PROSUM
RECOMMENDATIONS REPORT

ProSUM

Prospecting Secondary raw materials in the Urban mine and Mining wastes

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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.

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EXECUTIVE SUMMARY

This Report presents the recommendations arising from the ProSUM Project. It contains recommendations designed to continue to improve the knowledge base for secondary raw materials with the overarching objective of increasing recycling and supply of such materials. It specifically addresses data availability, data quality, data harmonisation, data structure and data presentation.

The report contains a complete list of recommendations arising from the work undertaken in the project covering the 'urban mine' of electrical and electronic equipment, batteries and vehicles, their wastes, and mining wastes. It is the culmination of three years' work which has resulted in:

- The characterisation of products in terms of CRM content;
- A comprehensive review and screening of all available data to characterise products;
- An assessment of the factors affecting CRM content in products and the future trends for products;
- A comprehensive review of existing and development of new methodologies for sampling and analysis of products;
- An assessment of the current stocks of products held in households and business;
- The quantification of flows of waste products not captured by national reporting on producer compliance;
- A new model to quantify stocks and flows of products, their waste and material flows;
- A comprehensive review and screening of all available data to characterise waste flows;
- A comprehensive review of existing and development of new methodologies for sampling and analysis of wastes;
- An evaluation of relevant product waste flows and mining wastes deposits;
- Creation of the Urban Mine Platform (UMP) including a unified data model and code lists and meta data system;
- Expansion of the Minerals Knowledge Data Platform (MKDP) for mining wastes;
- And a new harmonised classification system to describe data in the urban mine.

The results of the project are described in the Final Project Report. A detailed list of Deliverable Reports is provided in *Annex 1*. **The Urban Mine Platform is available at www.urbanmineplatform.eu**

A summary of the recommendations is shown in **Table 1**. The main report provides a full explanation for each individual recommendation.

The recommendations have been collated by opportunities for:
1. Improving the characterisation of the material content in products (Table 2);
2. Improving the characterisation of the material content in waste (Table 3);
3. Improving the quantification of stocks and flows in the urban mine (Table 4);
4. Improving harmonisation, quality and interoperability of data (Table 5);
5. Expanding the scope of the UMP (Table 6);
6. Increasing the knowledge base on material recovery and supply (Table 7).

The recommendations cannot be implemented by the ProSUM Consortium in isolation and target stakeholders to implement the recommendations are also identified in this report. The priority of the recommendation is indicated by importance and urgency. Importance is in relation to improving the knowledge base and, hence, the EU's ability to define and supply available secondary raw materials. High denotes a very significant impact on data, medium a significant impact on data, and low some improvement. Urgency has been assessed by the extent to which the recommendation would quickly improve data where one year is high, within 2-3 years is medium, and within 5 years is low.

Table 1 Project Recommendations

Recommendation	Product/ Waste	Stakeholder	Importance	Urgency
Improving the characterisation of material content in products (P)				
P1 Establish a working group with automotive industry, recyclers and EC to design and fund comprehensive work to characterise Vehicles for CRMs.	Vehicles	ACEA, EGARA, EC, ORAMA Consortium, Researchers	H	H
P2 Develop a pilot approach for manufacturers to declare the composition and content of target EEE products.	EEE	DIGITALEUROPE, CECED, EERA, WEEE Forum	H	M
P3 Improve the accuracy of composition data for batteries including data on trace and critical elements and battery electronics.	BATT	Battery Producers, Researchers	M	M
P4 CENELEC prEN45558 include a mandatory requirement that summary data shall also be provided to relevant maintained/recognised knowledge platforms.	EEE	EC, CENELEC	M	L
P5 Review ProSUM Classification System to ensure compatibility with the emerging EC CEN/CENELEC European StandardprEN 45558.	EEE	ORAMA Consortium	M	L
Improving the characterisation of materials in wastes (W)				
W1 Work with WEEE and BATT Producer Responsibility Organisations and recyclers to undertake further sampling and analysis to characterise waste input to treatment facilities, and from treatment facilities to end-processing.	WEEE, BATT	WEEE Forum, Eucobat	H	M
W2 Produce a list of target mining waste sites for further prospecting.	MW	EGS	M	L
W3 Building on the work undertaken in ProSUM, develop and implement defined quality methods for sampling and analysing wastes.	WEEE, BATT, ELV, MW	Researchers	L	L
W4 Undertake further work to determine the material content of ashes and slags from metal processing.	MW	EGS	L	L

Recommendation	Product/ Waste	Stakeholder	Importance	Urgency
Improving the quantification of stocks and flows (F)				
F1 Amend vehicle fleet statistics as reported by Eurostat to expand on vehicle characteristics that are crucial for CRM content, such as further specification of drivetrain types (especially electrified ones) and segment.	Vehicles	EC, Eurostat, MS vehicle registries	H	H
F2 Develop a specification for data needs, sample sizes, meta data descriptions and costs for sampling to improve battery data quality.	BATT	ORAMA Consortium	H	H
F3 Improve data on the unknown whereabouts of WEEE and batteries through waste sampling.	WEEE, BATT	Member States, ORAMA Consortium, ProSUM Consortium	H	H(WEEE) M(BATT)
F4 Develop reporting of vehicle fleets to minimise the number of vehicles of unknown whereabouts.	ELV	EC, Eurostat, MS vehicle registries	H	M
F5 Improve data on unknown whereabouts of WEEE by making adoption of EN 50625 standards legally binding.	WEEE	EC	M	M
F6 Undertake household waste surveys to measure the stocks and residence times of EEE and batteries in households.	WEEE, BATT	Member States, PROs	M (WEEE) M (BATT)	M
F7 Improve timeliness, frequency and granularity of WEEE (flows) reporting to Eurostat.	WEEE	EC	M	L
F8 Investigate mining waste flows.	MW	Researchers, mining and processing companies	M	L
F9 Collect data on the amount and types of batteries separated from WEEE and ELV at treatment facilities and sent to battery recyclers.	BATT	Member States	M	L
F10 Amend the ELV Directive to include a requirement for reporting vehicle age and the destination of vehicles exported for recycling and Eurostat to publish.	ELV	EC, Eurostat	L	L
F11 Produce publicly available reports related to the quality of reported data under the WEEE, Batteries and ELV Directives.	WEEE, BATT and ELV	EC, Eurostat	L	L

Recommendation	Product/ Waste	Stakeholder	Importance	Urgency
Improving harmonisation, quality and interoperability of data (H)				
H1 Improve harmonisation for data reporting for batteries within and across Member States particularly concerning collection and recycling.	BATT	EC	H	H
H2 The ProSUM component and material code list should be further refined and statistical data reconciliation for consolidating composition data be enabled within the UMP.	EEE, BATT, ELV	ORAMA Consortium. PolyCE Consortium	H	H
H3 Review the mining waste database model, code lists, and harvesting methods to facilitate future improvements to the common harmonised database.	MW	ORAMA Consortium	H	H
H4 Gather national material account data on Eurostat and establish 'ProSUM projects' to create material accounting for each Member State.	WEEE, BATT, ELV	NSIs, ORAMA Consortium	H	M
H5 Set criteria for producing harmonised data on secondary raw materials from EC funded research and projects, and seek ways for EU funded project networks to co-operate to share structured data.	All	EC, EASME, ORAMA Consortium, Researchers	M	M
H6 Provide structured input to the EU Raw Materials Scoreboard in 2020.	All	ProSUM Consortium	L	L
Expanding the scope of the UMP (U)				
U1 UMP scope is expanded to include recoverability, waste treatment data and regional spatial representation of waste flows.	WEEE, BATT, ELV	ORAMA Consortium, ProSUM Consortium	H	M
U2 UMP scope is expanded to include other waste products including: plastics, other forms of transportation, other metal scrap and construction and demolition waste.	Metals, minerals and plastics	ProSUM Consortium, PolyCE Consortium, EC	L	L
Improving the knowledge base on material recovery and supply (R)				
R1 Determine current and future potential recovery rates.	WEEE, BATT, ELV	WEEE Forum, Eucobat, SCRREEN Consortium, Researchers	H	M
R2 Utilising the maps generated in the UMP as a starting point, further work should be undertaken to determine the viability of recovering CRMs from mining waste deposits.	MW	EGS, SCRREEN Consortium, Researchers	M	M

A number of recommendations are considered to be of high importance:

Product Composition

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 and a predicted change in drivetrain to electric, this product group 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 EEE products and the composition of EEE is largely derived from waste sampling. There is little data available for new products coming onto the market. A pilot approach is needed 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.

Waste Composition

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 are arriving for treatment with their most valuable components missing. This impacts on the composition of the output fractions from the treatment process. Data on the output fractions from treatment are commercially sensitive and not widely shared. Better data on this would allow for better quantification of the losses of materials before and after treatment.

Stocks and Flows

F1 Unambiguous statistics about vehicle segments coupled to other statistics for drivetrain and mass are required to better quantify the elements contained within vehicles.

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

F3 To improve data on 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 required across Member States.

F4 A significant number of vehicles leave the stock without being recorded as recycled to exported as used vehicles. The reporting of data for active and inactive vehciles needs improving.

F5 Where 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. If actors on the market were legally required to handover WEEE to certified plants, more data of a higher quality on WEEE generated would be available.

The highest number of recommendations have 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 little data on their fate or whereabouts. More work is urgently required to substantiate the amount of waste products managed outside of the official extended producer responsibility regime. Without better understanding, it will only ever be possible to estimate these unknown whereabouts. At present this equates to around 60% of Waste Electrical and Electronic Equipment (WEEE), 50% of batteries and 40% of end-of-life vehicles (ELV). The actions recommended require extensive work and are given high importance and urgency due to the extent to which data must be improved. This is detailed in Table 4 in the main report.

Improving Harmonisation, Quality and Interoperability of Data

H1 The data compiled by Eurostat reflects different interpretations of the Batteries Directive with respect to the reporting of batteries collection. For example, the maximum weight of the battery in the 'Portable' category varies between 1 and 10 kg among the EU Members States. The definitions 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 need updating in the ORAMA project, 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 manufacturing.

Expanding 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.

Improving 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 and to determine the physical and economic limits of recycling and recovery.

During the lifetime of the project an External Expert Advisory Board (EEAB) has provided advice and guidance to help steer the project. This EEAB was comprised of stakeholders who are representative of the end-users of the ProSUM data and the UMP (see Annex 2 for members of EEAB). The EEAB has been consulted most of the recommendations presented in this report.

Given the importance of the ProSUM findings to policymakers, in particular, the European Commission, officials from DG Growth, DG Environment, DG Joint Research Centre and EASME have also been consulted.

Whilst the Project Consortium has made every effort to consult on the recommendations, there are obviously a wide range of views held, and the recommendations should not be considered as endorsed by, or the view of, any one organisation listed in this report. The Project Consortium are grateful for the support, advice and constructive criticism which we have received from both the EEAB, the EC and members of the ProSUM Information Network.

Throughout the report reference is made to the Directives covering WEEE, batteries and ELV. These are: DIRECTIVE 2012/19/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 4 July 2012 on waste electrical and electronic equipment (WEEE) (recast); DIRECTIVE 2006/66/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 6 September 2006 on batteries and accumulators and waste batteries and accumulators and repealing Directive 91/157/EEC (and amendments) ; and Commission Directive (EU) 2016/774 of 18 May 2016 amending Annex II to Directive 2000/53/EC of the European Parliament and of the Council on end-of-life vehicles.

1. Introduction

Securing access to raw materials is a societal challenge. The European Commission states that "reliable and unhindered access to certain raw materials is a growing concern within the EU and across the globe" (European Commission, 2017). For on-going or emerging transitions to more "clean technologies" such as solar panels, energy-efficient lighting and electric vehicles, material resource availability may even become a governing factor (European Commission, 2016). The Commission's list of critical raw materials (CRMs) for the EU combines raw materials that are both of critical importance to the EU economy and of high risk associated with their supply. This list was expanded from 14 to 27 CRMs in September 2017.

The ProSUM project has focused on rich sources of CRM: waste electrical and electronic equipment (WEEE), end-of-life vehicles (ELV), batteries and mining wastes. In undertaking this work, data has also been collated on secondary raw materials, primarily as base metals, precious metals, CRMs and shown by components, materials and elements as 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. ProSUM provides data for improving the management of these wastes and enhancing the resource efficiency of collection, treatment and recycling. A wide range of end-users are addressed, including the recycling industry (collectors, treatment facilities and processors), producers, producer compliance schemes, policymakers and academia.

The ProSUM inventory is accessed via a user-friendly, open-access portal to the Urban Mine Platform, on arisings, stocks and flows of WEEE, ELVs, batteries and the Minerals Knowledge Data Platform (MKDP) on mining wastes. A link to primary mineral resources is provided through the MKDP (originally developed by the Minerals4EU project). To maintain and expand the UMP in the future, updated protocols, standards and recommendations for additional statistics as well as improved reporting on CRMs in these waste flows have been developed. Furthermore, harmonised methodologies for characterising the CRM content of these waste streams are suggested.

Until now data on primary and secondary raw materials have been available in Europe but have largely been scattered amongst a variety of institutions including government agencies, universities, NGOs and industry. The data are often stored in databases with their own design and architecture making it difficult and time consuming to merge or compile. Moreover, where data relates to the composition of waste, different and, often incomplete, sampling and analytical approaches may have been used which makes it challenging to aggregate and compare data.

The inventory held in the UMP also sets the basic architecture to include a larger part of the urban mine in the future.

The project is the culmination of the nearly three years work which has resulted in:

- The characterisation of products in terms of CRM content;
- A comprehensive review and screening of all available data to characterise products;
- An assessment of the factors affecting CRM content in products and the future trends for products;
- A comprehensive review of and development of new methodologies for sampling and analysis of products;
- An assessment of the current stocks of products held in households and business;
- The quantification of flows of waste products not captured by national reporting on producer compliance;
- A new model to quantify stocks and flows of products, their waste and material flows;
- A comprehensive review and screening of all available data to characterise waste flows;
- A comprehensive review and development of methodologies for sampling and analysis of wastes;
- An evaluation of relevant product waste flows and mining wastes deposits;
- Creation of the UMP including a unified data model and code lists and meta data system;
- Expansion of the MKDP for mining wastes;
- And a new harmonised classification system to describe data in the urban mine.

See Annex 1 for a complete list of ProSUM Deliverable Reports.

2. Description of the approach

In collating the recommendations, the following issues have been considered:

- The provision of better data and intelligence to ProSUM UMP end-users;
  - Filling data gaps
  - Improving data quality and confidence levels
  - Improving granularity to improve decision making
- Through harmonising and standardising the way data is collected and presented;
  - Possibilities to improve data consolidation techniques and the ProSUM classification system
  - Possibilities to improve national and EU data reporting
  - Sharing of data and intelligence more widely
- 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;
  - Opportunities to work with other projects producing data on secondary raw materials
  - Opportunities to expand the UMP to other wastes and materials
- Providing updates to the UMP through;
  - Interoperability with data from Eurostat and national statistics
  - Updating data arising from new research, publications, studies and reports
- The ability to improve and expand the UMP;
  - Meeting end-user requirements
  - Widening the wastes and products included
- Intelligence on what the data tells us about the size of the urban mine;
  - Expanding the knowledge base to identify secondary raw material availability (commodities)
- Opportunities to support policy making by an improved evidence base;
  - Linkages to the Raw Materials Scoreboard
  - Data to support on-going work such as CENELEC standard
- Opportunities to share knowledge on raw materials and recycling.

The recommendations have been collated by opportunities for:

Section 3 Improving the characterisation of material content in products;
Section 4 Improving the characterisation of the material content in wastes;
Section 5 Improving quantification of stocks and flows in the urban mine;
Section 6 Improving data harmonisation, quality and interoperability of datasets;
Section 7 Expanding the scope of the UMP;
Section 8 Increasing material recovery and supply.

There are an increasing number of initiatives, activities and EU and nation-wide studies that collect and collate data, where more networking, harmonisation and data sharing would help to improve the overall knowledge base.

The recommendations cannot be implemented by the ProSUM Consortium in isolation and target stakeholders to implement the recommendations are also identified in this report, together with the importance and urgency. The priority of the recommendation is indicated by importance and urgency. Importance is in relation to improving the knowledge base and, hence, the EU's ability to define and supply available secondary raw materials. High denotes a very significant impact on data, medium a significant impact on data, and low some improvement. Urgency has been assessed by the extent to which the recommendation would quickly improve data where one year is high, within 2-3 years is medium, and within 5 years is low.

A brief explanation is provided against each recommendation.

3. Recommendations to improve characterisation of material content in products

Table 2 describes recommendations to better characterise products by their material content. The recommendations have been drawn up based on the limitations in available data observed during the project. They are supplemented with new opportunities which have arisen during the project which were not part of the original project scope.

Table 2 Recommendations to improve characterisation of material content in products

Recommendation	Product/ Waste	Stakeholder	Importance	Urgency
P1 Establish a working group with automotive industry, recyclers and EC to design and fund comprehensive work to characterise Vehicles for CRMs.	Vehicles	ACEA, EGARA, EC, ORAMA Consortium and Researchers	H	H
Vehicles is the product group with the least available data for composition, but vehicles dominate the stocks and waste quantities estimated for many elements. To reduce the uncertainty of estimates and provide more granular mapping of elements, actors should work together to find a cost effective and efficient way of producing and sharing product data to support recycling infrastructure development. IMDS (international material declaration system) and IDIS (international dismantling information system) are currently used by the automotive industry to monitor legal requirements on hazardous substances and recyclability, and pre-treatment and dismantling information for selected components, respectively. IMDS is a closed confidential system and IDIS has limited information on CRMs. Developing an approach where targeted elements and components, such as electronic components, could be better mapped and shared publicly using IMDS and IDIS (whilst respecting industry confidentiality) should be considered as an option.				
P2 Develop a pilot approach for manufacturers to declare the composition and content of target EEE products.	EEE	DIGITALEUROPE, CECED, EERA, WEEE Forum	H	M
Little data was available concerning the recent composition of products. Therefore, the composition of products was primarily derived from waste product analysis. This gives rise to large uncertainty in the extrapolation of data. A pilot would be relatively costly if it required sampling of products and components being put on the market. It could be executed in the medium term utilising the 'hot spots' for products and components identified in the project. Producers and recyclers should work together to find a cost effective and efficient way of producing and sharing product and component data, e.g. printed circuit board and magnets, to support recycling infrastructure development. This could reflect the emerging CENELEC European Standard prEN 45558. To support implementation of Article 15 of the WEEE Directive, an initiative has already been established between the WEEE Forum, CECED, DIGITALEUROPE and EERA. The WEEE Forum has agreed in principle to be responsible for hosting and maintaining a platform of Information for Recyclers. The platform will allow WEEE processing and treatment operators to download data sheets that show which product families have components which contain hazardous substances. It will be a tool to train operatives to identify and handle products and components in the correct way. Once this platform is operational, and implantation has been successful consideration should be given to potentially expanding the scope and granularity by the inclusion of A Full Materials Declaration and Bill of Materials.				
P3 Improve the accuracy of composition data for batteries including data on trace and critical elements and battery electronics.	BATT	Battery Producers/ Researchers	M	M
In general, there is a clear relation between the chemistry type of a battery (often indicated on the label, according to IEC standards) and its chemical composition, at least for the major material contents. Composition data are often published by the manufacturers, in the form of safety data sheets. These should be expanded to include data on trace elements, CRM and electronics. Collection organisations and recyclers would also benefit from improved and more accurate composition data for major and trace elements including CRM. Better composition data would allow a better understanding of the changes over time of the battery composition, and of the composition and raw material content of battery electronics. The sampling and chemical analysis of the batteries in stocks and generated as waste would also improve the accuracy of data for spent batteries.				

Recommendation	Product/ Waste	Stakeholder	Importance	Urgency
P4 CENELEC prEN45558 include a mandatory requirement that summary data shall also be provided to relevant maintained/recognised knowledge platforms.	EEE	EC, CENELEC	M	L
CENELEC are working on a standard CEN-CENELEC TC10 Material Efficiency Aspects for Ecodesign. This standard (prEN45558) will provide a general methodology for declaration of the use of energy-related products in support of the implementation of EU Raw Materials Initiative. It will specify a procedure for the declaration of CRMs. It will be essential in supporting manufacturers of energy related products to obtain information and report on the use of certain CRMs needed to comply with specific requirements in product specific legislation in future. The standard is linked to prEN45555 – General methods for assessing the recyclability and recoverability of energy-related products, where the information to be gathered on the CRMs with the support of the upcoming prEN45558 can be used, for example by manufacturers to prove (and improve) recyclability of products and their components (including CRMs).				
P5 Review ProSUM Classification System to ensure compatibility with the emerging EC CEN/CENELEC European Standard prEN 45558.	EEE	ORAMA Consortium	M	L
The draft prEN45558 includes declaration by name of substance or substance group, location of CRM in the product e.g. the components, and mass or mass % of substance group. Once further information is available, the ProSUM classification system should be reviewed to ensure interoperability with data which may arise from this reporting.				

4. Recommendations to improve the characterisation of material content in wastes

Table 3 describes recommendations to better characterise wastes by material content. The recommendations have been drawn up based on the limitations in available data observed during the project and opportunities to improve this situation.

Table 3 Recommendations to improve characterisation of material content in wastes

Recommendation	Product/ Waste	Stakeholder	Importance	Urgency
W1 Work with WEEE and BATT Producer Responsibility Organisations and recyclers to undertake further sampling and analysis to characterise waste input to treatment facilities, and from treatment facilities to end-processing.	WEEE, BATT	WEEE Forum, Eucobat	H	M
WEEE received at treatment facilities may have missing components because of theft. This impacts on the economics of treatment and the data collected on input weights and output data on fractions for supposed whole units. Data on the outputs from WEEE treatment and recycling facilities and the capacity of such facilities are commercially sensitive and, therefore, not available and very difficult to collect. Harmonised sampling protocols have been developed and tested during ProSUM and are available for this purpose. These protocols identify methods for identifying product types and numbers and the absence of components (typically high in valuable elements). It is important that methods for distribution analysis based on product counts and dismantling analyses are implemented to improve statistical evaluation. Further work should be undertaken with recyclers to more comprehensively quantify the theft of valuable components and its impact on recycling and reporting. This could be supported through Horizon 2020 value chain projects. Under the WEEE 2020 Raw Material Commitment, the WEEE Forum and other signatory partners have committed to undertake activity to demonstrate the potential to increase collection and recycling rates from WEEE by minimising losses along the value chain. The WEEE Forum in cooperation with contracted recyclers should now take this work forward building on the data produced by ProSUM. A vital first step will be to determine material losses during treatment.				
W2 Produce a list of target mining waste sites for further prospecting.	MW	EGS	M	L
It would require a massive budget to sample all of the mineral waste deposits in the EU. It is recommended that certain deposits, selected from ProSUM data, are targeted for further investigation. Selection criteria include size, active or recently closed deposits/plant, and relatively high concentration of CRM. Although mining waste deposits may be inhomogeneous, they contain traces of the ore from which the waste is derived. Several CRM occur in small amounts associated with the main metals due to chemical similarities and these metal associations can be used to evaluate the contents of CRM in both primary and secondary deposits. Some knowledge of these metal associations e.g. Indium and Zinc in base metal ores and PGM in Nickel-Copper ores already exist but would need to be further developed. ProSUM data on the amount and content of CRMs in mining waste, linked to existing primary commodity data in Minerals4EU, forms a basis for such investigations.				
W3 Building on the work undertaken in ProSUM, develop and implement defined quality methods for sampling and analysing wastes.	WEEE, BATT, ELV, MW	Researchers	L	L
Existing sampling theory was developed for the mining industry and is not directly applicable to highly heterogeneous wastes such as WEEE and batteries. This prevents calculation of minimum sample masses and corresponding uncertainties related to sampling. Improved methods will lead to more accurate and comparable results from analysis.				

Recommendation	Product/ Waste	Stakeholder	Importance	Urgency
W4 Undertake further work to determine the material content of ashes and slags from metal processing.	MW	EGS	L	L

Whilst the project did not include wastes from the metal producing industry, e.g. the ash and slags from smelters and blast furnaces, the data model and code lists have been created. Therefore, these wastes could be easily included in the future but would require characterisation.

5. Recommendations to improve the quantification of stocks and flows in the urban mine

Table 4 describes recommendations to improve the quantification of stocks and flows. The recommendations have been drawn up based on the limitations in available data observed during the project and opportunities to improve this situation.

Recommendation	Product/ Waste	Stakeholder	Importance	Urgency
F1 Amend vehicle fleet statistics as reported by Eurostat to expand on vehicle characteristics that are crucial for CRM content, such as further specification of drivetrain types (especially electrified ones) and segment.	Vehicles	EC, Eurostat, MS vehicle registries	H	H

Available statistics allowed a correlation of element contents with common drivetrain types and mass, but not with different levels of equipment, such as electric and electronic systems. The level of equipment could be assumed to correlate to segment, and as a proxy for level of segment, cylinder capacity is used. This is not optimal, especially considering the growing number of vehicles with no internal combustion engine, hence, no cylinder volume. Instead, unambiguous statistics about vehicle segments coupled to other statistics for drivetrain and mass is required. For electrified drivetrains, proprietary information about vehicles put on the market was used in ProSUM. If the market for such drivetrains continues to increase, as is expected, a differentiation of electric propulsion power types in public statistics would be very useful, to correlate to contents in battery and other electric drivetrain components.

Recommendation	Product/ Waste	Stakeholder	Importance	Urgency
F2 Develop a specification for data needs, sample sizes, meta data descriptions and costs for sampling to improve battery data quality.	BATT	ORAMA Consortium	H	H

For some battery types like primary lithium-based batteries, it was not possible to link the data on battery flows put on the market or in stocks to the composition data because available data did not differentiate the different sub-chemistries. Sampling of waste batteries to derive the sub-chemistries in the flows which could then be linked with composition data (to complete data presenting the families of electrochemical systems, e.g. lithium-ion batteries) would help reduce the uncertainty on the quantification of stocks and flows of batteries. Data available for industrial and automotive batteries is also very scarce as there are no reporting requirements in either the Batteries Directive or ELV Directive. Improving batteries data is complex and requires a clear specification developing. (See also Improving the characterisation of products P3).

Recommendation	Product/ Waste	Stakeholder	Importance	Urgency
F3 Improve data on the unknown whereabouts of WEEE and batteries through waste sampling.	WEEE, BATT	Member States, ORAMA Consortium, ProSUM Consortium	H	H (WEEE) M (BATT)

WEEE is collected and recycled through a number of routes outside of Producer Responsibility Organisations and therefore not reported in the 'collected' flows. There are still some major data/knowledge issues with unreported flows for products, the unknown whereabouts. A lot of this WEEE is being collected and recycled. More work is needed to substantiate the flows described as 'unknown whereabouts' and complementary flows e.g. WEEE in scrap and the reuse, refurbishing and export of business to business products.
Some WEEE is recycled in the metal scrap stream and in some cases this will be to the same standards as reported WEEE collection and recycling and could contribute to substantiated estimates as allowed under Article 16 of the WEEE Directive.
Moreover, it would be desirable if all actors involved in the collection, trade and recycling of WEEE, were required to report on the quantity and fate of the WEEE they manage. It is also believed that small WEEE and batteries are commonly disposed of with municipal waste.
For batteries, the complementary flow data is largely for waste batteries in municipal waste. No data are available for batteries disposed of in packaging, batteries not properly treated in Member States, or batteries disposed of in WEEE and ELV. For these flows a feasibility study should be developed to derive the methodology.
Further sampling, particularly for large domestic appliances in light iron and mixed metal scrap, is required. Sampling using standard methods would improve data on the amount of small WEEE and batteries actually disposed of in municipal waste. Some Member States already undertake periodic waste stream sampling. Such sampling methodologies could be harmonised and undertaken more frequently. (See also Improving the characterisation of material content in wastes W1).

Recommendation	Product/ Waste	Stakeholder	Importance	Urgency
F4 Develop reporting of vehicle fleets to minimise the number of vehicles of unknown whereabouts.	ELV	EC, Eurostat, MS vehicle registries	H	M

It is well known that a significant number of vehicles leave the stock without being recorded as recycled or exported as used vehicles. This gap of vehicles of unknown whereabouts has been investigated by the EC. Partly, the gap appears to be attributable to unreliable data of used vehicles traded within the EU and differences in countries' reporting of active and inactive fleets. The magnitude of this gap may represent an untapped source of elements.

Recommendation	Product/ Waste	Stakeholder	Importance	Urgency
F5 Improve data on unknown whereabouts of WEEE by making adoption of EN 50625 standards legally binding.	WEEE	EC	M	M

There is evidence to suggest that mandatory conformity of WEEE treatment operations with EN 50625 standards on WEEE treatment and handling, specifically in France, Ireland, Lithuania and the Netherlands, leads to improvements in the amount and quality of reporting. If actors on the market were legally required to handover WEEE to certified plants, more data of a higher quality on WEEE generated would be available.

Recommendation	Product/ Waste	Stakeholder	Importance	Urgency
F6 Undertake household waste surveys to measure the stocks and residence times of EEE and batteries in households.	WEEE, BATT	Member States, PROs	M (WEEE) M (BATT)	M

Surveys have previously been undertaken at a Member State level, usually by market research organisations, and are, therefore, not harmonised or consistent in scope. Standardised consumer surveys would allow for more precise determination of stocks of WEEE and batteries, to increase the reliability of total stocks and derived lifespan information, and consequently reduce error propagation for stocks and waste generated. Such surveys should be based on the protocols developed in ProSUM which provide guidance in issues such as whether the product is still working, whether it was purchased second-hand, and consumer hoarding and disposal behaviour. Further work is needed to determine efficient and effective survey distribution channels.

Recommendation	Product/ Waste	Stakeholder	Importance	Urgency
F7 Improve timeliness, frequency and granularity of WEEE (flows) reporting to Eurostat.	WEEE	EC	M	L

Amending the Member State reporting requirements of the WEEE Directive and statistics related to EU legislation to report on both the hazardous and CRM content of WEEE should be considered. It is already a requirement that hazardous and specified components are removed from WEEE under Annex VII of the WEEE Directive. It is recommended that the removal of such components should be reported at Member State level. This could be implemented under Article 16 of the WEEE Directive.
In addition, the European Commission should consider taking initiatives to improve the timeliness and quality of Eurostat and trade statistics. MS WEEE data for a given year should be submitted to Eurostat in month 9 of the following year. The reporting for international trade of metal scrap should distinguish for scrap containing WEEE.

Recommendation	Product/ Waste	Stakeholder	Importance	Urgency
F8 Investigate mining waste flows.	MW	Researchers, mining and processing companies	M	L

The flow of mining waste from mines to waste rock dumps and from plants to tailing dams were not a focus of the project. However, such flows are at the most favourable sites for extraction and recovery of CRM since the material is easily accessible, fresh and newly milled, and the permits and infrastructure are in place.

Recommendation	Product/ Waste	Stakeholder	Importance	Urgency
F9 Collect data on the amount and types of batteries separated from WEEE and ELV at treatment facilities and sent to battery recyclers.	BATT	Member States	M	L

It is a requirement that batteries embedded in WEEE and ELVs are separated at treatment facilities and sent for recycling. Very limited data are available on these batteries. There is no data on the batteries that are in deregistered or exported used vehicles, collected by manufacturers for replacement, refurbishment or repurposing, inside WEEE or improperly discarded by users. Data is required for these sources and those batteries removed at certified and authorised treatment. This data would improve waste flow information in the UMP. (See also Improving the characterisation of material content in wastes W1).

Recommendation	Product/ Waste	Stakeholder	Importance	Urgency
F10 Amend the ELV Directive to include a requirement for reporting vehicle age and the destination of vehicles exported for recycling and Eurostat to publish.	ELV	EC, Eurostat	L	L

Vehicle content differs over time, but there is no information about the age distribution of ELVs reported as recycled. This affects the uncertainty of estimated composition. The certificate of destruction issued for all recycled vehicles should include the vehicle model year.
Information about member state destinations of vehicles or dismantled components exported for recycling and reuse is requested in reporting guidelines for the ELV Directive, but not reported by Eurostat. Destinations are important for establishing the geographical location of recovery potentials.
The information should then be included in the statistics for ELVs reported by Eurostat.

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Recommendation	Product/ Waste	Stakeholder	Importance	Urgency
F11 Produce publicly available reports related to the quality of reported data under the WEEE, Batteries and ELV Directives.	WEEE, BATT, ELV	EC, Eurostat	L	L

It is not possible to assess the quality of reported data provided under the EEE, ELV or BATT Directive. The data reports provided by reporting member states should be made publicly available.

6. Recommendations to improve data harmonisation, quality and interoperability of datasets

Table 5 describes recommendations to improve the harmonisation, interoperability and quality of datasets. The recommendations have been drawn up based on the limitations in available data observed during the project and opportunities to improve this situation.

Table 5 Recommendations to improve harmonisation, quality and interoperability of data

Recommendation	Product/ Waste	Stakeholder	Importance	Urgency
H1 Improve harmonisation for data reporting for batteries within and across Member States particularly concerning collection and recycling.	BATT	EC	H	H
The data compiled by Eurostat reflects different interpretations of the Batteries Directive with respect to the reporting of batteries collection. For example, the maximum weight of the battery in the 'Portable' category varies between 1 and 10 kg among the EU Members States. The definitions need to be applied in the same way in all EU Member States which would allow for more consistent data.				
H2 The ProSUM component and material code list should be further refined and statistical data reconciliation for consolidating composition data is enabled within the UMP.	EEE, BATT, ELV	ORAMA Consortium. PolyCE Consortium	H	H
The component and material code lists were developed at the start of the project. The code list should be updated to reflect the practical implementation of incorporating actual product and component data into the structure first developed. The H2020 project PolyCE, of which UNU is a partner, should refine and further develop the polymer code lists from ProSUM. The main difficulty with consolidating data from different sources lies in the fact that they use different sets of components and materials to describe products. When estimating the average composition of a product, the normal approach is to choose a list of materials and components that is compatible with data from different sources. This usually requires aggregating some of the data to a higher level, e.g. grouping all types of aluminium alloys as one material, or several different printed circuit boards as one component, even though more detailed data is available. This leads to a loss of information. Statistical data reconciliation is a method that can be used to estimate the composition on the most detailed level available, while still taking into account the more aggregated data.				
H3 Review the mining waste database model, code lists, and harvesting methods to facilitate future improvements to the common harmonised database.	MW	ORAMA Consortium	H	H
Refinement of the data gathering procedures will be necessary to improve the way common data is described.				

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Recommendation	Product/ Waste	Stakeholder	Importance	Urgency
H4 Gather national material account data on Eurostat and establish 'ProSUM projects' to create material accounting for each Member State.	WEEE, ELV, BATT	NSIs, ORAMA Consortium	H	M
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. Some Member States have developed national material accounting for a wide range of sectors. Some sectors have a very large contribution to the national economies, e.g. the automotive sector in Germany, France, Sweden, Spain and Romania. The 'ProSUM approach' could be implemented at a Member State level to better identify the availability of SRMs linked directly to manufacturing. Sector specific mass balances could be undertaken in individual countries. Many of these sectors have a widespread supply chain, both within and outside of Europe. Hence it is recommended to develop improved harmonised formats for reporting from NSIs to Eurostat. Some of this research and specific cases studies are planned in the ORAMA project. This could be tested in the framework of RMIS 2.0 for research related to criticality assessment, material efficiency indicators and policy interventions.				
H5 Set criteria for producing harmonised data on secondary raw materials from EC funded research and projects, and seek ways for EU funded project networks to co-operate to share structured data.	All	EC, EASME, ORAMA Consortium, Researchers	M	M
Over 35 person years of effort have been used to develop the data structure and improve data availability and data sharing in the UMP. If steps are not taken to encourage more harmonisation in data gathering and production, massive amounts of resource and data manipulation will always be required to compare data. Researchers engaged in producing data on the composition of products are encouraged to use more standardised code lists and protocols, such as those developed in ProSUM. Where the European Commission is paying for this research and data to be produced, there is an opportunity to continue to build on and expand the knowledge base on secondary raw materials to contribute to the European Innovation Partnership on Raw Materials and its Strategic Implementation Plan. The Horizon 2020 programme is funding projects that contribute to the knowledge base, each of these projects have their own networks and databases. These projects should be encouraged to share data and intelligence. This should build on protocols such as those provided by ProSUM and further developed in the EU H2020 project ORAMA.				
H6 Provide structured input to the EU Raw Materials Scoreboard in 2020.	All	ProSUM Consortium	L	L
The EU Raw Materials Scoreboard gives an overview of the challenges related to raw materials. It consists of 24 indicators grouped into five thematic clusters. The Scoreboard's purpose is to provide quantitative data on the EIP's general objectives and on the raw materials policy context. It presents relevant and reliable information that can be used in policymaking in a variety of areas. The Scoreboard will, for example, contribute to monitoring progress towards a circular economy, a crucial issue on which the European Commission recently adopted an ambitious Action Plan. The Scoreboard is published every two years and a draft version for 2018 is currently under consultation. Data held in the UMP could help to support indicator setting and monitoring.				

7. Recommendations to expand the scope of the UMP

Table 6 describes recommendations to expand the scope of the UMP. The recommendations are based on: opportunities to provide more detailed intelligence to end-users, particularly industry, to increase recovery of secondary raw materials; and the possibility to expand the waste types included to incorporate a larger 'urban mine'. A separate business plan, Deliverable 6.3, provides recommendations to maintain and update the UMP in future.

Table 6 Recommendations to expand the scope of the UMP

Recommendation	Product/ Waste	Stakeholder	Importance	Urgency
U1 UMP scope is expanded to include recoverability, waste treatment data and regional spatial representation of waste flows.	WEEE, BATT, ELV	ORAMA Consortium, ProSUM Consortium	H	M
The presentation of composition data by materials and elements is for totals and does not take into account the extent to which these materials and elements are recoverable. Further work is necessary to determine the extent to which the materials and elements in the urban mine can be recovered, physically, economically and with optimised environmental benefit. During end-user surveying at the start of the project, it was apparent that the recycling industry (collectors, dismantlers, pre-processors and processors) would see benefit from greater spatial representation and data on the flows of waste products and components after pre-processing. This level of detail was beyond the scope and budget for the project. The Horizon 2020 funded ORAMA project will be undertaking work to further refine the UMP. This should include expansion of the classification system, unified data model and code lists for the UMP. Any further work should take into account the Specifications for the application of the United Nations Framework Classification for Resources to Anthropogenic Resources being developed by the Expert Group on Resource Classification (EGRC) Working Group on Anthropogenic Resources. These specifications include definitions for secondary raw materials, anthropogenic stocks and the extent to which secondary raw materials are extractable economically or there is feasibility for extraction. Gathering of data to determine recoverability will require a substantial investment, most likely as part of a new Horizon 2020 project. Calls to be investigated.				
U2 UMP scope is expanded to include other waste products and materials including: plastics, other forms of transportation, other metal scrap and construction and demolition waste.	Metals, minerals and plastics	ProSUM Consortium, PolyCE Consortium, EC	L	L
The urban mine is bigger than the scope of wastes in ProSUM which focussed on those products with the potential to contain CRMs. In terms of considering the potential to supply secondary raw materials from the actual urban mine, it would make sense to expand the scope of the UMP to include other similar materials and elements as contained in the UMP and MKDP e.g. wastes high in metals and minerals content. Also, materials in the ProSUM products where some data is known to be available and they present a recycling challenge e.g. plastics in WEEE and ELV. Data gathered on plastics during ProSUM should form the basis of more detailed quantification. The PolyCE project is researching plastics recovery potential, and intelligence should be shared between these consortia.				

8. Recommendations to improve material recovery and supply

Table 7 describes recommendations to move forward the results of the ProSUM project by identifying not just the content of the urban mine but the extent to which it can be mined.

Table 7 Recommendations to improve material recovery and supply

Recommendation	Product/ Waste	Stakeholder	Importance	Urgency
R1 Determine current and future potential recovery rates.	WEEE, BATT, ELV	WEEE Forum, EERA, EBRA Eucobat, EGARA, SCRREEN Consortium, Researchers	H	M
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. To establish their potential as commodities, the following parameters need to be known: concentration and dispersion; route to market; value of materials and the physical limits of recycling/recovery; and the economic viability of exploitation. Further work is necessary to determine the physical limits of recycling and recovery. Moreover, these data would provide insights to feed the discussion on the measurement and measurability of recycling rates and the definition of legal targets regarding recycling efficiency.				
R2 Utilising the maps generated in the UMP as a starting point, further work should be undertaken to determine the viability of recovering CRMs from mining waste deposits.	MW	EGS, SCRREEN Consortium, Researchers	M	M
The locations of mining waste sites with potentially high CRM content have been identified together with their composition where sampling has been undertaken. The extent to which it is economically viable to recover metals and mineral from these deposits is unknown. EGS will produce a list of potential sites to determine next steps with industry and other researchers.				

9. Concluding comments

This project has been a phenomenal undertaking, the work to gather and consolidate available data was significant in its own right, but added to this the consortium have also developed a new data structure to harmonise existing and future data, and built the UMP to provide easy access to high quality charts, data and accompanying explanations. The most important recommendation going forward is that this work does not stop, and that all partners involved work with the EC to ensure that this valuable resource is maintained and exploited to ultimately increase material recycling.

These recommendations provide a small window into the overall results of the project, the primary result being the UMP and the data it holds. The Urban Mine Platform, together with the knowledge base (structured and unstructured data and documents), and the mining waste map viewer can be found at www.prosumportal.eu. A separate final project report provides a summary of the detailed work and outcomes of the project. In addition to the recommendations described above, more detailed recommendations are also contained in the detailed reports which describe the work and outputs for each deliverable. These reports are listed in Annex 1.

Annex 1

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	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

Annex 2

ProSUM EEAB Members

EEAB Member	Role and Organisation
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
Barbara Reck	Research Scientist, Centre for Industrial Ecology, Yale University
Hanna Schweitz	Manager Secondary Raw Materials, Boliden

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RECHARGE

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Materials Science and Technology

cbs

Geoscience for a sustainable Earth
brgm

SGU
Sveriges geologiska undersökning

wrap

1919
CZECH GEOLOGICAL SURVEY

GEUS

GeoZS
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Project Coordinator   weeeforum

Urban Mine Platform

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