve both industry and policy making and create an added value on EU as well as on the data source level. It should provide a service containing the raw materials information infrastructure and intelligence, and could, if deemed appropriate, be organised as a permanent body. Close international co-operation could eventually lead to a world knowledge base on raw materials.

A EURMKB, providing a service at European level, should together with Members States collect, store, maintain, up-grade, analyse and disseminate data and information along the whole value chain on European raw materials. The raw materials are from primary and secondary sources, as well as stocks in use, namely metals, industrial minerals, construction materials, wood and natural rubber. The issue of confidential information should be addressed.

Data and information will be collected from sources such as EUROSTAT, JRC, Member States' relevant agencies, other national and international organisations, Member States and EU funded projects and programmes, as well as industry. The EURMKB will apply EU and global standards; maintain and up-date the data and information and make it available to public through internet and publications. Selected parts of data and information will be analysed and reported to public as an expertise, such as Material Flow Analysis (MFA) for metals, including the recycling value chain of given applications (e.g. end-of-life vehicles, including tyres or WEEE). Spatial data will be available in an INSPIRE-compliant way, as well as in 3D when appropriate.

Data, information and expertise will serve the society; in particular markets (including investors, mining, wood based, recycling and down-stream industries), MS governments and other lower level (regional, local) authorities, as well as the citizens (education, general public...).

3.2 European Mineral Resources Data Infrastructure

The data on the Urban Mine and mining wastes is presented on two platforms, both based on the Minerals Knowledge Data Platform (MKDP) developed under the Minerals4EU project. Expansion of the MKDP has been undertaken to include a wider set of mining wastes to be included. The UMP, formerly known as UMKDP, is designed as a fully-fledged extension to the MKDP which aims to become the future European Mineral Resources data infrastructure. This means there is a sustainable system designed to facilitate data updates and maintenance and allowing access to information across the resources value chain. This is the first time that it is possible to have the capability to combine information on primary and secondary resources.

3.3 The MKDP

The architecture for collating, storing and showing mining waste data were devised in EU-FP7 ProMine project, and then re-used within the Minerals4EU project: harmonised datasets are harvested and delivered according to INSPIRE (plus extensions) data model and the ERML v2 data model. This data model associates mining waste information with specific mineral deposits. However, it does not include data on the presence, type or amounts of CRMs. Within ProSUM, the initial data model has been extended and improved and new code lists were developed to describe:

- Density, volume and area of the deposit;
- Extraction, amount and composition; and
- Mining, processing and transformation activity.

The addition of the processing and transformation activity introduced to the model allows for a more detailed description of downstream activities like smelting and will make it possible to include slags and fly ashes in future.

3.4 The UMP

A totally new unified data model for the Urban Mine has been set up and new code lists or vocabularies have been developed for the Urban Mine linked to the Classification System. Harvesting templates, detailed Excel spreadsheets (called 'portrayals'), were developed to ensure that data from different sources on products, stocks and flows, compositions, and wastes were described in the same way, with the same fields and using the same vocabulary. This allows harvesting/uploading harmonised datasets into the ProSUM Harvesting Database. One of the major advances of the ProSUM project is that by using a harmonised classification system on which the central data model is based, heterogeneous data are transformed into a standard format, allowing for the linking of multiple data sources and the reprocessing of new, updated and homogenous information.

3.5 The ProSUM portal

The portal aims to give simplified, user-friendly and efficient access to existing and future data on secondary raw materials in the Urban Mine and mining wastes. From the portal www.prosumportal.eu it is possible to access:

- The Urban Mine Platform with applications to explore and view data and generate charts.
- The map viewer to map mining wastes stocks and also view data related to primary resources, all being served by the EU-MKDP.
- Search the 'knowledge base', the data and documents which have been used to describe the Urban Mine.

3.5.1 The Urban Mine Platform

The UMP developed during the project has a number of services and applications that allow the user to access and explore the data. For the purposes of marketing and simplicity, the name Urban Mine Platform is being used with end-users. Access to data in the Urban Mine Platform is via nine main pages (accessed through tiles), for EEE, vehicles and batteries for the Urban Mine (POM, stock and waste arisings), composition, and waste flows. The "Urban Mine" and "composition" charts cover the years for:

- EEE: Between 2000 and 2020, with the data shown for the years 2016-2020 being forecasts. EEE "Waste flows" charts only cover the years between 2010 and 2015.
- ELV: market input, stock and waste generated potential is for 2001 – 2020. For waste generated the data available is for 2005-2020, with 2015 as the first forecasted year for all graphs.
- BATT: Here the data for market input is for 2000 to 2015 and the stock and waste generated amount are projected in addition until 2020.

The applications, primarily bar charts, metadata descriptions and data downloads, were developed based on end-user requirements which were surveyed at two points in the project. As an example a key requirement was the elements in stock by waste category and by country, now and in the future. The applications allow the end-user to generate a chart showing the amount of a relevant element, e.g. platinum, in the stock in EEE, vehicles and batteries for any given country from 2000 to 2020. It is also possible to search by components and materials, and for products POM and waste generated. It is possible to generate charts of waste flows; however, these are described by product categories only due to the granularity of the product data in waste flows.
For each chart shown it is possible (to follow later) to download the data into an Excel spreadsheet.
See **www.urbanmineplatform.eu** to explore the data, charts and metadata.

3.5.2 The knowledge base – accessing documents and metadata

It is possible to access information from unstructured and structured sources. The unstructured data includes all of the reports and information sources that were screened during the project. Using the "data search" function and key words all documents in the ProSUM bibliography can be accessed.

The ProSUM Metadata Catalogue is integrated in the ProSUM Portal and is accessible via a tab on the homepage. It is the central access point to metadata concerning data on secondary sources of raw materials from the Urban Mines. It provides tools for compilation of those metadata in a standardised format that will allow users to effectively search through the database.

Also for each chart generated in the applications on the Urban Mine Platform, there is a button "more information" which provides a full and detailed explanation of the data including: the approach taken to produce the data, link to the source data, a description of the data quality, and the author in ProSUM. **Figure 9** and **Figure 10**.

In order to make the data discoverable in the most efficient way, the catalogue is fully compliant with international standards and supports the distributed system of metadata administration. Only digital and structured information (non-geographic and spatial datasets or dataset series and spatial data services) are described by metadata in this catalogue.

The ProSUM Metadata Catalogue is also accessible directly via: **http://prosum.geology.cz.**

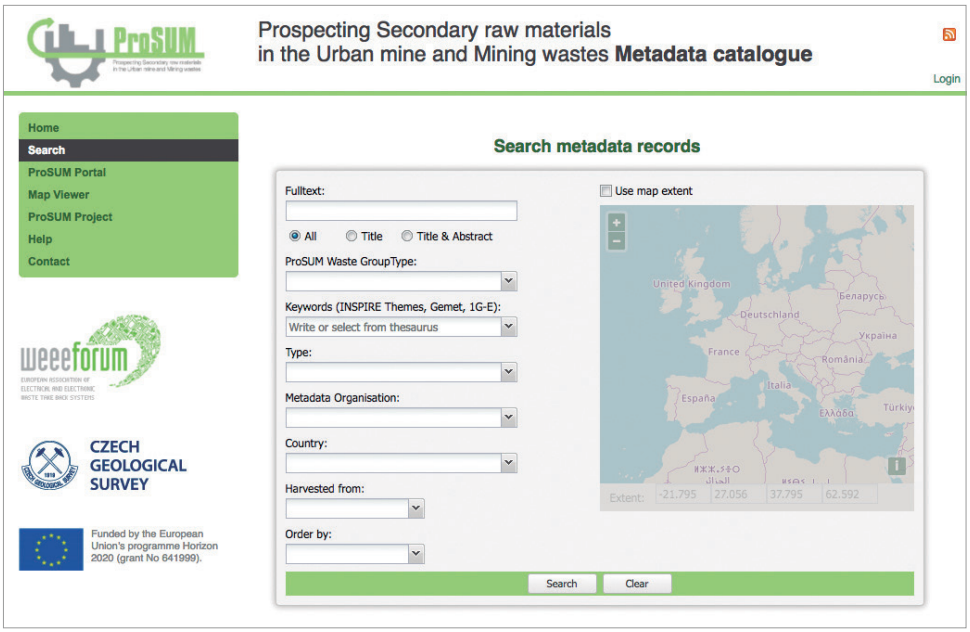


Figure 8. The search page of the ProSUM Metadata Catalogue.

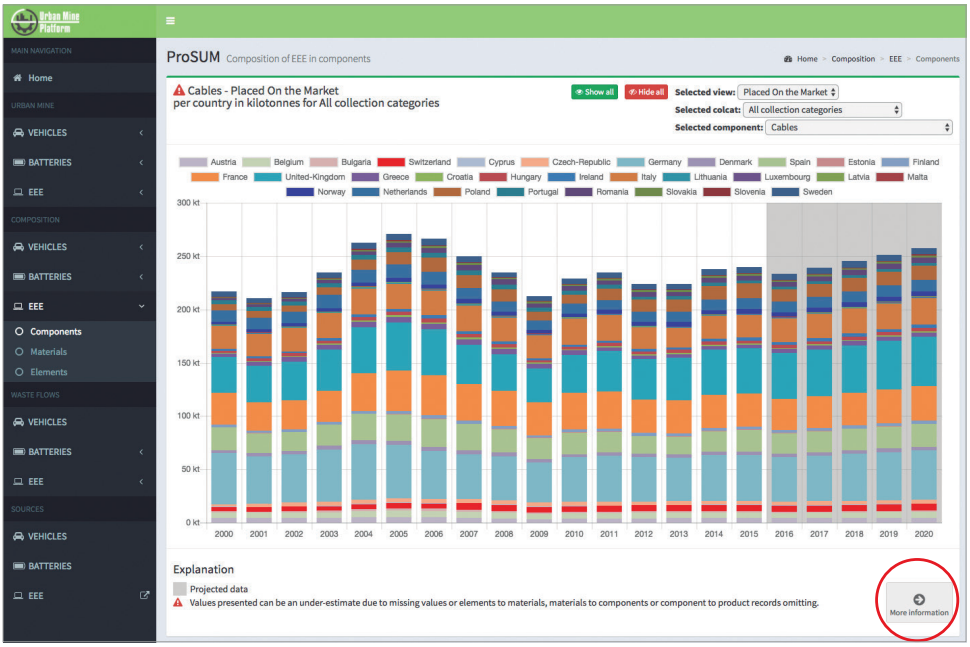


Figure 9. Example of the link between the ProSUM Metadata Catalogue and Portal – link to the metadata record providing more detail information concerning the data displayed.

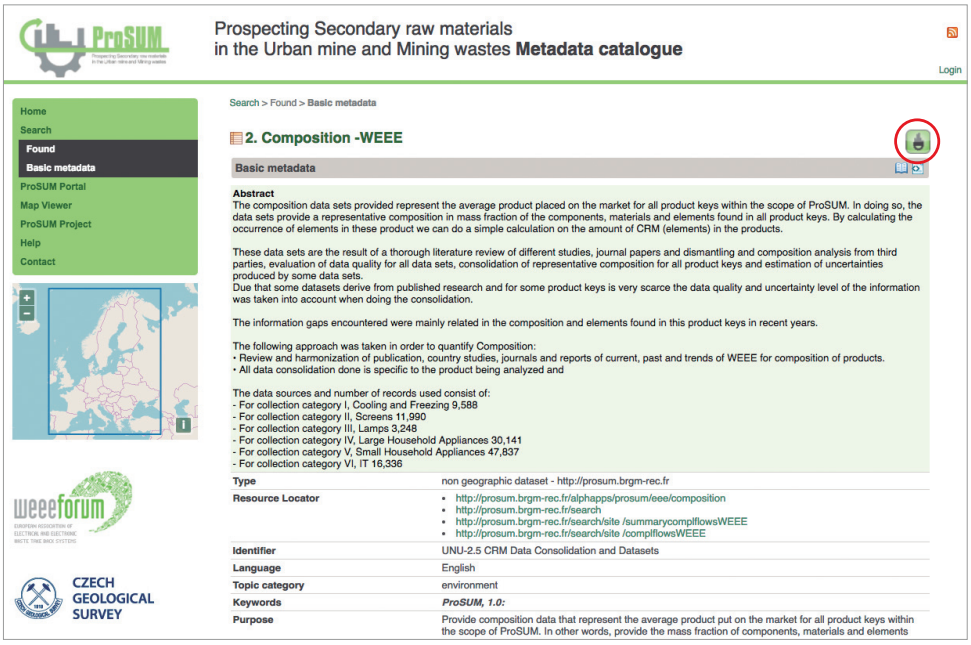


Figure 10. Example of the link between the ProSUM Metadata Catalogue and Portal – link to the Portal Urban Mine Application.

4. Material characterisation methods for products and components

To quantify the resources contained in the Urban Mine, data about the composition of products and wastes is indispensable. In two separate tasks of the ProSUM project, some of the practical methods for obtaining such data, including sampling, sample preparation and chemical analysis methods, were tested and validated. The goals of these two tasks were to (i) identify pitfalls and sources for systematic errors during sampling, sample preparation, and chemical analysis, (ii) identify possible improvements, and (iii) discuss the potential for methodological simplifications to reduce efforts of future data generation. This was done through six case studies covering metal alloys, residues from thermal treatment of lithium ion batteries, tailings from a closed iron ore mine, printed circuit boards from desktop PCs and the light waste fractions resulting from the mechanical treatment of end of-life vehicles and EEE. The goals, scope, approach and results of the case studies are presented in the technical annexes of Deliverables 2.6 and 4.3 (see **www.prosumproject.eu** for more details).

The following conclusions were drawn from the investigations regarding sampling, sample preparation, and chemical analysis:

4.1 Sampling

Sampling of composite products and heterogeneous waste flows is challenging and frequently leads to unrepresentative samples and consequently to unrepresentative data. In conclusion, there is a clear need to adapt the existing sampling theory, which was developed for the mining industry, to waste flows and validate approaches for calculating minimum sample mass/size.

Parameters of interest, such as the average mass of products of a given type, frequently do not follow a normal distribution. This may lead to false predictions when traditional statistical variables such as mean and standard deviation are used. Methods for distribution analysis based on product counts and dismantling analyses should be implemented to address the shortcomings of traditional methods.

4.2 Sample preparation

Preparation of waste samples (particle size reduction and homogenization) requires a combination of processes due to the presence of many different materials. However, as demonstrated for the case of the light fraction from mechanical treatment of ELV, a more elaborate sample preparation procedure may lead to larger losses or contaminations, and thus increases the likelihood of errors. Spiking of samples before preparation is recommended as a tool to detect errors and validate the procedure.

4.3 Chemical analysis

Chemical analysis of (waste) products and flows is an expensive and laborious procedure to generate compositional data. Measurement of CRM in heterogeneous materials is not a routine exercise, and application of routine in-house methods can easily result in substantial systematic errors, as illustrated in the cases on metal alloys, mining tailings, battery ash and printed circuit boards. Nevertheless, chemical analysis is often the only option to obtain compositional data and can, if done correctly, give precise, detailed information on the composition of specific samples of products or wastes. In order to avoid biased data in the ProSUM UMP, the validation of analysis methods by means of generic quality assurance methods is recommended.

As a general conclusion, it is suggested that future prospecting of the Urban Mine at the national or regional level should rely more on manufacturers' ex ante data to reduce efforts and costs. Ex post waste analysis studies based on chemical analysis could be a valuable complementary approach to validate manufacturers' data and would still have an important role to play for characterisation of smaller material flows. However, neither of the two approaches was originally created to prospect the Urban Mine. Adapting and developing methods to reduce data uncertainties will be a key issue for future work.

Figure 11. *Participants of the Special Interest Group (SIG) workshop "Characterising the Urban Mine and Mining Waste" on sampling and analysis organised by TU Berlin and Empa and held at Aurubis in Hamburg, Germany on February 13, 2017.*

5. The Urban Mine – What the batteries data tells us

The ProSUM project distinguishes seven categories of batteries: the primary batteries based on zinc and on lithium, the rechargeable batteries based on lithium, lead, nickel metal hydride (NiMH) and nickel-cadmium (NiCd) and other batteries. The major changes in the stocks and flows of batteries and for the CRMs they contain are linked to the applications in which batteries are used. Consequently, the most important factor influencing stocks and flows is the variation in the relative share of different battery technologies on the market.

5.1 Put on the market

In 2017, around 2.7 million tonnes of batteries were put on the market in the European Union, Switzerland, and Norway. The data on batteries put on the market come from a range of scattered sources including industrial associations, market research institutes and national public authorities. Automotive and industrial lead-based batteries dominate the market and the volumes of rechargeable lithium-based batteries POM are increasing, as shown in **Figure 12**.

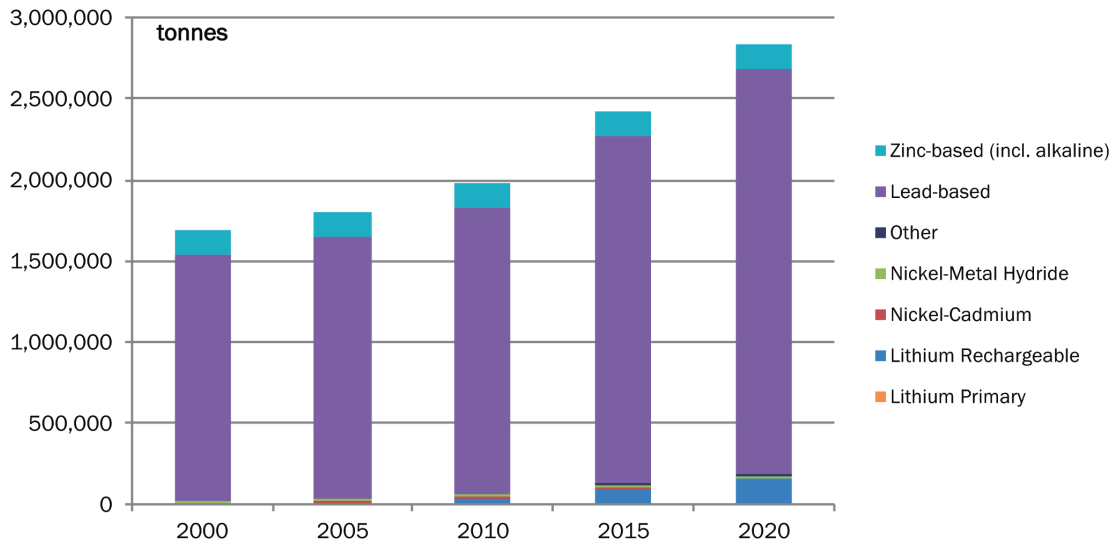


Figure 12. *Battery cells POM in tonnes, EU28+2.*

The increase in sales volumes for lithium-ion batteries is illustrated in **Figure 13**. The increase is linked to the development of the market for electric mobility and, to a lesser extent, to some portable applications like tablets and cordless tools. Changes are also occurring at the technology level. Lithium cobalt dioxide batteries are losing market shares, and volumes of lithium manganese oxide and lithium nickel manganese cobalt oxide batteries put on the market are increasing.

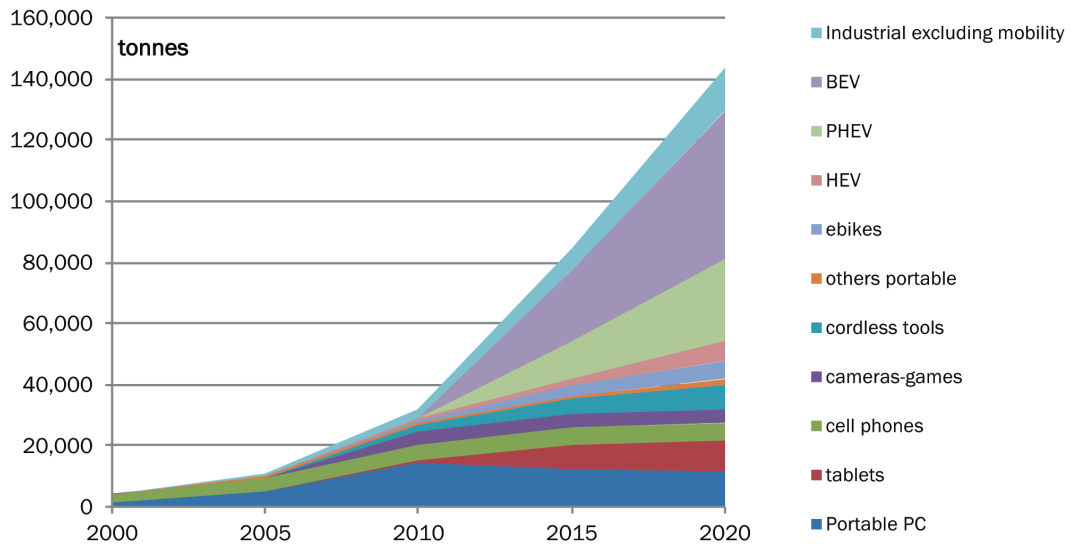


Figure 13. *Cells of lithium-ion batteries POM in the EU28+2 per application in tonnes.*

These batteries contain amongst other elements, lead (Pb), aluminium (Al), copper (Cu), cobalt (Co) and lithium (Li) with different mass fractions. The composition data has been combined with the data on the stocks and flows of batteries to estimate the flows of elements contained in the batteries, see **Figure 14**.

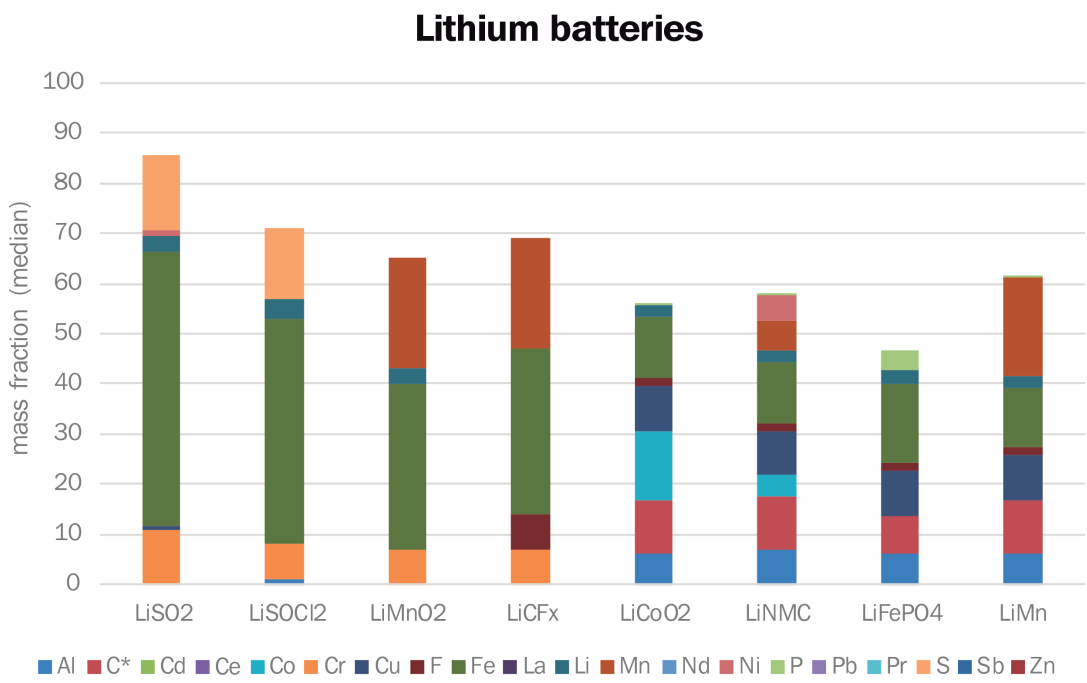


Figure 14. *Composition data showing the mass fractions of specific elements in lithium-based batteries (C*: natural graphite).*

Figure 15 shows the evolution of the quantities in tonnes of lithium, copper, cobalt and aluminium contained in the batteries POM. While the quantities of lithium, copper and aluminium, which are mainly embedded in the lithium-ion batteries, increase, the quantity of cobalt remains approximately stable. The reason is that the average cobalt content in the lithium-ion batteries is decreasing over time due to the proliferation of cobalt-poor and cobalt-free technologies, which is offset by an increase in the volumes of lithium-ion batteries POM.

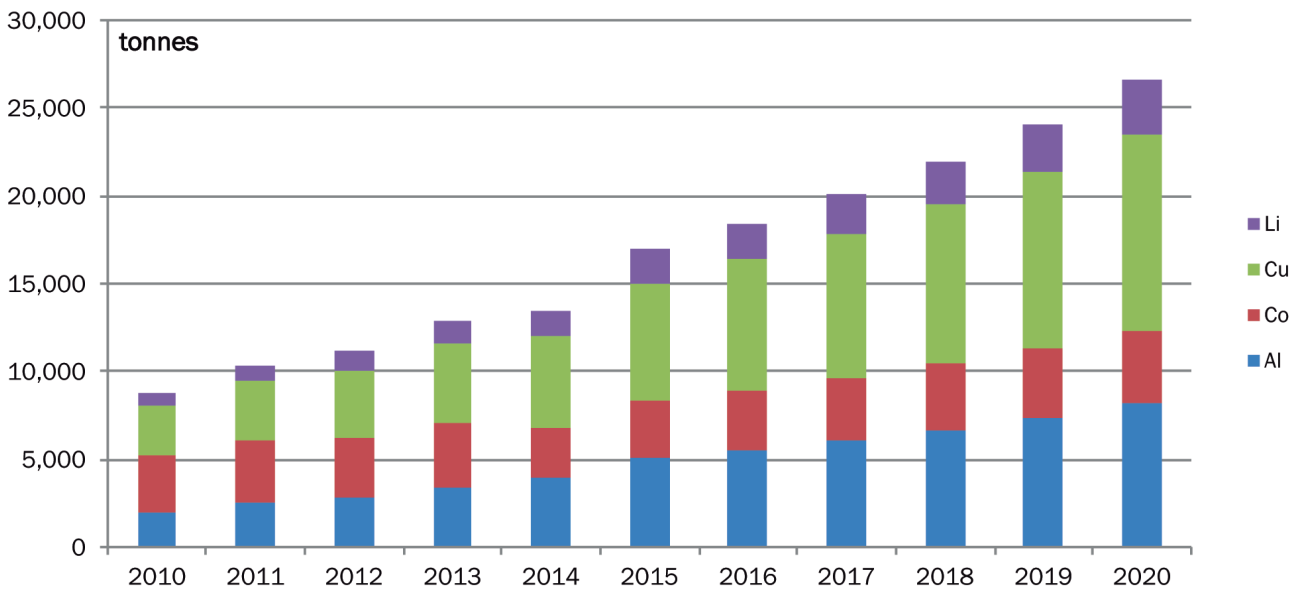


Figure 15. *Selected elements in batteries placed on market 2010 – 2020, EU28+2, in tonnes.*

5.2 Batteries in an average household

There are over 9 million tonnes of batteries still being used or stored before actually becoming waste. **Figure 16**, which excludes the lead-based batteries, shows the increasing stocks of lithium-ion batteries. This seems well in line with the number of EEE products in stock, where a certain share of the 36 smaller items will contain one or more batteries. Moreover, the modelling results are corroborated by survey results measuring how many batteries are in use and unused in households.

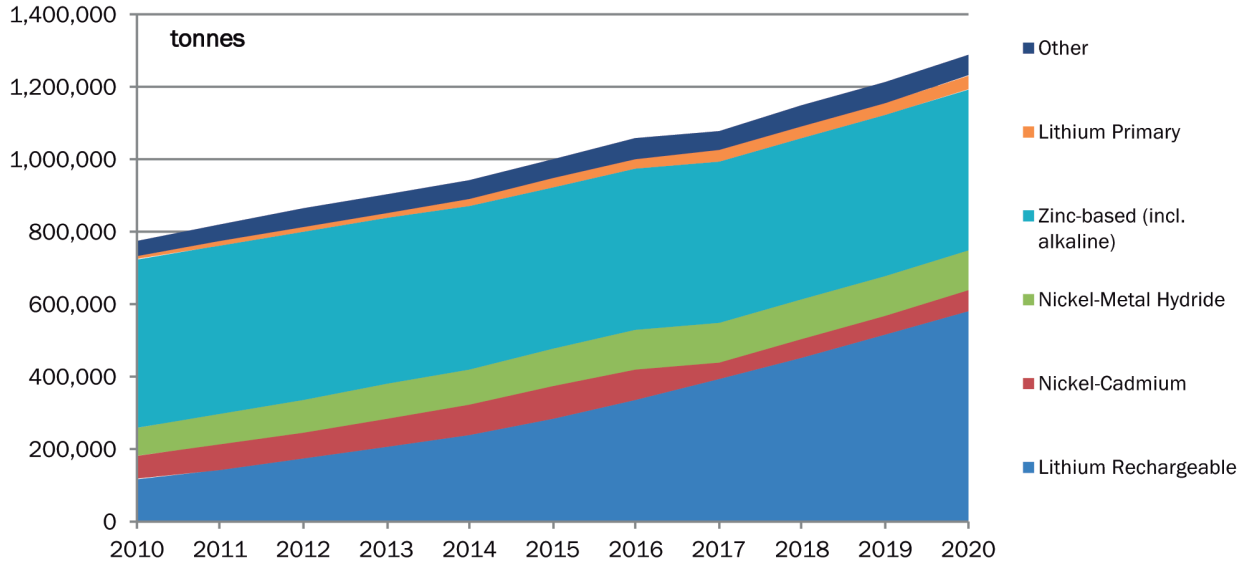


Figure 16. *Batteries in stock in EU28+2 from 2010 to 2020, excluding Pb-batteries, in tonnes of cells.*

Figure 17 shows the amounts of batteries in the households in weight and in pieces. Whereas the lead-based batteries dominate in weight, the zinc-based batteries dominate when counting the number of batteries in pieces. This is due to the low average weight of the zinc-based batteries, and the high average weight of the lead-based batteries

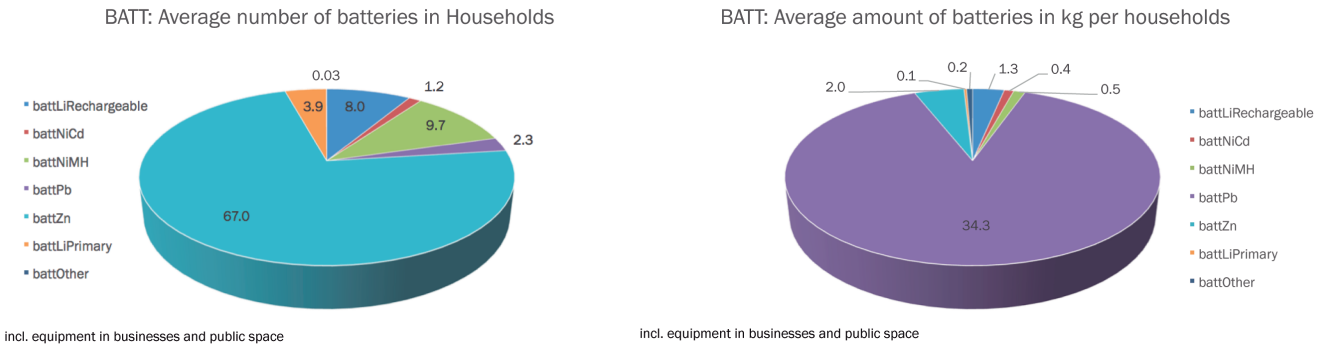


Figure 17. *Amount of batteries per household in pieces (left) and weight (right), EU28+2, 2015.*

5.3 Fate of materials in waste batteries

The amount of elements in waste batteries generated, being products discarded by consumers and businesses, is approximately two million tonnes in 2015. **Figure 18** shows the amounts of selected elements they contain. The masses of lithium, copper and aluminium contained in the waste batteries generated are expected to increase by 10-15% annually between 2015 and 2020. The mass of cobalt is expected to remain constant.

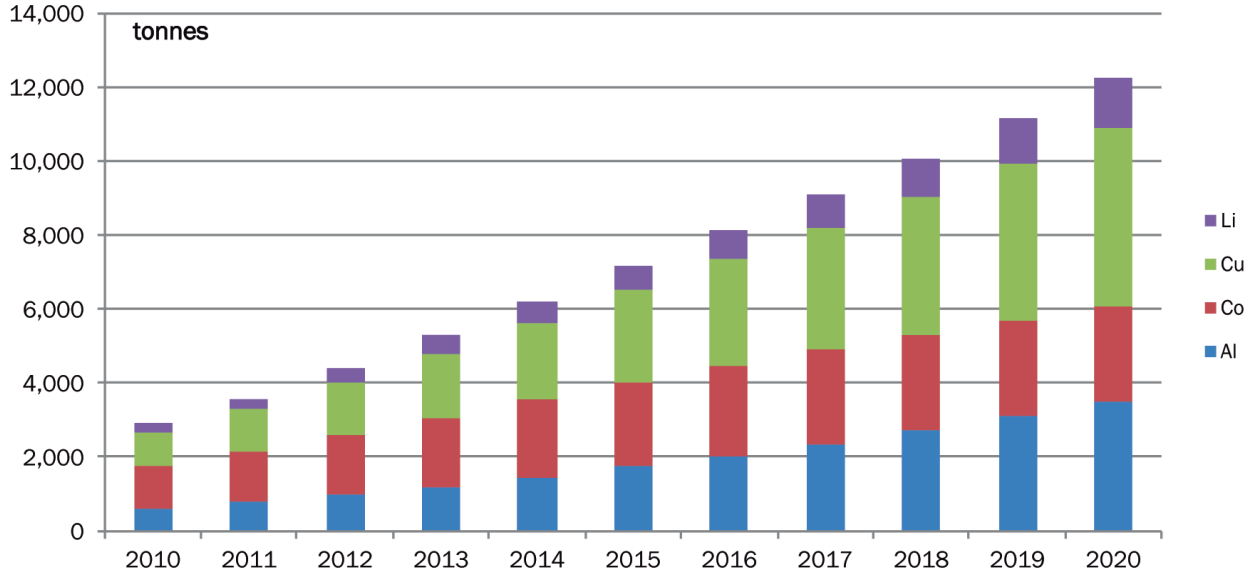


Figure 18. *Selected elements in the waste batteries theoretically available for collection in 2010 – 2020, EU28+2, in tonnes.*

A substantial amount of end of life batteries is unreported. From the waste batteries generated, around 50% of the waste flow is estimated to be captured by producer responsibility organisations and reported to EU member states. The available data are mainly describing the collection of portable batteries, for which reporting is required by the EU Batteries Directive. There is probably a significant lack of information for the industrial batteries. **Figure 19** shows the stocks and flows for six selected elements, chosen due to their relative abundance in batteries. The estimated quantities for the selected elements in officially reported collection are shown on the right-hand side of **Figure 19**. As a result, around 85% to 90% of the aluminium (Al), the copper (Cu), the lithium (Li) and the cobalt (Co) from waste batteries is estimated to end up in the unreported flow. Around 37% of Iron (Fe) is in reported collection.

5.4 Overall material stocks and flows of batteries

Figure 3 shown in the Executive Summary illustrates the evolution of the stocks of neodymium, aluminium, copper, cobalt and lithium contained in the batteries in stocks in the European Union. The quantities of lithium, copper and aluminium increase quicker than the quantity of cobalt, due to the decrease over time of the average cobalt content in the lithium-ion batteries POM.

Figure 19 shows not only the stocks, but also the flows of batteries and of six selected elements (aluminium, copper, iron, cobalt, lithium and neodymium) in the Urban Mine of EU28 in 2015. The main elements lead and zinc are not represented.

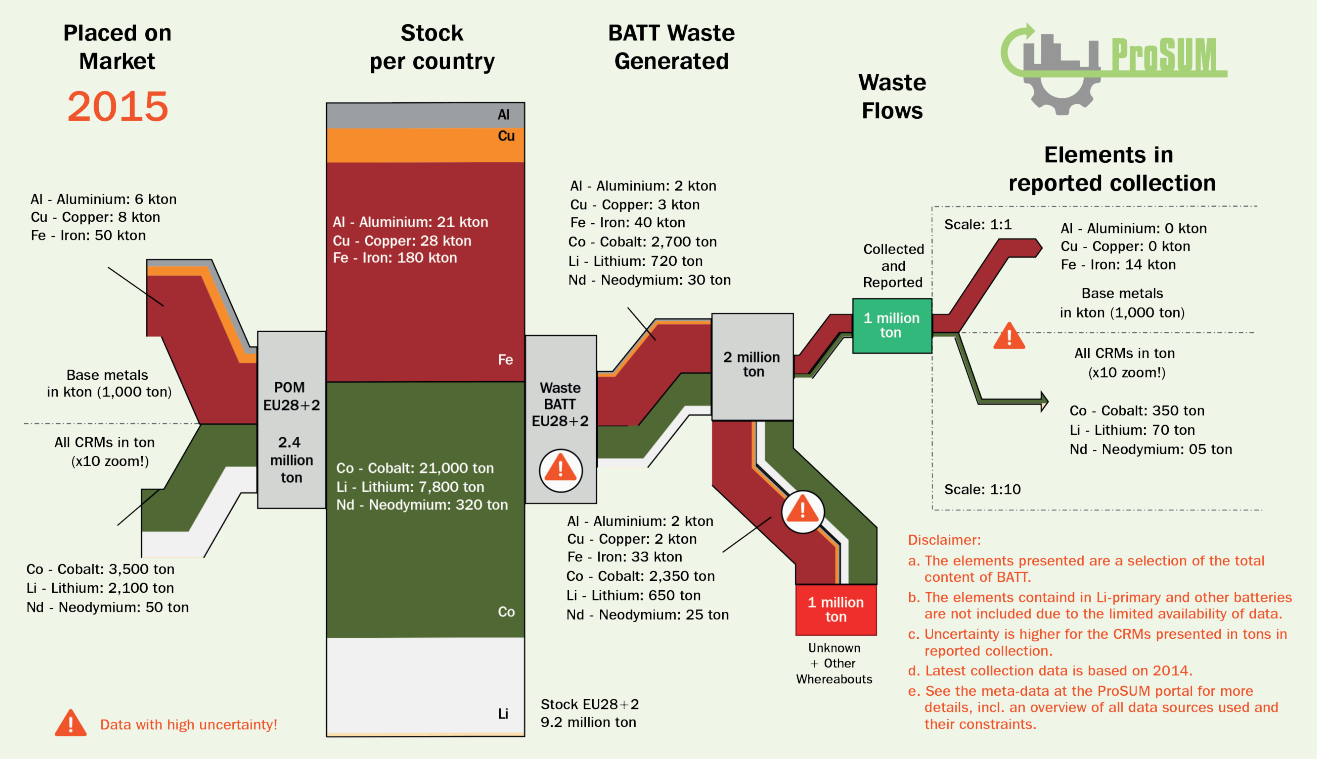


Figure 19. *Stocks and Flows of batteries and selected elements they contain in the Urban Mine, EU28+2, 2015.*

Base metals are the predominant material flows within batteries with almost 50,000 tonnes of iron estimated to go onto the market in 2015. Lithium and cobalt are around 2,000 to 3,000 tonnes in comparison. Whilst around 50% of batteries are of unknown or other whereabouts, there is more than a corresponding 50% loss in cobalt and lithium, e.g. over 300 tonnes of cobalt are estimated to be in reported collected batteries compared with 2,300 tonnes in the unknown and other whereabouts. This reflects the nature of the lithium-ion batteries, which are smaller and embedded in products like laptops that also mainly end up in unreported reuse, recycling and trade channels.

6. The Urban Mine – What the EEE data tells us

The ProSUM project has quantified the market input, stocks and waste flows for WEEE for all six collection categories, including specifically:

1. Cooling and Freezing appliances (Cat. I, C&F), primarily consisting of metal dominated fridges, freezers and air conditioners.
2. Screens (Cat. II), consisting of CRT and LCD dominated TVs, monitors and portable PCs.
3. Lamps (Cat. III, LMP), consisting of glass dominated fluorescent energy saving lamps, etc.
4. Large household appliances (Cat. IV, LHA), primarily consisting of metal dominated washing machines, dryers, oven and hoods, etc.
5. Small Household Appliances (Cat. V, SHA), primarily consisting of plastic dominated kitchen appliances, personal care, tools and toys, etc.
6. IT appliances (Cat. VI, IT), primarily consisting of precious metal dominated desktops computers, printers, mobile phones, etc.

6.1 Put on the market – Rapidly changing products and consumption

The ProSUM approach for determining market input, stocks and WEEE generated has been adopted in the common methodology for determining EU collection rates by the European Commission for the EU28+2[1]. To illustrate the evolution in production and consumption of electronics, one of the most dynamic categories is Screens. Representing the last two decades, **Figure 20** illustrates the volumes placed on the market. Whilst LCD screens have replaced CRT screens with an associated reduction in weight, in pieces much more TVs are purchased per household.

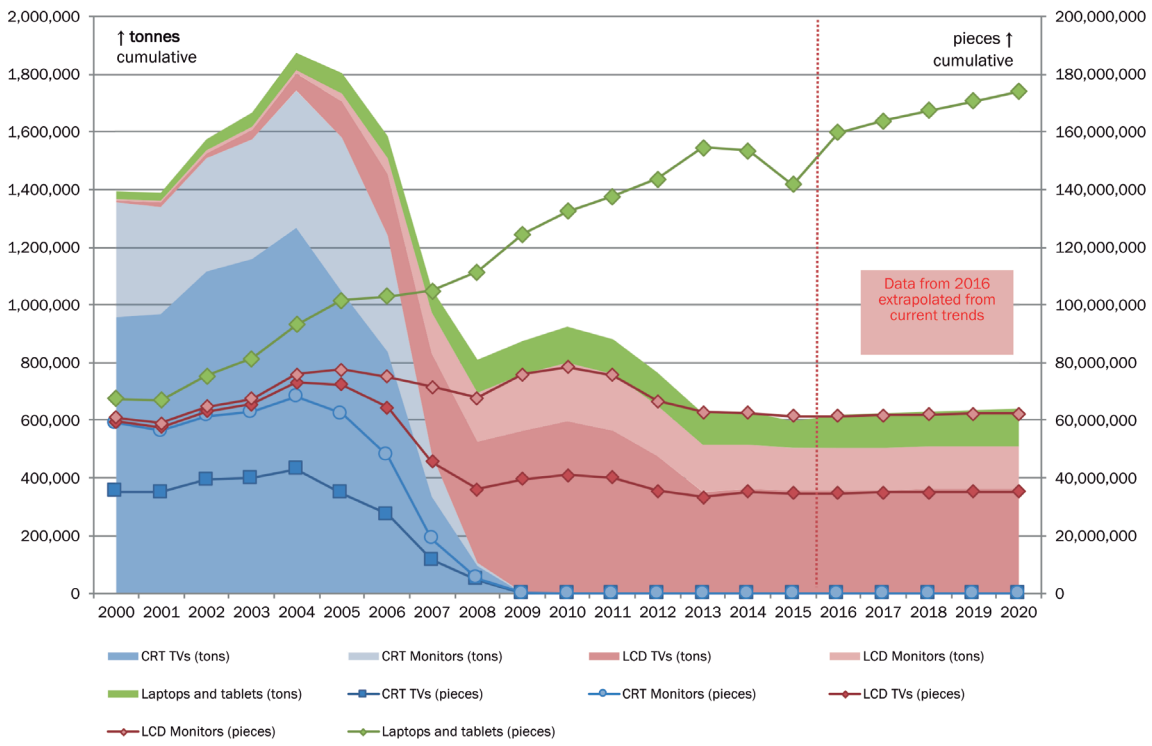


Figure 20. *Quantities of screen appliances placed on market 2000 – 2020 in tonnes (left) and pieces (right).*

At the same time electronic components are getting smaller and screen diameters are increasing, which all have an impact on the stocks and flows of materials. The net effect is displayed in **Figure 21** (actual sales until 2015, forward projection until 2020 based on current market trends). A less visible aspect in **Figure 20** is that modern screen devices have a lower average weight per piece due to miniaturisation of components such as precious metal rich printed circuit boards. This affects the secondary raw material content flowing in and out of the 'Urban Mine'. To estimate this, the ProSUM consortium processed and consolidated 133 data sources for screen compositions into a harmonised structure. The results are shown in **Figure 21**, showing the quantities for gold (Au) as the prime value driver in recycling, silver (Ag) and palladium (Pd), and the critical raw materials indium and neodymium over time.

[1] http://eur-lex.europa.eu/eli/reg_impl/2017/699/oj

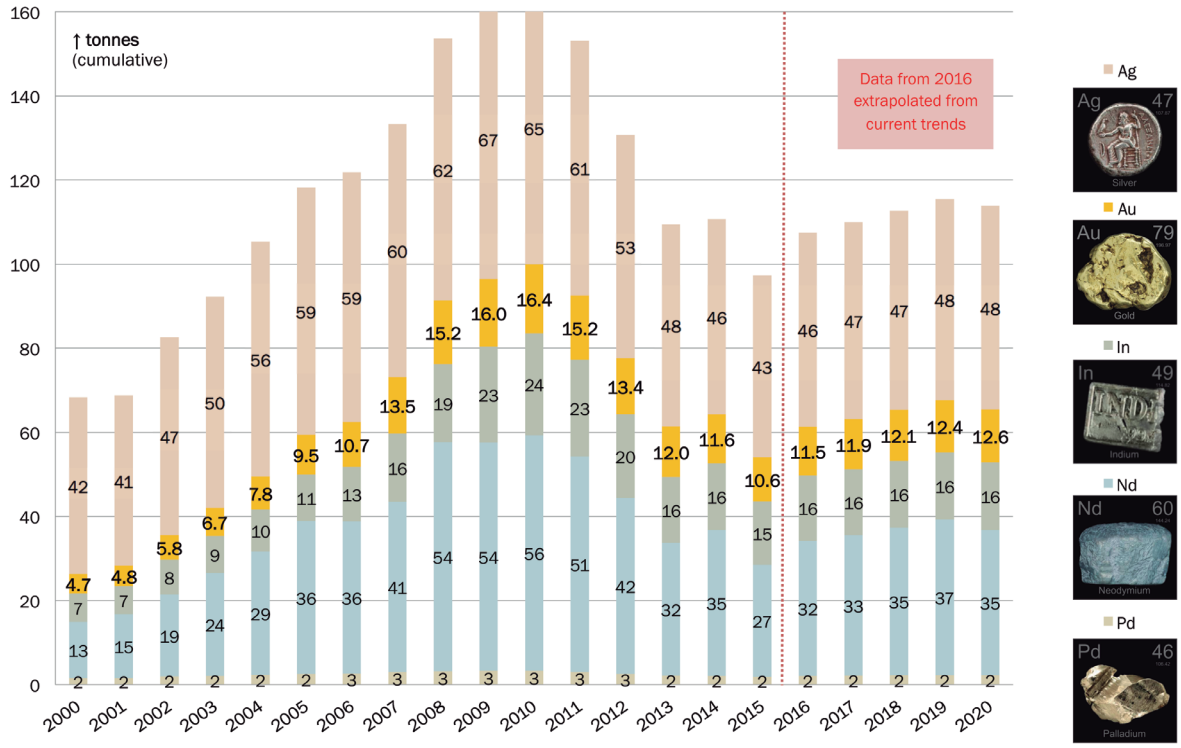


Figure 21. Selected precious metals and CRMs in screens placed on market 2000 – 2020, EU28+2, in tons.

6.2 Products, components and metals in an average household

Figure 22 shows the current stock of CRT (cathode ray tubes) and LCD (liquid crystal displays) devices for 2015 for all EU Member States. The stock is the accumulated market input minus waste generated volumes for one year. The graph shows new LCD TVs and monitors plus laptops and tablets placed on the market on the left. Significant amounts of old CRTs are in the stock, often referred to as the Urban Mine from electronics, still being used or stored before actual disposal. The amount of WEEE generated, being products discarded by consumers and businesses, is estimated at 1.25 million tonnes and is dominated by old CRT products. From this WEEE generated, close to 50% of the waste flow is captured by producer responsibility organisations and reported to EU Member States. Detailed, time dependent ProSUM modelling, has estimated the presence of relevant chemical elements over time.

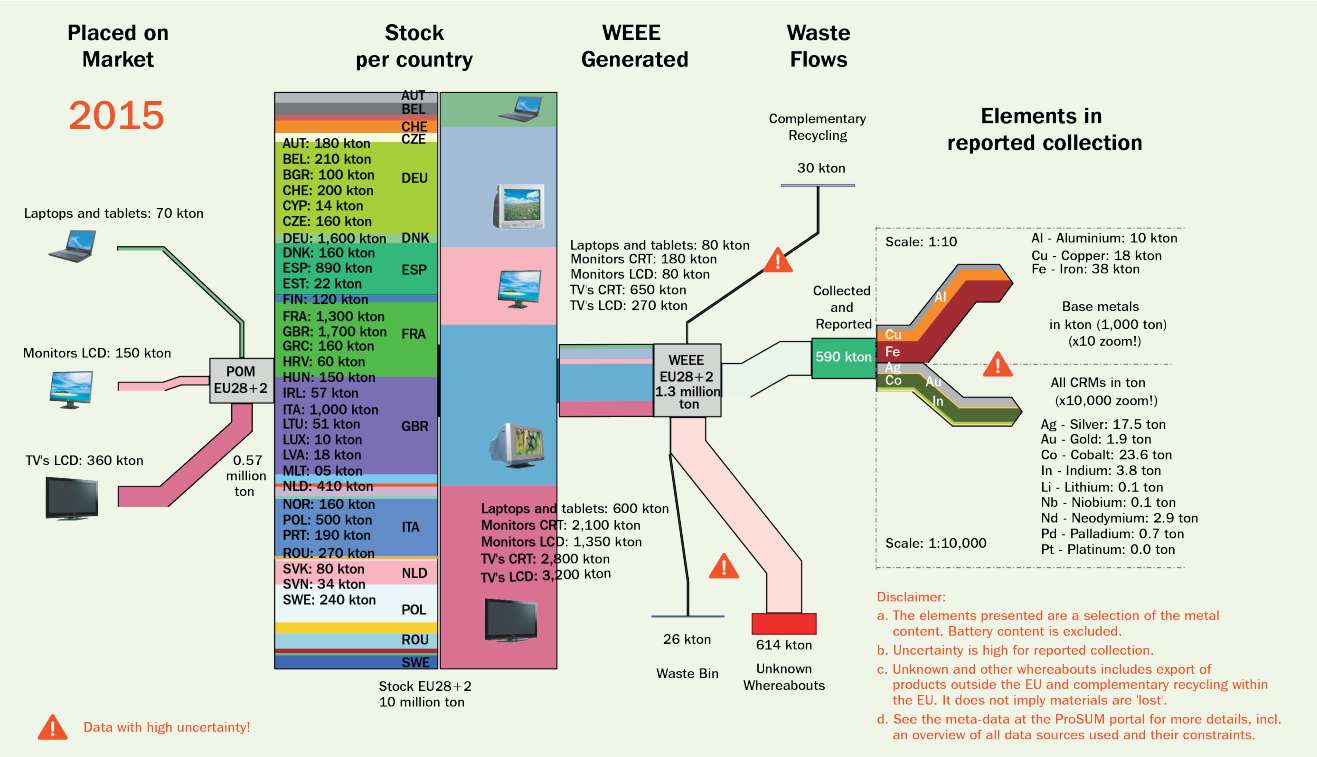


Figure 22. Stocks and Flows of Screen products in the Urban Mine in 2015 and elements in reported collection, EU28+2.

Similarly, **Figure 23** shows the effect of the various trends on the components accumulating in stock over the years with the lines represented on the left axis and the base metals content on the right axis. Interestingly, the copper content, for example, actually declined with half a million tonnes over recent years due to less cables and coils in LCD devices compared to the older CRTs that are now rapidly disappearing in households and businesses. At the same time, steel and aluminium content used in LCD housing increased significantly.

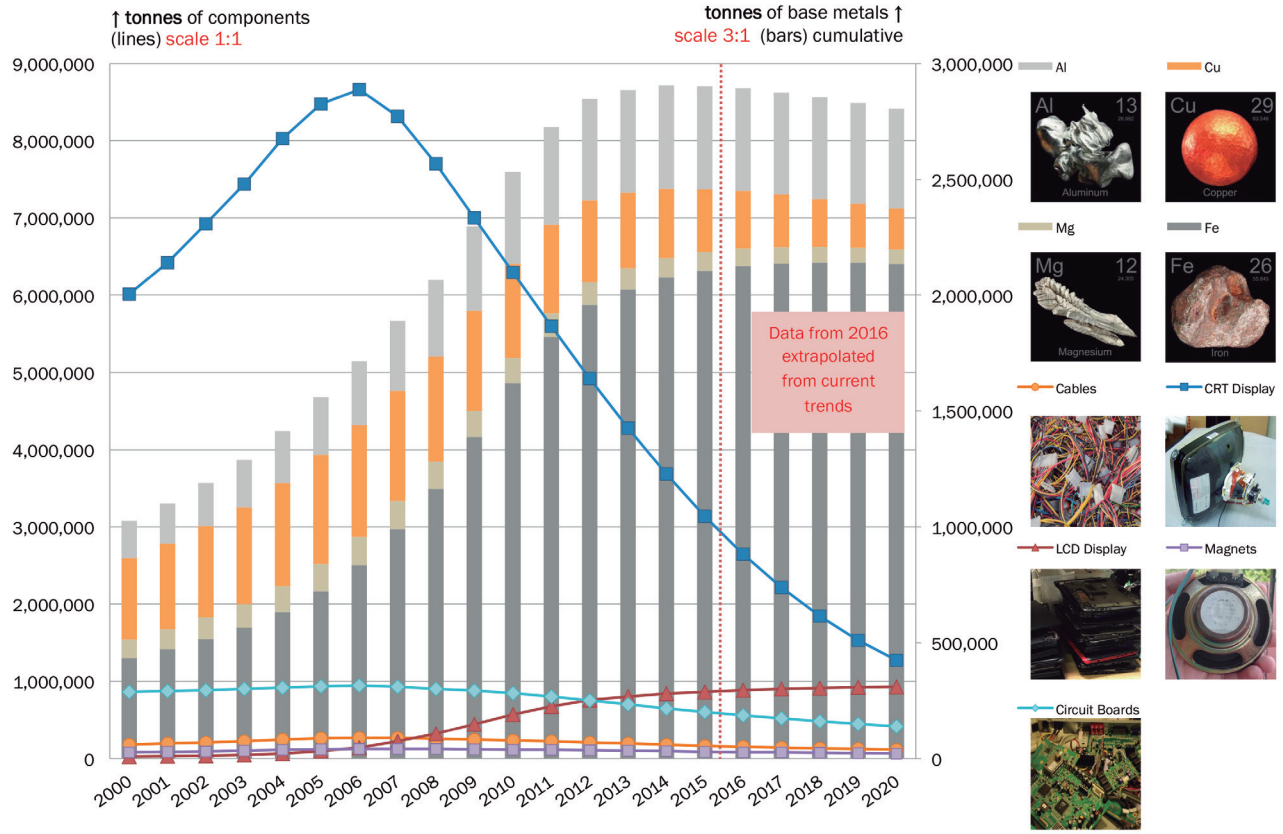


Figure 23. *Selected components (left axis, lines) and base metals (right axis, bars) in stock 2000-2020, EU28+2, in tonnes.*

6.3 Fate of materials in WEEE

The products, components and materials in the Urban Mine for Screens, become waste at some point. **Figure 24** is the response from the market input amount against the lifespan used in the stock and flow modelling. The materials placed on the market and adding to the stock of used and hibernated products, become waste generated. Here, the good news for recyclers specialised in this treatment category is that the precious metal content, despite the miniaturisation and drastic reduction in printed circuit board average weight will continue to increase in the coming years, primarily due to the high peak in pieces placed on market in the CRT to LCD replacement years in between 2005 and 2008.

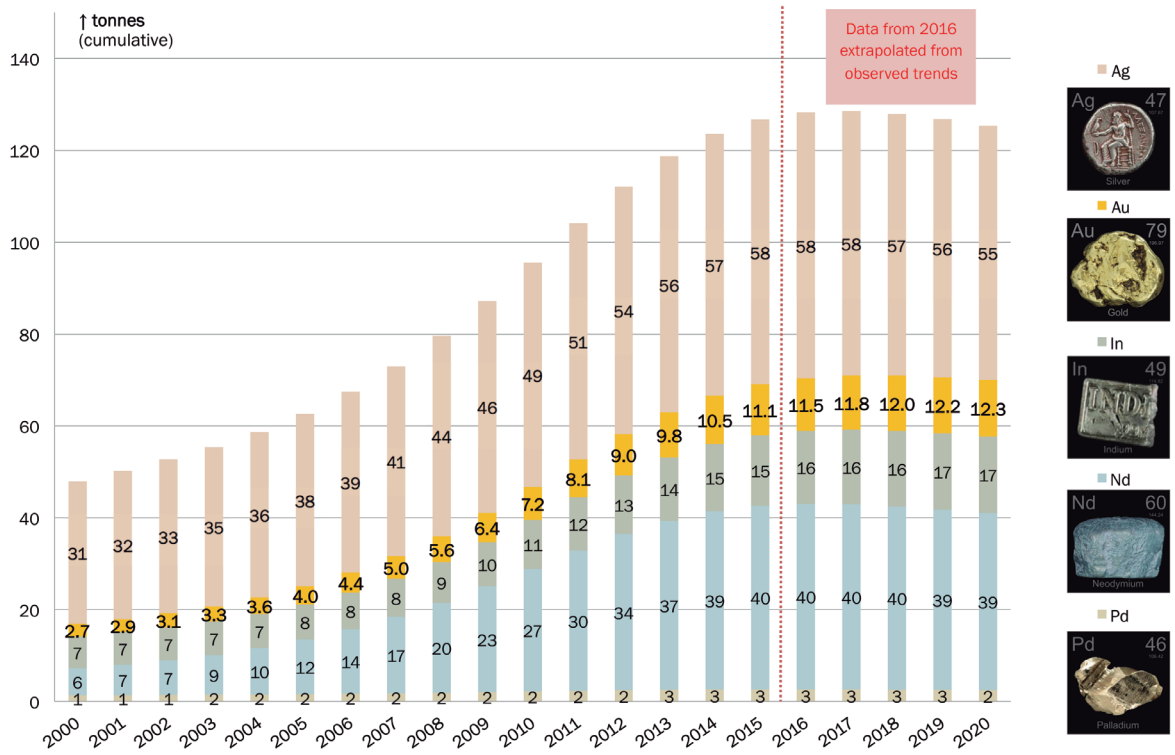


Figure 24. Selected precious metals and CRMs in screens in waste 2000-2020, EU28+2, in tonnes.

6.4 Overall material stocks and flows of WEEE

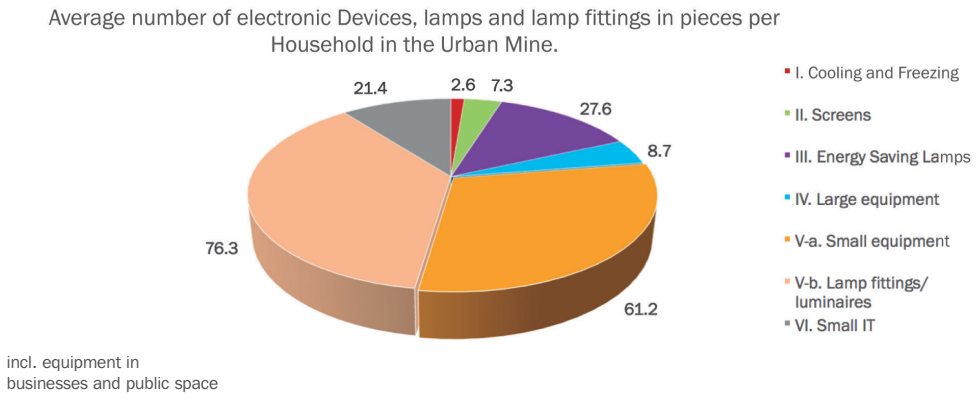
If all of the EEE in stock in households, businesses and public space was shared out between each EU28+2 inhabitant, each person would own close to 44 EEE products plus another 45 (energy saving) lamps and light fittings, which are counted separately.

The in total 89 products per person include on average:

- 1.1 Cooling devices like fridges, freezers and air conditioners, representing on average 52 kg per person;
- 3.2 Screens, including TVs, monitors, laptops and tablets, for a weight of 21 kg per person;
- 3.8 Large household appliances, like washing machines, dryers, hoods, large heaters, for a weight of 99 kg per person;
- 12 Energy saving and special lamps[2], representing 1.0 kg per person;
- 27 Small appliances like kitchen equipment, personal care, tools and toys, representing 49 kg per person; and finally:
- 33.1 Luminaires and lamps fittings, including those for special lamps installed in public space, representing 14 kg per person.
- 9.3 Small IT items like printers, mobile phones, keyboards and phones, representing 12 kg per person.

These numbers are highlighted in below pie charts in **Figure 25** both in pieces and in weight per average household.

[2] Traditional incandescent and halogen lamps are not included in the scope of the WEEE Directive, hence the higher number of fittings.



Collection Category	pcs/person	kg/person	pcs/household	kg/household
I. Cooling and Freezing	1.1	52	2.6	120
II. Screens	3.2	21	7.3	48
III. Energy Saving Lamps	12	1.0	28	2.4
IV. Large equipment	3.8	99	8.7	228
V-a. Small equipment	27	49	61	113
V-b. Lamp fittings/luminaires	33	14	76	33
VI. Small IT	9.3	12	21	27
Total	89	248	205	571

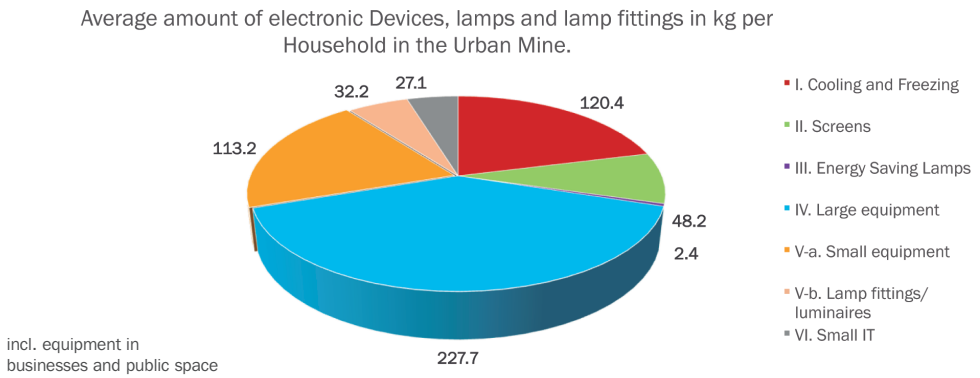


Figure 25. *Average number of electronics in pieces (top) and in kg (bottom) per average EU household.*

Dependent on the country and the income levels, these averages per person range from 220 kg per inhabitant in Latvia up to 350 kg per person in Norway. That equates to around 205 products including lamps and fittings and 570 kg per average EU household in 2015.

6.5 Where does the WEEE end up?

The term **complementary flows** refers to all waste flows that are not reported at Member State level by the official compliance systems, and others, according to the ELV, batteries and WEEE Directives. A certain portion of these flows are exported, incinerated or landfilled.

The term also **includes non-compliant treatment** e.g. recycling with other waste streams such as mixed metal scrap. This type of recycling does not always meet the same efficiency and treatment standards as the officially reported amounts, and is financed via other (mainly market) mechanisms.

Another example is **B2B waste collected and recycled** that is not reported to producer compliance schemes and/or national authorities. The amount of WEEE and batteries treated this way is very difficult to quantify. Where data is available, it is mainly estimated from a limited number of observations. The term non-compliant does not necessarily imply substandard treatment, but rather refers to quantities not being declared to national/ EU levels. Other terms commonly used are complementary treatment or unreported treatment. The term unreported is not utilised as often, as this waste is declared to regional authorities but under different reporting regimes.

There is significant trade and complementary recycling taking place for the WEEE flows. The size of complementary flows for WEEE in the EU is displayed in **Figure 26** for the year 2015. It illustrates totals for all collection categories combined. A more detailed breakdown of this tonnage, per year and individual collection category is available in the portal in the third menu "Waste Flows – EEE". The data available in the UMP covers the years 2010-2015. It should be noted that a rather conservative quantification approach is taken here. The values above should therefore be regarded as minimum amounts for the various flows. Especially for WEEE in metal scrap, there is considerable upwards potential.

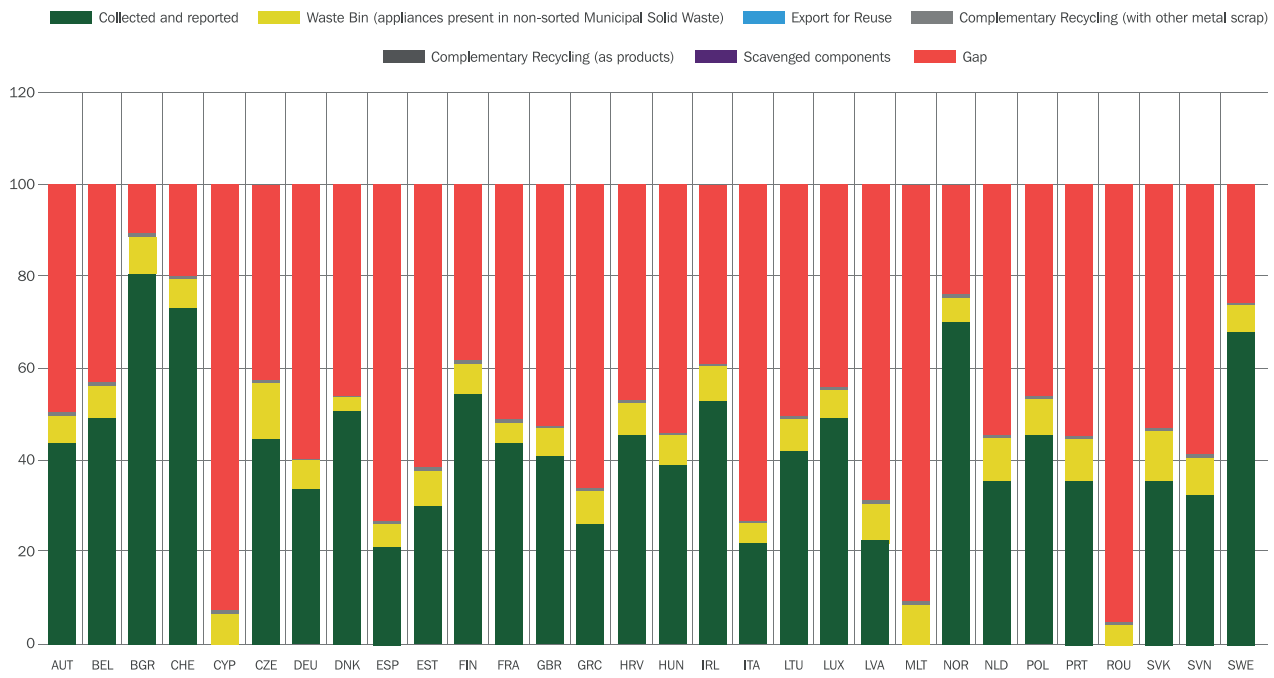


Figure 26. *Collected and complementary WEEE Flows 2015 against WEEE Generated (100%) in percent, EU28+2.*

In addition to complementary recycling flows, also the scavenging of valuable products and components from the official collection channels significantly reduces the valuable material content. For components, such as printed circuit boards, cables and hard-disks, the scavenging of value leads to a significant diversion of material value to non-reported trading and complementary recycling. For products this specifically appears with relatively new and valuable devices in the market like LCD screens and laptops and tablets to other trading and export flows. Here, a large amount of products goes elsewhere, which can be visualised by means of counting products in the reported return streams versus their supposed presence from the WEEE generated calculations.

The 'scavenging' effect of screens is visualised in **Figure 27**. On the left hand side is the composition of the collection flow if the selected precious metals and CRMs were similarly present in products as the waste generated amount. However, due to the increased trade in laptops and tablets and, to a lesser extent, LCD TVs as well as the lack of other outlets for relatively less valuable CRTs, the actual presence in the richest products is significantly lower in the officially reported collection channels.

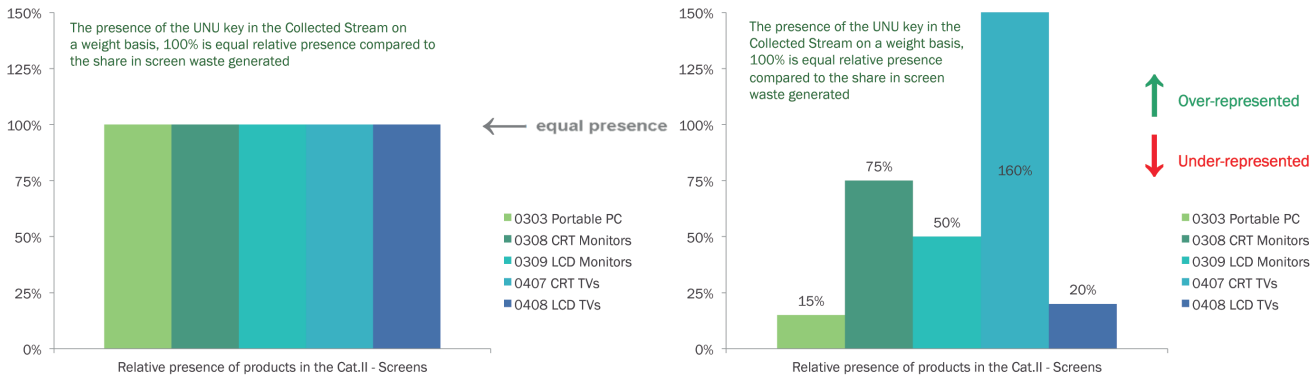


Figure 27. *Selected precious metals and CRMs in screens in waste 2000-2020, in tonnes.*

Due to the substantial trade in laptops and tablets ending up in unreported complementary reuse, recycling and trade channels, the amount of indium (In) in reported collection is 25% of the total waste generated (3.8 tonnes out of 15.3 tonnes). Slightly over 50% of copper (Cu) is in reported collection (18,300 tonnes of 36,200 tonnes). The flows of elements are shown in the **Figure 2**. The estimated quantities for 10 of the most relevant elements in officially reported collection are shown there on the right hand side. The estimated totals should be regarded as recycling input rates; actual recycling levels are again much lower, especially for elements like neodymium and indium as there currently is no direct economic incentive to recover them.

As a summary, **Figure 28** illustrates the substantial amount of raw materials and precious metals in particular in the Urban Mine in 2015. Here the Sankey diagram shows the contribution of all EEE collection categories. It shows that gold, being the key value driver behind material recycling, primarily comes from printed circuit boards in LCD TVs and laptops plus tablets from Cat. II - Screens, from desktops, mobile phones in Cat. VI – IT appliances.

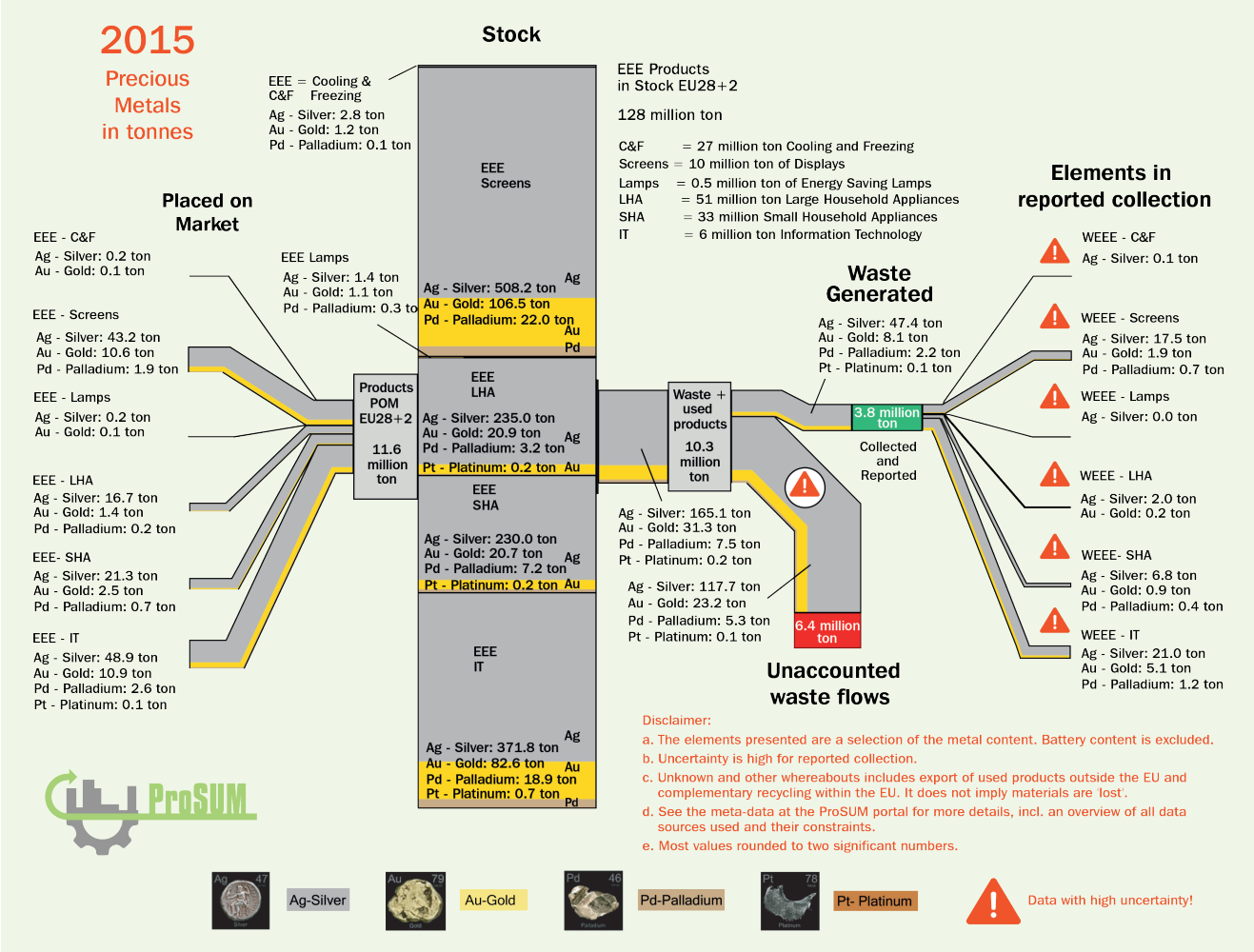


Figure 28. *Stocks and Flows of precious metals in electronics in the Urban Mine, EU28+2, 2015.*

7. The Urban Mine – What the vehicles data tells us

The ProSUM project has quantified the market input, stocks and waste flows for motorised road vehicles included in the ELV Directive (i.e. up to 3.5 tonnes). The vast majority of these vehicles are passenger cars. Vehicles were classified in 63 vehicle types so that CRM content could be correlated to drivetrain type, total mass and, as a proxy for level of segment, cylinder capacity. 28 metals have been considered which are present in materials such as steel and iron, aluminium, copper and magnesium, in components such as catalytic converters, in electric vehicle (EV) motor magnets and battery cells, and systems such as electrics and electronics. For each vehicle type, year and country, metal compositions were multiplied with the number of vehicles, to calculate total metal contents of stocks and flows. While the number of different vehicle types travelling through the European fleet is relatively well known through official statistics – the estimated uncertainty is typically a low single digit percentage – public data on their CRM composition is sparse compared to other product categories. It has only been possible to estimate differences in composition between vehicle types for some elements. Furthermore, some changes in composition over time were estimated. Overall, results on CRM contents in vehicle stock and flows should only be used taking these limitations into account.

7.1 New vehicles on the market

During the past 15 years, the shares of petrol and diesel vehicles put on the market have changed significantly. Currently, growth rates of electrified vehicles (EV) are high, but EVs still only made up 2% of new vehicles in 2014. Most of the EV diffusion is concentrated to a few countries, with the highest levels of market share reaching around 15% for BEV (battery electric vehicle), and 30% for BEV, PHEV (plug-in hybrid electric vehicle) and hybrids together, in 2014. **Figure 29** illustrates the total number of new vehicles over different drivetrains. Used vehicles imported to the EU are few in relation to new ones and not included in below **Figure 29** through **Figure 32**. The total mass of new vehicles in 2014 was estimated at 18 million tonnes. A few countries hold the majority of these. For example, in 2014, over 70% of all new vehicles in the EU28+3 were put on the market in Germany followed by France, UK, Italy and Poland.

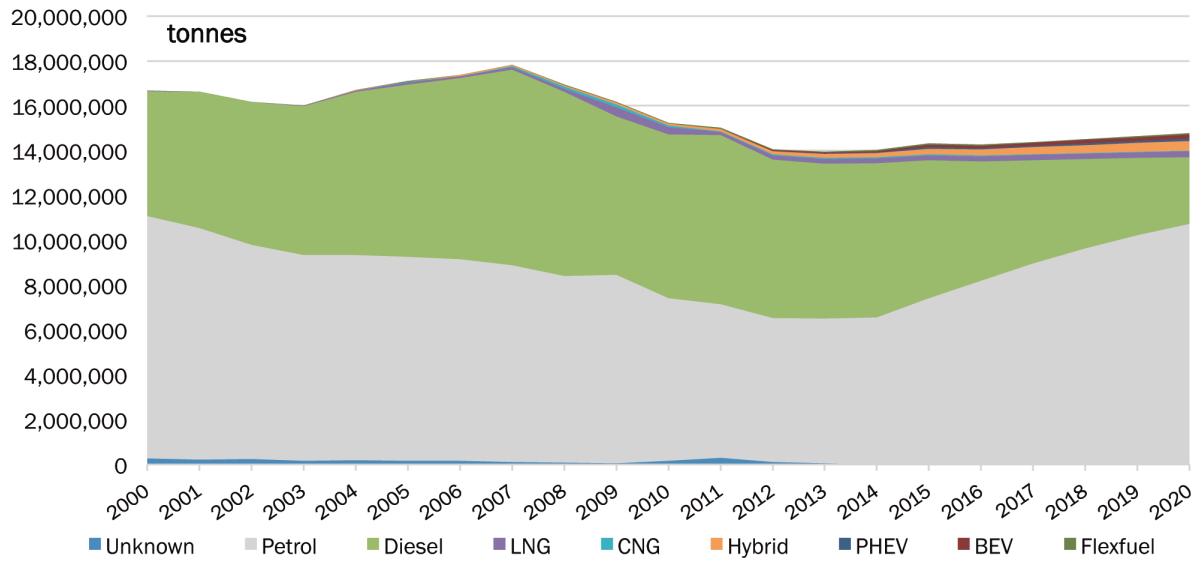


Figure 29. *Total number of vehicles put on market in EU28+3. Data from 2005 to 2014, extrapolated trends from 2015 to 2020 [tonnes]. BEV=battery electric vehicle, FC=fuel cell, PHEV=plug in hybrid electric vehicle, HEV= hybrid electric vehicle.*

As requirements have changed and car designs and available materials have evolved, vehicles have become heavier and with more diverse materials used. For example, increased control of tail-pipe emissions from internal combustion engines requires more platinum group metals (PGM) and REE (rare earth elements), at different mixes and amounts depending on fuel used. The push for mass-reduction designs introduces a greater variety of steels, aluminium and magnesium and their alloying elements. Electric and electronic (EE) systems are increasingly present in vehicles to enable, for example, safety and driver assistance features, powertrain control and infotainment. EE systems contain e.g. precious metals, gallium, tantalum and REE. These trends are common for all vehicles, irrespective of drivetrain, but with electrified drivetrains new components such as traction batteries (included in Batteries in ProSUM), electric motors and power electronics add to CRM content.

The number of new vehicles decreases somewhat over the period, but quantities of most elements still increase. An example is the increase of neodymium due to increased content in the EE system, extrapolation to the future is significantly reinforced by the EV market growth (**Figure 30**).

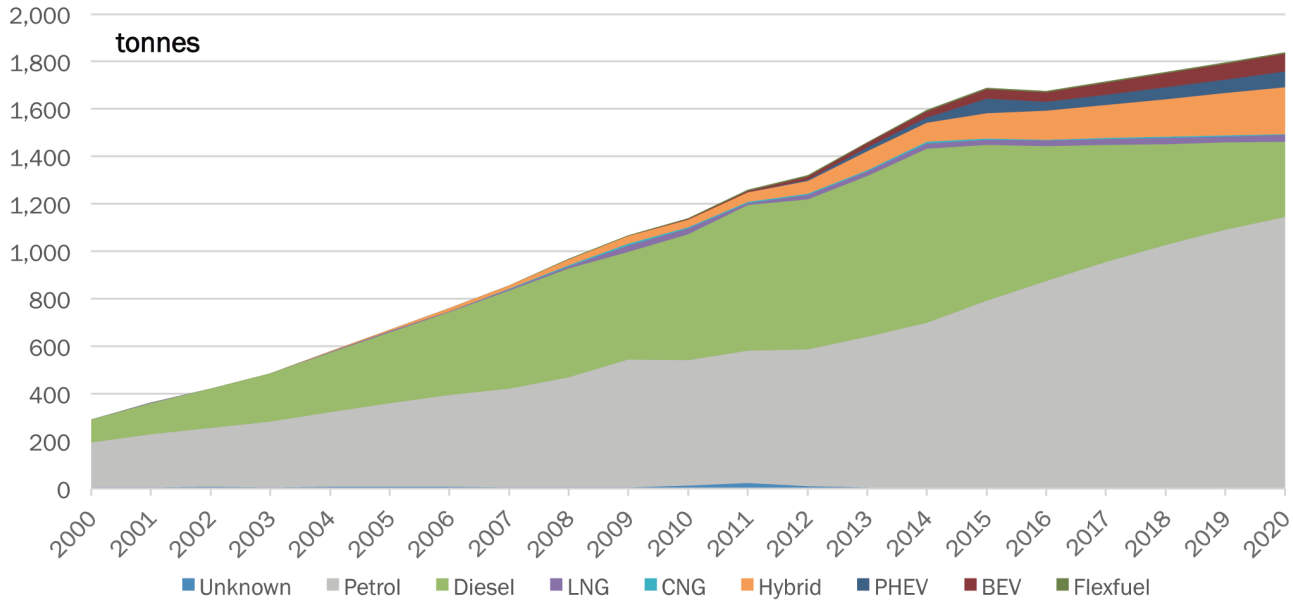


Figure 30. *Neodymium in new vehicles POM in EU28+3. Historic data from 2005 to 2014, extrapolated trends from 2015 to 2020 [tonnes]. BEV=battery electric vehicle, FC=fuel cell, PHEV=plug in hybrid electric vehicle, HEV= hybrid electric vehicle.*

7.2 Vehicles and metals in the active fleet (stock)

The European vehicle fleet is slowly growing and amounted to around 260 million vehicles in 2014, ranging from 0.2 to 0.7 vehicles per capita over member states. Similar to new vehicles, the active fleet is heavily dominated by petrol and diesel drivetrains. Other drivetrains are rare, with electrified drivetrains representing no more than a small share even towards the end of the extrapolated period. The fleet represents over 300 million tonnes of materials. The most common metals are iron, aluminium and copper present in millions of tonnes. Other CRMs occur in significantly lower orders of magnitude, such as neodymium, niobium, cobalt and silver occurring in thousands of tonnes. Examples of increasing fleet metal quantities are neodymium, tripling over the period (**Figure 31**), and aluminium increasing by two thirds.

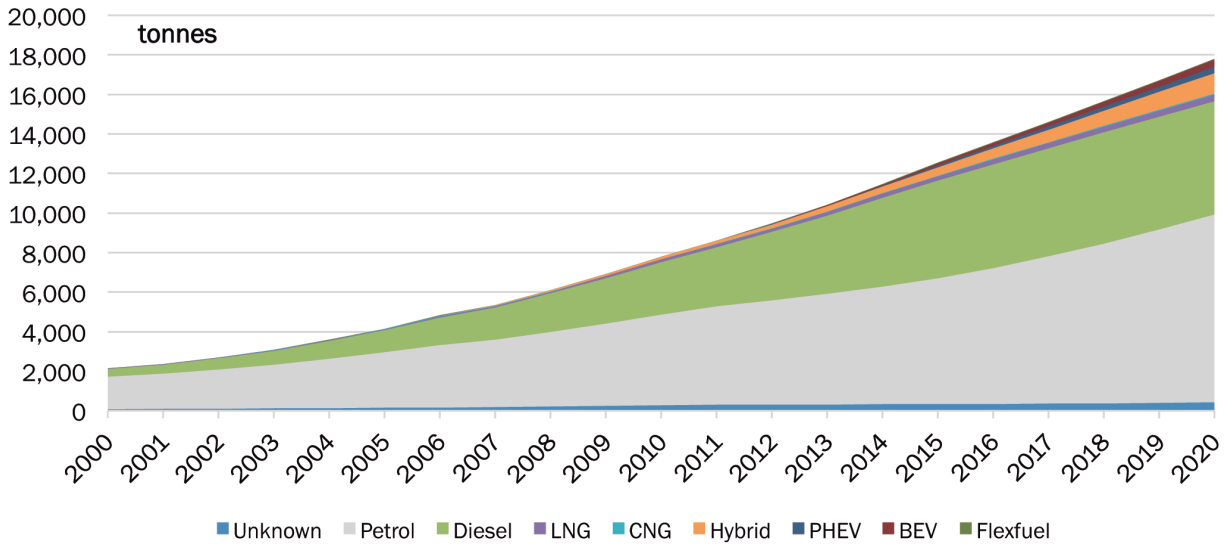


Figure 31. *Neodymium in the active vehicle fleet in EU28+3. Historic data from 2005 to 2014, extrapolated trends from 2015 to 2020 [tonnes]. BEV=battery electric vehicle, FC=fuel cell, PHEV=plug in hybrid electric vehicle, HEV= hybrid electric vehicle.*

7.3 Waste generation and destinations

Vehicles reported as recycled, end of life vehicles (ELV), are estimated to around 8 million tonnes in 2014, although public statistics admits to underreporting a somewhat lower mass. A smaller quantity of vehicles is reported as exported for use outside the EU. ELVs almost exclusively consist of petrol and diesel drivetrains, over the studied period. Estimates show that they are a significant source of metals, such as neodymium. Due to long vehicle lifetimes, few EVs reach end of life until after the period. When they do and if current diffusion increases, ELVs will become even more important as a source for secondary raw materials in the EU.

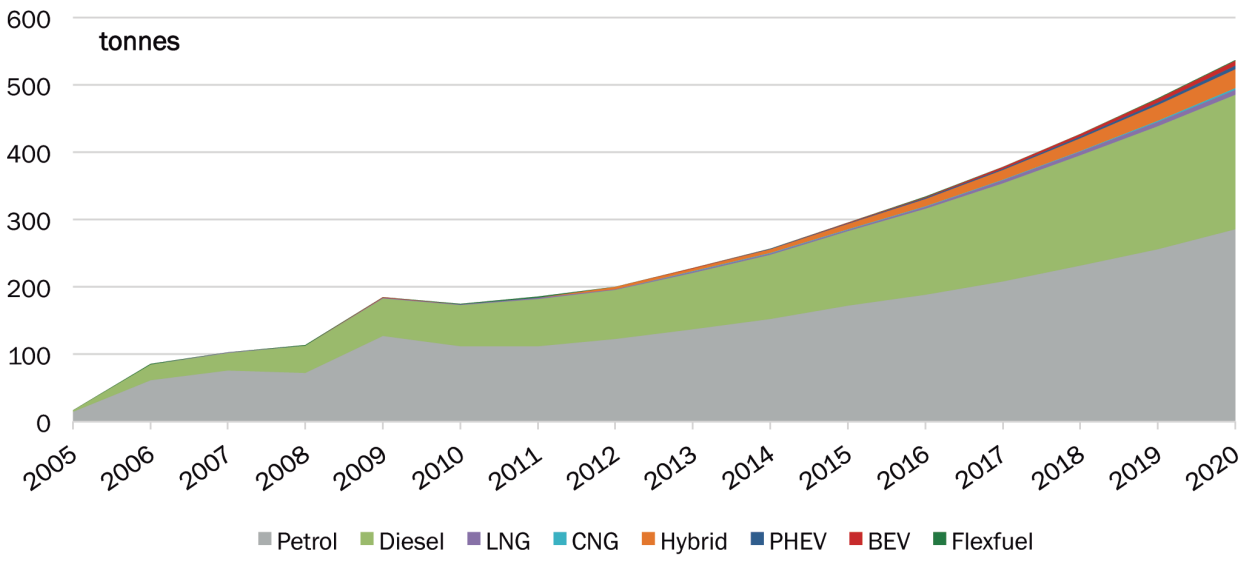


Figure 32. *Neodymium contained in registered ELVs at final treatment in EU28+3. Historic data from 2005 to 2014, extrapolated trends from 2015 to 2020 [tonnes]. BEV=battery electric vehicle, FC=fuel cell, PHEV=plug in hybrid electric vehicle, HEV= hybrid electric vehicle.*

Through the modelling of stock and flow shifts, a significant number of vehicles are estimated to leave the registered fleet without being reported, so-called "vehicle of unknown whereabouts" (**Figure 33**). Recurrently investigated by e.g. the EC, this gap partly appears to be attributable to unreliable data of used vehicles traded within the EU, but also to unreported exports outside of the EU and recycling.

7.4 Overall material stocks and flows of vehicles

As a summary, a Sankey diagram illustrates the substantial amount of metals in vehicles in the European Urban Mine in 2015 (**Figure 33**). The base metals iron, aluminium and copper make up nearly 88% of the total mass of ELVs, while shares of other elements are in single percentages or less. Most elements occur in larger quantities in ELVs than in WEEE and batteries. The exceptions are cobalt and lithium present in batteries (which includes vehicle batteries), and indium in WEEE. Of similar magnitude is neodymium in ELV and WEEE. It can thus be concluded that registered ELVs are significant sources of CRM. Moreover, the precious metals gold and silver are found in comparable amounts in vehicles versus EEE placed on the market. The in-use stocks of gold and silver are estimated to be larger in vehicles than in EEE, owing to the longer lifetime of vehicles.

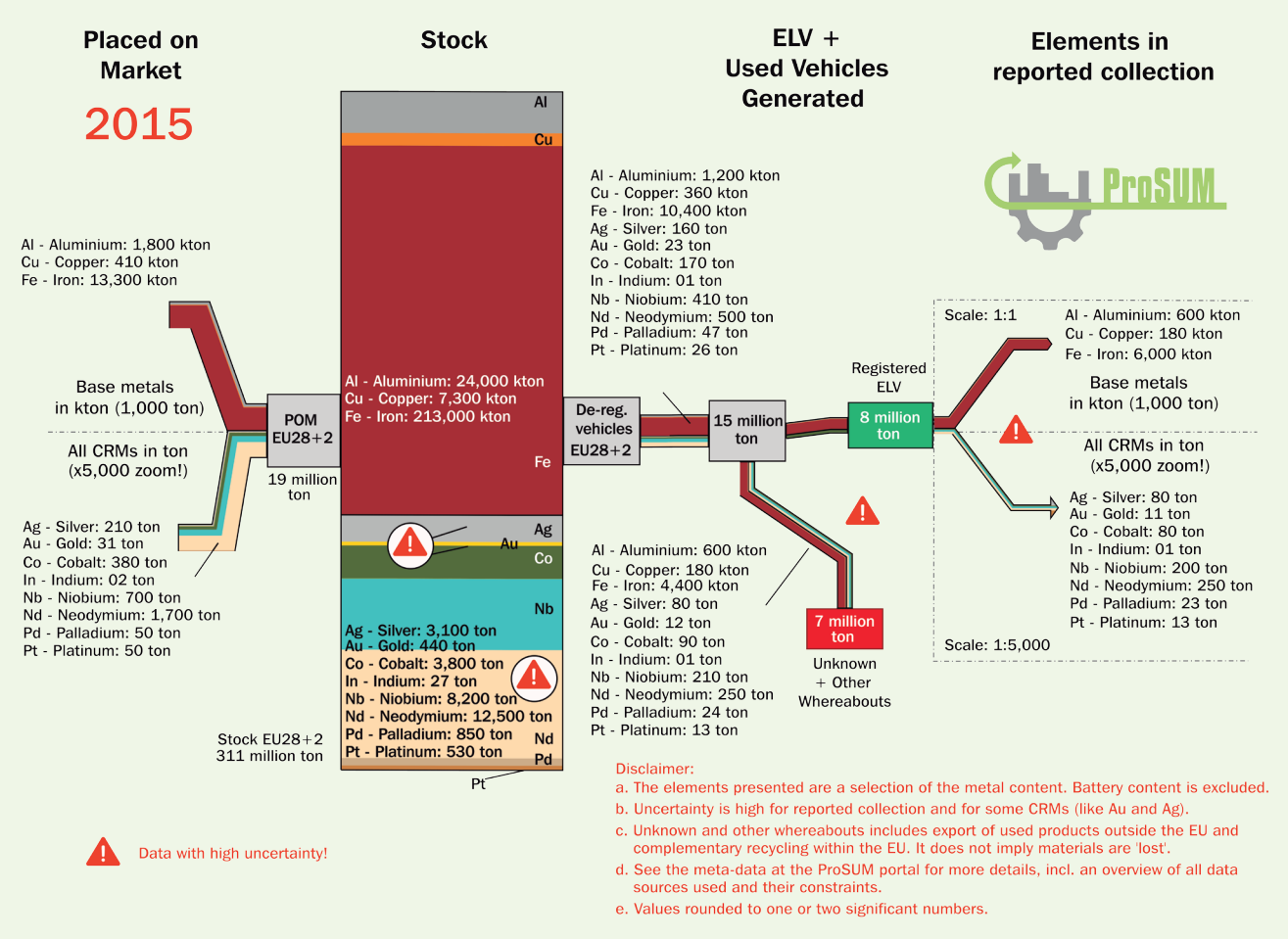


***Figure 33**. Stocks and Flows of metals in vehicles in the EU28+2 in 2015 in ktonnes (thousand tonnes for base metals) and tonnes (for CRMs).*

8. Mining Waste

8.1 Database and results

Mining waste differs in many aspects from the other product groups in ProSUM in that there is no EU legislation that requires recycling, there is no major recycling industry, there are sparse Eurostat statistics on mining waste and only at country level. The metals occur as metal-bearing minerals, the mining waste deposits are commonly very large but of low metal grade and the waste is best described at deposit level. A large amount of knowledge and information about mining waste is available but that information mainly concerns the raw materials that were in demand in society in the past, that is, iron, base metals and precious metals or environmentally hazardous elements such as arsenic, sulphur, cadmium and mercury. Today, when new technologies in modern society requires data about metals and minerals, which was previously only of academic interest, the ProSUM project aims at expanding the mining and mineral processing knowledge base to include these as well.

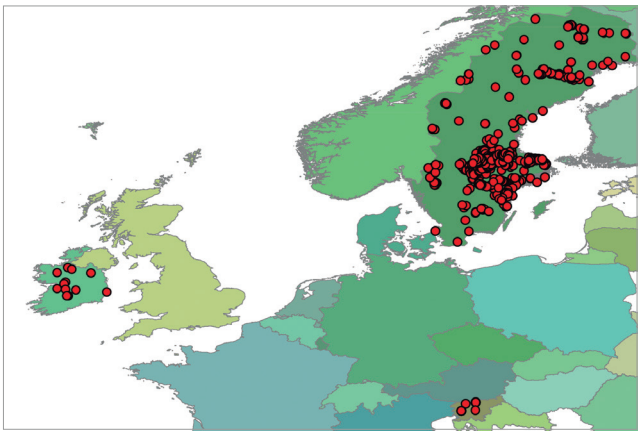
For that purpose the project has gathered data and conducted sampling and analysis of mining waste in order to present complete characterizations of this waste group, including CRMs. The main focus in the data gathering have been locations of mines (already available in Minerals4EU) and mineral processing plants, types of processes that produced the waste, types of wastes and amount and composition of the waste. This data is stored in a ProSUM extension to the Minerals4EU database, thus enabling the link between primary raw materials in a mine to secondary raw materials in the mining waste. The amount and composition of the mining waste and the quality of these observations are essential to the usefulness of the database. For the quality assessment on data on amount and composition of mining waste, two code lists have been developed, one to describe the methodology for the amount determination of the mining waste and the other how the composition was determined. These were originally meant to make it possible to store also low-quality data in cases where better data did not exist but serves well as quality indicators.

Table 4. *Type of information on mining waste from mines (left column) and mineral processing plants (right column). Important information, besides name and location, is the type of mining/processing activity, waste type, the amount of waste generated and the composition of the waste. For this information, there are complete code lists, from Minerals4EU or developed within the project. Amount estimation method and Composition estimation method indicates the source and quality of information.*

Examples of information in database for:	Examples of information in database for:
Waste from mines	Waste from mineral processing plants
Name	Name
N_coordinates	N_coordinates
E_ coordinates	E_coordinates
Start of mining activity	Start of processing activity
End of mining activity	End of processing activity
Present status	Present status
Mining Activity Type	ProcessingActivity
Produced Product	ProducedProduct
Product Type	ProductType
Amount Estimation Method	AmountEstimationMethod
Waste Type	WasteType
Waste Amount_ton	WasteAmount_ton
Composition Estimation Method	CompositionEstimationMethod
Fe_%	Fe_pc
Cu_%	Cu_pc
Co_%	Co_pc
Ga_%	Ga_ppm
and many more elements …	and many more elements

Table 4 shows some of the types of information for mining waste at mine sites and at mineral processing plants respectively that have been collected.

As an example of the type of data that will be available through web pages, the result from a test-harvesting of data is shown in **Figure 34**, **Figure 35** and **Figure 36** with data from Ireland, Sweden and Slovenia.



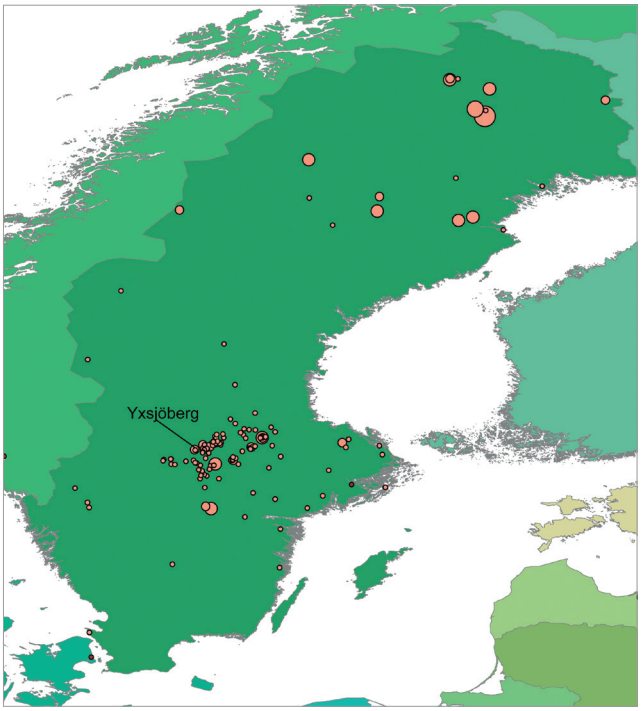
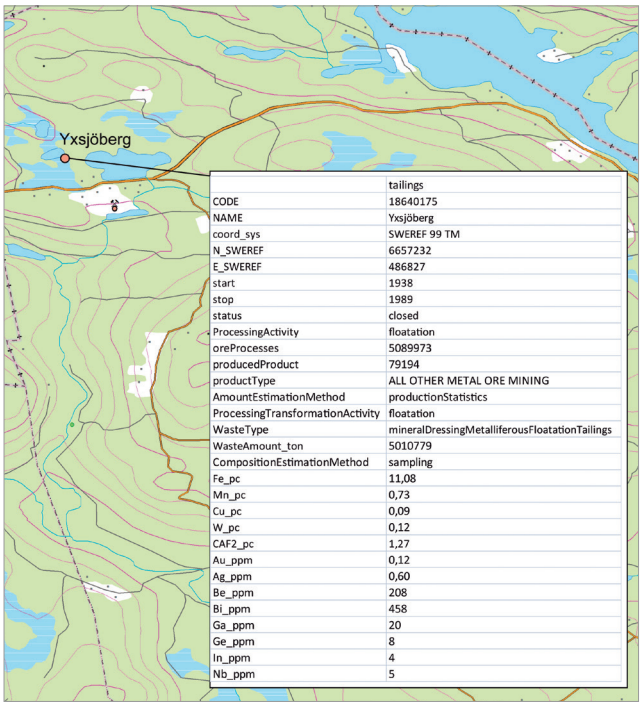


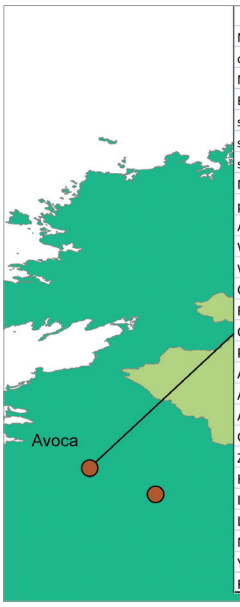
Figure 34. *(top, left) Distribution of mining waste sites in Irleand, Sweden and Slovenia Image created in GIS software from a test dataset delivered in ProSUM format, (middle, left) Distribution of mineral processing plants with talling dams in Sweden. Locations of the figure 35, the Yxsjöberg plant in south-central Sweden are marked.*

Figure 36. *(bottom, right) shows a detail from the map in Figure 34 together with data for the waste rocks at the Avoca mine, Irleand. The waste rocks are gold and silver bearing but also enriched in REE and zirconium and hafnium.*



	tailings
CODE	18640175
NAME	Yxsjöberg
coord_sys	SWEREF 99 TM
N_SWEREF	6657232
E_SWEREF	486827
start	1938
stop	1989
status	closed
ProcessingActivity	floatation
oreProcesses	5089973
producedProduct	79194
productType	ALL OTHER METAL ORE MINING
AmountEstimationMethod	productionStatistics
ProcessingTransformationActivity	floatation
WasteType	mineralDressingMetalliferousFloatationTailings
WasteAmount_ton	5010779
CompositionEstimationMethod	sampling
Fe_pc	11,08
Mn_pc	0,73
Cu_pc	0,09
W_pc	0,12
CAF2_pc	1,27
Au_ppm	0,12
Ag_ppm	0,60
Be_ppm	208
Bi_ppm	458
Ga_ppm	20
Ge_ppm	8
In_ppm	4
Nb_ppm	5

Figure 35. *(above) Detail from the map in Figure 34 together with data for the processing plant at Yxsjöberg copper-tungsten mine. The tailings contains high levels of beryllium and bismuth as well as high levels of copper and tungsten.*



	waste_rock
NAME	Avoca
coord_sys	Irish Grid
NAME	319298
E	181537
start	
stop	
status	historic
MiningActivityType	OpenPitAndUndergroundMining
productType	ALL OTHER METAL ORE MINING
AmountEstimationMethod	productionStatistics
WasteType	mineralExcavation
WasteAmount_ton	
CompositionEstimationMethod	
Fe_pc	13,60
Cu_ppm	2264,00
Pb_ppm	14443
Au_ppm	1,57
Ag_ppm	23,50
As_ppm	1034,00
Ga_ppm	46,94
Zr_ppm	>500
Hf_ppm	38,00
In_ppm	4,60
Li_ppm	38
Nb_ppm	109
Y_ppm	199
REE_ppm	908

8.2 ProSUM, Minerals4EU and future work

Eurostat reports that mining and quarrying industry in the EU28 generated 534 million tonnes of waste by 2014 (Eurostat, data for 2014). As the countries with the largest amount of generated waste are also the most important metal mining countries in the EU, it can be concluded that the majority of the waste volume is made up of mining waste.
Eurostat does not collect information about the accumulated amount of mining waste – the stock or the composition of the waste and since the waste amounts are merged at country level, the information becomes meaningless for metal exploration, including CRM exploration. To be useful, data on mining waste must be reported and accounted for on deposit level and that is exactly the kind of data that ProSUM mining waste participants collects.

The ProSUM Mining waste project divides mining waste into two groups; the mining waste generated at the mine during the mining activity, commonly described as waste rock, and the waste generated by the processing of ore at a concentrator, dressing plant or similar in the form of tailings or sludge. Location- wise the waste rock is reported together with the mine whose location is given in Minerals4EU database while the location, activity and generated waste of the processing plant called for an extension of the Minerals4EU database.

The data from the participating organisations, mainly geological surveys, will be uploaded in local databases, design according to the agreed database structure, and then harvested and merge into a common database on mining waste, in the same way as the data collection takes place today in Minerals4EU.

With the ProSUM project, work on documenting and characterising mining waste in Europe has begun, but the work is far from being completed. The project has developed guidelines for future work, a common database is in place, new code list have been developed and we can already identify locations for further work and exploration. What is needed for a future improvement of the database is more complete characterisations of the thousands of mining waste sites in Europe. A complete characterization include further sampling and modern multi-element analyses of the waste in order to identify CRMs, to estimate amounts and metal grades, and to better understand where they occur in nature.

***Figure 37**. Sampling of tailings in front of the head frame of the Mimer iron mine, central Sweden. Photo, Magnus Ripa, SGU.*

9. Conclusions, Recommendations and Next Steps

9.1 Conclusions

The data and intelligence available through the ProSUM portal will help in increasing the amount of secondary raw materials recycled from waste flows of electrical and electronic equipment, vehicles and batteries and assist the EU in developing a circular economy. It will allow policymakers and other stakeholders to take measures to improve Europe's position on raw material supply and make it less reliant on markets in third countries. The platform will meet future end-user needs by maintaining, updating and expanding the platform and, therefore, remain to facilitate the knowledge base on secondary raw materials in the EU.

The UMP has been designed to allow the user to select, produce and download charts 'on-demand' for previously unavailable or scattered information. The data includes elements in relatively high occurrences, as well as their carrying materials, components and products materials in these waste products. This includes mainly base metals, precious metals and those also listed as CRMs. The knowledge base is complemented with an extensive library of more than 800 source documents and databases. The centralised database is built on the Unified Data Model, which is a classification system and harmonised set of code list for all elements, materials and components in products, as well as for products placed on the market, in use or unused in stocks within the Urban Mine, the waste generated at end of life and the flows of waste generated. Furthermore, all methodologies, calculation steps and data constraints and limitations are made explicit, allowing the user to review key information and to get an idea of the data quality of the sources used for this massive prospecting effort.

Relatively speaking, **batteries** constitute the smallest sector with a market input, stock and waste generated potential of respectively 2.7 million, 9 million and 2 million tonnes for 2015, of which about 90% consist of lead batteries. Nevertheless, smaller volumes of nickel-metal hydride, zinc-based and lithium-based batteries are a significant source for lithium (7,800 tonnes), cobalt (21,000 tonnes) and manganese (114,000 tonnes) in the Urban Mine. Whilst around 50% of batteries are of unknown whereabouts, there is more than a corresponding 50% loss in cobalt and lithium. Only over 300 tonnes of cobalt are estimated to be in reported collected batteries compared to 2,300 tonnes in the unknown and other whereabouts. This reflects the fact that lithium-ion batteries are embedded in products that also end up in unreported reuse, recycling and various trade and export channels.

Dependent on the country and the income levels, the average per capita stock of **EEE products** ranges from 220 kg in Latvia up to 350 kg in Norway. That equates to around 205 products including lamps and fittings and 570 kilogrammes per average EU household in 2015. This totals a market input of 11.6 million tonnes, an Urban Mine of 129 million tonnes and a waste generated volume of 10.3 million tonnes. Gold, being the key value driver behind material recycling, primarily comes from printed circuit boards in LCD TVs, laptops, tablets, desktops and mobile phones and totals to 230 tonnes in-stock, roughly equal to 8% of the total annual world gold production. Other significant occurrences are plastics (26.5 million tonnes), copper (4.1 million tonnes), neodymium (12,000 tonnes), indium (300 tonnes) and silver (1,300 tonnes).

The **vehicle** fleets in Europe are relatively well documented and comprise of 260 million vehicles representing 311 million tonnes on the road in 2014 for the EU28+3. The base metals iron, aluminium and copper make up nearly 88% of the total mass of vehicles. Due to their weight and relatively much longer residence time, most elements occur in larger quantities in vehicles than in EEE and batteries in the Urban Mine. In total 213 million tonnes of steel, 24 million tonnes of aluminium and 7.3 million tonnes of copper are present. For precious metals, 850 tonnes of palladium in car catalysts and the EE system and 530 tonnes of platinum are determined as significant occurrences in car catalysts. From a modelled 15 million tonnes deregistered, 8 million tonnes are of vehicles are estimated to leave the registered fleet for reported recycling and one million tonne are of vehicles reported for export for use outside the EU, the rest, 6 million tonnes, are so called "vehicles of unknown whereabouts".

The **mining wastes** data will be held in the Minerals Knowledge Data Platform (MKDP), which lies within the ownership and development work of the Minerals4EU Foundation. The not for profit Minerals4EU Foundation's overall scope is to provide a one-stop-shop to official and verified data, information and knowledge on mineral resources, and to act as contact point through which stakeholders can easily and transparently access its products and expertise. Work on characterizing mining waste in Europe is far from complete. The ProSUM project has developed guidelines for future work, a common database, new code lists and suggestions of locations for further work and exploration. Going forward, a more complete characterization of the thousands of mining waste sites in Europe is required to further improve and expand the database.

9.2 Recommendations

A separate detailed report accompanies this report and sets out the full project recommendations together with rationale. In collating the recommendations, the following issues have been considered:

1. The provision of better data and intelligence to UMP end-users;
2. Through harmonising and standardising the way data is collected and presented;
3. Allowing for the collation and comparison of past, present and future data to build the knowledge base on SRM/CRMs for the entire Urban Mine;
4. Providing updates to the UMP;
5. The ability to improve and expand the UMP;
6. Intelligence on what the data tells us about the size of the Urban Mine;
7. Opportunities to support policymaking by an improved evidence base;
8. Opportunities to share knowledge on raw materials and recycling.

The largest number of recommendations has been identified for quantifying stocks and flows. This shows the significant challenges and limitations of the data to that which is 'officially reported'. Many waste products with a high metal content are valuable and traded with scarce data on their fate or whereabouts. More work is urgently required to substantiate the amount of waste products managed outside the official extended producer responsibility schemes. Without better understanding and altered reporting mechanisms, it will only ever be possible to roughly estimate these unknown whereabouts. At present this equates to around 60% of WEEE, 50% of batteries and 40% of vehicles. The actions require extensive work and are given high importance and urgency.

The recommendations have been collated by opportunities. A number of recommendations are considered to be of high importance. The letter and number denotes their place in the main recommendations report:

9.2.1 How to improve the characterisation of material content in products

P1 Vehicles dominate the stocks and waste generated in the urban mine but they are the product group with the least available data on composition. With an increasing number of electronics and an increasing mix of alloyed metals within vehicles plus a predicted change in drivetrains to electric, getting better composition data has the highest priority. A cost effective and efficient solution needs to be found whereby manufacturers can produce and share data on the composition of vehicles.

P2 Little data is available for the composition of newer EEE products since the composition of EEE is largely derived from waste sampling. A pilot approach is proposed to enable producers to declare the composition of target products. This is particularly important for recycling infrastructure given the trend to an increasing number of products with a higher number of elements used but in decreasing amounts.

P3 Whilst the chemistry of different battery types is widely understood for major elements, data is lacking on trace elements, CRMs and electronics. Higher granularity data would provide a better understanding of the changes in battery composition over time. It is recommended that safety data sheets are expanded to include this information.

9.2.2 How to improve the characterisation of the material content in wastes

W1 For WEEE and batteries, a significant challenge is the reliability of data for the input and output waste streams reported for treatment facilities. WEEE, particularly small WEEE, is collected in mixed categories and the distribution of product types in these loads is estimated. An increasing number of products arrive for treatment with their most valuable components missing. This affects the composition and value of output fractions from treatment. Better data on this would allow for better quantification of the losses of materials before and after treatment, which is currently beyond the scope of ProSUM.

9.2.3 How to improve the quantification of stocks and flows in the Urban Mine

F1 Unambiguous statistics about vehicle segments coupled with other statistics for drivetrain and mass are required to better quantify the elements contained within vehicles. If vehicle fleet statistics reported by Eurostat included this information, it would be easier to estimate CRM content in vehicles.

F2 Available data for batteries does not allow for the differentiation of sub-chemistries for some battery types such as lithium based batteries. Further detailed work is needed to outline a clear specification and approach for improving battery flow data through sampling and analysis in particular.

F3 To improve data for complementary flows and the unknown whereabouts of WEEE and batteries, further sampling is required. This should include: large domestic appliances in light iron and mixed metal scrap, and small WEEE and batteries actually disposed of in municipal waste. Harmonised sampling approaches are also required across Member States.

F4 A significant number of vehicles leave the stock without being recorded as recycled or exported as used vehicles. The reporting of data by Eurostat for active and inactive vehicles needs improving.
F5 Where certain Member States have adopted mandatory conformity with EN 50625 standards on WEEE treatment and handling for WEEE treatment operators, improvements have been seen in the amount and quality of reporting. When made legally binding, more data of higher quality on WEEE treated would become available.

9.2.4 How to improve data harmonisation, quality and interoperability of datasets

H1 The data compiled by Eurostat reflects different interpretations of the Batteries Directive with respect to the reporting of batteries collection. The definitions and average weights need to be applied in the same way in all EU Member States which would allow for more consistent data.
H2, H3 The code lists for the Urban Mine and mining wastes developed within the project need updating in the H2020 ORAMA project focusing on improving data quality and harmonisation, building on the work undertaken in ProSUM and lessons learned about data consolidation.
H4 The inability to easily produce reliable national statistics about reserves, resources, stocks, and flows of raw materials at Member State level is a major limitation in establishing supply chain security and a circular economy. The 'ProSUM approach' could be implemented at a Member State level to better identify the availability of SRMs linked directly to national manufacturing.

9.2.5 How to expand the scope of the UMP

U1 The scope of the UMP should be expanded to include better spatial representation for treatment and waste flows and the inclusion of recoverability. This added granularity would assist the recycling industry in determining the future availability of materials.

9.2.6 How to improve the knowledge base on material recovery and supply

R1 The material composition of the Urban Mine (WEEE, BATT, ELV) has been characterised as far as possible using available data. Further work is necessary to establish how viable these reserves/resources are and to determine the physical and economic limits of recycling and recovery

The recommendations cannot be implemented by the ProSUM Consortium in isolation. See www.prosumproject.eu, for the Deliverable Report 6.4, which targets stakeholders to implement the identified recommendations, together with the importance and urgency of above improvement options.

9.3 Next steps: Maintaining the knowledge base

Due to the fact that most data will be publicly available for free in the coming years, the UMP is not directly commercially exploitable as of yet. A Business Plan has been prepared as a Deliverable of this project and describes the platform's customers and early adopters, applications and services, costs and revenues, communication channels and tools as well as governance. It identifies ways in which the project's results and data can be maintained and updated in 2018 and 2019 and in advance of 2020, the target year for the UMP to become a financially independent and viable undertaking.

In terms of services that will be offered during the transition years, the most feasible solution seems to be to concentrate on a model assuming services of a Minimum Viable Product nature, for the most promising customer segments and servicing others with automated services. To that effect, the partners will seek to understand better the (potential) end-users' needs (market analysis and market testing) and, on that basis, develop (new) services and applications. A network of data providers will be set up. Whenever possible, the Urban Mine Platform and its potential will be promoted.

Furthermore, in 2018-2019, ORAMA, a Horizon 2020 project, will show how to create robust Material Systems Analyses and Sankey diagrams for stocks and flows, connect data with JRC's Raw Materials Information System (RMIS: http://rmis.jrc.ec.europa.eu/), identify best practices in projects, support policies and investments in primary and secondary raw material industries and develop protocols to update data.

After the end of the project, the Urban Mine Platform Information Network will remain the forum where professionals involved in prospecting the secondary raw materials in the Urban Mine meet, where both the future UMP managers and data providers meet customers. The advantages of the UMP will be explained to potential customers, whilst the customers will inquire about the latest changes to data and protocols, or applications and services. The UMP management will actively reach out to the stakeholders community, mainly through the Urban Mine Platform group on LinkedIn.

The future of the UMP depends on (strategic) partnerships. Some of these partnerships will give rise to synergies, whereby the interaction between stakeholders produces a total effect that is greater than the sum of the individual efforts. Others will be a means to minimise costs, influence policymakers, understand product and recycling technology trends, undertake marketing, raise funding, or better access data.

10. About Us

10.1 The ProSUM consortium

BRGM - Bureau de Recherches Géologiques et Minières

BRGM, the French Geological Survey, is a French Public Institution responsible for mobilising the Earth Sciences in the sustainable management of georesources and the subsurface domain. BRGM's research and development programs, financed by the Ministry of Research, support innovation and work towards advancing the Earth Sciences in strategic areas, both on a national and international scale. BRGM is involved in a high standard of research activities under the supervision of the Research Division, which ensures the quality of the undergoing research projects. BRGM activity covers the whole spectrum of the management of mineral resources, from fundamental research (e.g. ore forming processes, metallogenic syntheses, predictive mapping, etc.), including exploration, expertise, development of geological and mining data infrastructures, management of after mine problems, to raw material economy. In the same way, BRGM has an international expertise in information systems, being part or leading European drafting teams and working group of the INSPIRE directive. At national level, it is in charge of the development and hosting of the National Environment Portal and of the National Geo-catalog (national catalog for INSPIRE), and of the "National Portal about Environment". Promoting interoperability in geosciences and environmental information, BRGM is contributing to OGC development and to GeoSciML and ERML (through IUGS/CGI).

Website: www.brgm.eu

CBS - Centraal Bureau voor de Statistiek

Centraal Bureau voor de Statistiek (Statistics Netherlands or CBS) is responsible for the collection and processing of data in order to publish statistics to be used by policymakers and by scientists. In addition to its responsibility for official national statistics, CBS has the task of producing EU statistics. The mission of CBS is to publish reliable and coherent statistical information that meets the needs of society. In view of this mission, the quality of the statistical information must be guaranteed. For this reason CBS developed a system of quality assurance based on the highest international criteria.

Website: www.cbs.nl

CGS - Czech Geological Survey

The Czech Geological Survey is a state-funded organisation that compiles, stores, interprets and provides objective expert geological information for the state administration, the private sector and the public. The research institute is supervised by the Ministry of the Environment and is responsible for providing the state geological service in the Czech Republic. It is the only institution with the mission to systematically investigate the geological composition of the whole Czech territory since 1919. The main fields of expertise include research on mineral resources, assessment of their economic potential and mining impact, geological research and mapping, geochemistry, applied geology, natural risks, management and delivery of geodata.

Website: www.geology.cz

Chalmers University of Technology

Chalmers University of Technology focuses on research and education in technology, natural science, architecture, maritime and other management areas. The Division of Environmental Systems Analysis conducts research to find more sustainable technology solutions to better meet environmental and resource constraints faced. Among other, technology assessments in the fields of vehicles, materials and end-of-life management are carried out, often in collaboration with industry. Examples of recent research topics are circular economy measures for manufacturing industries, policy for recycling of scarce metals in vehicles and life cycle environmental impacts of electrified vehicle components.

Website: www.chalmers.se

C-tech Innovation

C-Tech Innovation Ltd is an independently owned research and technology development company (50+ employees), providing research and innovation services to companies, universities and governmental bodies. The company is a leading centre for the development of novel and technological processes, which are used to replace or enhance conventional process routes. C-Tech has extensive experience in the industrial materials processing sector, including technology for recovery of materials from WEEE.

Website: www.ctechinnovation.com

EGS - EuroGeoSurveys

EuroGeoSurveys (EGS) is the organisation of the Geological Surveys of Europe, the national institutions responsible for the geological inventory, monitoring, knowledge and research for the security, health and prosperity of the society. Its mission is to provide public Earth Science knowledge to support the EU's competitiveness, social well-being, environmental management and international commitments. EGS operates on a European scale, working with industry, universities and research centres, and putting its knowledge base at the disposal of all European citizens, institutions and media. In particular, EGS provides a unique, independent, source of scientific expertise and advice to the EU institutions on all matters related to on-shore and offshore geological resources and/or hazards. With the support of its 37 national members, EGS actively contributed, and still contributes, to a number of EU policy and legislative developments.

Website: www.eurogeosurveys.org

Empa

Empa is the interdisciplinary research and services institution for material sciences and technology development of the ETH Domain. Empa's R&D activities are oriented to meeting the requirements of industry and the needs of society, and link applications-oriented research with the practical implementation of new ideas. Safety, reliability and sustainability of materials and systems form a common thread running through all Empa activities. The priorities of Empa's research are structured in five Research Focus Areas with the following topics: Nanostructured Materials, Sustainable Built Environment, Health and Performance, Natural Resources and Pollutants, and Energy. Empa's Technology and Society Laboratory (TSL) aims at creating and transferring knowledge for the transition to a more sustainable society, with a focus on the analysis and evaluation of material and energy stock and flows associated with novel materials and emerging technology applications.

Website: www.empa.ch

Eucobat

Eucobat is the European association of national collection schemes for batteries. The members ensure that all spent batteries are collected and recycled in an environmentally sound way. The objectives of Eucobat are to represent the interests of the national compliance organisations for batteries in Europe and monitor the EU Battery Directive 2006/66/EC.

Website: www.eucobat.eu

GeoZS - Geological Survey of Slovenia

The Geological Survey of Slovenia (GeoZS) is a public research institute (90 employees) established by the Government of the Republic of Slovenia. Scientists, researchers, technicians and project managers, among them 64% with high education, contribute to production of geological maps, assessment of natural and anthropogenic geological hazards to living environments, expertise in fields of groundwater, mineral resources, geothermal energy resources and natural geological heritage. All activities are supported by Geological information Centre, responsible for collection, processing, storage and dissemination of geological data within the framework of a single information system.

Website: www.geo-zs.si

GEUS

GEUS has worked intensively with the development and operation of databases and exchange-formats for geological, geophysical and mineral resources data for more than 25 years. GEUS runs nation-wide databases for boreholes, geochemistry, geophysics, geological samples, digital reports, digital maps and geological models integrated with a large number of web-services for query and update of these data used on-line by local and regional administrations throughout Denmark. GEUS has the long-term responsibility of collecting basic geo-scientific information about natural resources in Greenland and Denmark, as well as the experience in resource assessments and evaluation.

Website: www.geus.dk

RECHARGE

RECHARGE has a very good understanding and knowledge about the Batteries Urban Mine in Europe, and can bring a significant contribution to the project, based on its members' information. Batteries and WEEE flows are similar in several aspects, particularly at the end of life, where most of the rechargeable portable batteries are collected with the WEEE.

Website: www.rechargebatteries.org

SGU - Geological Survey of Sweden

The Geological Survey of Sweden (SGU) is a central governmental agency under the Ministry of Enterprise, Energy and Communications for matters relating to the geology of Sweden and the management of mineral resources. Information from SGU is used by exploration companies in their search for mineral resources. At present SGU has about 260 employees and an annual turnover that totals 28 M. SGU is a member of ETP-SMR High Level Group and is also a partner in the ongoing ERA-MIN.

Website: www.sgu.se

TUB - Technische Universität Berlin

The Technische Universität Berlin (TUB) is a public research and education institution with 30,000 students, 6,000 academic staff members and 300 professors. Research activities under the Chair of Circular Economy and Recycling Technologies include the transition of waste management towards a circular economy for selected product systems. Recycling-oriented characterisation methodologies have been developed and adapted to the need of new recycling systems in particular for strategic raw materials for example for WEEE, batteries, photovoltaic systems. The Research Centre "Forschungsschwerpunkt Technologien der Mikroperipherik" (TMP) at the Technische Universität was responsible for the collection and consolidation of the data on batteries and brought expertise on technologies established and in development.

Website: www.tu-berlin.de

TU Delft - Technische Universiteit Delft

Technische Universiteit Delft (°1842), is the oldest, largest and most comprehensive university of technology in the Netherlands (ranking 19th in the 2014 QS World University Rankings – Engineering and Technology). TU Delft has a strong research profile with the main focus on engineering and applied sciences. The Valorisation Centre educates engineers and PhD graduates and conducts breakthrough scientific research in the fields of mechanical engineering, maritime engineering and materials science. It undertakes coherent and innovative research dedicated to developing, producing, characterising and manipulating materials, with a focus on metals.

Website: www.tudelft.nl

UNU - United Nations University

UNU is an autonomous organ of the UN General Assembly dedicated to generating and transferring knowledge and strengthening capacities relevant to global issues of human security, development, and welfare. The University operates through a worldwide network of research and training centres and programmes. The Bonn (Germany) based Sustainable Cycles (SCYCLE) Programme hosted by UNU's Vice Rectorate in Europe is providing world-class research and action on e-waste. SCYCLE aims to enable societies to reduce the environmental burden caused by the production, consumption and disposal of ubiquitous goods. SCYCLE is leading in global quantification and qualification of e-waste flows, authoring the2014 and 2016 Global E-waste Monitors, with more detailed e-waste generated/arising analyses carried out in individual EU Member States, such as e.g. the Netherlands, Belgium, France, Italy, Romania, Ireland and the Czech Republic.

Website: www.unu.edu

WEEE Forum

The WEEE Forum, set up in 2002, is a Brussels-based international not-for-profit association speaking for 34 not-for-profit electrical and electronic equipment waste (WEEE) producer compliance schemes – alternatively referred to as 'producer responsibility organisations' (PRO). The 34 PROs are based in Europe, Oceania and North America: Australia, Austria, Belgium, Canada, Czechia, Cyprus, Denmark, Estonia, Italy, Greece, France, Iceland, Ireland, Lithuania, the Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom. It is the biggest organisation of its kind in the world. In 2016, its member organisations reported collection and proper de-pollution and recycling of 2,100,000 tonnes of WEEE. Members in 2017: Amb3E, ΑΝΑΚΥΚΛΩΣΗ ΣΥΣΚΕΥΩΝ, ASEKOL, Australia New Zealand Recycling Platform, Ecodom, Eco-systèmes, Ecotic, ECOTIC, EES-Ringlus, EGIO, Electrocyclosis Cyprus, ElektroEko, Elektrowin, El-Kretsen, elretur, Environ, EPRA, Fotokiklosi, Norsirk, Recipo, Recupel, Remedia, RENAS, Repic, Retela, RoRec, SENS e-Recycling, SWICO, UFH, Úrvinnslusjóður, Wecycle, WEEE Ireland, WEEE Malta and Zeos. See also 15 Years On brochure.

Website: www.weee-forum.org

WRAP

WRAP have been working in the field of resource efficiency and security for over 12 years with a clear focus on ensuring robust and secure markets for resources and products. In March 2012 Defra and BIS (British Government Departments) published their Resource Security Action Plan which included the delivery by WRAP of two actions: development of material flows diagrams to understand the key materials within electrical and electronic equipment and how they move through the UK economy; and to set up and delivery of trials to recover CRMs (critical raw materials) from WEEE (waste electronic and electrical equipment).

Website: http://www.wrap.org.uk

10.2 The Advisory Board

The project consortium was supported by an external Advisory Board made up of experts in their sectors who helped us to steer the project direction. We would like to express our most sincere gratitude to:

Katerina Adam, *Associate Professor, School of Mining and Metallurgical Engineering, National Technical University of Athens*

Peter Coonen, *Managing Director, Bebat and Sortbat*

Christian Dworak, *Specialist Product Related Environmental Protection, BSH*

Karen Hanghoj, *Chief Technology and Education Officer, EIT RawMaterials*

Christer Forsgren, *Environment and Technical Manager, Stena Metall*

Shunichi Honda, *Programme Officer, UNEP*

Thomas Marinelli, *Head of Environmental, Health and Well-Being, Philips International (until October 2016)*

Barbara Reck, *Research Scientist, Centre for Industrial Ecology, Yale University*

Hanna Schweitz, *Manager Secondary Raw Materials, Boliden*

Annex 1 - List of Project Deliverables

List of reference deliverable reports. These are all available at **www.prosumproject.eu**

Number	Deliverable name	WP Number	Lead Participant
D1.1	List of EEAB members	WP1	WEEE Forum
D2.1	CRM Parameters Characterisation	WP2	Empa
D2.2	Available CRM data for components	WP2	TU Delft
D2.3	Factors affecting CRM parameters composition	WP2	TU Delft
D2.4	CRM Trends and Scenarios	WP2	TU Delft
D2.5	CRM Data Consolidation and Datasets	WP2	Empa
D2.6	CRM Sample Preparation and Chemical Analysis	WP2	Empa
D2.7	Protocols on CRM Product and Component Content and Quality Assessment	WP2	Empa
D3.1	Historic and Current Stocks	WP3	UNU
D3.2	Complementary Product Flows	WP3	WRAP
D3.3	Products Stocks and Flows	WP3	UNU
D3.4	CRM Stocks and Flows Model	WP3	UNU
D3.5	CRM Stocks and Flows Methodology	WP3	UNU
D3.6	Protocol for Stocks and Flows Update and Quality Assessment	WP3	UNU
D4.1	Waste Flow Studies	WP4	TU Berlin
D4.2	CRM Assessment Strategy	WP4	TU Berlin
D4.3	Waste and Tailings Characterisation	WP4	Empa
D4.4	Protocols for CRM Content in Waste Flows and Data Quality Assessment	WP4	TU Berlin
D5.1	Specification of End-user Requirements	WP5	C-Tech
D5.2	Secondary Raw Materials Availability	WP5	C-Tech
D5.3	Review and Harmonisation of Data	WP5	CBS
D5.4	Qualification of Flow Data and Coherent Estimates	WP5	BRGM
D5.5	Data Models and Code Lists	WP5	GEUS
D5.6	Creation of the Metadata System	WP5	CGS
D5.7	UMP	WP5	BRGM
D6.1	EU Information Network	WP6	WEEE Forum
D6.2	EUIN Business Plan	WP6	WEEE Forum
D6.3	UMP Business Plan	WP6	WEEE Forum
D6.4	Recommendations	WP6	WEEE Forum
D6.5	Communication Plan	WP6	WEEE Forum
D6.6	Final Technical Report	WP6	WEEE Forum

Register to participate and receive updates:
in LinkedIn: Urban Mine Platform Information Network
More information:
www.prosumproject.eu
www.prosumportal.eu
www.urbanmineplatform.eu

Get in touch:
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EuroGeoSurveys European Geoscience for Society – The Geological Surveys of Europe
United Nations University UNU-VIE SCYCLE Sustainable Cycles Programme
TU Delft
RECHARGE
Empa Materials Science and Technology
brgm Geoscience for a sustainable Earth
SGU Sveriges geologiska undersökning
wrap
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Project Coordinator weeeforum

Urban Mine Platform

ProSUM
Prospecting Secondary raw materials in the Urban mine and Mining wastes