Futu RaM

Future availability of secondary raw materials

FutuRaM conceptual and methodological framework

Milestone 6

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Table 1 Version History

VER. NO.	DATE	REASONS FOR RELEASE	RESPONSIBLE
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2.0	17.05.2023	First final draft to partners	K. Remmen
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5.0	09.06.2023	Final version available to chare with WP1 partners	K. Remmen

Notice

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1 Executive Summary

This executive summary provides an overview of the milestone report M6 for the FutuRaM project, focusing on the development of the first draft of the FutuRaM framework. The purpose of this report is to outline the progress made in the project and present the draft concepts and methods developed thus far.The milestone report begins with an introduction, highlighting the purpose of the report and its significance in the FutuRaM project. It then describes the three pillar approach taken to develop the FutuRaM framework, which includes decision meetings including the development team, the FutuRaM open discussion forum, and Knowledge Meetings to facilitate collaboration and knowledge sharing.

The report then presents the FutuRaM draft concepts and methods, which are divided into various categories. These include terminology, classification and data collection methods, post-consumer waste framework, pre-consumer waste flows, data quality, scenarios, technology development for recovery pathways, technology development for products, UNFC (United Nation Framework for Resource Classification) and secondary raw material and waste treatment model. For each category, the report provides an overview of the concept, the methodology employed, and the next steps to be taken. These steps are crucial for further development and refinement of the FutuRaM framework. The next chapter described the data model, knowledge base, and data delivery portal. This is a summary of Milestone 8. Particular to mention is the example model for scandium in the annex of the report, demonstrating a possible practical application of the framework.

In the conclusions and outlook section, the report emphasizes the importance of stakeholder engagement and feedback in shaping the FutuRaM framework. It also provides recommendations for the next steps to be undertaken in the project. Overall, this milestone report showcases the progress made in the development of the FutuRaM framework in the first year of the project and provides a roadmap for future steps. It emphasizes collaboration, data availability and quality, as well as stakeholder engagement as key elements for the next steps within FutuRaM.

2 Introduction and purpose of the Milestone report

This Milestone report is a draft of the conceptual and methodological framework for FutuRaM. The purpose of this report is to show the current status of the concepts and methods developed within in the WP 2-6. In addition, next steps should be discussed and drafted by the respective responsible WP and task leader. The status presented in this document will help the FutuRaM consortium to monitor the progress and identify deviations to the proposed FutuRaM concept in the upcoming project month. The report provides valuable insights into the project activities. We will gain a clear understanding of the current situation, which is necessary for developing a realistic plan for further needed steps. This report will be used as a reference point within the consortium. The methods and concepts will be further consolidated in the second phase of Task 1.1, under consideration of (i) insights from their application in the respective WPs, including the case studies in WP5, (ii) the specificities of the waste streams addressed in FutuRaM, and (iii) the stakeholder perspectives.

3 Approach to develop the FutuRaM framework

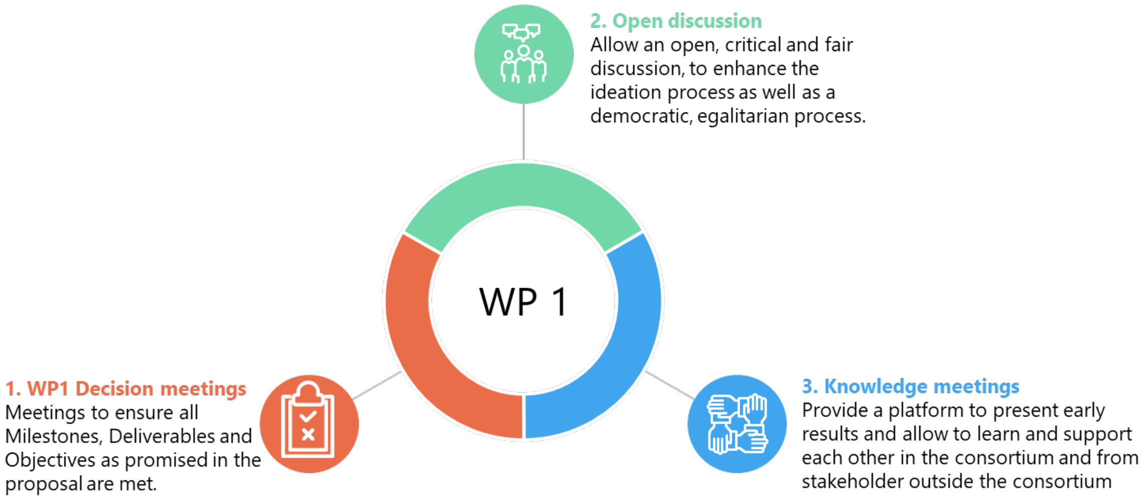

Figure 1: Overall WP 1 concept

FutuRaM is a multi- and interdisciplinary project. The expertise of the consortium covers the objectives set out in the call, hence the goals FutuRaM aims to achieve. Each partner has a clearly defined role within the project and will contribute specific knowledge that will enable a successful project. It is acknowledged that the disciplines are diverse and one of the aims of WP1 will be to ensure that these disciplines integrate and combine effectively. The partners have expertise in mass balancing, foresight, recycling technologies, economic assessment, environmental assessment, and state-of-the-art methodologies, datasets from official statistics. To achieve this a three pillar approach as depicted and described in Figure 1 was chosen. The three pillars are described in detail in the next section of this chapter.

3.1 WP 1 decision meetings

In order to accomplish the FutuRaM goals, the consortium partners need to actively engage in developing and creating concept and methods that aligns with the desired outcomes. It needs to be that questions and topics addressed in work package (WP) meetings are thoroughly answered, in a collaborative and solution-oriented environment. The solution to the challenges in FutuRaM will be presented in the WP 1 decision meeting there other, not involved partners can provide their input and feedback. The aim is to find the best possible solution for FutuRaM which than again can be implemented in the WP. The process for these meeting can be found in Annex 7.1. One key element of WP1 are the development groups. The aim and task of these groups is described below.

3.1.1 Development Team

The agile working process within the FutuRaM development groups consists of small groups of 4-6 partners led by one designated group leader. A high level scheme of the development team process within WP1 T1.1 can be seen in Figure 2. The development groups work on specific questions and topics, with one permanent group consisting of "Waste Stream Leader" (a representative of each waste stream). The purpose of these groups is to develop and create content and results that align with FutuRaM's objectives. The questions and topics addressed by the WPs should be discussed in these smaller groups. The result is a concept which then can be presented to a bigger audience in the WP 1.1 decision meetings, open discussion forum or project management meetings. The group structures and organizes their work on their own, with the group leader taking responsibility. Documentation is carried out in a structured manner to ensure transparency among all parties involved. WP 1 provides support to the groups throughout the process. The outcome of these development groups can be found here. The following topics have been discussed in the first 12 M of FutuRaM:

- Terminology
- Scenarios
- Interlinkages between waste streams
- Technology integration
- Including Scrap codes into the Framework
- Secondary Raw Materials (2RM)
- UNFC

It is recommended to further use this agile working process as it allows for a flexible and collaborative approach to problem-solving within the consortium. By working in small groups, partners can focus on specific issues and share knowledge and expertise. The group leader is responsible for ensuring that the group stays on track and that the work aligns with FutuRaM's objectives. By dividing into smaller groups, the consortium can work more efficiently and effectively, allowing for quicker progress towards achieving the project's goals.

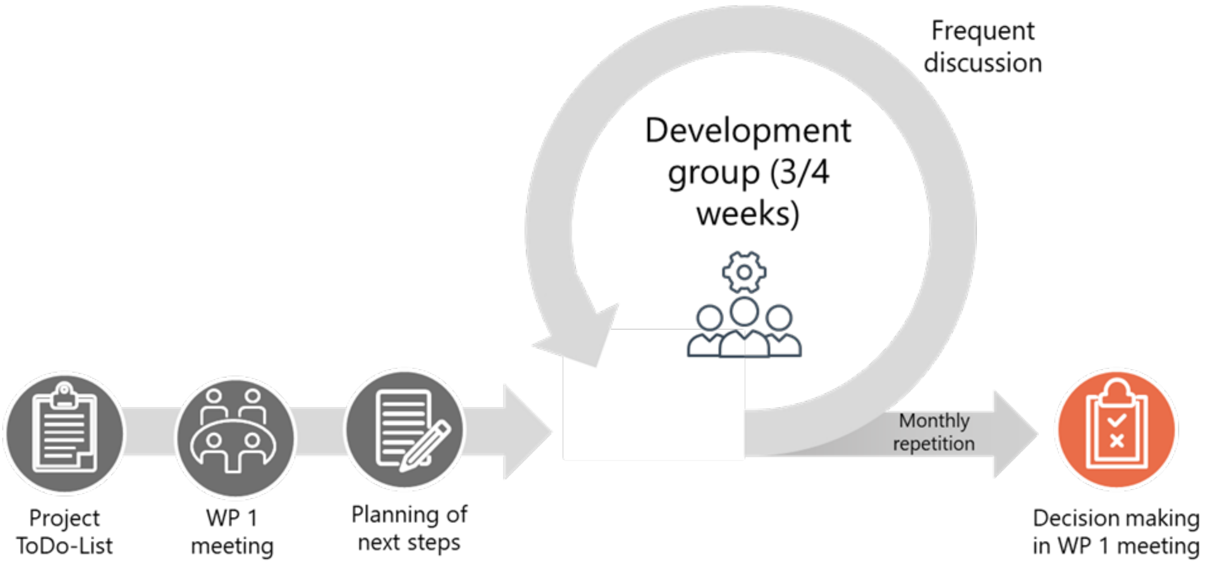

Figure 2: Agile Working process in WP 1

3.2 Open discussion forum

The open discussion forum (ODF) is an essential component of FutuRaM, which will be used to enable discussions across the whole consortium and hence all internal stakeholders. Every partner of the FutuRaM project has access to the ODF and can propose relevant topics, ensuring that all voices are heard and considered (see Figure 3). The purpose of the "Open Discussion" meetings is to provide input and discuss topics that need to be developed to reach FutuRaM's goals. The list of topics is curated by

WP 1 T 1.1 lead by Empa, who will support the development and creation of content and results that align with FutuRaM's objectives. WP 1 is actively supporting the ODF and the project's success relies on the active participation and meaningful contributions of all partners to this platform. To facilitate the discussions a standardized template was developed to inform the consortium members about the topics to be discussed. The template developed for the exploitation ODF can be found in Annex 7.2. During the first 12 M the following topics were discussed in the ODF:

- Data Model
- Terminology
- Scenarios
- Exploitation

The ODF was thought to be held every month, however this did not prove practical as this did not align with the projects time line. Since March 2023 it was decided to change to bi-monthly meeting. In addition, it was decided to invited external stakeholders to provide input during the discussion (see March ODF Exploitation). The May 2023 ODF will be used to carry out the first FutuRaM policy working group meeting.

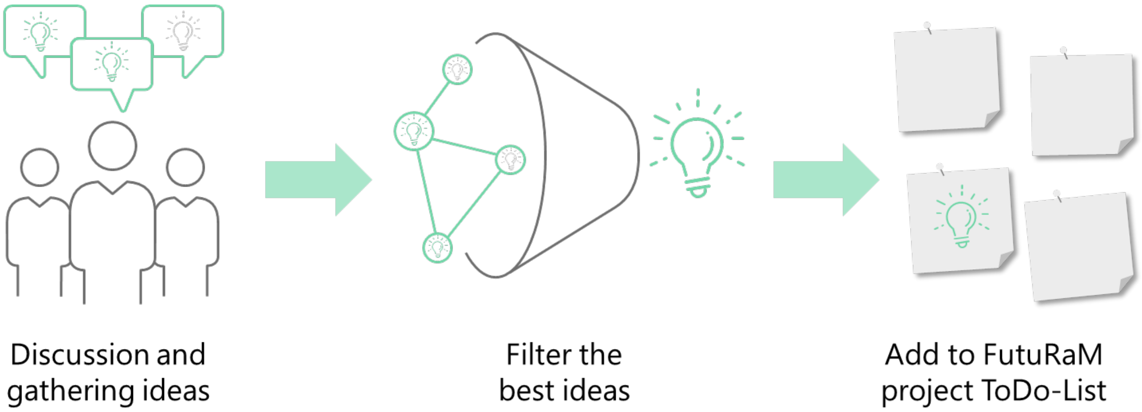

Figure 3: Concept of FutuRaM Open Discussion Forum

In general, it can be concluded that the ODF is a successful tool to integrate stakeholders (internal and external) at an early stage of the project. The next step will be to discuss a stronger interaction of WP 7 using this tool within the project.

3.3 FutuRaM Knowledge Meeting

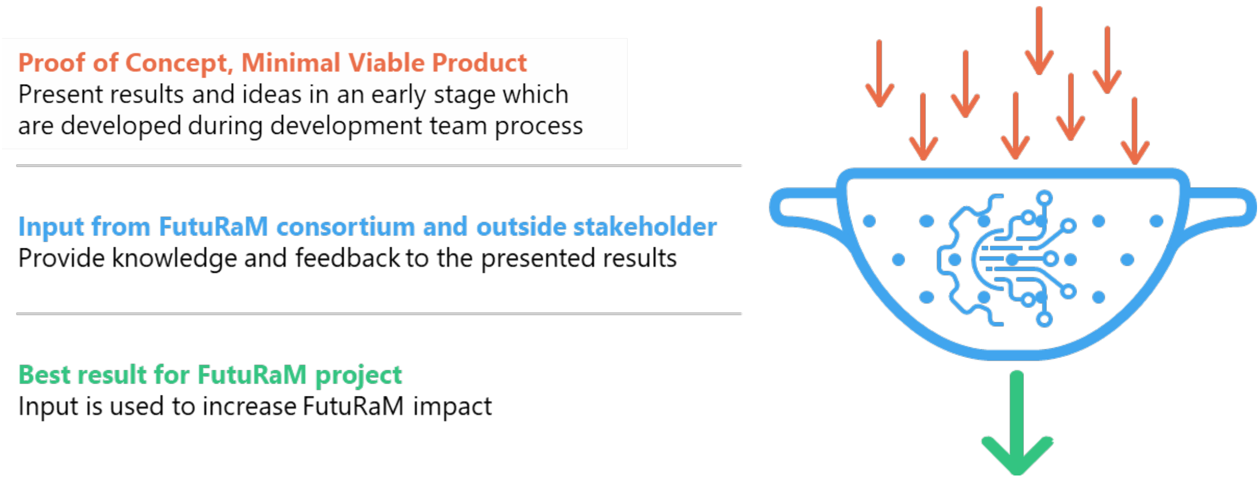

Figure 4: Concept for FutuRaM Knowledge Meeting

The third of the WP1 concept are knowledge meetings. The concept of these meetings is depicted in Figure 4. The aim of these meetings is to allow partners to have the same level of knowledge. The FutuRaM project will aim on presenting Proof of Concept, Minimal Viable Product, and current status updates. By presenting results early, partners can provide input and help identify the best solutions for the project. The consortium encourages learning from others for their own research, case study, waste stream, etc., as this will aid in finding the most effective solutions for FutuRaM's objectives. During the first year of FutuRaM two knowledge meetings were conducted):

- FutuRaM Framework
- UNFC Seminar

It is highly recommend to increase the frequency of these meetings and together with the scientific coordinator develop a schedule for the topics to be presented. In addition, the knowledge meeting can be a useful resource for younger researchers to (i) increase their knowledge on a certain topic and (ii) to present their findings to a larger audience and test their research hypothesis.

4 FutuRaM Draft Concepts and Methods

The main aim of FutuRaM as stated in the GA can be found in the information box below. The FutuRaM Framework will go beyond the approach chosen in ProSUM by including recovery pathways and thus 2RM recoverability into the scope. Moreover, two additional waste streams (SLASH, CDW) will be studied compared to ProSUM, which requires further adaptations. Hence, a whole set of new concepts and methods need to be developed and harmonised across the project. Furthermore, the chosen approach needs to be compatible with existing frameworks and platforms. To summarise, FutuRaM aims at making a connection between existing data sources and using available data to answer the questions of the future availability and recoverability of secondary raw materials.

FutuRaM Main Aim

The Future Availability of Secondary Raw Materials (FutuRaM) project seeks to (1) develop knowledge on the availability and recoverability of secondary raw materials (2RMs) within the European Union (EU), with a special focus on critical raw materials (CRMs), to enable fact-based decision making for their exploitation in the EU and third countries, and (2) disseminate this information via a systematic and transparent Secondary Raw Materials Knowledge Base (2RM-KB)

4.1 Terminology

One of the first steps taken was the collection and harmonization of currently existing terminology. A preliminary report was prepared and shared with relevant stakeholder in the consortium. Below you will find a summary of the process as well as the resulting list of relevant definitions. This action is crucial to further develop FutuRaM concepts and methods.

4.1.1 Concept

A literature review was performed regarding the concepts relevant within FutuRaM (e.g., “recovery" "recycling"). These terms were searched in relevant policy and scientific documents (including scientific articles and reports). It is noteworthy that this search was not intended to deliver a comprehensive overview of the existing literature. It rather intended to cover documents overarching for the FutuRaM project; in particular EU policy documents, scientific literature, and reports from key institutions (e.g., United Nations Statistics Division (UNSD), United Nations Economic Commission for Europe (UNECE), United Nations Environment Programme (UNEP)). This review in particular aimed at capturing the way the respective documents define or more generally approach these concepts.

4.1.2 Method

The compilation of these existing definitions further led to the identification of additional terms of interest in the context of FutuRaM. That is, this literature search and analysis as presented here contributed to building the FutuRaM terminology both: i) by reporting existing definitions and ii) by contributing to setting the list of terms considered of importance for the project. In the preceding H2020 project ProSUM (Grant Agreement No. 641999, www.prosumproject.eu) terms such as « recovery », « recycling, and « recoverability » were not defined. Hence, the ProSUM terminology is not fully, directly, applicable to FutuRaM. Yet, a number of interlinked concepts were defined in ProSUM (e.g., components; van Straalen et al., 2015), and further considered in FutuRaM terminology as described in Table 2.

4.1.3 Next steps

Recoverability and Recyclability are topics that are addressed starting from M19 in Task 3.3. Therefore it is proposed to address these topics later, as the definition of these terms also requires necessary knowledge currently still under development. In addition during the project new concepts are developed hence the terminology needs to be continuously updated. A further ongoing task is the refining of the waste stream specific terminology. This as well is an ongoing process. The current status and next steps for the terminology are defined in Table 1.

Table 1: Current status and next steps - Terminology

Topic/ Content	Not available	Draft	Finalised	Next Steps/Reference to other FutuRaM reports and deadlines
Basic terminology available		X		Consortium needs to agree, will be achieved by finalizing M6 report
Define Terminology for Recoverability and Recyclability	X			Task 3.3 starting in Month 19
Further define terminology needed for newly developed concepts		X		Concepts and Methods still under development will be added as soon as possible. M x will further feed into this.
Define waste stream specific terminology		X		Ongoing

Table 2: Terminology and Definitions used in FutuRaM

Term	Definition	Reference for definition	
Waste	"'waste' means any substance or object which the holder discards or intends or is required to discard "	EU binding policy	Waste Framework Directive - Directive 2008/98/EC
	To be added MINW "waste resulting from prospecting, extraction, treatment and storage of mineral resources and the working of quarries covered by Directive 2006/21/EC of the European Parliament and of the Council of 15 March 2006 on the management of waste from extractive industries (OJ L 102, 11.4.2006, p. 15)."	EU binding policy	Directive 2006/21/EC
Pre-consumer material	"Material diverted from the waste stream during a manufacturing process. Excluded is reutilization of materials such as rework, regrind or scrap generated in a process and capable of being reclaimed within the same process that generated it."	Standard	ISO 14021:2016 EN 45557:2019 (which uses ISO 14021:2016 definition)
Post-consumer material	"Material generated by households or by commercial, industrial and institutional facilities in their role as end-users of the product which can no longer be used for its intended purpose. This includes returns of material from the distribution chain."	Standard	ISO 14021:2016 EN 45557:2019 (which uses ISO 14021:2016 definition)
Component (only valid for ProSUM POM model)	Uniquely identifiable part or subunit of products. Components are usually mechanically removable in one piece and are considered indivisible for a particular function or use. A component can consist of other components e.g. a printed circuit board may contain a capacitor which is also a component. Some products may contain other products as components, for instance, a car has a battery. Other terms include subsystem, part, cluster of parts, or assembly.	ProSUM	ProSUM D5.3 (van Straalen et al., 2015)
Component Group Type (only valid for ProSUM POM model)	The Component Group Type aggregates all components included on a 'Component List' to a higher level of component groups. The aggregation is based on characteristics, application purposes, and composition.	ProSUM	ProSUM D5.3 (van Straalen et al., 2015)
Component List (only valid for ProSUM POM model)	A comprehensive list of components contained with products.	ProSUM	ProSUM D5.3 (van Straalen et al., 2015)
Material (only valid for ProSUM POM model)	The term material is used ambiguously in geological science and in engineering science. Materials in natural systems are distinctly different from engineered materials. The term 'Materials' as used here refers to 'engineered materials' that are composed, manufactured and processed to achieve intended properties.	ProSUM	ProSUM D5.3 (van Straalen et al., 2015)
Material Group Type	Defines the main categories in which materials are clustered into lists.	ProSUM	ProSUM D5.3 (van Straalen et al., 2015)
Material Type	The specification of the above mentioned material groups into material types.	ProSUM	ProSUM D5.3 (van Straalen et al., 2015)
Material List	The list of constituent materials within the material types.	ProSUM	ProSUM D5.3 (van Straalen et al., 2015)
Composite Material	A composite material or composite is a material made from two or more distinct constituent materials with significantly different physical or chemical properties that, when combined, produce a material with characteristics different from the individual components (adapted from Wikipedia, 2015).	ProSUM	ProSUM D5.3 (van Straalen et al., 2015)
Engineered Materials	Refined and processed raw materials to achieve specific functions and specifications e.g. alloys.	ProSUM	ProSUM D5.3 (van Straalen et al., 2015)
Substances	Any (chemical) element or compound composed of uniform units (Brunner and Rechberger, 2004). All substances are characterized by a unique and identical constitution and are thus homogeneous.	ProSUM	ProSUM D5.3 (van Straalen et al., 2015)
	" a chemical element and its compounds in the natural state or the result of a manufacturing process"	EU	European Chemicals Agency

Recycling	“any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations”	EU binding policy	Waste Framework Directive - Directive 2008/98/EC
Reuse	“ ‘re-use’ means any operation by which products or components that are not waste are used again for the same purpose for which they were conceived ”	EU binding policy	Waste Framework Directive - Directive 2008/98/EC
Recovery	"‘recovery’ means any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy.", as in the Waste Framework Directive.	EU binding policy	Waste Framework Directive - Directive 2008/98/EC
Secondary raw material (2RM)	“Secondary raw materials are materials and products which can be used as raw materials by simple re-use, or via recycling and recovery.”	Report/database	RMIS, 2022
	According to the Waste Framework Directive (EU, 2008), ’recycling’ means any recovery operation by which waste materials are reprocessed into products, materials or substances, whether for original or other purposes. It includes the reprocessing of organic material but does not include energy recovery or reprocessing into materials that are to be used as fuels or for backfilling operations. The above definition implies that only waste can be recycled. The status of waste is not defined by its chemical, physical or mechanical material properties or by its product composition or lifetime. Instead, in accordance with the Waste Framework Directive, it is defined by the fact that a holder discards or intends or is required to discard it. The recycling process ends at a single, determinate point at which a secondary raw material is produced. At this point, it is no longer waste, cannot be distinguished from a primary raw material and can be traded in the same way as all other commodities. Eventually, products that contain secondary raw materials as recycled content can be discarded as waste, from which materials can be recycled.	Report	Investigating Europe’s secondary raw material markets EEA Report No 12/2022
Material recovery	recovery operation of any kind, other than energy recovery and the reprocessing into materials that are to be used as fuels or other means to generate energy	Standard	EN 45555:2019 (CSN, 2019)
Supply	Total supply = Domestic production + imports *Still on-going discussion how these concepts are useful for FutuRaM framework*	Statistical Standard	SEEA Central Framework
Use	Total use = Domestic use + exports = Intermediate consumption + Household final consumption + consumption in gross capital formation + exports *Still on-going discussion how these concepts are useful for FutuRaM framework*	Statistical Standard	SEEA Central Framework
Recyclability	Ongoing Process see Chapter 4.8		
Technical recoverability			
Economic recoverability			
Recoverability			
UNFC			
Aligned System	A classification system that has been aligned with UNFC as demonstrated by the existence of a Bridging Document that has been endorsed by the Expert Group on Resource Management.	UNFC	United Nations Framework Classification for Resources Update 2019

			ECE ENERGY SERIES No. 61
Anthropogenic Material	An Anthropogenic Material is physical matter without any attribution from an economic, legislative, social, or environmental perspective, and without a specification of the aggregate state (solid, liquid, gaseous). Anthropogenic materials include, for instance, mineral materials, sewage sludge, biomass, and off-gas.	UNFC	UNFC GUIDANCE EUROPE Guidance for the Application of the United Nations Framework Classification for Resources (UNFC) for Mineral and Anthropogenic Resources in Europe
Anthropogenic Resource	An Anthropogenic Resource is a concentration or occurrence of Anthropogenic Material of intrinsic economic interest, in such form, quality and quantity that there are Reasonable Prospects for eventual economic exploitation. It is recognized that in traditional resource classification systems, the quantity is subdivided into resources and reserves with elaborate definitions of the two. UNFC does not use these terms but refers to "Classes" (Section C) instead. The term "Anthropogenic Resource" has been adapted from the term "Mineral Resource" as defined in CRIRSCO.	UNFC	UNFC GUIDANCE EUROPE Guidance for the Application of the United Nations Framework Classification for Resources (UNFC) for Mineral and Anthropogenic Resources in Europe
Anthropogenic Material Product	Is a quantity that is saleable in markets. The cumulative quantities are equivalent to "Sales Production" according to UNFC (see Table 4). It is noted that the term Anthropogenic Material Product does not necessarily correlate with legal Product declarations. Guidance for Projects with multiple Anthropogenic Material Products and energy quantities is given in section III.C.	UNFC	UNFC GUIDANCE EUROPE Guidance for the Application of the United Nations Framework Classification for Resources (UNFC) for Mineral and Anthropogenic Resources in Europe
Bridging Document	A document that explains the relationship between UNFC and another classification system, including instructions and guidelines on how to classify estimates generated by application of that system using the UNFC Numerical Codes.	UNFC	United Nations Framework Classification for Resources Update 2019 ECE ENERGY SERIES No. 61
Category	Primary basis for classification using each of the three fundamental Criteria of environmental-socio-economic viability (related Categories being E1, E2, and E3), technical feasibility (related Categories being F1, F2, F3 and F4), and degree of confidence (related Categories being G1, G2, G3 and G4). Definitions of Categories are provided in Annex I of Part I of UNFC.	UNFC	United Nations Framework Classification for Resources Update 2019 ECE ENERGY SERIES No. 61
Competence	The power of a person, business, court, or government to deal with something or take legal decisions.	UNFC	UNFC GUIDANCE EUROPE Guidance for the Application of the United Nations Framework Classification for Resources (UNFC) for Mineral and Anthropogenic Resources in Europe
Class(es)	Primary level of resource classification resulting from the combination of a Category from each of the three Criteria (axes).	UNFC	United Nations Framework Classification for Resources Update 2019 ECE ENERGY SERIES No. 61
Criteria	UNFC utilizes three fundamental Criteria for reserve and resource classification: favorability of environmental-socio-economic conditions in establishing the viability of the project (E axis); maturity of technology, studies and commitments necessary to implement the project (F axis); and, degree of confidence in the estimate of quantities of products from the project (G axis). These Criteria are each subdivided into Categories and Sub-categories, which are then combined in the form of Classes or Sub-classes.	UNFC	United Nations Framework Classification for Resources Update 2019 ECE ENERGY SERIES No. 61

Critical Raw Materials	Raw materials are materials or substances used in the primary production or manufacturing of goods. Critical Raw Material are raw materials that are economically and strategically important for the economy but have a high-risk associated with their supply. For the European Commission, following the work of Blengini et al (2017): CRM are raw materials of high importance to the economy of the EU and whose supply is associated with high risk. Criticality is calculated following the methodology of Blengini et al. (2017).	UNFC	UNFC GUIDANCE EUROPE Guidance for the Application of the United Nations Framework Classification for Resources (UNFC) for Mineral and Anthropogenic Resources in Europe
Effective Date	The date for which assessments are valid.	UNFC	UNFC GUIDANCE EUROPE Guidance for the Application of the United Nations Framework Classification for Resources (UNFC) for Mineral and Anthropogenic Resources in Europe
Foreseeable Future	The period of time that a Project can make a reasonable projection of the occurrence of future conditions, events or other factors that determine the environmental-socio-economic viability or technical feasibility of a Project.	UNFC	UNFC GUIDANCE EUROPE Guidance for the Application of the United Nations Framework Classification for Resources (UNFC) for Mineral and Anthropogenic Resources in Europe
Evaluator	Person, or persons, performing estimation and/or classification.	UNFC	United Nations Framework Classification for Resources Update 2019 ECE ENERGY SERIES No. 61
Generic Specifications	Specifications (as documented in this Specifications Document) that apply to the classification of products of a resource project using UNFC.	UNFC	United Nations Framework Classification for Resources Update 2019 ECE ENERGY SERIES No. 61
Identified Project	An identified project is a project associated with a known source.	UNFC	United Nations Framework Classification for Resources Update 2019 ECE ENERGY SERIES No. 61
Known Source	A source that has been demonstrated to exist by direct evidence. More detailed specifications can be found in relevant source-specific Aligned Systems.	UNFC	United Nations Framework Classification for Resources Update 2019 ECE ENERGY SERIES No. 61
Mapping Document	The output of a comparison between another resource classification system and UNFC, or between that system and existing Aligned Systems, which highlights the similarities and differences between the systems. A Mapping Document can provide the basis for assessing the potential for the other system to become an Aligned System through the development of a Bridging Document.	UNFC	United Nations Framework Classification for Resources Update 2019 ECE ENERGY SERIES No. 61
Minerals Source	A Minerals Source is a concentration or occurrence of material quantity of intrinsic commercial or Political interest, in such form, quality and quantity from which a benefit is produced.	UNFC	UNFC GUIDANCE EUROPE Guidance for the Application of the United Nations Framework Classification for Resources (UNFC) for Mineral and Anthropogenic Resources in Europe

Numerical Code	Numerical designation of each Class or Sub-class of resource quantity as defined by UNFC. Numerical Codes are always quoted in the same sequence (i.e. E;F;G).	UNFC	United Nations Framework Classification for Resources Update 2019 ECE ENERGY SERIES No. 61
Potential Source	A source that has not yet been demonstrated to exist by direct evidence, but is assessed as potentially existing based primarily on indirect evidence. More detailed specifications can be found in relevant source-specific Aligned Systems.	UNFC	United Nations Framework Classification for Resources Update 2019 ECE ENERGY SERIES No. 61
Product (differs from Product for ProSUM POM approach)	Products of the project may be bought, sold or used, including electricity, heat, hydrocarbons, hydrogen, minerals, and water. It is noted that with some projects, such as for renewables, the products (electricity, heat etc.) are different from the sources (wind, solar irradiation etc.). In other projects the products and sources may be similar e.g. in petroleum projects both the sources and products are oil and/or gas, although the fluid state and properties may change from reservoir to surface conditions.	UNFC	United Nations Framework Classification for Resources Update 2019 ECE ENERGY SERIES No. 61
Project	A Project is a defined development or operation which provides the basis for environmental, social, economic and technical evaluation and decision-making. In the early stages of evaluation, including verification, the Project might be defined only in conceptual terms, whereas more mature Projects will be defined in significant detail. Where no development or operation can currently be defined for all or part of a source, based on existing technology or technology currently under development, all quantities associated with that source (or part thereof) are classified in Category F4. These are quantities which, if produced, could be bought, sold or used.	UNFC	United Nations Framework Classification for Resources Update 2019 ECE ENERGY SERIES No. 61
Prospective	Used in association with Projects as Prospective Projects: Where the existence of a developable Product is based primarily on indirect evidence and has not yet been confirmed.	UNFC	UNFC GUIDANCE EUROPE Guidance for the Application of the United Nations Framework Classification for Resources (UNFC) for Mineral and Anthropogenic Resources in Europe
Qualified Expert	An independent person with education, training, and relevant professional experience in a discipline pertinent to a Project, acting in compliance with the professional standards of competence and ethics established by his/her professional organization. This person is responsible for the standards and methodologies used for collecting, analyzing, and verifying information used in qualified assessments.	UNFC	UNFC GUIDANCE EUROPE Guidance for the Application of the United Nations Framework Classification for Resources (UNFC) for Mineral and Anthropogenic Resources in Europe
Remediation (or Reclamation)	The restoration of a Project site conditions that are required by regulatory or other provisions.	UNFC	UNFC GUIDANCE EUROPE Guidance for the Application of the United Nations Framework Classification for Resources (UNFC) for Mineral and Anthropogenic Resources in Europe
Reasonable Expectations	High level of confidence. This term is used within the E1 classification and concerns the likelihood that all necessary conditions will be met. It is also used in the F1.3 Sub-category and concerns the likelihood that all necessary approvals/contracts for the Project to proceed to development will be forthcoming.	UNFC	UNFC GUIDANCE EUROPE Guidance for the Application of the United Nations Framework Classification for Resources (UNFC) for Mineral and Anthropogenic Resources in Europe
Reasonable Prospects		UNFC	UNFC GUIDANCE EUROPE Guidance for the Application of the United Nations

	Moderate level of confidence. This term is used within the E2 and E3 classification and concerns the likelihood that all necessary conditions will be met		Framework Classification for Resources (UNFC) for Mineral and Anthropogenic Resources in Europe
Sources	Sources, such as bioenergy, geothermal, hydro-marine, solar, wind, injection for storage, hydrocarbons, minerals, nuclear fuels and water, are the feedstock for resource projects from which products can be developed. The sources may be in their natural or secondary (anthropogenic sources, tailings, etc.) state.	UNFC	United Nations Framework Classification for Resources Update 2019 ECE ENERGY SERIES No. 61
Specifications	Additional details (mandatory rules) as to how a resource classification system is to be applied, supplementing the framework definitions of that system. Generic Specifications provided for the UNFC in this Specifications Document ensure clarity and comparability and are complementary to the source-specific requirements included in Aligned Systems, as set out in the relevant Bridging Document.	UNFC	United Nations Framework Classification for Resources Update 2019 ECE ENERGY SERIES No. 61
Specifications Document	Specifications for the application of the United Nations Framework Classification for Resources (UNFC).	UNFC	United Nations Framework Classification for Resources Update 2019 ECE ENERGY SERIES No. 61
Sub-categories	Criteria of environmental, social and economic viability, technical feasibility, and degree of confidence.	UNFC	United Nations Framework Classification for Resources Update 2019 ECE ENERGY SERIES No. 61
Sub-classes	Optional subdivision of resource classification based on project maturity principles resulting from the combination of Sub-categories. Project maturity Sub-classes are discussed further in Annex III of this Specifications Document	UNFC	United Nations Framework Classification for Resources Update 2019 ECE ENERGY SERIES No. 61
Système International d'Unités	Internationally recognized system of measurement and the modern form of the metric system. Prefixes and units are created and unit definitions are modified through international agreement as the technology of measurement progresses, and as the precision of measurements improves. Abbreviated to SI.	UNFC	United Nations Framework Classification for Resources Update 2019 ECE ENERGY SERIES No. 61
UNFC	United Nations Framework Classification for Resources.	UNFC	United Nations Framework Classification for Resources Update 2019 ECE ENERGY SERIES No. 61
Viable	A Project is Viable when it has been confirmed to be economically, socially, technically, and environmentally feasible and satisfies all the relevant Criteria of the E, F, and G Axes that are required for it to proceed.	UNFC	UNFC GUIDANCE EUROPE Guidance for the Application of the United Nations Framework Classification for Resources (UNFC) for Mineral and Anthropogenic Resources in Europe

4.2 Classification and data collection

4.2.1 Concept

In one of the first steps the classification and data collection framework were defined. This is mostly related to WP3 and 4. The central objective of WP3 is to provide harmonized and consolidated data sets on current and future product and waste compositions. This includes to suggest a framework for future product and waste composition forecast and monitoring. WP4 will create a consistent dataset of stocks and flows of 2RMs with focus on CRMs.

In Figure 5 the concept for data collection and classification within WP 3 is depicted. The light green parts of the pyramid indicate that these decisions can be made individual within the waste streams. The dark blue parts of the pyramid are harmonized over the waste streams in the WPs. The concept was developed accordingly for WP4, an updated version can be found later in the report (Figure 5). The aim of the FutuRaM classification and data collection concept is to align and be compatible with existing frameworks and classifications systems. In the following sub chapter, the corresponding methodological steps on how to choose the elements and materials is described.

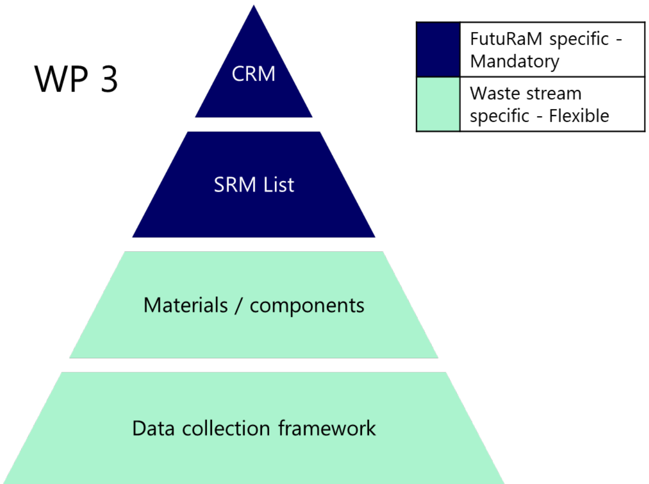

Figure 5: Classification and data collection concept within FutuRaM for WP3

4.2.2 Method - Composition data developed in WP3

The ProSUM process for data collection serves as a basis for the composition data collection in FutuRaM. Data mapping will be carried out, here the available data sources are identified and categorized to ensure comprehensive coverage. This step helps in creating a structured framework for data collection. Following data mapping, there is a crucial step of linking the collected data to the developed flow charts (see chapter 4.5). This step helps visualize the flow of materials throughout the entire lifecycle, facilitating a better understanding of waste generation, processing, and future composition. The generic flow charts later will support the development of the Sankey diagrams, currently under discussion as one final output. Process data templates are then created, which serve as standardized formats for data collection. These templates are designed with code lists and other relevant components to ensure consistency and comparability across different data sources. This is reported in Milestone 7 as part of WP3. Before finalizing the data collection process, test-runs are conducted to validate the templates and identify any potential issues or inconsistencies. This helps in refining the data collection approach and improving the quality of the final results. A step-wise and systematic approach is chosen. First, waste generated data is updated and new data is collected. Then, the focus shifts to processed waste flows, capturing information on how the waste is managed and processed. Lastly, future waste composition data is collected, providing insights into the expected composition of waste in the future.

As described above WP3 will provide data sets on current and future product and waste compositions, hence the decision which elements and materials will be studied during FutuRaM for each waste stream need to be made in this WP. The methodological steps on how to reach this aim are listed below:

CRM - Critical Raw Materials

As stated in the GA, FutuRaM will provide answers on the availability and recoverability of CRM. The list of critical raw materials was updated in March 2023, hence this list will be used during FutuRaM. In the revised list, also strategic raw materials are included (namely copper and nickel). The 2023 CRM including strategic raw materials can be found in Figure 6. Copper and nickel are not listed as CRM but will be covered in FutuRaM, as they belong to the category of strategic raw materials. During the project time of FutuRaM the CRM List will be updated (in 2026), hence it is important to apply a wider scope and anticipate changes. Therefore also materials and elements not on the current list will be part of FutuRaM.

Table 4: 2023 Critical raw materials 2023, including Strategic Raw Materials

2023 Critical Raw Materials (*Strategic Raw Materials in italics*)			
aluminium/bauxite	coking coal	*lithium*	phosphorus
antimony	feldspar	LREE	scandium
arsenic	fluorspar	*magnesium*	*silicon metal*
baryte	*gallium*	*manganese*	strontium
beryllium	*germanium*	*natural graphite*	tantalum
bismuth	hafnium	niobium	*titanium metal*
boron/borate	helium	*PGM*	*tungsten*
cobalt	*HREE*	phosphate rock	vanadium
		*copper**	*nickel**

Figure 6: 2023 CRM including strategic raw strategic raw materials

Recovery pathways, as nowadays mostly the bulk materials, such as ferrous materials or aluminum alloys are recycled. In addition, knowledge of the material context of the 2RM is important to evaluate the quality of the recycling process (see Chapter 4.5 and Chapter 4.8). The lists of 2RM will be harmonized for all waste streams in WP3. Figure shows the process flow in WP3, which will be explained in the following sections.

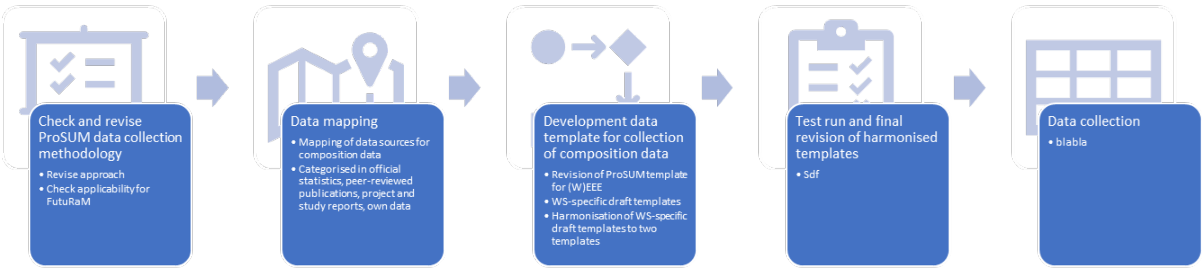

Figure 7: Process flow in WP3

Check and revise ProSUM approach for collection of composition data

The first step of WP3 was to revisit the data collection templates applied in the parent project ProSUM, where collection templates were created for the waste streams BATT, ELV, and WEEE, for empirical data collection as well as literature research. These templates, on the example of the WEEE template, served as basis for the development of FutuRaM templates for the collection of composition data. The data types and information collected in the ProSUM template were explained and used as a blue print by all six waste streams. This activity produced five draft templates for BATT, CDW, ELV, WEEE, and SLASH as well as the MINW template suggested in ProSUM, ORAMA, and Mintell4EU [refer to projects], which were submitted to WP3 in M9.

Data mapping

In parallel, potential data sources for composition data were mapped, with a focus on the categorization in:

- Official statistics
- Peer-reviewed publications
- Project reports and other studies
- Own data (from FutuRaM consortium partner or related project partners)

Harmonization of templates

The harmonization process of the composition data templates included the following steps:

- Extraction and listing of all data types from the draft templates
- Designation of use of data types in the different draft templates
- Identification which data types are universally relevant and which data types are WS-specific
- Categorization of data types in the following categories:
  - Waste flow description
  - Product description
  - Component description
  - Material description
  - Element
  - Value generation
  - Data quality
  - Notes and references
- Identification and selection of final data types

An important classification issue for collection, harmonization, and consolidation of composition data is the assignment of a parameter value to the object described by the parameter value, i.e. if the composition data is e.g. for an element in a product, element in a material, material in component, etc. Figure 8 depicts the approach to specify this in FutuRaM. Here, we set a hierarchical link between waste streams, products, components, materials, and elements. This bases on the ProSUM approach, with flow – product – component – material – element. In FutuRaM, we renamed the top level with the term "waste stream" and distinguish for each level, if this refers to a waste stream/product/component/material/element in a stock or in a flow. This approach facilitates a mathematically consistent modelling and data reconciliation for the stocks and flows and consequently the scenarios and prevents double-counting as well as mass balancing issues.

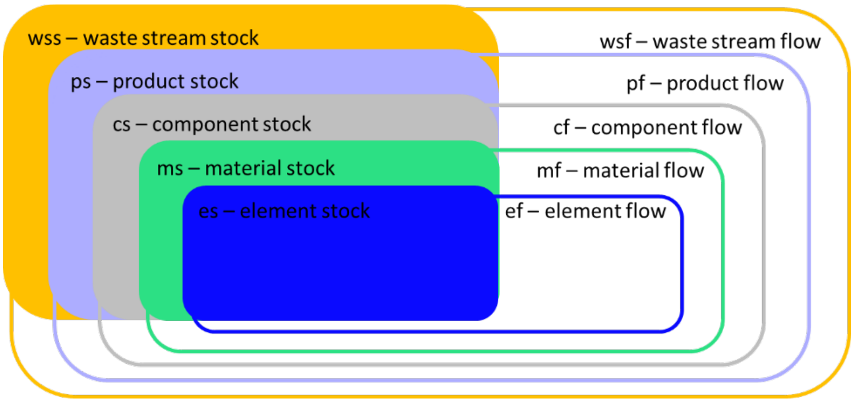

Figure 8: Hierarchical structure of composition data description

Table 3 and Table 4 summarize the data categories, the data types, and a short description for each data type for post-consumer WS (BATT, CDW, ELV, and WEEE) as well as for low-/deposit-centric WS (MINW, SLASH).

The harmonized templates for collection of composition data were then introduced and explained to all six waste streams. The templates for collection of composition data are accompanied and completed by a set of code lists, which will be tested, revised, further developed, and completed within the process of data collection. The data types and their code lists are arranged in a hierarchical way, where (W)EEE are e.g. describe by three levels of UNU EEE keys or material information/composition is detailed In up to four hierarchical levels.

Test runs and final revision of templates

Subsequently, five WS (BATT, CDW, ELV, WEEE, and SLASH) executed test runs with a few data entries, to check feasibility and applicability as well as to improve unclarified parts. The feedback from the test runs was used to revise and finalize the templates.

For MINW the process was slightly different. Here, the MINW group checked and aligned the existing MINW data types with the data types in the template for flow-/deposit-centric WS. The MINW group is connected/embedded to the GSEU project where all the geosurveys in Europe are associated and data collection is executed over both projects, with project background in Minerals4EU, ProSUM, and ORAMA. The final templates are submitted in time as milestone M7 and provided for the whole project consortium.

Table 3: WP 3 Data categories, the data types, and a short description for each data type for post-consumer WS (BATT, CDW, ELV, WEEE)

dataCategory	dataType	description
stock_flow	dataEntryID	unique identifier for data entry
stock_flow	relatedFutuRaM-WS	designation of data entry to FutuRaM WS
stock_flow	use/EoL	data entry refers to use phase or EoL phase
stock_flow	uinqueStockOrFlowName	unique stock or flow name, as depicted in WS-specific flow chart
stock_flow	LoWchapter	chapter in the list of waste, described in Commission Decision 2001/118/EC
stock_flow	LoWsubChapter	sub-chapter in the list of waste, described in Commission Decision 2001/118/EC
stock_flow	LoWkey	list of waste code, described in Commission Decision 2001/118/EC
stock_flow	ISRI	scrap specification codes from the Institute of Scrap Recycling Industries (ISRI)
stock_flow	HS	Harmonized System Codes
product description	productID	unique identifier for each characterised product
product description	productKeyLevel1	product key to describe the product; allocation table designates the product key name
product description	productKeyLevel2	product sub-key to describe the product; allocation table designates the product key name
product description	productKeyLevel3	product sub-sub-key to describe the product; allocation table designates the product key name

product description	descriptionFromDataSource	description used for product in original data source
product description	similarityBetweenProductDescriptionAndKey	similarity between description for product in original data source and in product key
product description	productionYear	year in which the product was produced/manufactured
product description	yearEntryEOLphase	year when the product entered the end-of-life phase
component description	componentID	unique identifier for characterised component
component description	componentKeyLevel1	description of the component from code list componentKeyLevel1
component description	componentKeyLevel2	description of the component from code list componentKeyLevel2
component description	componentDescription	component description from original data source
component description	similarityBetweenMaterialdescriptionAndKey	similarity between description for component in original data source and in component code list
component description	embeddedComponent	designation to other FutuRaM WS for embedded components (e.g. battery in electric vehicle)
material description	materialKeyLevel0	designation of material to metals, organics, minerals, and mixed/unspecified

material description	materialKeyLevel1	designation of material to main material groups within m0
material description	materialKeyLevel2	designation of material to subgroups within the material groups m1
material description	materialKeyLevel3	designation of material to alloy and other subgroups within the material groups m2
material description	materialKeyLevel4	description of the material from code list materialKeyLevel4
material description	materialDescription	material description from original data source
material description	similarityBetweenMaterialDescriptionAndKey	similarity between description for material in original data source and in material code list
element	element	designation of chemical element, if the data entry refers to an element mass fraction
parameter	parameterCode	designation of what the parameter refers to (e.g. e-m for the mass fraction of an element in a material)
parameter	parameter	designation of what the parameter describes (e.g. mass, mass fraction, volume, etc.)
parameter	sampleOriginLocationNUTS-0	country where sample originates
parameter	value	numeric (measurement) value
parameter	valueType	designation of the value type (e.g. single value, mean value, median, etc.)
parameter	valueLowerLimit	minimum value, if a range is given, in addition to/instead of a single or mean value)

parameter	valueUpperLimit	maximum value, if a range is given, in addition to/instead of a single or mean value)
parameter	unitOfMeasurementValue	unit of measurement assigned to the value (e.g. ppm, mg/kg, Mg, etc.)
value generation	valueGeneration	designation of how the value was generated (e.g. BOM, measured, estimated, modelled)
value generation	digestionMethod	designation of digestion method, if measurement includes wet digestion
value generation	measurementMethod	designation of measurement method, if value is the result of a measurement
value generation	measurementYear	year in which the measurement was executed
value generation	measurementLocationNUTS-0	country where the measurement was executed
value generation	dataSetType	designation to what the value refers to, i.e. if it is product-specific/site-specific or generic
data quality	uncertaintyFromReference	uncertainty as given in the original data source
data quality	unitOfMeasurementUncertainty	unit of measurement assigned to the uncertainty from the original data source
data quality	uncertainty%	uncertainty from original data source divided by the value, given in percent
data quality	uncertaintyType	type of uncertainty given in the original data source
data quality	dqValidity	FutuRaM data quality code for the DQ dimension validity
data quality	dqAccuracy	FutuRaM data quality code for the DQ dimension accuracy
data quality	dqConsistency	FutuRaM data quality code for the DQ dimension consistency
data quality	dqIntegrity	FutuRaM data quality code for the DQ dimension integrity
data quality	dqTimeliness	FutuRaM data quality code for the DQ dimension timeliness

data quality	dqCompleteness	FutuRaM data quality code for the DQ dimension completeness
data quality	dataQualityMean	mean value of all six FutuRaM DQ dimensions
data quality	dataQuality	resulting FutuRaM DQ category
criticality	criticality2023	designation, if element was assessed as critical in the EU criticality list in 2023
criticality	criticality2020	designation, if element was assessed as critical in the EU criticality list in 2020
criticality	criticality2017	designation, if element was assessed as critical in the EU criticality list in 2017
criticality	criticality2014	designation, if element was assessed as critical in the EU criticality list in 2014
criticality	criticality2011	designation, if element was assessed as critical in the EU criticality list in 2011
notes and references	reference	original data source, given as [author, year]
notes and references	rights	rights assigned to the data from the original data source
notes and references	notes	notes and comments regarding the data, original data source, or data entry
notes and references	referenceURL	reference URL (permanent URL, if available)
notes and references	dataProcessor	person who entered the data entry
notes and references	dataProcessorInstitution	institution of data processor

Table 4: WP 3 Data categories, the data types, and a short description for each data type for pre-consumer WS (MIN, SLASH).

dataCategory	dataType	description
stock_flow	dataEntryID	unique identifier for data entry
stock_flow	uinqueStockOrFlowName	unique stock or flow name, as depicted in WS-specific flow chart
stock_flow	processSpecification	specification of the process producing the waste flow
stock_flow	processSpecificationDetailed	additional information on the process producing the waste flow, if available
stock_flow	processConditionSpecification	specification of the process conditions of the process producing the waste flow
stock_flow	stock_flowOriginLocationNUTS-0	country where flow originates
stock_flow	siteName	name of the site (plant or mine)
stock_flow	sampleName	name of the sample
stock_flow	geographicalCoordinatesLatitude	geographical coordinates of flow origin - latitude
stock_flow	geographicalCoordinatesLongitude	geographical coordinates of flow origin - longitude
stock_flow	LoWchapter	chapter in the list of waste, described in Commission Decision 2001/118/EC
stock_flow	LoWsubChapter	sub-chapter in the list of waste, described in Commission Decision 2001/118/EC
stock_flow	LoWkey	list of waste code, described in Commission Decision 2001/118/EC
stock_flow	descriptionFromDataSource	flow description from the original data source

stock_flow	similarityBetweenFlowDescriptionAndLoWkey	similarity between description for flow in original data source and in flow code list
stock_flow	grainSize	grain size of material/mineral in flow
material description	materialKeyLevel0	designation of material to metals, organics, minerals, and mixed/unspecified
material description	materialKeyLevel1	designation of material to main material groups within m0
material description	materialKeyLevel2	designation of material to subgroups within the material groups m1
material description	materialKeyLevel3	designation of material to alloy and other subgroups within the material groups m2
material description	materialKeyLevel4	description of the material from code list materialKeyLevel4
material description	materialDescription	material description from original data source
material description	similarityBetweenMaterialDescriptionAndKey	similarity between description for material in original data source and in material code list
mineral description	mineral-I	mineral I accounting to the specified element in the flow
mineral description	mineralDescription	mineral description from original data source

mineral description	similarityBetweenMineralDescriptionAndcodeInmineralCodelist	similarity between description for material in original data source and in material code list
element	element	designation of chemical element, if the data entry refers to an element mass fraction
parameter	parameterCode	designation of what the parameter refers to (e.g. e-m for the mass fraction of an element in a material)
parameter	parameter	designation of what the parameter describes (e.g. mass, mass fraction, volume, etc.)
parameter	value	numeric (measurement) value
parameter	valueType	designation of the value type (e.g. single value, mean value, median, etc.)
parameter	valueLowerLimit	minimum value, if a range is given, in addition to/instead of a single or mean value)
parameter	valueUpperLimit	maximum value, if a range is given, in addition to/instead of a single or mean value)
parameter	unitOfMeasurementValue	unit of measurement assigned to the value (e.g. ppm, mg/kg, Mg, etc.)
value generation	valueGeneration	designation of how the value was generated (e.g. measured, estimated, modelled)
value generation	samplingMethod	applied sampling method
value generation	digestionMethod	designation of digestion method, if measurement includes wet digestion
value generation	measurementMethod	designation of measurement method, if value is the result of a measurement

value generation	measurementYear	year in which the measurement was executed
value generation	measurementLocationNUTS-0	country where the measurement was executed
value generation	dataSetType	designation to what the value refers to, i.e. if it is product-specific/site-specific or generic
data quality	uncertaintyFromReference	uncertainty as given in the original data source
data quality	unitOfMeasurementUncertainty	unit of measurement assigned to the uncertainty from the original data source
data quality	uncertainty%	uncertainty from original data source divided by the value, given in percent
data quality	uncertaintyType	type of uncertainty given in the original data source
data quality	dqValidity	FutuRaM data quality code for the DQ dimension validity
data quality	dqAccuracy	FutuRaM data quality code for the DQ dimension accuracy
data quality	dqConsistency	FutuRaM data quality code for the DQ dimension consistency
data quality	dqIntegrity	FutuRaM data quality code for the DQ dimension integrity
data quality	dqTimeliness	FutuRaM data quality code for the DQ dimension timeliness
data quality	dqCompleteness	FutuRaM data quality code for the DQ dimension completeness
data quality	dataQualityMean	mean value of all six FutuRaM DQ dimensions
data quality	dataQuality	resulting FutuRaM DQ category
criticality	criticality2023	designation, if element was assessed as critical in the EU criticality list in 2023

criticality	criticality2020	designation, if element was assessed as critical in the EU criticality list in 2020
criticality	criticality2017	designation, if element was assessed as critical in the EU criticality list in 2017
criticality	criticality2014	designation, if element was assessed as critical in the EU criticality list in 2014
criticality	criticality2011	designation, if element was assessed as critical in the EU criticality list in 2011
notes and references	reference	original data source, given as [author, year]
notes and references	rights	rights assigned to the data from the original data source
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notes and references	referenceURL	reference URL (permanent URL, if available)
notes and references	dataProcessor	person who entered the data entry
notes and references	dataProcessorInstitution	institution of data processor

4.2.3 Next steps - Composition data developed in WP3

The next steps (see Table 5) after submission of milestone M7 in month 12 is the data collection, which will be finalized as milestone M12 in month 18. This task is currently planned and coordinated with the six waste streams. The data collection will be executed in a step-wise approach:

- Composition of waste generated
  - Update of ProSUM data for additional metadata (i.e. metadata defined in the FutuRaM template for composition data, which is not part of the ProSUM template for composition data)
  - Update of ProSUM data for the years 2017 to 2022
  - Update of ProSUM data for potential new products
  - Data collection for new WS CDW and SLASH
- Composition of processed waste flows (if available)
- Composition of future products and flows

Table 5: Data composition current status and next steps

Topic/ Content	Not available	Draft	Finalized	Next Steps/Reference to other FutuRaM reports and deadlines
Data mapping		x		Works towards Milestone M12
Focus list for most relevant products, components, materials, and elements		x		Works towards Milestone M12
Data collection	x			Works towards Milestone M12
Data consolidation	x			Consolidation of collected data, including stakeholder involvement
Finalize consolidated composition data sets to feed into T2.3 and T4.3	x			Milestone M12
Harmonization of template drafts and creation of two harmonized templates (post-consumer and flow-/deposit-centric)			X	Milestone M7
Development and drafting of WS-specific templates for collection of composition data			X	Work towards milestone M7

4.2.4 Method - Classification systems - WP4

WP4 will provide current and future trends of 2RMs and CRMs (D4.1 - Month 36). This will be achieved first through creating a consistent dataset of stocks and flows for all the six waste streams in the scope of the project (M18 - Month 24), which will then be integrated with the composition information of WP3, and the recovery assessment under current and future scenarios.

A focus within WP4 is to ensure the alignment of classification and data collection within the existing frameworks. The data collection framework is specific to each WS, where a common classification and aggregation level is also used to map the stocks and flows.

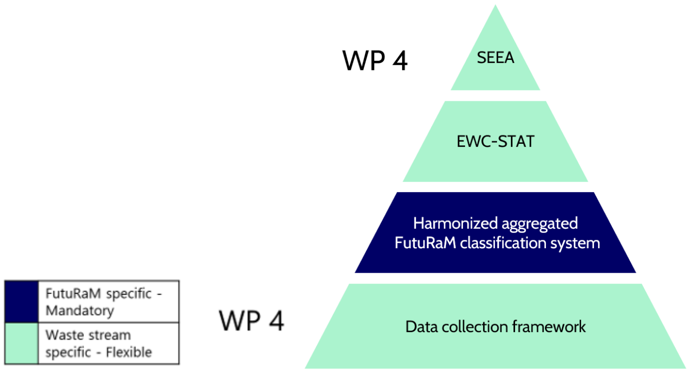


Figure 9: Classification and data collection concept within FutuRaM - WP4

The pyramidal structure proposed during the initial phase of the project cannot be adapted for all WS, as not all of them will be using EWC and SEEA for the data collection and modelling process within WP4. From the perspective of WP4, it is possible to distinguish between how the data is collected/modelled (data collection framework), and how it is presented as output (aggregated framework). The data collection framework will be flexible for each WS based on their data availability, while the aggregated FutuRaM framework, being still independent for each WS, needs to be agreed and be simple and communicative enough with respect to the project goals and the final users of the project outcomes (e.g. WEEE will use the EU-6 collection categories indicated in the WEEE Directive, BATT will use the 5 categories indicated in the new Batteries Regulation). However, it was decided not to remove the EWC and SEEA as two layers of the pyramid, as the data entries EWC-STAT and SEEA are typically very aggregated, but to rather make them flexible, as those WS for which is possible, will try to create a link with these (see Figure 9). For an overview on all WS interlinkages see Figure 13.

A summary on the data collection framework and aggregated classification system can be found in Table 6.This whole part on data collection, describing the classification system is valid for the complete data collection (i.e. WP3+4).

Table 6: Summary on the data collection framework and aggregated classification system

	WEEE	BATT	ELV	MIN	SLASH	CDW
Aggregated FutuRaM Classification System	6 EU categories from WEEE Directive	5 categories in accordance with the new Batteries Regulation	675 vehicle keys combining four properties as used in Eurostat statistics on vehicles as products (not waste): type of vehicle, weight range, and drivetrain type and cylinder volume. Any of these four can be used as main classification property	In Min4EU DB there are odes for 2 types of wastes for mineral excavation and 8 types of waste for mineral dressing. In Eurostat wastes from "Mining and quarry" NACE code.	13 categories in from EWC-Stat	2 built environment categories
Data Collection Framework	54 UNU-KEYs	7 BATT Keys, 19 BATT sub-keys and additional sub-sub-keys (e.g. NMC is further divided into NMC111, NMC523, NMC622, etc.).	675 vehicles KEYs	Based on Min4EU DB data model and code list. Data specific site by site. Still under consideration, but several based on the type of mining or processing undertaken to extract the ore	31 sub-categories from EWC-Stat	6 built environment subcategories, multiple built environment archetypes, further differentiated by construction year (first draft, to be refined)

The framework adopted should be linkable to the European Waste Classification for Statistics (EWC-STAT[1]), which is used to classify the information related to waste for statistical purposes. Although not being used for data collection by all WS, the EWC-STAT codes should be linkable to the classification systems in use and serve as a common reference, as this is the legal EU classification used in EU waste statistics. A more detailed description of the respective data collection and aggregated framework per waste streams is provided below.

WEEE

In the case of WEEE, the recast of the WEEE Directive lists six categories which are representative of the e-waste collection streams in practice are being used as aggregated FutuRaM classification system. These categories are: (1) temperature exchange equipment (referred to as cooling and freezing; (2) screens and monitors (referred to as screens); (3) lamps; (4) large equipment; (5) small equipment and (6); small IT and telecommunication equipment with an external dimension of less than 50 cm.

Moreover, 54 categories named as UNU-KEYs can be grouped into the six primary categories of the recast of the WEEE Directive (Annex 7.3). The classification of UNU-KEYs was developed by the SCYCLE team formerly part of the United Nations University (UNU) and now transitioned to United Nations Institute for Training and Research (UNITAR) and envelops all possible Electrical and Electronic Equipment (EEE). The UNU-KEYs are constructed such that product groups share comparable average weights, material compositions, EoL characteristics and lifespan distributions. The UNU-KEYs are linked to the HS codes that are linked to all possible W(EEE) items (about 700 products).

In addition, the UNU-KEYs and the EU-6 used to classify WEEE are used also by CDW to specify the overlaps across waste streams, in particular for those WEEE embedded in CDW which are under the scope of the WEEE Directive. On the contrary, ELV will not use the UNU-KEYs since no EEE in vehicles is part of the scope of the WEEE directive. ELV will treat such components as any other vehicle component with specific names relevant for the vehicle context.

Both the UNU-KEYs and the six categories from the WEEE Directive can be linked to the EWC-STAT codes Level 2 (Annex 7.3), while the correlation with the six digits List of Waste codes implies a higher level of uncertainty since the it requires the distinction between hazardous and non-hazardous waste, which is currently not accounted for in the UNU-KEYs and six categories classifications.

BATT

In the case of the battery waste stream, 5 categories are being investigated in the framework of FutuRaM, which are based on the new battery regulation. These categories are: (1) starting, lighting, and ignition (SLI) batteries, (2) light means of transport (LMT), (3) portable batteries, (4) electric vehicles (EV) and (5) industrial batteries.

Leaning on the work that was developed under ProSUM, BATT are classified based on the 7 most common electrochemical systems. Furthermore, the 7 BATT-keys are further divided into 19 BATT-sub-keys (Annex 7.3) which will be used for data collection and modelling. The BATT-sub-keys are in some instances further divided into BATT-sub-sub-keys to better specify their composition. In view of the fast-

[1] https://ec.europa.eu/eurostat/documents/342366/351806/Guidance-on-EWCStat-categories-2010.pdf

changing battery market with new technologies or cathode/anode compositions under development, slight changes might have to be applied in the course of this project.

The keys are classified by chargeability type and electrochemical subsystem. Trade codes such as the EU List of wastes, ProdCom and CN, and the United Nations Committee of Experts on the Transport of Dangerous Goods are then linked to each individual BATT-key, BATT-sub-key and BATT-sub-sub-key (Annex 7.3).

ELV

The classification system for ELV (Annex 7.3) has been developed under ProSUM and further developed in a study finalized in 2022, commissioned by the Joint Research Centre. The 675 vehicles KEYs are all on the same level and can be chosen as main and sub-categories depending on the issues addresses. They allow to cover all possible combinations of vehicle type, vehicle powertrain, vehicle weight classes and vehicle cylinder volume, currently used in existing statistical databases.

MINW

Waste is also classified by the type of mining or processing undertaken to extract the ore (revised version based on the Mining Waste directive - 2006/21/EU and its vocabulary (2000/532/EC). In the framework of mineral resources data bases, mining wastes are included as a type of mineral resources (anthropogenic deposit type).

A data model and vocabularies for mining wastes was developed in the framework of MIN4EU/MINTEL4EU project. This data model concerns also vocabularies for all the different types of commodities. Historical MINW stock data is hold by geological surveys in general. It is a geographical database: X and Y location, waste volumes, exploited commodities, chemical or mineralogical content, environmental and geotechnical risks, etc. This information is not always available in these databases.

Geo-Z harvest data from geosurveys. Presently data from X countries and Y data providers is harvested. In FutuRaM it is expected to use MIN4EU data model for MINW.

SLASH

The classification for SLASH follows that of the EWC-Stat, this includes 13 categories at Level 3. Data will be collected and modelled for a further 31 sub-categories (See Annex 6.3). This allows for a wide study of slags, sludges, and ashes from diverse sectors.

CDW

The part described for CDW is going beyond the methodology described for the other waste streams however it lacks a detailed description of the classifications used.

The CDW categories are currently under development, but are likely to be subdivided into 2 categories and further disaggregated into 6 built environment subcategories, multiple built environment archetypes, further differentiated by construction year. Note that for CDW flow calculations, there will be two modelling procedures: One based on National Statistics, and one based on spatial data. The former relates to similar procedures followed in SLASH (see above), while the latter is detailed below:

Estimating the European stock

The spatial modelling of CDW will be stock driven, this means that we will start by estimating the building stock in Europe. For this we want to know the footprint of buildings and their heights.

Material intensities and building classification

To know which materials are contained in the stock, this stock data will be linked with material intensity data. This data classifies buildings into different categories, based on their age, use type (residential/non-residential), construction type (e.g. brick vs timber buildings), and building type (e.g. row house vs multi-family home). Each category has per material an intensity per m2 or volume assigned. These intensities can then be linked to the building stock. This way, we can model for a variety of materials (e.g. concrete, timber, brick, steel etc.) how much is currently contained in the European stock. The material intensities used will be extracted from a material intensity database collected by academic researchers.

Outflows (Demolition waste quantification)

With the knowledge of the stock, and its age, we can model with the use of lifetime distributions when a building is likely to be demolished or renovated. This will likely also be based on similar classification categories as used for the material intensities. This will help to model both demolition as well as renovation waste.

Inflows (Construction waste quantification)

Modelling the inflows can be done in several ways, the most basic being that each demolished building will be replaced by a similar new one. Depending on time and data availability, more complex modelling might be possible, but is not necessary. Based on this work, construction waste can be modelled.

Data

The data that we are using is from the EUBUCCO database (https://eubucco.com/). This database collected individual building footprint for European countries, together with some characteristics. In EUBUCCO, for 73% of buildings in Europe the height is known, for 24% the age, and for 46% the use type. The database has one big advantage in that it is harmonies, which makes necessary automation for such a big study area more easily possible. However, it does lack some detail and the characteristics are not complete. There are multiple ways to fill in the missing building characteristics that we will explore, and such approaches will add additional uncertainties to be described following the procedures of Section 4.3.

Waste Treatment

Reporting on the final waste treatment is proposed to be consistent with the recovery and disposal operations pursuant to Annex II of the Waste Statistics Regulation Code Types of recovery operations. In waste statistics, there are five reporting items, which are grouped to the Recovery (R) or disposal (D) operations used in EU waste licensing and statistics (see Table 7). For more information see: [Manual for the Implementation of (europa.eu)]

Table 7: Waste Treatment classification

Reporting Item		Recovery (R) or disposal (D) operations	
1	energy recovery (R1)	R1	Use principally as a fuel or other means to generate energy
2	waste incineration (D10)	D10	Incineration on land
3	recovery (other than energy recovery) (R2 to R11) 3a recycling 3b backfilling	R2	Solvent reclamation/regeneration
		R3	Recycling/reclamation of organic substances which are not used as solvents (including composting and other biological transformation processes)
		R4	Recycling/reclamation of metals and metal compounds
		R5	Recycling/reclamation of other inorganic materials
		R6	Regeneration of acids or bases
		R7	Recovery of components used for pollution abatement
		R8	Recovery of components from catalysts treatment resulting in benefit to agriculture or ecological improvement
		R9	Oil re-refining or other reuses of oil
		R10	Land treatment resulting in benefit to agriculture or ecological improvement
		R11	Use of wastes obtained from any of the operations numbered R1 to R10
Item 4	landfilling (D1, D5, D12)	D1	Deposit into or onto land (e.g. landfill, etc.)
		D5	Specially engineered landfill (e.g. placement into lined discrete cells which are capped and isolated from one another and the environment, etc.)
		D12	Permanent storage (e.g. emplacement of containers in a mine, etc.)

5	other forms of disposal (D2, D3, D4, D6, D7)	D2	Land treatment (e.g. biodegradation of liquid or sludgy discards in soils, etc.)
		D3	Deep injection (e.g. injection of pumpable discards into wells, salt domes or naturally occurring repositories, etc.)
		D4	Surface impoundment (e.g. placement of liquid or sludgy discards into pits, ponds or lagoons, etc.)
		D6	Release into a water body except seas/oceans
		D7	Release into seas/oceans including sea-bed insertion

4.2.5 Method - Post-consumer Waste Framework - WP 4

The measurement framework for post-consumer waste statistics follows a mass balance approach over the entire life cycle from product to waste, including final treatment and recycling. The UNECE Waste Statistics Framework expands the scope of waste statistics to include informal, uncontrolled and illegal waste-related activities (see Figure 10). As a results, the framework covers production, imports, and exports, placing on the market, stock during the use phase, waste generation, waste management, and other waste-related activities.

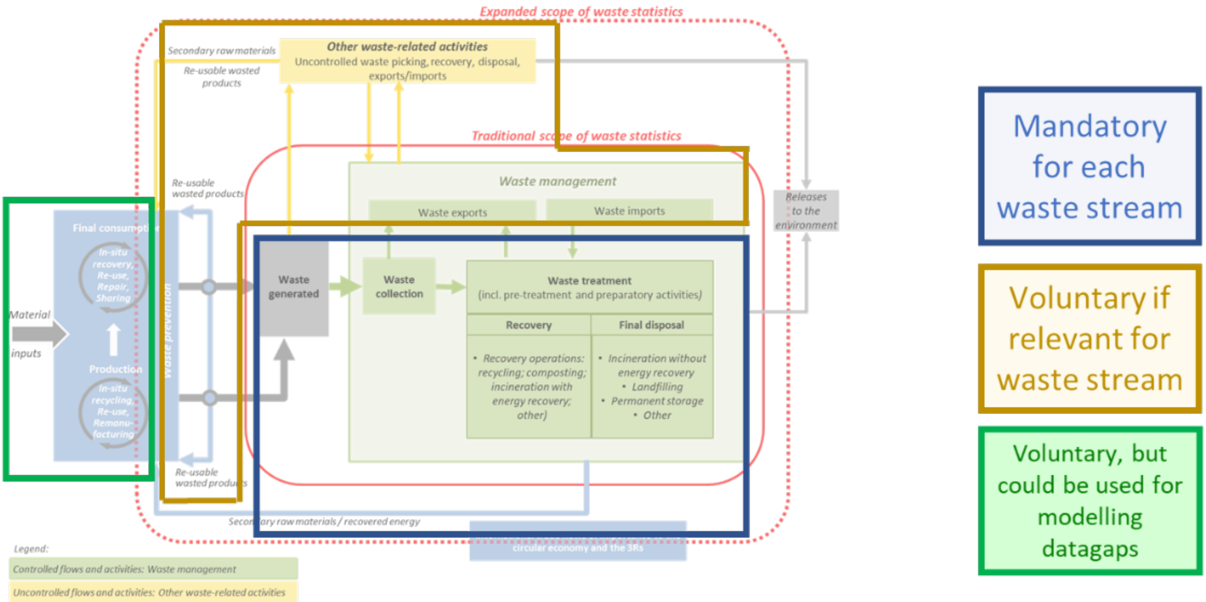


Figure 10 Aligning the FutuRaM Framework to the European Statistics Framework on Waste Statistics

The UNECE Waste Statistics Framework is extended to the post-consumer waste flows and the pre-consumer waste flows (MIN, SLASH). The main features of the framework are described more in detail below.

Placed on market

Placed on the market (also commonly referred to as "put on the market" means the first time a product is sold on the market within the territory of a Member State on a professional basis (Directive 2012/19/EU). The POM can be coming from a national registry as a legal implementation of the extended producer responsibility requirements, or statistically calculated through a variety of data sources, and for what concerns the post-consumer waste streams (i.e. BATT, ELV, WEEE) should imply using the apparent consumption methodology, which is a mass balance approach of adding up imports of domestic production and subtracting exports within a country and a time period.

Stock

Material reservoirs (mass) within the system analyzed that can be expressed through the physical unit of kilograms and tones (per inhabitant or household). This flow allows to quantify what is currently in the use-phase (e.g. batteries, vehicles, EEE and buildings in use by the consumers) and will become waste in the future, which is essential for the post-consumer waste streams. In the case of ELV, import of used vehicles is also added to the mass balance to determine the amount of vehicles in stock.

Preparation for reuse

This flow is present in two phases of the framework, before and after the waste generation. In particular, preparation for reuse can happen when a functioning product is repaired/refurbished before it becomes waste generated and re-enters the market through an extension of its service lifetime. If the product is exported abroad and enters the stock phase market again in another country, then it should be referred to as "export for reuse". Alternatively, preparation for reuse can take place after a product has already become waste (after waste generation), but during some pre-processing steps (e.g. checking and cleaning) it is identified as still functioning and therefore is diverted to repair and reuse. This can involve whole products, but also components. From a statistical perspective, reuse prior to waste generation can be modelled through a lifetime extension, while reuse happening after waste generation and during the recovery process can be modelled through transfer coefficients (see chapter 4.8), depending on data availability. The destination of reused products/waste/components (e.g. re-entering the system at the stock phase) won't be considered in the model due to high complexity and too much uncertainty.

Waste Generation

Means any substance or object in the categories set out in Annex I of Directive 2006/12/EC which the holder discards or intends or is required to discard. For some waste streams, this flow can be referred to differently, such as in the case of the ELV which has the concept of "vehicles leaving the stock". Please note that, in the FutuRaM accounting framework, this is the amount of waste prior to collection.

Waste management

In general, waste management involves the collection, transportation, storage, recycling and disposal of waste. Waste management can be undertaken by an economic unit within a legal framework, but waste handling carried out by informal economic units (e.g. informal waste recycling) and illegal waste-handling also exist. In this context, "waste management" and "other waste related activities", as proposed by the UNECE's Waste Statistics Framework, are distinguished. In that framework, waste management is defined as the set of lawful activities carried out by economic units of the formal sector, both public and private, for the purpose of the collection, transportation, and treatment of waste, including final disposal and after-care of disposal sites.

Waste collection

The waste that is legally (usually separately) collected, reported and regulated by national transposition of the national (or EU) legislative framework. This happens through separate collection at municipal collection points, retailers, pick-up services and other take-back schemes. The final destination for the waste that is collected is a state-of-the-art treatment facility, which performs full recovery in an environmentally-sound way. In the case of the ELV, this flow is referred to as vehicles "registered for recycling",

Waste exports

The waste that is exported and recycled abroad according to the national standards of the receiving country.

Waste treatment

The waste that is reported as treated and recycled under the producer compliance regime within the member state and recorded in national and European statistics[2], according to the Disposal and Recovery Codes (Waste Management Act, 1996 as amended)[3].

Waste treatment according to the EU legislative framework requirements should take place in a state-of-the-art treatment facility which operates recovery of the waste to the maximum extent, including then management and final disposal of the residues and unrecovered fractions, which can be either landfilled or incinerated, and become part of the SLASH waste stream (for an overview on all WS interlinkages see Figure 13.

The generation of secondary raw materials (scrap metals, plastics, residues, etc.), including CRM, from the recycled waste, is excluded from the traditional scope of waste statistics. In fact, in the waste treatment section of the framework, flows are no longer at product/waste level, but rather at component, material and element level. However, these flows could be modelled, and FutuRaM will in fact expand the traditional scope of waste statistics and focus also on the waste treatment section of the framework, with all the flows occurring during the treatment phase at component, material and element level being investigated through waste stream specific flowcharts (see Chapter 4.5):

Other waste-related activities

The "other waste-related activities" including also selective dismantling of the valuable parts, recovery of just some metals and fractions, with the remaining part left untreated, mixing of waste that should be separately collected with other wastes, waste dumping, waste-picking, uncontrolled landfilling, etc. and may include the informal sector. Waste can also be managed by waste managers involved in various processes such as collection, dismantling, and metals recovery, using operations that do not guarantee

[2] Methodology - Waste - Eurostat (europa.eu)
[3] Explanation_of_Recovery_and_Disposal_Codes_TB.pdf (epa.ie)

environmentally sound management, and are of inferior quality. An example is waste being mixed and not source-separated and ending up in landfills or incinerated.

For BATT, "other waste-related activities" implies a quantification of the following flows:

- BATT ending up in the mixed residual waste,
- BATT which are not separately collected and end up being treated as embedded in ELV in "other waste related activities"
- BATT which are not separately collected and end up being treated as embedded in WEEE "other waste related activities",

For WEEE, "other waste-related activities" implies a quantification of the following flows:

- WEEE in metal scrap, which is not separately collected and ends up collected as mixed with other metal waste,
- WEEE that is discarded in the mixed residual waste,

For ELV, "other waste-related activities" implies a quantification of the following flows:

- ELV gap, which consists in the difference between vehicles leaving the stock after the use phase, and the sum of exported used vehicles and vehicles registered as recycled. NB technically, "other waste-related activities" are not entirely correct in the case of vehicles since vehicles leave the stock both as product and waste.

CDW, "other waste-related activities" implies a quantification of the following flows:

- CDW in metal scrap, which is not separately collected and ends up collected as mixed with other metal waste,
- CDW that is discarded in the mixed residual waste,

4.2.6 Method - Pre-consumer waste flows WP 4

Some concepts are specific to pre-consumer streams, and some requires additional comments and diverge from those of the UNECE Waste Statistics Framework. These differences are detailed below:

Historical stocks

The historical stocks represent 2RM present in old waste storage facilities (landfills, tailings) not related to ongoing activities. It is a concept applicable here to mining waste and metallurgical industry wastes. The historical mining activity in Europe create amounts of mining wastes and tailings. National and European databases identify these sites, and these databases contain information about metal content, surfaces, volumes, environmental risks, etc. An overview of several national databases was published by Zibret et al (2020) (Figure 10).

Table 1. Responsible organisation for preparing and keeping the National mine waste registries and basic information about the registries.

Country	Abbreviations	Name	Reference	Total No. of Sites	No, of Sites with Detailed Assessment	Measured Substances
France	GEODERIS	GEODERIS	[31–33]	3144	200	Pb, Zn, As, Cd, Cr, Hg, Cu, V, Mo, Co, Ni, Se, Sb, Tl
Spain	IGME	Instituto Geológico y Minero de España	[34]	370	370	Pb, Zn, As, Cd, Cr, Hg, Cu, V, Mo, Co, Ni, Se
Italy	ISPRA	Istituto Superiore per la Protezione e la Ricerca Ambientale	[35]	650	220	Asbestos, Ag, As, Cd, Cr, Co, Cu, Hg, Mn, Pb, Ni, Tl, Zn, Sb, Sn, Be, V, CN, Fluoride, Aromatic compounds, TPH C > 12
* UK	BGS EA NIDoE	British Geological Survey Environment Agency (England and Wales) Scottish Government Northern Ireland Department of Environment	[36–40]	404	0	Harmful substances are measured in downstream water and not in waste material
Hungary	MBFSZ	Magyar Bányászati és Földtani Szolgálat	[41]	1046	71	Ag, Au, As, Be, Cd, Cr, Cu, Hg, Mo, Ni, Pb, Sb, Se, Sn, Th, Tl, U, Zn
Slovenia	ARSO	Agencija Republike Slovenije za okolje	[42–44]	173	78	As, Ba, Cd, Co, Cr, Cu, Hg, Mo, Ni, Pb, Zn
Portugal	DGEG, EDM	Direcção Geral de Energia e Geologia	No references	199	39	Cd, Cu, Ni, Pb, Zn, Cr total, Cr^{6+}, Hg, Co, Mo, As

* This study was conducted in the period between 2017–2019, when the UK was still the European Union member state.

Figure 11: An overview of some national databases was published by Zibret et al (2020).

For SLASH, historical stocks concern old industrial landfills or slag heaps. As for mining wastes, national databases store the information of some of these sites: location, surfaces, main characteristics, metal content.

Production and Waste generated

This stage of the activity refers to any substance or object in the categories set out in Annex I of Directive 2006/12/EC which the holder discards or intends or is required to discard. Specifically, for the flow-/deposit-centric wastes streams this would represent the annual waste flows generated from the mining, incineration, or metallurgical activities. For the flow-/deposit-centric waste flows this activity combines the “put-on-market" and "waste generated" concepts from the post-consumer flows. As MINW and slags are a consequence of the mining, incineration, and the metallurgical production of metals, the production of raw materials is a key parameter in the assessment of future availability of 2RMs.

In mining the waste production is the quantity of wastes generated by extractive sector. In EUROSTAT annual statistics are available. The database does not provide an "extractive waste" category; however, it does contain the waste generated and reported by the source, and the extractive industries could be linked to the NACE code "B mining and quarrying". The different wastes reported by operators are then divided into different waste categories. An example can be found in Figure 12.

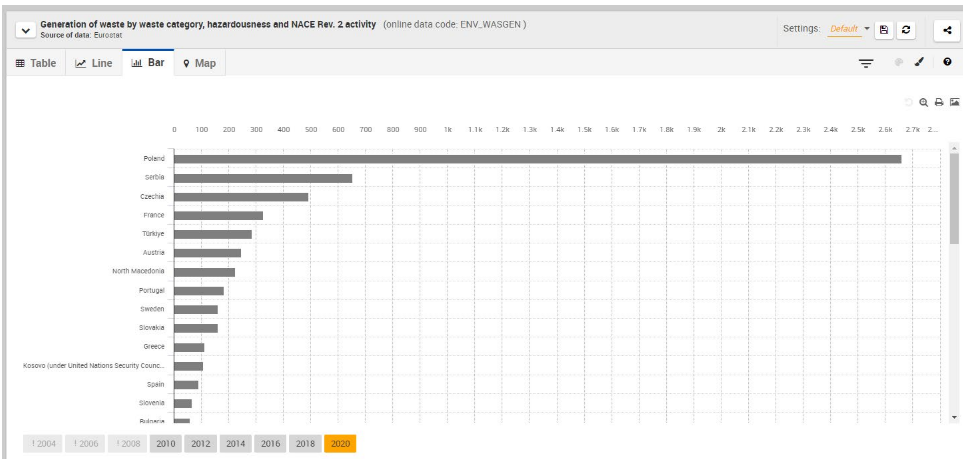


Figure 12: Extraction of wastes generated by mining & quarries sector, by country, in 2020. Waste category "metal wastes, non-ferrous W62). Source: Eurostat.

For slags this activity represents the annual metallurgical production in Europe (e.g. steel, copper, aluminum). For ashes this activity represents is the annual combustion processes related to energy and municipal waste.

Waste collection

The term waste collection as used in end-of-life products is not applicable to MINW and SLASH. All wastes generated form mining, incineration, and metallurgical activities should be declared. All these additional flows need to be considered in the framework, as they contribute to determining the amount of waste that goes to recycling and the amount of 2RM/CRM that can be made available through these processes.

The integration of the MINW and SLASH in the waste statistics framework is synthesized in Figure 13, showing the interlinkages among the sources of generated waste, and whether they could be considered as pre-consumer or post-consumer waste. However, in waste statistics, the source of waste generation is usually accounted for and pre-consumer and post-consumer are not distinctions. The conceptual harmonization is that post-consumer in Figure 13 could be generated from all NACE activities and households, and pre-consumer could be generated at specific NACE activities.

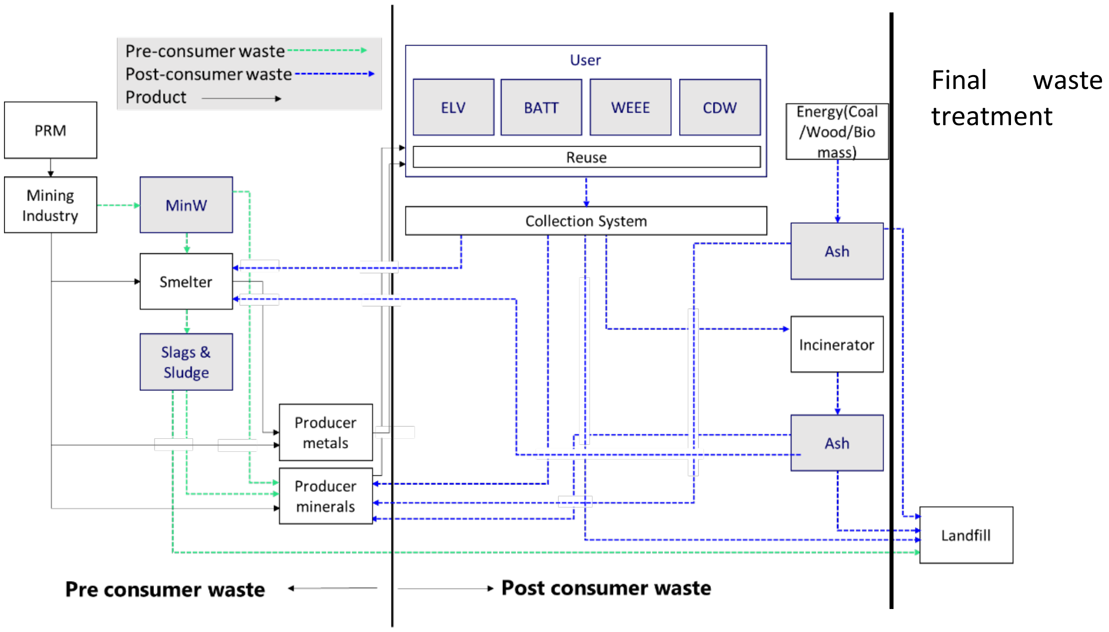


Figure 13: Overview of WS interlinkages and their source of generation

In EU waste statistics, the generation of waste is attributed to either production or consumption activities. The actor handing over the waste to the waste management system is regarded as the source. For FutuRaM, it is suggested to adapt to this as much as possible, considering a further breakdown of economic activities according to the NACE rev. 2 classification. The Statistical Classification of Economic Activities in the European Community, commonly referred to as NACE (for the French term "nomenclature statistique des activités économiques dans la Communauté européenne"). Three of these activities are linked to the waste management and will contain secondary waste: Waste collection, treatment and disposal activities; materials recovery (division 38), Remediation activities and other waste management services (division 39) and Wholesale of waste and scrap (class 46.77). In addition to the waste generated by businesses waste is generated by households. Summary, the source is distinguished between:

- Households
- NACE activities (economic activities)
    - Section A: Agriculture, forestry and fishing 1 NACE 01+02+03 Agriculture, hunting and forestry; Fishing and aquaculture
    - Section B: Mining and quarrying NACE 04 to 09 Mining and quarrying
    - Section C: Manufacturing NACE 10+11+12 Manufacture of food products + beverage + tobacco NACE 13+14+15 Manufacture of textiles + wearing apparel + leather and related products NACE 16 Manufacture of wood and wood products NACE 17+18 Manufacture of pulp, paper and paper products + printing and reproduction or recorded media NACE 19 Manufacture of coke, refined petroleum products NACE 20+21+22 Manufacture of chemicals, chemical products + basic pharmaceutical products and preparations + rubber and plastic products NACE 23 Manufacture of other non-metallic mineral products 10 24+25 Manufacture of basic metals + fabricated metal products 11 26+27+28+29+30 Manufacture of computer, electronic and optical products + electrical equipment + machinery and equipment + motor vehicles, trailers and semi-trailers + other transport equipment NACE 31+32+33 Manufacture of furniture + other manufacturing + repair and installation of machinery and equipment
    - Section D: Electricity, gas, steam and air conditioning supply NACE 34+35 Electricity, gas, steam and air conditioning supply
    - Section E: Water supply, sewerage, waste management and remediation activities NACE 36+37+39 Water collection, treatment and supply + Sewerage + Remediation activities and other waste management services
    - NACE 38 Waste collection, treatment and disposal activities; materials recovery
    - Section F: Construction NACE 41+42+43 Construction
    - Section G to U: Services activities (this includes Sections G – U, and excludes 46.77 Wholesale and retail trade; Repair of motor vehicles, motor cycles + Transportation and storage + Accommodation and food service activities + Information and communication + Financial and insurance activities + Real estate activities + Professional, scientific and technical activities + Administrative and support service activities + Public administration and defense; compulsory social security + Education + Human health and social work activities + Arts, entertainment and recreation + Other service activities + Activities of households as employers; undifferentiated goods - and services – producing activities of households for own use + Activities of extraterritorial organizations and bodies
    - NACE 46.77 Wholesale of waste and scrap

The waste statistics framework described in this chapter, including the integration of MINW and SLASH, comprises several flows, but not all are equally relevant to all the Waste Streams. Table 7 summarizes the applicability of the waste statistics framework to the FutuRaM Waste Streams, specifying the main flows will be quantified mandatorily, optionally, and those which are not applicable.

*Table 8 Applicability of the waste statistics framework to the FutuRaM Waste Streams (Q = Quantified, O = Optional, NA = Not Applicable) *ELV refers to the Waste Generated as "vehicles leaving the stock". **MINW and SLASH refers to historical stock.*

Applicability	BATT	CDW	ELV	MINW	SLASH	WEEE
Placed on Market	Q	NA	Q	NA	NA	Q
Stock	Q	Q	Q	Q**	Q**	Q
Preparation for reuse	O	O	Q	NA	NA	O
Waste Generation	Q	Q	Q*	Q	Q	Q
Waste Collection	Q	Q	Q			Q
Waste Imports/Exports	O		O	O	O	O
Other waste related activities	O	O which ones (see above?)	O			O

4.2.7 Next steps - Stocks and Waste Flows Characterization - WP4

Currently, WS are exploring data availability and are exploring possible modelling approaches for the quantification of the waste generated. This model is already available from ProSUM for BATT, ELV and WEEE, while for the other WS it is going to be developed under FutuRaM. In some cases, different modelling approaches will have to be harmonized, as in the case of CDW.

Data alignment steps among different WS are foreseen to complement the WS specific models. This is for instance the case of BATT and WEEE, where the WEEE model will be used to quantify portable batteries embedded in WEEE, and BATT and ELV, where the ELV model will be used to quantify the batteries in the automotive sector. Similarly, the WEEE embedded in CDW (from the built environment) will be quantified through the WEEE model. The WS models will also have to integrate a common data quality assessment system (see chapter 4.3), as well as the outcomes from the scenarios storylines (see chapter 4.5) to perform future projections. A complete dataset on product and waste stocks and flows will be available for Milestone 18 (Month 24).

Part of the scope of FutuRaM is to gain a deeper understanding of the treatment section of the waste statistics framework, to get a better estimation of what is recycled from the six waste streams analyzed. For this reason, all the flows that are no longer at product/waste level, but rather at component, material and element level (2RM) will be mapped through specific flowcharts, and modelled (see 2RM and Waste Treatment Model in chapter 4.9), including also the interlinkages among different waste streams. This will allow also to align the flow-/deposit-centric waste flows to the framework, which will be adapted accordingly. The final outcome of WP4 will be presented in D4.1 Future Trends of 2RM and CRM (Month 36).

In addition in WP4 it needs to be discussed whether imports and exports have to be mandatory in the FutuRaM framework. According to GA, and also considering the CRM act, it is required to discuss how the supply and demand of CRMs will be handled within FutuRaM.

Table 9: Stocks and Waste Flows Characterization - Current status and next steps

Topic/ Content	Not available	Draft	Finalized	Next Steps/Reference to other FutuRaM reports and deadlines
Definition of a classification systems (for data collection and FutuRaM aggregated		X MINW	X BATT, ELV, WEEE, CDW, SLASH	
Definition of the statistics framework			BATT, ELV, WEEE, CDW, MINW, SLASH	
WS specific models for quantification of waste generated		X BATT, CDW, MINW, SLASH	X ELV, WEEE	Proposed timeline: Month 12 - Month 16
Common data quality assessment system		X		Proposed timeline: Month 12 - Month 16
Alignment on data across WS (e.g. BATT in WEEE, BATT in ELV etc.)		X		Proposed timeline: Month 12 - Month 16
Complete dataset on product and waste stocks and flows (2010-2021)	X BATT, CDW,	X ELV, WEEE		Proposed timeline: Month 12 - Month 16

	SLASH, MINW			
Integration of projections according to three scenarios in the dataset	X			Proposed timeline: Month 16 - Month 20
Complete dataset on product and waste stocks and flows (2010-2050)	X			Proposed timeline: Month 12 - Month 24 Ready for the WP4 Milestone 18 (Month 24)
Complete dataset on 2RM/CRM flows (2010-2050)	X			Proposed timeline: Month 18-Month 36 Ready for the WP4 Deliverable 4.1 (Month 36) To be developed in conjunction with 2RM and Waste Treatment Model (see chapter 4.9)
CDW	X			Add used classification
MINW	X			Define CGI classification
Supply and Demand	X			How is FutuRaM handling supply and demand of CRMs

4.3 Data Quality

Figure 14: Rules to assess the data quality

In FutuRaM we will use data from different sources with a large range of qualities. To make informed conclusions and suggests decisions to the EU, we should not only rely on the values of the data, but we also have to incorporate their quality, to guarantee that conclusions and recommendations are science based.

4.3.1 Concept

There are six rules to assess the data quality (see Figure 14).

1. **Validity:** Degree to which the data is within defined requirements (e.g., given weight range)
2. **Accuracy:** Degree to which the data represents the reality
3. **Consistency:** Degree to which the data is equal within and between datasets
4. **Integrity:** is the overall accuracy, completeness, and consistency of data
5. **Timeless:** Degree to which the data represents the reality
6. **Completeness:** Degree to which necessary data is available for use

There are four qualitative levels of data quality with 1 as highest quality and 4, the lowest, marking no availability of any information about the data quality. These four levels are in line with UNFC.

4.3.2 Method

The level of data quality is determined following these steps:

1. If there is no information or not reliable information concerning the value of property (e.g., concentration) then the data quality of this value is automatically 4.
2. Go through the six different aspects of data quality and assign to each aspect a level between 1 and 3 (very reliable, reliable and less reliable) depending how well the given aspect is fulfilled.
3. Determine the mean of the six levels of the data quality attribute.
4. Use the following rules to assign the final data quality level
    a. 2.3 ≤ mean value → date quality level 3
    b. 1.3 ≤ mean value < 2.3 → date quality level 2
    c. mean value < 1.3 → data quality level 1

The following example will illustrate how to apply the data quality framework proposed. During an exploration of a mining waste site an element was observed at one location. Then the determined concentration gets the data quality level of 4. Only if the element was observed at other locations in the same mining waste site, then data quality levels 1 to 3 should be used. The better the site has been investigated, the better the data quality score will get, as we can predict the approximate amount of this element in the mining waste site.

4.3.3 Next steps

The next step in terms of data quality involve the application of the described method. Here it is important to apply it to all data collected as well as to integrate the data quality approach into the developed models (see Chapter 4.8). Prior to the application it is important to train the partners involved. An additional step will be the inclusion of data uncertainties to demonstrate we are depicting data ranges but not single values. A summary of the next steps can be found in Table 9.

Table 10: Current status and next steps data quality

Topic/ Content	**Not available**	**Draft**	**Finalized**	**Next Steps/Reference to other FutuRaM reports and deadlines**
General concept to determine data quality			X	Some adaptation for the different waste streams might be required. Based on feedback during data collection of the different waste streams
Potential individual adoption for the needs of some waste streams	X			It will be done only, if there are some justified needs of a waste stream
Concept to transform data quality information into value ranges and distributions	x			Proposed timeline: Month 12 – 16 Coordination with the modelling group required
Discussion with the modelling group, how to implement data distributions	x			Proposed timeline: Month 16 to 20 It is up to the modeler and the consortium to decide how data distributions should be handled
Explanation and training of the various groups of the consortium on the meaning, need and handling of data	x			Proposed timeline: Month 36 to 48 This includes various means to bring the information first to the consortium and then to the different stakeholders and politics.

distributions and no single values				

4.4 Scenarios

The development of the scenarios was discussed during a meeting on 20 January 2023 with representatives of DG GROW. The aim was to understand which type of scenarios would be the most useful for DG GROW. The following paragraphs summaries and conclude on the discussion and hence sets the conceptual framework for the scenarios. The ensuing discussion emphasized that FutuRaM needs to include the targets that DG GROW is setting for specific elements/materials/waste streams, following the ambitions of the EU Green deal. The content was shared with DG GROW in a letter.

4.4.1 Concept

With respect to the waste streams that are analyzed in FutuRaM, the following waste stream-specific developments aligned with DG GROW targets have to be taken into account:

- BAT: The EU has agreed to a new law on more sustainable and circular batteries in December 2022 which entails recycling targets for cobalt, nickel, lead, copper and by 2026 and by 2030.
- ELV: Currently under review now and to be completed during 2023.
- WEEE: Directive about to be evaluated with a review likely in 2024.
- CDW: No activity currently planned.
- MINW: Focus is currently on human health and environmental impact rather than waste or commodity potential. But the CRM Act promotes the recovery of critical raw materials in mining wastes. New EU mining targets implies also new mining activity in Europe and consequently new mining wastes.
- SLASH: No activity currently planned.

The targets that result from the planned and ongoing review processes are non-negotiable and legally binding, and thus should be incorporated in the FutuRaM scenarios. These targets, however, are only applicable to post-consumer products, namely WEEE, BAT and ELV. This envisioned future in which legally binding targets for collection, reuse and/or material recycling are achieved can be implemented as the recovery scenario. If there are no targets set for a specific consumer product category, then approach targets similar to the WEEE directive and in line with the EU Green Deal. For the circularity scenario, FutuRaM will also consider the effects of ‘re-x’ strategies and the proposed ‘eco-design’ requirements for sustainable products (e.g., longer lifetimes, increased reusability, reparability, recyclability).

However, for waste that that does not consist of discarded consumer products, but instead results from industrial production activities, in particular for MinW, and for SLASH, specific scenarios related to mining, metallurgy, and waste and fuel combustion need to be developed. For mining wastes scenarios will integrate parameters such as the future European primary production aligned with EU objectives (for example new lithium mines) and consequently the new mining wastes generated. The scenarios will account for increasing resource use effectiveness and production process efficiency, thus indicating lower volumes and quality of generated production residues (both by-products and waste such as red mud, waste rock, slags, etc.) per unit of product (expressed either as product mass or product value), whether that product is a metal (e.g., a copper cathode), metal alloy (e.g. aluminum alloy n° 5183) or metal product (e.g. cold rolled stainless steel sheet). Ashes are highly diverse, and each specific type will have a specific storyline that is congruent within each scenario.

FutuRaM should also take into account geopolitical considerations and thus supply chain resiliency for satisfying the product demand in the scenarios. The growth in material demand for the energy and mobility transitions can be satisfied either by an increase of mining and metallurgy activities within the EU, or by growing imports from raw material producing countries outside the EU. Increasing domestic EU production to minimize geopolitical supply risk, may indicate more EU production residue generation even under an increased production efficiency and resource effectiveness. The increase of domestic industrial activity, as a response to an envisioned increased internal demand, supposes an equivalent rise of societal approval for mining and refining activities on EU territory. If the increased demand is, however, satisfied by imports from non-EU countries, the corresponding production residue volumes in the form of slags and ashes will also be generated outside the EU, while domestic volumes will decline, or at best, stabilize. FutuRaM is not conducting interviews and surveys, but literature analysis on the subject will be carried out. It is likely that the results will not be able to be explicitly included in the scenarios, but levels of acceptance by consumers for mining and refining activities in the European Union territory in our scenarios can be incorporated. Most likely, the extent of explicit inclusion of geopolitical and trade factors will be limited to the targets in the CRM act which set mandates for local sourcing and supply chain diversification.

In conclusion, WEEE, ELV and BAT waste material recovery will follow as many targets in the EU as possible (e.g., from the CRM act, or the Circular Economy Strategy). For SLASH and MINW, recent trends in waste generation and extract plausible ranges of generation toward 2050 will be evaluated. For CDW, embedded WEEE will follow EU targets, and bulk waste will incorporate storylines and scenarios that are congruent with those of SLASH and MINW. Various drivers will be assigned to move between these ranges and will be key to the specific, harmonized storyline for the scenario. Finally, the targets and storylines will be aligned with assumptions on technology development.

4.4.2 Method

Factors

In a first step factors which are outside the scope of FutuRaM modelling and which are most critical need to be identified. For those outside scope, by eliminating them or shifting them to the background, excessive variability and uncertainty can be reduced and the models can be more focused on the parameters, which are critical to the purpose of the FutuRaM project. We are not attempting create yet another set of broad, all-encompassing scenarios or integrated assessment models like the Shared Social Pathways (SSPs). The goal of FutuRaM is to provide insight into the current state of the 2RM system and to describe the possibilities for its future development toward 2050. Thus, the focus should be held on factors most relevant to the material recovery system (which will include selected aspects of a technological, legal, social, economic and environmental nature). For example, factors such as population and GDP will not vary across the scenarios as it would not provide additional insight and only serve to make more uncertain any conclusions regarding the impacts of changes to the more critical factors.

Storyline development

Developing scenario storylines for a model about the material flows of 2RM systems can be a complex and challenging task. However, a combination of back casting and forecasting can be an effective approach to develop these storylines.

Back casting involves starting from a desired future scenario and then working backward to identify the steps needed to achieve that scenario. In the context of an MFA model for recycling and recovery systems, this involve imagining a future where recycling rates are much higher, and waste production is greatly reduced. The back casting process involves identifying the policy changes, technological advancements, and societal shifts that would be required to achieve this future state.

On the other hand, forecasting involves making predictions about future events and trends based on past data and current trends. This involves forecasting the future availability of raw materials, consumer behavior trends, and the development of new recycling technologies.

By combining back casting and forecasting, scenario storylines can be developed that incorporate both future goals and predictions about the likely path to achieving those goals. This approach can provide a comprehensive understanding of the material flows of recycling systems and the potential impact of different policy and technology interventions on those flows.

In order to incorporate the needs of policy makers (who want to know the possible effects of the decisions) with factors that are largely legislatively independent, developing scenario storylines for FutuRaM's models requires a combination of back casting and forecasting. This approach can provide a more holistic understanding of the future trajectory of recycling systems and the potential strategies for achieving desired outcomes.

Modelling feasibility

During the development of the storylines, the feasibility of quantitatively modelling the scenarios was a constant consideration. Given the complexity of the 2RM system and the high levels of uncertainty and incertitude for certain scenario drivers, some factors were omitted if they were not deemed to provide useful potential for valid modelling.

For many other drivers/factors, their modelling feasibility does not present a great deal of complication, as they can enter the computational models in the form of constant or formulaic parameters. These parameters will be based on assumptions, estimates and trends that will be derived from information collected from literature, expert/industry opinions, and other data that is available to the project. The difficult task is therefore, not how to integrate them into the model, but to develop the parameters in a way that most closely represents a set of reasonable projections based on the information available.

The process of developing these parameters will be transparent and all assumptions and estimations (and their incorporation into the models) will be clearly documented. Furthermore, a global sensitivity analysis (GSA) will be conducted to test the robustness of the models and to identify the most critical elements (i.e., those whose fluctuations have a large impact on the model's results. In this way, those using the models can look 'under the hood', checking the imbedded assumptions and the uncertainties. They can thereby have a clearer picture of how the results have been calculated and an understanding of how reliable each data point may be.

4.4.3 Next steps

The report from 2.1 will soon be finalized and released for stakeholder feedback. Formation of working groups for 2.2 and 2.3 has begun and alignment with WP3 and WP4 is ongoing.

Data collection:
Collect relevant data on learning curves, technology forecasts, and market uptake trends for each identified technology. This process may involve:

- Conducting literature reviews.
- Analyzing industry reports.
- Reviewing market analyses.
- Engaging with experts in the field.

Potential data sources could include:

- Research papers and theses. (there are many that also include different scenarios)
- Patents. (maybe inefficient for our purposes, since the often lack hard data)
- Technology roadmaps. (EU has dozens of these)
- Industry surveys. (speaking to experts, getting rough data from them)
- Market studies. (maybe inaccessible due to cost €2000+, but could be worth it)

Figure 15 depicts how the data produced in 2.2 and 2.3 will fit into the SRM recovery model.

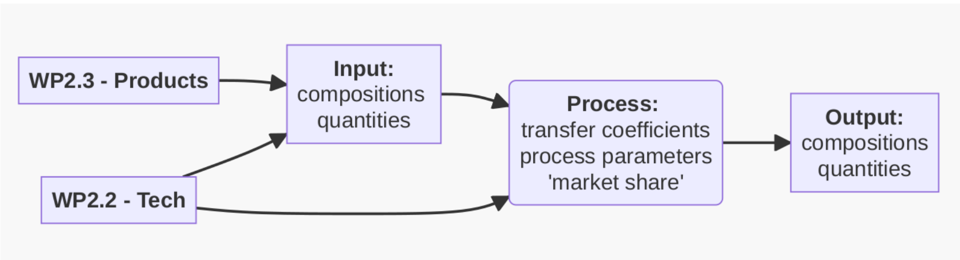


Figure 15: Relationship between WP2.2/3 and the recovery model

Table 10 summarizes the current status and next steps for the scenario development within FutuRaM.

Table 11: Current status and next steps - Scenarios

Topic/ Content	Not available	Draft	Finalized	Next Steps/Reference to other FutuRaM reports and deadlines
2.1.1 - Marker Scenario mapping		x		Feeds 2.1.2. Toward milestone 11 ETA: May/June 2023
2.1.2 - Scenario methods		x		Feeds 2.1.2. Toward milestone 11 ETA: May/June 2023
2.1.2 - Scenario storylines		x		Conclusion of 2.1, milestone 11 Feeds 2.2, milestone 17 June 2023: draft released for responses November 2023: storylines finalized
2.2.1 - Emerging	x			Feeds 2.2.3/4/5. Toward milestone 17 Connection to WP 3, 4.1 and 4.2

technology: products				June 2023: data collection plan released for responses
2.2.2 - Emerging technology: recovery	x			Feeds 2.2.3/4/5. Toward milestone 17 Connection to WP 3, 4.1 and 4.2 June 2023: data collection plan released for responses
2.3.1 - Future compositions	x			Feeds tasks 2.3.2 and 3. Toward milestone 17 June 2023: data collection plan released for responses

4.5 Technology development - Recovery pathways[4]

4.5.1 Concept

One of the aims of FutuRaM is to extend the POM model developed in ProSUM, by including recovery pathways, this is crucial to be able to make assumptions on recycling technologies for the future scenarios. In a first step the current situation needs to be mapped and recovery pathways need to be defined (Figure 16). This should be done by defining the recycling pathway which need to be able to describe all chosen 2RM and hence CRM routes. The complex nature of recovery pathways makes it important to focus on "lead elements" (mostly critical raw materials) when it comes to defining the system. This is in line with the approach of classification and data collection as described in Chapter 4.2. For all pathways, transfer coefficients need to be defined for the element, the material and component level. Here it is important to state that it is key to find a balance between a generic approach and detail to meet the FutuRaM goals. A generic approach can be more adaptable and efficient, but it may sacrifice specificity and accuracy. Detail can provide greater accuracy and precision, but it may require more time and resources, hence it is important to balance the two approaches.

[4] During the discussion and also in the available documentation the topic was called Recycling pathways, however, due to the definitions as can be found in Chapter 4.1 the name was changed to recovery pathways.

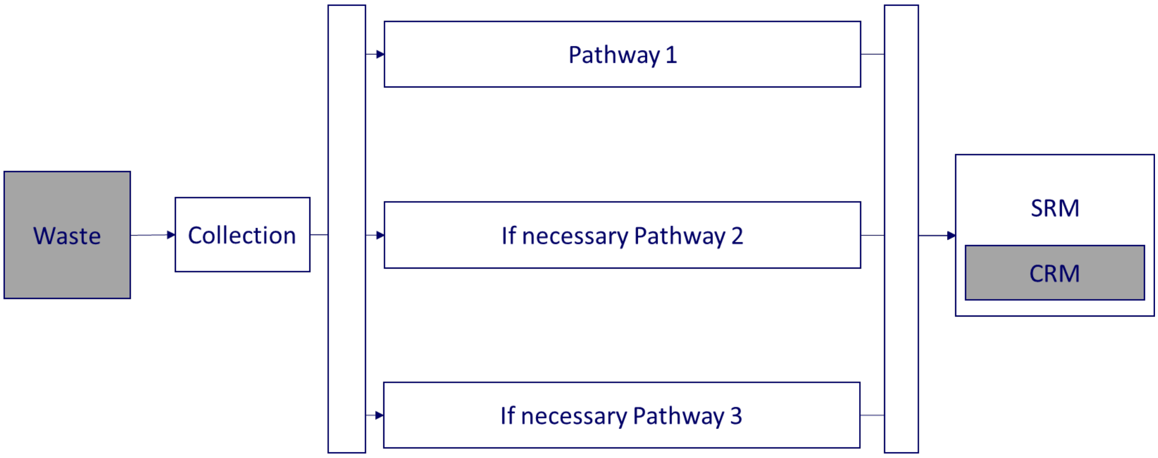


Figure 16: Conceptual design of recovery pathways within FutuRaM

For example, using standards such as EN 45558 can be helpful in defining the pathways (see Figure 17). It is also important to note that the described current and future recovery pathways provided can be generic for the EU and do not need to be specific to a country. This is addressing the availability of data and hence the meaningfulness of the described pathways. In order to analyses the quality of recycle, a minimal quality requirement for 2RM (secondary raw material) output should be defined (see 4.8). By focusing on lead elements using existing standards, directives and date the recycling process can be mapped and set the base for a digital twin of the EU resource recovery landscape.

The first step is to develop the pathways based on the current situation to determine what is possible nowadays. In principle, for each pathway and the steps within the pathways, transfer coefficients for elements, materials and components need to be developed. This involves harmonizing and consolidating the opinions of experts, existing data and standards to identify which recovery pathways and transfer coefficients are applied today. Afterwards the scenarios for the future are developed. Thus, the next step is to decide on the development of recycling technologies until 2050 which need to be in line with the storyline developed (see Chapter 4.4). Here is recommended to start with the BAU scenario. In this scenario available technologies but also emerging technologies can be considered. Once these technologies have been selected, it is necessary to update transfer coefficients and pathways to represent the development of new recycling technologies. Finally, this step needs to be repeated for the other scenarios. The approach will allow the development of waste management strategies that address the current and future waste management challenges. The data sets generated from the recycling pathway development will provide a basis for informed decision-making.

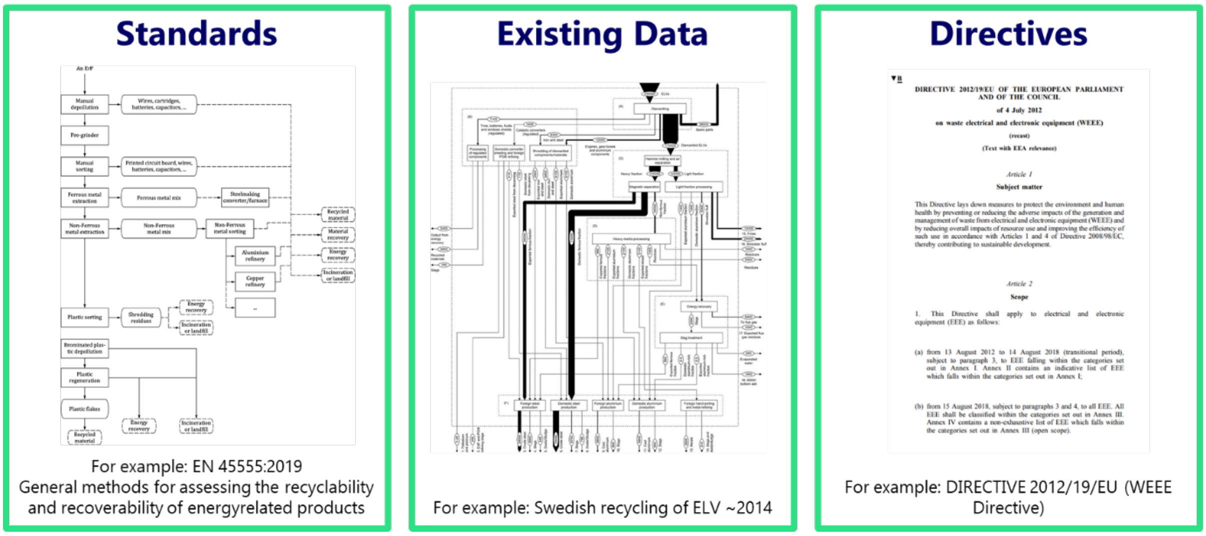


Figure 17: Options and possibilities to define recovery pathways

4.5.2 Method

All six waste streams developed flow charts visualizing the waste flows from waste generation to the final 2RM recovery or disposal of residues. The flow charts show the different recovery options respectively recovery pathways and are the visualization of the planned modelling. To harmonize the visual presentation and modelling approach of the different waste streams, all flow charts were then transferred into a joint layout where all processes were allocated to one of the following nine categories which are in line with the European Statistics Framework on Waste Statistics (see Figure 10).

- Fabrication / manufacturing / construction
- Distribution / use
- Collection
- Preparation for reuse
- Mechanical recovery processes
- Biological recovery processes
- Thermal recovery processes
- Chemical recovery processes
- Disposal processes

Based on the flow charts, transfer coefficients which will differ for the current and future situation as well as depending on the scenarios can be assigned to the different recovery pathways. An example flow chart for ELV can be found in Annex 7.4.

4.5.3 Next steps

It is further planned to create one FutuRaM flow chart combining the six different flow charts of the individual waste streams presenting the interlinkages between them and the common framework of the project. A summary is provided in Table 12.

Table 12: Recovery Pathways - Current status and next steps

Topic/ Content	Not available	Draft	Finalized	Next Steps/Reference to other FutuRaM reports and deadlines
Draft flow charts for each waste stream			x	Feeds into milestone M18
Harmonize WS-specific flow charts		x		Feeds into milestone M18
Consolidate WS-specific flow charts into one overarching flow chart, covering all six FutuRaM WS	x			Feeds into milestone M18

4.6 Technology development - Product

4.6.1 Concept

The objective of this product technology development approach is to analyze potential scenarios for waste generation and waste composition until 2050. The analysis will identify the products that may be used and their composition when placed on the market, lifetimes and market shares in 2022 and their rate of change until 2050. General assumptions about economic and population growth are developed in the scenario work and thus separate from product technology development. Similar to the recycling pathway, a variety of data sources can be used such as patent databases, academic and grey literature, expert opinions, market analyses.

The focus for the post-consumer waste streams WEEE, ELV and BAT should be on the changes in products used and how this will be reflected in the flows of waste generated from the products. The changes in products will appear as changes in flows placed on the market, used in the stock and flows leaving the stock mainly as waste to be recycled. In Figure an example for product changes for WEEE, screens placed on the market (ProSUM) is depicted. The figure illustrates a product technology shift from CRT to LCD displays. Hence, a change in the product keys, composition, and number of products over time can be seen. As new products are introduced, the demand for older technology decreases, leading to less products placed on the market and over time a decline in the stock of those products. This shift in technology has significant implications for waste generated and its composition and thus the 2RM recovery.

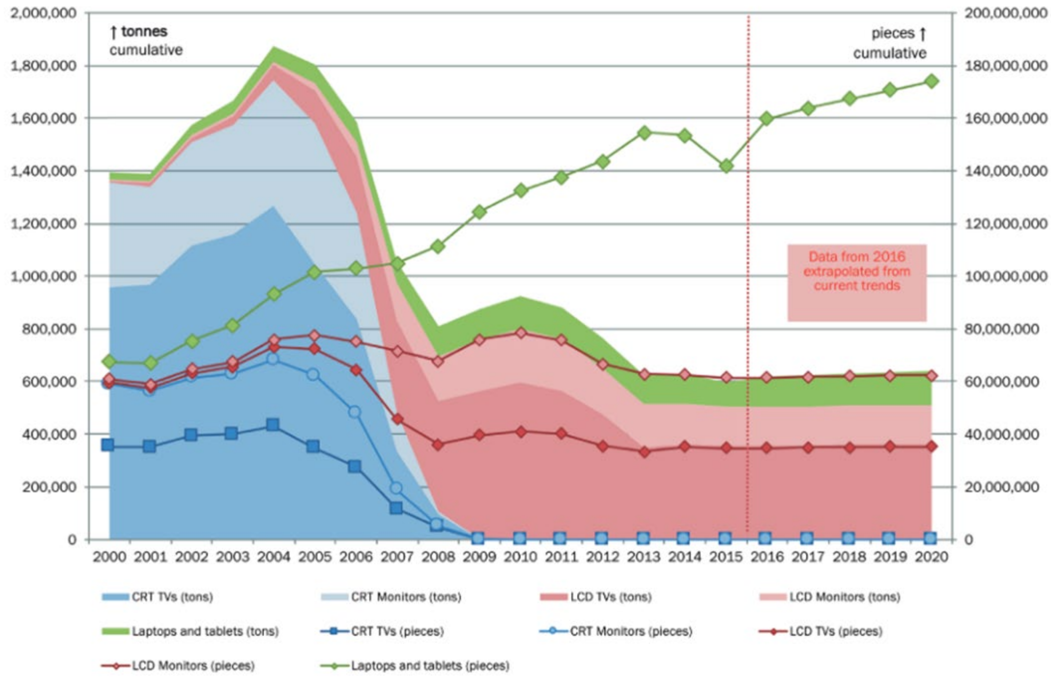


Figure 18: Screens placed on the market (ProSUM)

The approach differs for MINW and SLASH. The MINW will focus on already generated waste, while SLASH might focus on demand for metals and minerals, including demand for FutuRaM products, and waste generated by recycling of FutuRaM products. This still needs to be discussed and clarified by the SLASH group.

The importance of addressing future changes in product composition varies across different waste streams. For instance, it is very important for EEE resulting in new product keys, increasing numbers, and short product lifecycles leading to multiple product generations and hence also significant changes of the generated waste until 2050. For vehicles, addressing future changes in product technology is important because of the shift of keys and composition changes, but since vehicles have relatively long-lived product lifecycles, fewer product generations can be assumed to appear until 2050. Finally, for buildings and constructions, it may be considered less important because of their long-lived nature and mainly historic changes that will affect the generated waste until 2050. By understanding the variation in importance across different waste streams, this task can be tailored for the respective waste streams

4.6.2 Method

The method departs from the understanding that the main purpose of FutuRaM is to quantify secondary raw materials availability. This means that the emerging products to consider are those that can significantly impact generated waste until 2050 (see Table 13). As a consequence, less focus is given to quantifying emerging products placed on the market towards the end the period, unless they have short lifetimes and could impact waste before 2050.

All waste stream teams have provided an initial description of the product technology changes that they, based on their expertise, envision to study. The proposed following step is a limited study on emerging product technologies where sources to consult are e.g. scientific literature, technical reports, market reports and patent databases as well as expert interviews. The study should preferably be conducted by each waste stream team to benefit from its expertise. The scope of the study needs to be carefully designed in two respects: (1) focus on emerging products that would change the composition compared to current products (increasing or decreasing) and would leave the stock before 2050, and (2) available project resources for this task. The study should give sufficient basis for selecting what emerging products to include in the analysis and when in time they could become available. In addition, it should also account for the differences in product technology between the scenarios. Furthermore, an approach for their diffusion is needed, where the diffusion describes the period over which the product increases its market share and the rate at which this occurs. A distinction in approach between replacing/phasing out old products with new ones (changes within a keys) and introducing a new product type (a new key) is also needed. These are crucial issues which needs to be agreed upon and potentially also aligned with the scenario narratives.

It is suggested that emerging products are assumed to become available at the same time and that its diffusion is similar for all EU member states. However, since the current share of products (keys) already in the stock differs between member states, the future share will also differ.

Table 13: Current status and next steps - Technology development - Product

Example	**Product technology changes**
BAU	Keys, Composition/key, Market share/key (period and rate)
Potential difference to BAU:	
Circularity	Keys: no diff. Composition/key: as a consequence of increased reusability, reparability and longer life Market share/key: consider period for and rate of change (gradual or radical) Number of products: fewer as consequence of longevity, sharing, reuse etc.
Recoverability	Keys: no diff. Composition/key: as a consequence of increased recoverability Market share/key: consider period for and rate of change (gradual or radical) Number of products: no diff.

4.6.3 Next steps

The next steps are summarized in Table 14. More details about the planned methodology are given in 4.4.3.

Table 14: Technology development - Product current situation and next steps:

Topic/ Content	Not available	Draft	Finalized	Next Steps/Reference to other FutuRaM reports and deadlines
2.2.1 - Emerging technology: products	x			Feeds 2.2.3/4/5. Toward milestone 17 Connection to WP 3, 4.1 and 4.2 June 2023: data collection plan released for responses
2.3.1 - Future compositions	x			Feeds tasks 2.3.2 and 3. Toward milestone 17 June 2023: data collection plan released for responses
SLASH scenario	X			SLASH approach for product development

4.7 UNFC

The United Nations Framework Classification for Resources (UNFC) is a global standard for the classification and management of natural resources. The UNFC was developed by the United Nations Economic Commission for Europe (UNECE) to provide a common language and methodology for the classification of resources, which can be used to support investment decisions, policy development, and sustainable resource management.

The scope of the UNFC includes all types of natural resources, including primary energy resources, minerals, and water resources. Also, it can be utilized for projects in the scope of recycling and recovery of materials from anthropogenic resources. The classification system is based on a set of criteria known as UNFC axes, including the E-axis (environmental-social-economic viability), F-axis (technical feasibility), and G-axis (degree of confidence). UNFC axes are used to assess the maturity and viability of projects. Accordingly, the projects are classified into different classes specified by a numerical code consisting of three digits, which shows the status of E-, F-, and G-axis, respectively. Conventionally, the UNFC axis and its different classes are demonstrated in the form of a 3D space, as shown in Figure 18.

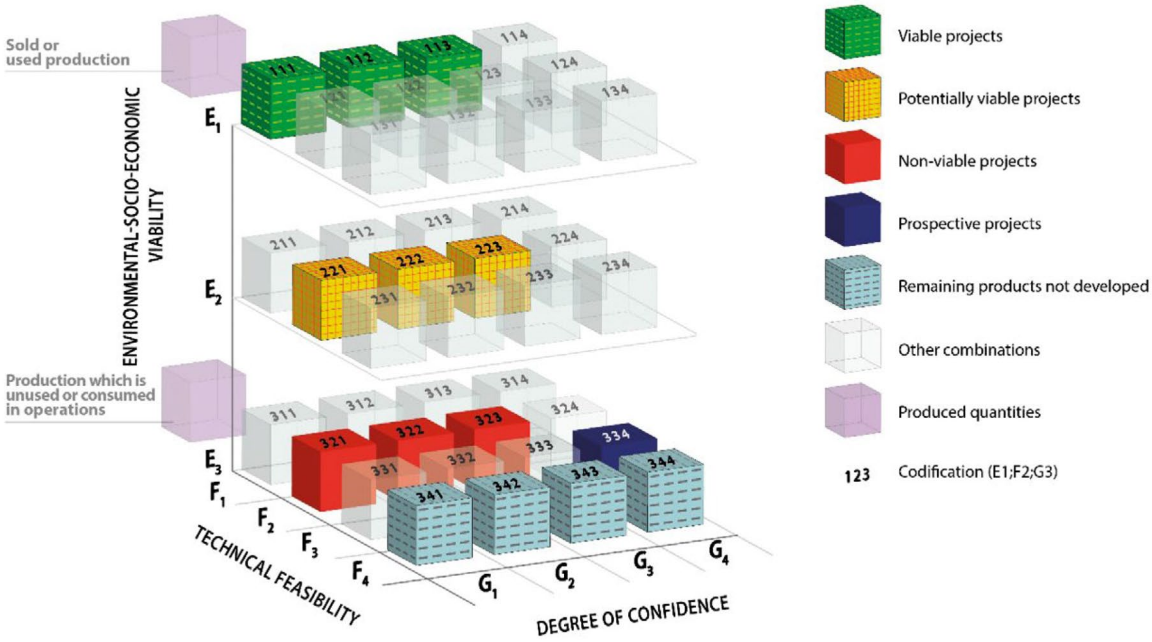


Figure 19: UNFC axes and examples of classes [5]

The UNFC is intended to be used by governments, industry, and other stakeholders to support sustainable resource management and investment decisions. By providing a standardized and transparent methodology for the classification of resources, the UNFC can help to improve the accuracy and comparability of resource assessments and support more informed decision-making.

In FutuRaM, WP5 is dedicated to applying UNFC to 19 case studies related to six waste categories, including BAT, ELV, SLASH, WEEE, CDW, and MINW. The objective of the WP is the development of a methodology to assess the recoverability of Secondary Raw Materials (SRM) and demonstrate its application to six selected waste streams at different scales. The result of the application of the methodology is to classify anthropogenic or urban mining projects according to their viability, i.e., it allows to distinguish between a potentially viable anthropogenic deposit and those that has been identified and measured, and a subset of that resource deposit for which the viability of extraction has been demonstrated. In addition, the potential quantity of resources to be extracted, the recoverability within a certain time frame, and the impact on the environment and society are communicated. This way, different anthropogenic recovery projects can be compared on a common playing field.

In the following, first the application areas of UNFC, realm of discourse and the importance of project size are explained. Then, the systematic procedure to develop the case studies will be presented. In addition, UNFC application on a national level, and the concept and methods on how the UNFC can be linked to other WPs are discussed.

[5] https://unece.org/DAM/energy/se/pdfs/UNFC/publ/UNFC_ES61_Update_2019.pdf

4.7.1 Concept

To better understand the UNFC application for the development of case studies on site-specific and national scales, it is important to know why projects are classified by UNFC, and at the end what kind of information is communicated. The next paragraphs deal with these issues.

Application Areas of UNFC

UNFC provides a snapshot of the current status of a project. As a part of the United Nations Resource Management System (UNRMS), UNFC is expected to facilitate the availability of relevant and reliable information on projects supporting international and national sustainable resources management, and also monitoring and management of production processes, in terms of economic, environmental and social sustainability aspects. Also, the alignment with the circular economy and the public communication required are other important aspects that can be addressed by UNFC. Among many others, UNFC as a tool is expected to address the following aspects[6]:

1) Industry business projects
   a. Maturity of a recovery project from different point of views, such as the regulatory requirements for an operating company
   b. Contribution of the project to the circular economy
   c. Contribution of the project to the UN Sustainable Development Goals (SDGs)
2) Provision of information to investors and potential investors in the public or private realm for financing, raising and allocating capital
3) Provision of information to governments regarding resource management
   a. In short-term, administration and surveillance projects on public and private scopes
   b. In the long term, the compilation of resource inventories, planning for technology development, and future material supply

While all these issues are related to the availability and recoverability of resources, they are not identical in terms of context, requirements, and information to be obtained. In addition, it is worth mentioning that the evaluation and classification of a project can lead to different UNFC classes depending on the criteria and requirements considered in the project assessment. For instance, considering or ignoring the project's alignment with sustainable development goals (SDGs) and CO2 emission limits can change the status of a project from a viable project to a non-viable project in the UNFC classification. Consequently, the classification and thus the UNFC code can only be understood in the context of the respective project. Therefore, two different aspects are introduced: The "Realm of discourse" and "project size".

Realm of Discourse (ROD)

In the EGRM/UNECE document, it is stated that "… *although there is some degree of commonality, the specific context and conditions under which the different users will evaluate and classify resources are not the same*", and for each type of project*, "resource evaluation and classification will have to meet a consistent set of conditions, that may differ from the others. Once these are met, evaluation scenarios will address conditions that apply to specific projects."*[1]

[6] 1801854 (unece.org)

The “Realm of Discourse” (ROD) describes the context and set of conditions of a project. It is important to clearly define the scope of the information provided in the ROD. It establishes the baseline condition for evaluation and classification for the intended purpose and thus forms the basis for decision-making.

We propose to develop standardized RODs for each type of project by defining the set of conditions taken into consideration. This enables the comparability of the case studies. In consequence, deviations from a standardized specification must be indicated and stated in the report.

Size of project

The size of a project and the scope of its assessment has to be defined. It can be a stock (e.g., a tailing) or a mass flow treated within a recycling facility. It may include the collection system, and cover the activities in a region or consider the processes in a country. With increasing the size of a project, the complexity increases. Viewing a project as part of a system can be helpful in this regard.

Figure 19 shows a schematic for a recycling project (in grey). The surrounding of the project boundary refers to the “environment” of the project. Physical flows (black arrows) indicate the material exchange between a project and its environment: A specific quantity of material is used/treated/recycled from a source within the project and at the reference point (RP), materials leave the project in the form of product, residue or emissions. The treatment process defines how much of the waste is recycled or recovered. Based on mass balance, the amount of the materials/ compounds/elements which can be brought to the market as well as get lost by emission or as a residue can be calculated. In the same way, energy and water exchange can be considered. These aspects can be expressed in the G and F categories.

For the E-axis, various aspects have to be considered in a project. In Figure 19, it is be shown with 4 different shells: 1) The economy considers all financial flows as revenues and costs (green and red dashed lines). 2) Their impact on society, shown in the next shell, can be positive (e.g., creation of jobs, infrastructure improvement), or negative (e.g., health issues for workers or population, loss of landscape). 3) The impact on the natural environment in the next shell (e.g., pollution due to emissions, consumption of water, energy requirements or disposal of waste). 4) For all these criteria, the legal aspects need to be considered (e.g., regulations or permits), which is presented in the outermost shell. It is important to understand that these spheres are interconnected and factors considered in one sphere can affect conditions in the other.

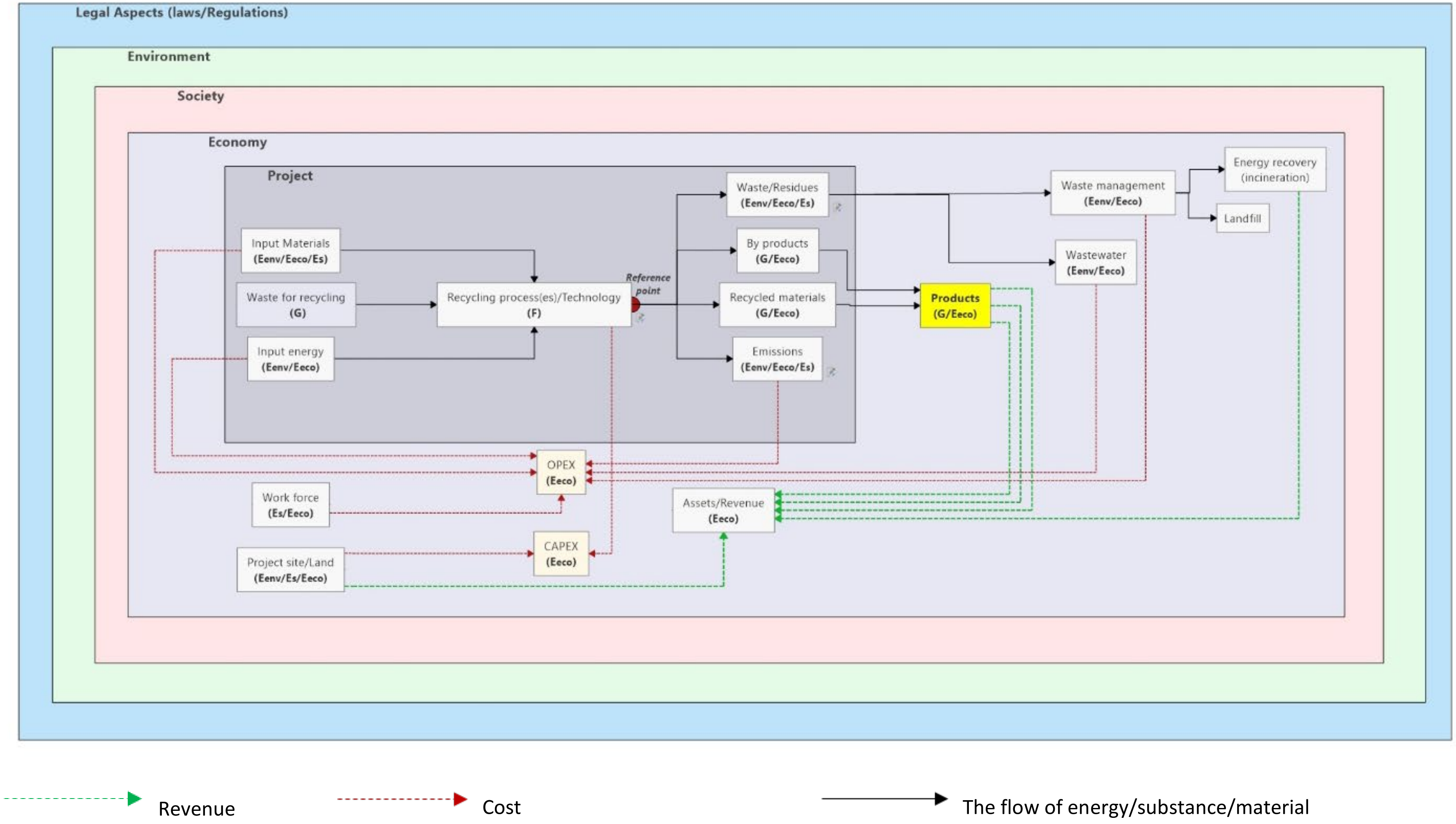


Figure 20: An exemplary outline of the scope of work for a recycling project

This principle enables us to consider a project from different perspectives and different sizes. Looking at a project on a regional or country level is equivalent to looking at a large system with many subsystems. In consequence, the summary of all these subsystems provides a bottom-up view of the whole system. This approach offers the potential for a more nuanced assessment with insights into the specifics of the project. The contribution of the actors involved and their interactions can be considered as well. Taking a top-down view from a higher-level perspective (regional or national) helps to understand the big picture, from policy to economics to businesses and partnerships. However, this also means a reduction in the detail of information available for the subsystems.

4.7.2 Method

In this part, the procedure for development of case studies and also the procedure for application of UNFC on a national level are presented, which also includes the method suggested for linking UNFC other WPs.

Procedure to develop the case studies

A systematic approach with seven stages is proposed to record the status of a project. It views a project as part of a system. A potential project topic could be exploring the recoverability of a single or several SRMs in a specific stock such as a tailing storage facility, or in a recycling facility with or without considering a collection system.

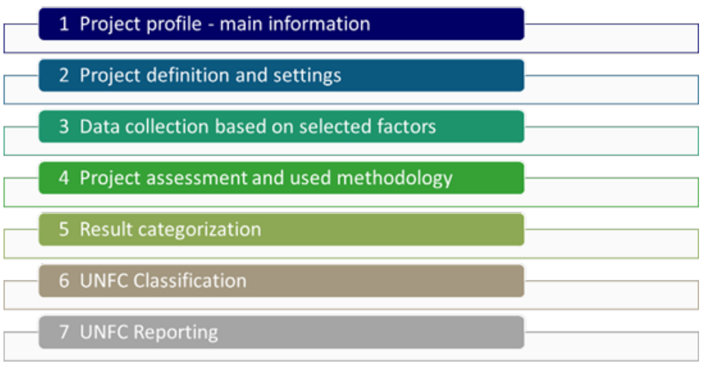


Figure 21: Seven stages for evaluation and classification of a case study

Stage 1 - Project Profile

Stage 1 includes all key information of the project, which includes two sets of data. The first set is the information that should be provided at the beginning of the procedure for project classification (Table 14), and second is the information that are collected during and at the end of the project assessment (Table 15). Project profile works as a checklist to provide an overview of the project.

- **Project title:** Description of the whole project in one sentence
- **Waste type/source**: The intended waste stream investigated in the case study within the FutuRaM project scope (BAT- WEEE – ELV – MINW – SLASH - CDW)
- **Geographical location**: position of the project on the Earth, e.g., location, city, region, country
- **Spatial level of the project:** project type in terms of being “national” or “site-specific”
- **Target SRM(s) and CRM(s):** the material(s) to be recovered

- **Contact person**: project developer or the main person as coordinator (name and contact information)
- **(Industrial) partners/contacts:** the partners who are involved in the development of the case study by different means (e.g., data collection, sampling, analysis, consultation, etc.)
- **Data quality:** the source of data used, namely, **1)** data from publications (e.g., paper, report, etc.) or provided by industrial actor **2)** sampling publicly available data that need to be updated **3)** new data sampling for the case study.
- **Lifetime of the project:** the period foreseen for the implementation project
- **Realm of Discourse:** context and condition for evaluation and classification (to be added after the evaluation and classification)
- **Estimated quantity:** the quantity estimated for the target material(s)
- **UNFC classification:** UNFC code obtained after the assessment (to be added after the evaluation and classification)

Table 15: Information for project profile at the beginning of the project assessment

Case study information	
Project title	
Waste type/source	*BAT- WEEE – ELV – MINW – SLASH - CDW*
The geographic location of the project site	*Including the spatial boundary of the project*
Spatial level of the project (commodity)	*geographical location / national or site-specific*
Target SRM and CRM	
Realm of Discourse *(to be added after the evaluation and classification)*	*context and condition for evaluation and classification (see stage 2)*
Contact person(s) / Institution	*Name / Position / email address*
(Industrial) partners/Contact	*Name / position / email address*
Lifetime of the project	*period for the project implementation*
Data quality	*available from literature (e.g., paper, report, etc.), collected data that need to be updated or new data collected for the case study*

Table 16: Information added to project profile during and after project classification

Case study information	
Estimated quantity	*Quantity estimated for the target material(s)*
UNFC classification *(to be added after the evaluation and classification)*	*EFG after evaluation and classification (stage 6)*

Stage 2 - Project definition and settings

In Stage 2, the setting of the project is defined. It serves as the basis for project assessment by UNFC; this is part of the information needed for reporting. It also provides the background information for the assessment and communication between all parties involved in the project development. Table 17 gives an overview of the seven steps with a brief explanation for each step.

Step 1: Title of the project

The title describes the whole project in one sentence. Example: "Recovery of CRMs X and Y from end-of-life magnets in company XY", "CRM X recoverable from end-of-life magnets in France".

Step 2: Terms of Reference

Terms of Reference (TOR) describes the purpose and structure of the project. It comprises four parts (Table 16):

- **Background information**: provides a brief description of the project, i.e., what are the key drivers and what problems and needs will be addressed after successful implementation ("what and why")
- **Objective(s)**: a brief description of the overall aim of the project, what is (are) the target SRM(s) and/or CRM(s), what the expectations or requirements exist or what specific benefits are expected
- **Scope of work** for the project. It specifies the activities required to accomplish the development or operation defined as the project and delineates the activities considered within the boundaries of the project. It includes the description of the system's boundary and the position of the reference point for SRM and CRM estimations.
- **Jurisdiction of the project**: government regulations that must be adhered to and/or permits obtained. It includes where it is located. A clear description of the jurisdiction is required in terms of regulations and laws and required permits.

Table 17: Terms of Reference and Its different parts

Title	Explanation
Background information	key characteristics of a project
Objective	The overall aim of the project (in terms of SMART - specific, measurable, achievable, relevant, time-bound)
Scope of the work	Required activities
Jurisdiction of the project	Requirements in terms of regulations and laws

Step 3: Realm of discourse

For the sake of comparability, resource evaluation and classification have to meet a consistent set of conditions. The "Realm of Discourse" (ROD)[7] was introduced by ESDG/UNECE to describe the context and set of conditions of a project. It establishes the baseline condition for evaluation and classification for the intended purpose and thus provides the basis for decision-making. Without knowing about the preconditions and factors taken into account in a project evaluation, the result of classification is not clear and interpretable. For further explanations, see the preamble document.

Step 4: Identification of stakeholder(s)

Although it is not mandatory for the development of the project, it is recommended to consider all potential interest groups. Directly involved stakeholders are those who are actively engaged in the development of the project; i.e., they contribute to the costs, but also to the benefits of a project. The agreement regarding project implementation is documented including the rights and interests of the stakeholders in the generated data and information. It is important to reach an agreement regarding the confidentiality of information. This has implications for the reporting document(s) developed in Stage 7. Indirectly involved stakeholders have no direct interest but are affected by the development of the project. However, their approval and broader acceptance for a project to proceed is needed. These requirements refer to the "social license" or "social license to operate" (SLO)[8], which have not yet been defined in more detail in UNECE documents.

Step 5: Level of data availability

The type of data used, its reliability, references, etc. must be recorded. All changes must be documented continuously.

Step 6: Potential risks

If certain potential risks that may cause problems in the implementation and development of a viable project (uncertainties) are known, they should be indicated at the beginning or during the course of the project.

Step 7: Scenarios

[7] 1801854 (unece.org)
[8] https://unece.org/sites/default/files/2021-02/ECE_ENERGY_GE.3_2021_6_SocEnvGuidance_final.pdf , page 4 and 5

Scenarios (simulations) can be used to optimize a project. They can serve to check the effects of the different parameters or boundary conditions. “In the context of UNFC, a scenario is a set of current and future events that are considered to describe the features of a project relevant to its potential commerciality and includes not only economics but other factors that control commerciality (access to the market, the probability of regulatory approval, etc.)”[6]

Table 18: Stage 2- Procedure to define a project – 1. Draft

Step	Topic	Definition	Intention/Implication	Example
1	Title	Subject of the project	Description of the whole project in one sentence	Li-ion recycling for the recovery of Ni, Co and Mg in Switzerland
2	Terms of Reference (TOR)	The framework and objectives of the recovery project	Background information, objective, scope and jurisdiction of the project.	The appraisal of potential existing for the extraction of Co, Ni, and Mg from obsolete Li-ion batteries (LIBs) in Switzerland in 2025 and specifying the impact of recent regulations in this regard
3	Realm of discourse (ROD)	The context and set of requirements and conditions governing the project assessment	Which aspects should be taken into account? The defined ROD has an impact on classification; based on that the UNFC class can differ. Specification of ROD as a standard default enables to comparison the results.	
4	Stakeholders	Interest groups directly and indirectly involved in the project	*Directly involved stakeholders* are those who are actively involved and are beneficiaries of the project. *Indirectly involved stakeholders* are those who are affected by the development of the project.	Project developers, Investor, governmental authorities, commonalities, people from the society, policymakers, Academia
5	Data quality	Quality of the available data/information	It determines the stage of the project’s maturity	Literature study
6	Potential risks	Preliminary risk assessment	Identify potential challenges and/or risks to project development which may hinder the project development	The dam of a tailing storage facility may fail
7	Scenarios (simulation series)	The different options for implementing the purpose of the study	Effect of different preconditions, ROD or boundary conditions on the project and its results	1. Different scenarios regarding the valorization of the products 2. Variation of specific aspects of a treatment plant 3. Comparison of different technologies to separate critical raw materials

Stage 3 – Data collection based on selected factors

Stage 3 provides a list of all the six main criteria for the three UNFC axis, factors and methods to be considered. It depends on the specifications in stage 2, in particular the ROD. The list ought to be completed using the available information. It comprises the documentation of the data, information in the form of figures or text.

Stage 4 - Project assessment and used methodology

Stage 4, project assessment, includes the documentation of methods and the sources used to evaluate the factors. It comprises the evaluation and interpretation of the data and information provided in Stage 3.

Please keep in mind that the project assessment only reflects a momentary snapshot. As the project evolves, it may be necessary to reassess and reclassify.

Stage 5 – Result categorization

In Stage 5, the results obtained in Stage 4 are converted into categories according to the UNFC principles. On this basis, the potentials and barriers as well as the drivers of a project can be identified.

Stage 6 – UNFC Classification

In Stage 6, all the different factors have to be rated to come up with a common UNFC code. The principle to be used has to be developed. It will mainly depend on the principles of a decision tree.

Stage 7 – UNFC Reporting

Reporting presents the results of the case study. It includes the TOR and ROD, the principles for the evaluation which could be part of the standardization or are based on the agreements established in Stage 2. Depending on the complexity of the project and the specific needs of the stakeholders involved, different reports can therefore be developed, e.g., to meet the requirements for confidential data.

UNFC application on a national level

UNFC is a project-based and principle-based system. It was originally aimed to be used for projects at company (site-specific) level. Recently, it is considered that UNFC can also be adapted for diverse national and regional requirements. Within the ORAMA project, Tom Bide of British Geological Survey proposed how UNFC can be used to inventory primary materials and mining projects at a national level by taking a bottom-up approach. Figure 21 shows the result of the UNFC bottom-up application for the UK case. Each individual project requires a data set. Every row represents a particular material as the main output of the intended project. The columns show for each extractable quantity the respective category of the E-, F-, and G-axis and the resulting UNFC class of the project. This principle can be used for stocks, e.g., mining waste or slag and ashes.

Commodity	Quantity (tonnes)	UNFC class
Ball clay	46 200 000	111
Ball clay	54 100 000	221
Ball clay	2 000 000	221+2
Ball clay	132 000 000	222+3
Ball clay	4 500 000	223
Barytes	9 000 000	111
Barytes	7 500 000	223
Brick clay	Confidential	111
Brick clay	Not quantified	221+2+3
Brick clay	650 000 000 000	344 (a)
Celestite	1 257 000	343
Celestite	3 698 000	344
Copper	5	221
Copper	16 671	222
Copper	127 045	223
Copper	594 000	322
Copper	59 498	333
Crushed rock aggregates	4 500 000 000	111
Crushed rock aggregates	Not quantified	221+2+3
Crushed rock aggregates	7 000 000 000 000	334 (a)
Crushed rock aggregates	Not quantified	344
Fluorspar	4 515 000	111+2
Fluorspar	20 000 000	333
Fullers Earth	2 210 000	312
Gold	1	111
Gold	5	112
Gold	45	111+2
Gold	3	221
Gold	107	222
Gold	107	223
Gold	4	333
Gypsum	50 000 000	111+2
Gypsum	Not quantified	221+2+3
Gypsum	1 340 000 000	344 (b)
Kaolin (China Clay)	Confidential	111
Kaolin (China Clay)	Not quantified	221+2+3
Kaolin (China Clay)	245 000 000	223 (a)
Lead	46 085	222
Lead	60 064	223
Lead	728	333
Lithium	3 300 000	333
Lithium	Not quantified	344
Mica	Not quantified	334
Mica	93 000 000	344
Nickel	51 300	333
Offshore sand and gravel	349 570 000	111+2
Offshore sand and gravel	Not quantified	221+2+3
Offshore sand and gravel	13 600 000 000	223
Offshore sand and gravel	77 200 000 000	333
Offshore sand and gravel	506 200 000 000	334
Onshore sand and gravel	761 000 000	111
Onshore sand and gravel	Not quantified	221+2+3
Onshore sand and gravel	2 460 000 000	333
Onshore sand and gravel	47 750 000 000	334 (a)
Phosphate rock	2 201 420	343
Polyhalite	248 000 000	112
Polyhalite	39 000 000	221
Polyhalite	793 000 000	222
Polyhalite	2 450 000 000	223
Polyhalite	282 700 000 000	334
Potash	640 000	211
Potash	11 500 000	221+2+3
Potash	7 600 000 000	334
Salt	4 000 000	112
Salt	Not quantified	221+2+3
Salt	2 000 000 000 000	334 (a)
Silica sand	62 000 000	111
Silica sand	40 000 000 000	334 (a)
Silver	21	111+2
Silver	4	221
Silver	130	222
Silver	87	223
Silver	2	333
Talc	Confidential	111+2
Tin	8 910	211
Tin	1 560	212
Tin	8 000	221
Tin	35 550	222
Tin	25 800	223
Tin	32 400	334
Tungsten	56 430	211
Tungsten	11 700	212
Tungsten	71 820	221
Tungsten	29 920	222
Tungsten	121 240	223
Tungsten	65 520	223
Zinc	88 376	222
Zinc	101 659	223
Zinc	21 200	333

Figure 22: Result of UNFC bottom-up application for primary resources in the UK[9]

However, when it comes to the extraction of materials from anthropogenic sources and inventory of secondary raw materials (SRMs) of end-of-life materials, the available data are typically on a national or regional level. Materials flow analysis (MFA) is the commonly used tool to show the amount of waste, its composition and the resulting products in terms of stocks and flows. The question is whether the UNFC can also be applied in such cases, i.e., is it possible to assign the appropriate UNFC classes to a specific type of waste estimated on a national level? The expected outcome of such an approach is shown in Figure 22. It illustrates what portion of a specific material existing in the waste is or can potentially be recovered by projects with different UNFC classes and levels of maturity.

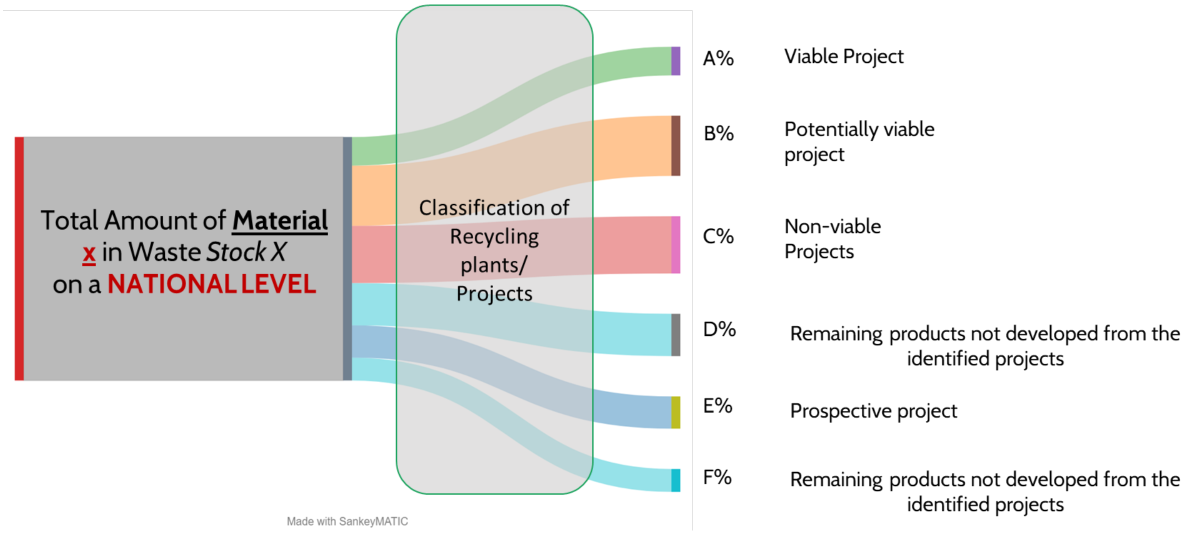


Figure 23: The outcome expected of UNFC classification on a national level

We developed a conceptual framework that connects the information provided by different working groups to the principles of the UNFC. The result is a modified version of the bottom-up approach

[9] https://unece.org/sites/default/files/2021-04/03_Tom_Bide_UK_UNFC_Case_study_0.pdf

described previously by linking the data of individual recycling projects representing different maturity levels with the data available at the national/regional level on waste flows and their compositions.

The conceptual framework consists of three main parts, as shown in Figure 23: on the left, (1) represents a database containing the amount of waste and its compositions calculated on a regional/national level (output of WP3 and WP4). On the right side, all projects represented by different treatment facilities are shown; the respective database (3) provides the needed information regarding the recycling and recovery processes. These databases are interlinked in the middle part by the UNFC with the different classes.

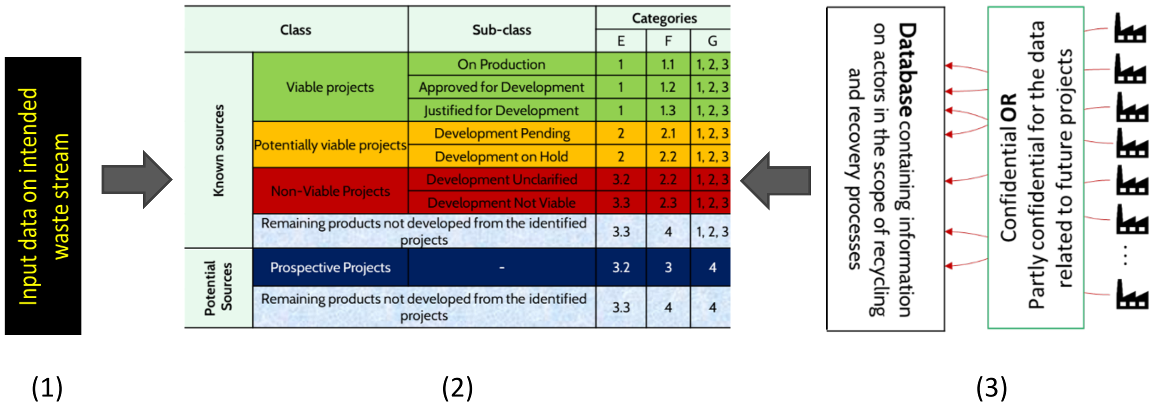


Figure 24: The conceptual framework for the application of UNFC

The structure of the two different databases is explained in the following. The database (1) related to waste streams (left side in Figure 23) is the one being developed through WP3 and 4. It contains data on target wastes in the FutuRaM project, including BAT, ELV, SLASH, WEEE, CDW, and MINW, their components, materials, and elements. It should be noted that the conceptual framework will be on different levels corresponding with the database structure designed by WP3. The dataset (3) on the right side in Figure 23 is related to the materials to be recovered from the respective waste stream by the recycling plants and projects. In total, this data covers the total capacity provided by the companies and projects. As for the national case the database will be developed on a national scale. Hence, the total amount of waste stock and/or flow and its compositions will be assessed with respect to the data related to projects in the recycling scope of intended waste. These data can be linked with the procedure developed under WP5, presented in Figure 23 with the middle part representing UNFC. This principle also offers the possibility to use the future results of the different scenarios developed in WP2 as input data for the calculations.

Table 18 shows a hypothetical example of a database (3) for batteries in the existing recycling plants in a country. It contains a list of the recycling plants with an annual capacity to treat a target waste type including the product amount of the target elements and/or their recycling efficiency. Based on the maturity level of the projects they can be classified and summarized to provide the total capacity regarding the respective UNFC class. The example in Table 18 shows an overview of all viable projects for treating batteries in a country X with a total capacity of 50,000 tons. They are classified as UNFC class E1F1G1,2,3 since they are at operation. It is worth mentioning that the capacity also can be specified in terms of material recovery, depending on the information collected from the recycling plants. It is the case about all databases described.

Table 19: Database for the existing recycling plants in country X for Waste Stream x (example for BAT) and recovered materials

	Waste type	Annual capacity (ton)	Target materials	Product quality	Recycling efficiency
Recycling plant 1	LIB (NMC)	5,000	Li		70%
			Ni		90%
			Co		90%
Recycling plant 2	Lead acid batteries	8,000	Acid		
			Plastic		
. . .					
Total $\sum(\text{ Capacity})$		50,000	E1 F1.1 G 1, 2, 3 (Viable projects on production)		
Total $\sum(\text{ sum of recovered material (e.g., Li, Ni, Co)})$		………			

Similarly, the capacity of all projects planned or under construction can also be summarized, as shown in Table 19. As observed, it is possible to calculate the total capacity of projects with the same UNFC class through the database. Thus, the capacity to manage the intended waste is estimated, which provides an important insight for the waste management on a national level. Furthermore, the database also makes it possible to estimate the capacity existing for recycling and recovery of a specific part of the waste. For instance, if the goal is to find the capacity for recycling LIBs, it is possible to filter out the data and show what portion of spent LIBs can be recycled with projects with different classes.

Last but not least, the database has the potential to illustrate the capacity existing on a national level for the recovery of materials within the waste. It all depends on the data provided about the related projects and recycling plants. Thus, the word "capacity" in the colored rows can be related to the amount of waste, a specific part of the waste, and/or a distinct material recovered from the waste stock.

Table 20: Dataset for future recycling plants planned or under construction in country X for Waste Stream x (example for BAT)

<table>
<tr><th></th><th>Target waste</th><th>Annual capacity (ton)</th><th>Target materials</th><th>Recycling efficiency</th><th>Product quality</th><th>UNFC classification</th></tr>
<tr><td rowspan="3">Recycling plant project 1</td><td rowspan="3">LIB (NMC)</td><td rowspan="3">5,000</td><td>Li</td><td>70%</td><td></td><td rowspan="3">Ex Fy Gz</td></tr>
<tr><td>Ni</td><td>90%</td><td></td></tr>
<tr><td>Co</td><td>90%</td><td></td></tr>
<tr><td rowspan="2">Recycling project plant 2</td><td rowspan="2">Lead acid batteries</td><td rowspan="2"></td><td></td><td></td><td></td><td>Ex Fy Gz</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>.
.</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="6">Class $(E1F1.2G1,2,3)$ = $\sum(\text{Capacity})$ (Projects Approved for Development)</td><td></td></tr>
<tr><td colspan="6">Class $(E1F1.3G1,2,3)$ = $\sum(\text{Capacity})$ (Projects Justified for Development)</td><td></td></tr>
<tr><td colspan="6">Class $(E2F2.1G1,2,3)$ = $\sum(\text{Capacity})$ (Development Pending)</td><td></td></tr>
<tr><td colspan="6">Class $(E2F2.2G1,2,3)$ = $\sum(\text{Capacity})$ (Development on Hold)</td><td></td></tr>
<tr><td colspan="6">Class $(E3.2F3G4)$ = $\sum(\text{Capacity})$ (Prospective Projects)</td><td></td></tr>
</table>

This principle enables to classify those sections of the waste stream which is not recovered. As shown in Table 20, both, remaining products not developed, e.g., they are still in the use phase (E3.3 F4 G1,2,3 – E3.3 F4 G4), and materials whose development is unclarified, e.g. dissipative losses, or brought to a landfill, (E3.2 F2.2 G1,2,3 – E3.3 F2.3 G1,2,3) can also be addressed.

Table 21: UNFC classification for parts of the waste considered as not recoverable or related to future projects

UNFC Class	Part of waste assigned to the intended class
E3.2 F2.2 G1,2,3 (Development Unclarified)	Part of materials mixed with other materials, dumped in the landfill
E3.3 F2.3 G1,2,3 (Development Not Viable)	Part of the products considered as dissipative loss, not collected, exported to other countries, lost in the course use or collection
E3.3 F4 G1,2,3 (Remaining products not developed from the identified projects)	Part of products in the use phase
E3.3 F4 G4 (Remaining products not developed from the identified projects)	Part of the products in use phase with very low certainty on the estimation about their quantity

The data collected through the databases explained above, can give an overview about different aspects of waste management and material recovery on a national level. Figure 24 is an example demonstrating how total amount of waste estimated on a national level can be covered by projects with different UNFC classes. With regard to the insights that such outputs can provide, they can be of high importance for utilization for a business model. The information on the right side of Figure 24, can be interesting for government and national authorities since they can get an overview of projects with different classes for recycling the intended waste stream, and accordingly, they can manage the projects existing in this regard. On the other hand, the information on the left side can provide valuable insight for different actors who have a role in recycling and recovery of the waste in question, including waste collectors and recycling companies because they can get a general idea on the hotspots and develop their future plans accordingly. Therefore, the suggested conceptual framework has potential for exploitation in a business model.

It is worth mentioning that the input data about the waste can also come from the future scenarios developed in WP2. In that case, it is possible to make comparison between the capacity required for recycling and recovery of SRM and CRM existing in the waste in question and the existing capacity existing on a national level or regional level through projects with different UNFC classes

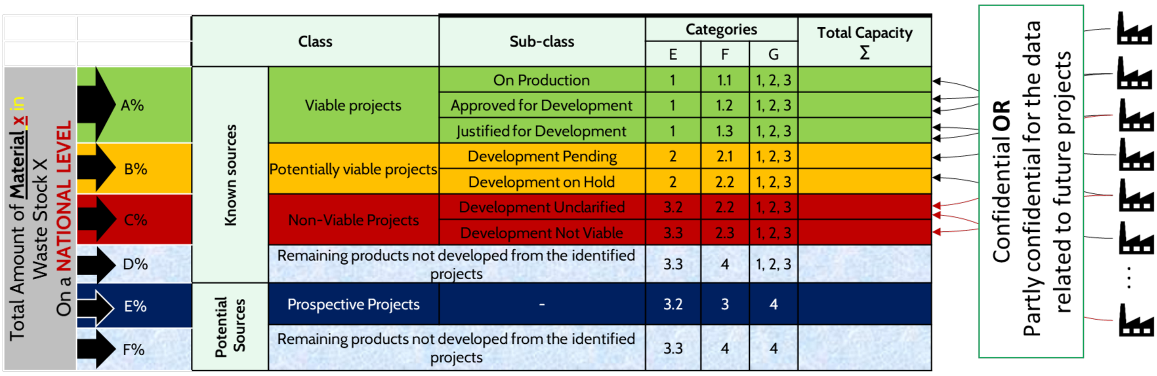


Figure 25: The outline of the recycling and recovery capacity for material x from the waste stock X on a national level through projects with different classes

4.7.3 Next steps

The procedure developed for case studies, aligned with UNFC, will be presented and shared with colleagues in WP5 and people involved in case studies to get their feedback. Concurrently, the procedure will be tested with one of the case studies. Regarding the UNFC application on a national level, the conceptual framework developed in this regard will be presented to colleagues (in the next WP1 meeting or in the FutuRaM consortium in Berlin) to show how WP2, 3 and 4 can be linked to WP5. It is also will be tested with one the case studies to evaluate its practicality. The next steps are summarized in Table 21.

Table 22: Current situation and next steps - UNFC integration

Topic/ Content	Not available	Draft	Finalized	Next Steps/Reference to other FutuRaM reports and deadlines
5.1.6 - Draft framework for the assessment (including 7 stages for development of case studies &		x		- Discussing the draft framework with colleagues in the FutuRaM - (If needed) Modification of the framework

UNFC application on national level)				- Feeds 5.1.4 (pilot case study - site specific) & 5.1.5 (pilot case study - national)

4.8 Secondary Raw Material and Waste Treatment Model in FutuRaM

The term Secondary Raw Material is essential for the FutuRaM project as the main aim of the project is stated in the GA as "[…] develop knowledge on the availability and recoverability of secondary raw materials within the European Union, with a special focus on critical raw materials […]".

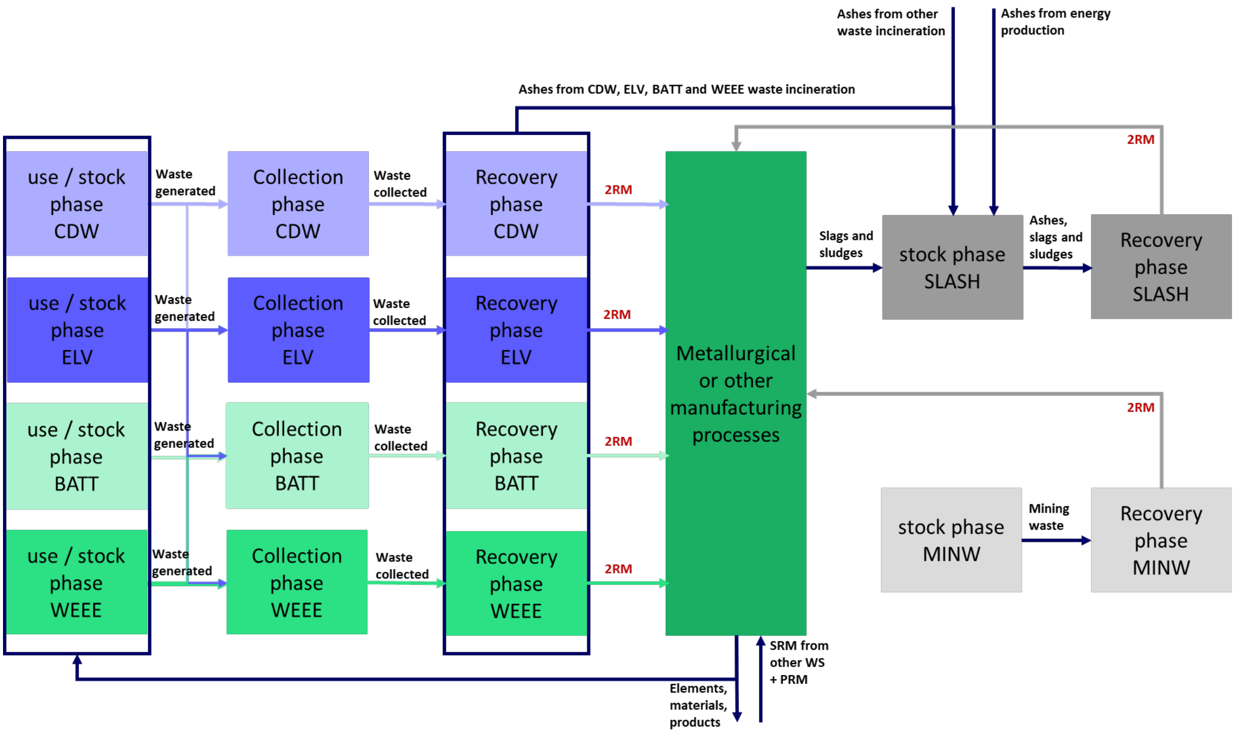


Figure 26: Overall FutuRaM system description, including system points where secondary raw materials (2RM) arise

Figure shows the overall FutuRaM system description from the use phase of the products from CDW, ELV, BATT, and WEEE, over the collection and recovery process steps for these post-consumer waste streams. After the recovery phase 2RM enter the refining step, which can be a metallurgical or another manufacturing process (e.g. plastic manufacturing). This refining phase produces a product, e.g. a metal (alloy) as well as slags and sludges, which are, together with ashes from incineration processes. In the recovery phase, covered by the waste stream SLASH. These slags, sludges, and ashes are processed in a recovery phase and subsequently also feed 2RM back to the refining phase. The sixth system point where 2RM arise is after the recovery phase of MINW.

4.8.1 Concept

The Waste Treatment Model goal is to quantify the present and future availability of 2RMs and CRMs arising from the six WS in the scope of the project under three future scenarios (BAU, circularity, high recovery). It integrates the outputs of individual stock and flow models from the product centric waste streams, i.e. BATT, CDW, ELV and WEEE, with MINW and SLASH (see Figure 26). This model is based on the depiction of the waste treatment processes represented in the WS flowcharts, and includes the main steps of the waste treatment process (e.g. dismantling, shredding, mechanical separation, smelting/refining etc.).

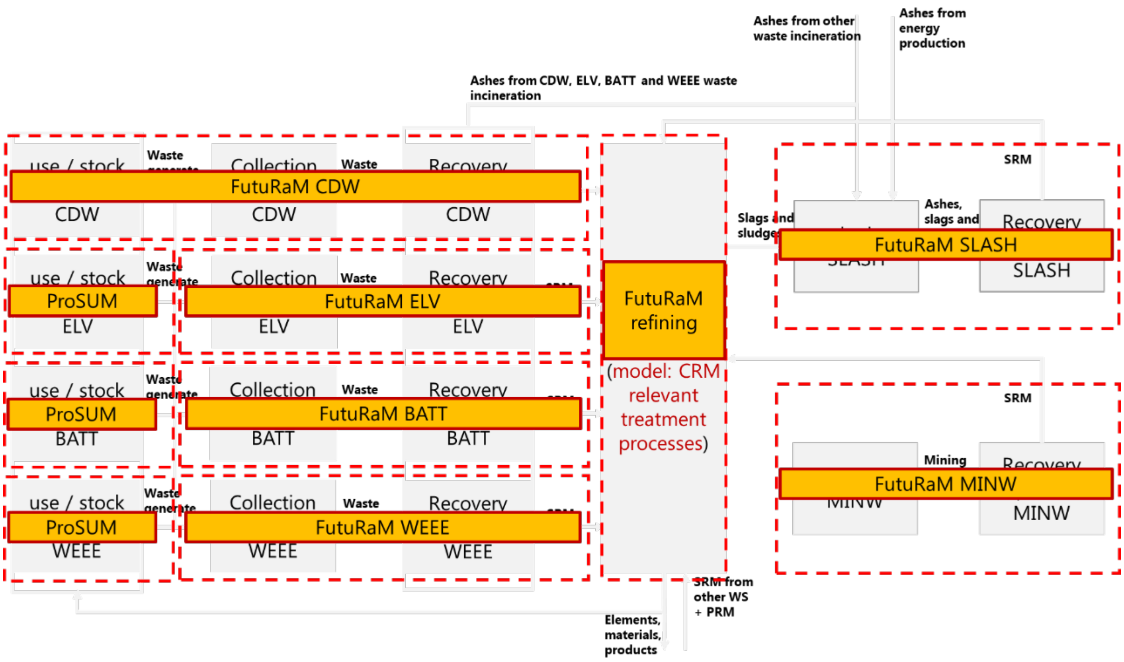


Figure 27: Concept of the Waste Treatment Model

The model should be flexible enough to handle the most common waste treatment pathways of any WS, and to accommodate all changes and implications deriving from the three future scenarios foreseen. For example, out of the total laptop which undergo waste treatment, part of them will go to a dismantling process (e.g. 50%) which as a first step of recovery ensures a better performance, while the rest will go directly to shredding, reducing the efficiency of the recovery process. This percentage could be considered to increase when looking at future scenarios of circularity and recoverability (e.g. 80% of the laptop going to dismantling).

Key building blocks of the Waste Treatment Model are the transfer coefficients, which are used to represent recovery pathways (distribution of flows) and recovery efficiencies (rates). These transfer coefficients depend on several factors, such as the inflow/outflow type, the process source/target, the time of reference and the scenario. The inflow and outflow type can include transformation of flows between different hierarchical levels (e.g. transformation of a product into a material). Thus, transfer coefficients should be aligned with the list of possible levels from the composition data of products-centric waste (WP3), the present recovery technologies, the future recovery technologies (see chapter 4.6), and the possible recovery rates development defined in each scenario (WP2).

The Waste Treatment Model for the FutuRaM project will be developed within WP4, synergizing with WP3 and leaning on the contributions and guidelines of all WS, and it will be then made available to all

WS for their independent use. The contributions and guidelines expected from the WS revolve around the mapping of the inputs and output flows and the transfer coefficients, which should reflect both for the current situation and for the three possible future scenarios. Also, to ensure consistency, the model should base on a list of flows and recovery processes which is harmonized among the WS. Within list, all 2RM in FutuRaM are covered. One relevant issue is the prevention of double counting for all data processing and modelling steps. This will be prevented by tagging the flow information (on composition as well as on amounts) with the location in the system.

An example carried out and prepared by VITO on the example for Sc in WEEE and SLASH can be found in Annex 7.5.

4.8.2 Method

The model is based on determined system of linear equations. In this system, known variables are both the inputs of different WS into the Waste Treatment processes and transfer coefficients, whereas unknown variables are intermediate flows between processes in the recovery chain and the output of the flows (2RM/CRMs). The inputs of product centric WS include waste generation of products (but also components, materials, and elements embedded), whereas the transfer coefficient dictates the separation of these inputs throughout the recovery processes. Figure exemplify the conversion of the data inputs of slag production into a system of linear equations. By respecting the principle of mass balance, the sum of inflows in each process must be equal to the sum of the outflows in each process. Additionally, new equations are added to the system via transfer coefficients that represents the relationships between flows in a process. The system is solved using linear algebra so all unknown flows can be determined.

All the data that will be feed into the model (i.e. input flow data and transfer coefficients) should also contain a data quality information. Data quality information will range from 1-4 (1 being the highest quality and 4 being the lowest see Chapter 4.3), in line with the data quality assessment proposed for the whole FutuRaM project and for the UNFC (G-axis) (see Chapter 4.7). The model should be able to track which data points, with their respective data quality information, were used as input to calculate a 2RM output. As a result, the 2RM output will have an overall data quality information associated too, which will derive from the combination of the data quality of the input data. The method for this combination can be as simple as an average of each data quality. This can be useful for the UNFC framework analysis that will be conducted in WP5.

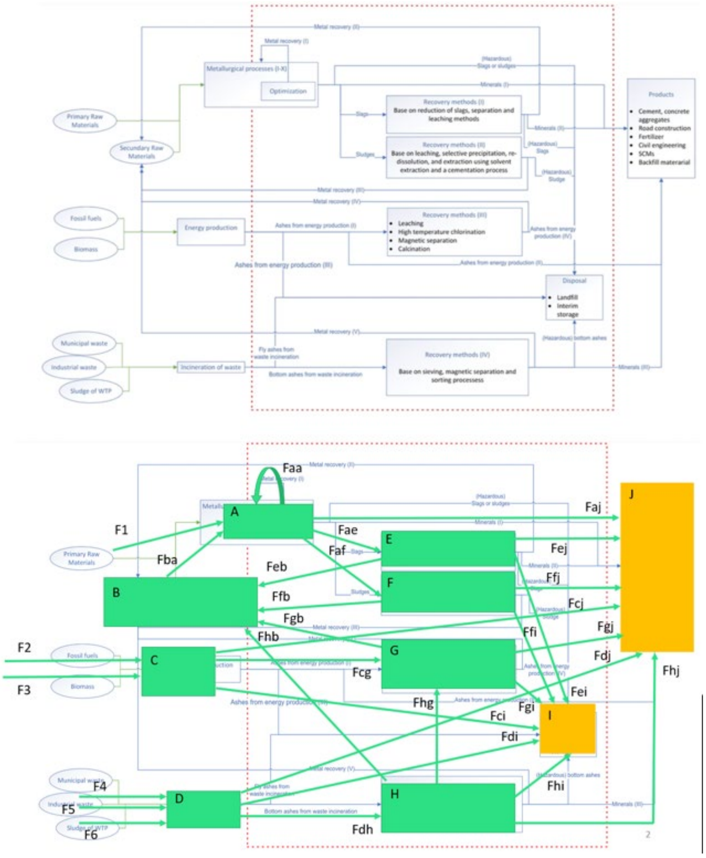


Figure 28: Model representing the slag production. Processes are identified by capital letters (A-J) and flows by letter F combined with numbers (if entering processes) or letters (if connecting process).

Approach

	In	=	Out
A:	F1 + Fba	=	Faj + Fae + Faf
B:	Feb + Ffb + Fgb + Fhb	=	Fba
C:	F2 + F3	=	Fcg + Fci + Fcj
D:	F4 + F5 + F6	=	Fdh + Fdi + Fdj
E:	Fae	=	Feb + Fej + Fei
F:	Faf	=	Ffj + Ffj + Ffb
G:	Fcg + Fhg	=	Fgi + Fgj + Fgb
H:	Fdh	=	Fhb + Fhg + Fhj + Fhi

Faj = taj(F1 + Fba)

Fae = tae(F1 + Fba)

Faf = taf(F1 + Fba)

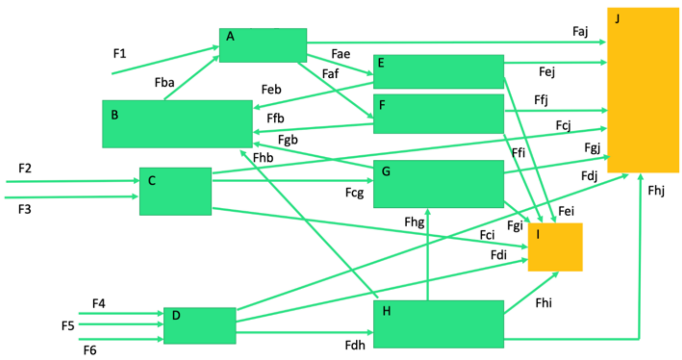


Figure 29: Linear system representing mass balance principle (sum of Inputs = sum of outputs) in each process. Process A depicts conversion of flows F1 and Fba Into Faj, Fae, Faf with transfer coefficients taj, tae, taf.

4.8.3 Next steps

From an operational perspective, the model will be first developed through a simplified “toy” version, which will allow to identify the main features needed. The toy version will be tested and refined during Q3 and Q4 of 2023, while 2024 onwards will be dedicated to the development, improvement and upgrade of the final model.

At a later stage in the project (T3.3, starting in month 19), the FutuRaM project will tackle the task to develop a method to assess the recoverability of the 2RM, on the basis of material Information, grades, and refining requirements. This is already prepared in the data collection of composition data within WP3 (see Table 22).

Table 23: Next steps for the FutuRaM Waste Treatment Model

Topic/ Content	Not available	Draft	Finalized	Next Steps/Reference to other FutuRaM reports and deadlines
Program/test toy model		X		Proposed timeline: Month 12 - 17 This will involve 4.2, 4.3
Harmonization of codes list (flows/stocks/processes/levels/2RMs)		X		Proposed timeline: Month 12 - 16 This will involve WP3+WP4
Transfer coefficients • Template development • Data collection • Gap filling procedures and consistency checks	X			Proposed timeline: Month 12 - 27 This will involve WP3 + WP4 (and inputs from each WS)
Improvement and run of the final model	X			Proposed timeline: Month 18 - 33 Ready for the WP4 Deliverable 4.1 (Month 36)

5 Data model, knowledge base and data delivery portal

Data modeling is not an independent task, but an action at the heart of the project. It is constrained by the data delivered to it (here by each of the waste and flows, and also by the data delivery needs: i.e. interoperable data provision services, and the final delivery (FutuRaM data portal).

The BRGM has hold several internal workshops with waste and flows, and in particular with UNITAR to identify what is expected from WP6.

5.1 Data portal

The first question that arises is ‘for whom do we design the portal?’, and also ‘what do we want to find there?’. WP6 has organized internal stakeholder meetings and the project management has contacted DG Grow in this regard. WP7 (communication, dissemination, exploitation) has an important contributing role in this area. In particular, it has begun to identify stakeholders to discuss the expectations of project third parties.

However, at this stage of the milestone, we are taking the following working options, which may be revised with regard to the contributions of WP7: the portal must be interpretable, usable by citizens, intermediary bodies (journalists, local authorities, etc.) and by the European Commission. The option is therefore to provide integrated data, by country, sector, materials, flows and scenarios.

This option is compatible with the functional obligation and by legal place not to be able to identify the actors who shared their data. Some scientists, or intermediary bodies, might want to download finer and anonymized data. Finally, the question of authentication and therefore of the marking of certain data with a level of authorization to consult them is not yet decided by the project, but its implementation must be permitted by the technical design of the model and the gate.

In conclusion, at the time of this milestone, we think it reasonable to expect from the data model: data (materials and objects) from the model must be integrated (or accumulated) by stock and flows, by country, and by scenario. Authentication must be possible. This preliminary conclusion means that FutuRaM data model does not need to include all detailed information but integrated ones. The data shall be available with respect to internal standards are FAIR data, independently of the portal.

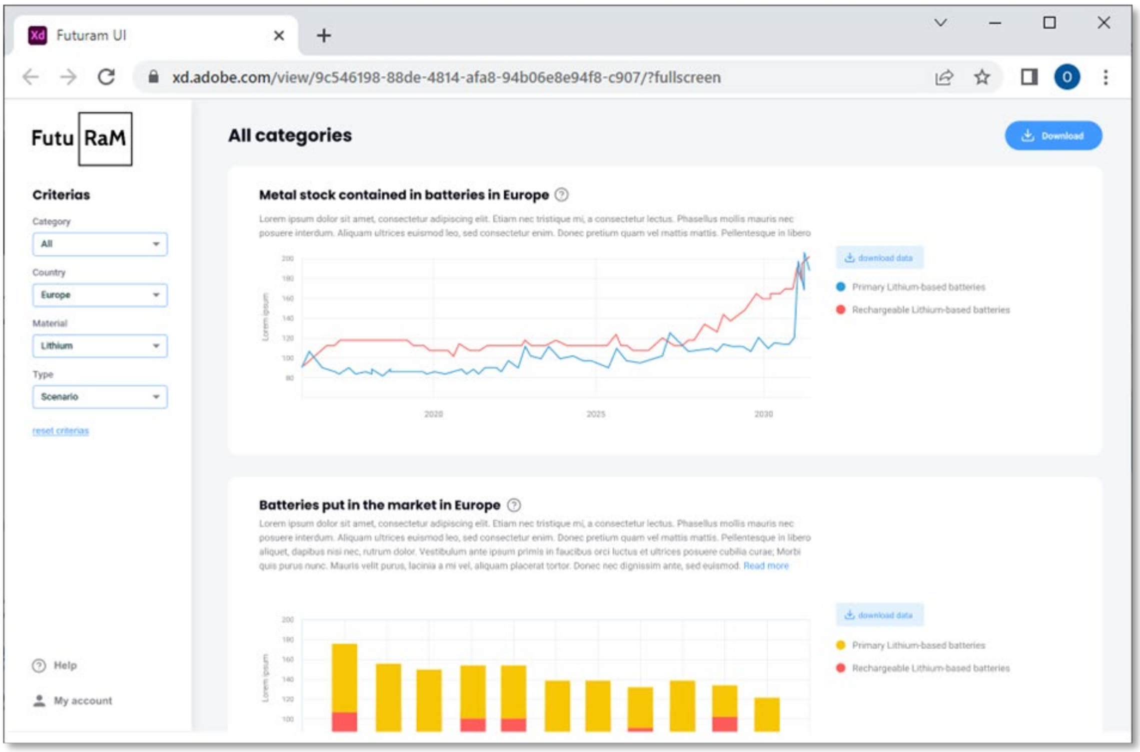


Figure 30: Tentative portal delivery

5.2 Data delivery to the database

The second constraint, after the use of data, and the delivery of data from stock and flow calculation (WP4). The functional aspect of the FutuRaM information system being inspired by that of the PROSUM project, it is then necessary to look at what was done then.

The most detailed data was then handed over to the project partner who was in charge of consolidating it (GEUS, Denmark). This one made the integration (products, materials, countries, stock and flow) and delivered them in the form of DUMP (binary copy) of the database to the actors of the information system. These then made the direct extraction to distribution bases. It then appears desirable, for FutuRaM, to remove the point of technical and functional complexity (the updates then took a lot of time), by allowing each waste stream stock and flow to put back in Excel/csv form, for example the stocks in Flow already integrated. The discussions that WP6 has organized with the stock and flows tend to confirm the feasibility of this option, and the possibility of carrying it out, either by the suppliers of the stocks and flows, or by the WP5 which on this project is responsible for the data reformatting.

As far as vocabularies are concerned, several cases should be distinguished:

- for mining wastes Geo-ZS provides the vocabularies and models from MIN4EU data model to be used at European level on the EGDI dissemination platform
- for Batteries, vehicles, WEEE the partners in charge will provide an updated version of the vocabularies and modeling used on PROSUM
- concerning the other sectors (SLASH and CDW) are working on the definition and modeling of concepts.

More detail about vocabularies is given in previous sections.

5.3 Data model delivery

Based on the 'Data portal' and the 'Data delivery to the database' comments and conclusion, the data model shall be implemented in June and July 2023 based on the FutuRaM_Template_Output_S&F_Model.xlsx files. One can summary the plan as follows (see Figure 30)

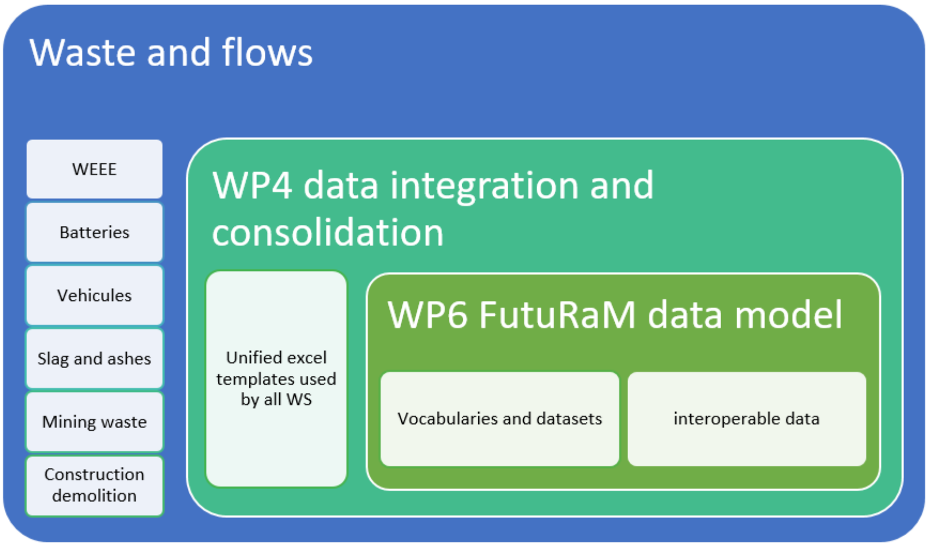


Figure 31: Data model

It is decided that Data portal is delivering mostly results from "stock & flow" calculation. Data composition collected in WP3 and used to calculate stocks should be shared with the community via scientific data repositories such as Zenodo (see Figure 31).

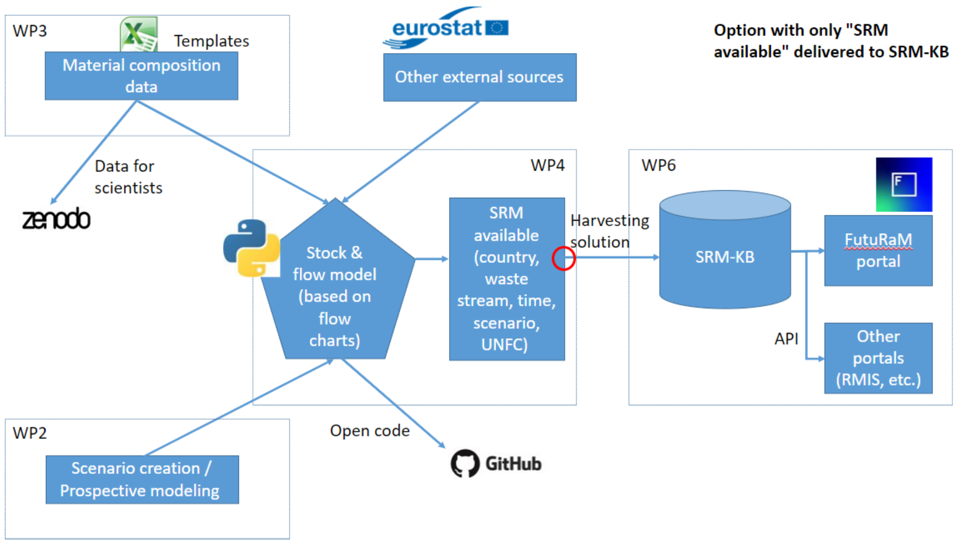


Figure 32: Overall data structure in FutuRaM

6 Conclusions and Outlook

In the second phase of Task 1.1, we will facilitate a comprehensive consolidation process, aiming to refine and strengthen the methods and concepts developed thus far. This consolidation will be guided by several important factors to ensure their effectiveness and relevance. Through this detailed and consolidation phase, we aim to create robust, practical, and stakeholder-driven methods and concepts for the FutuRaM framework.

Firstly, we will use the valuable insights gained from the practical application of these methods and concepts in the respective work packages and waste streams. By analyzing their implementation and outcomes within the different WPs, we can identify strengths, limitations, and areas for improvement. This feed-back loop will allow us to fine-tune our approaches and enhance their practicality and applicability. Secondly, we will take into account the unique characteristics of the waste streams addressed in the FutuRaM project. Each waste stream presents distinct challenges and opportunities, requiring tailored solutions. By considering the specificities of these waste streams, we can develop more precise and effective methods and concepts. Lastly, stakeholder perspectives will play a crucial role in shaping the consolidation process. We recognize that sustainable waste management requires the active involvement and collaboration of various stakeholders, including e.g. industry representatives and. Their input, expertise, and feedback will provide valuable insights and ensure that our methods and concepts align with real-world needs and expectations.

6.1 Stakeholder engagement and feedback

In order to advance the objectives of FutuRaM, it is essential to gather valuable input from various stakeholders. The inclusion of stakeholder perspectives, is carried out in Task 7.2. led by the WEEE Forum. The framework devolved within WP1 depends also on aim of the developed business plan and key exploitable results (KERs). The engagement of the stakeholder is vital to ensure that the business plan and developed KERs align with the needs and expectations of industry representatives, policymakers, and other key players in the field. Their input will provide valuable insights into the challenges, opportunities, and best practices, hence it is crucial to align the here developed draft framework in close collaboration with WP 7 (SPI and WF). By incorporating their expertise and addressing their concerns, we can enhance the relevance and effectiveness of the concepts and methods. This iterative feedback loop will help us refine our approach and ensure that the final outputs meet the highest standards. Furthermore, by this step will support identifying the required data and assessing its availability for implementing the FutuRaM framework.

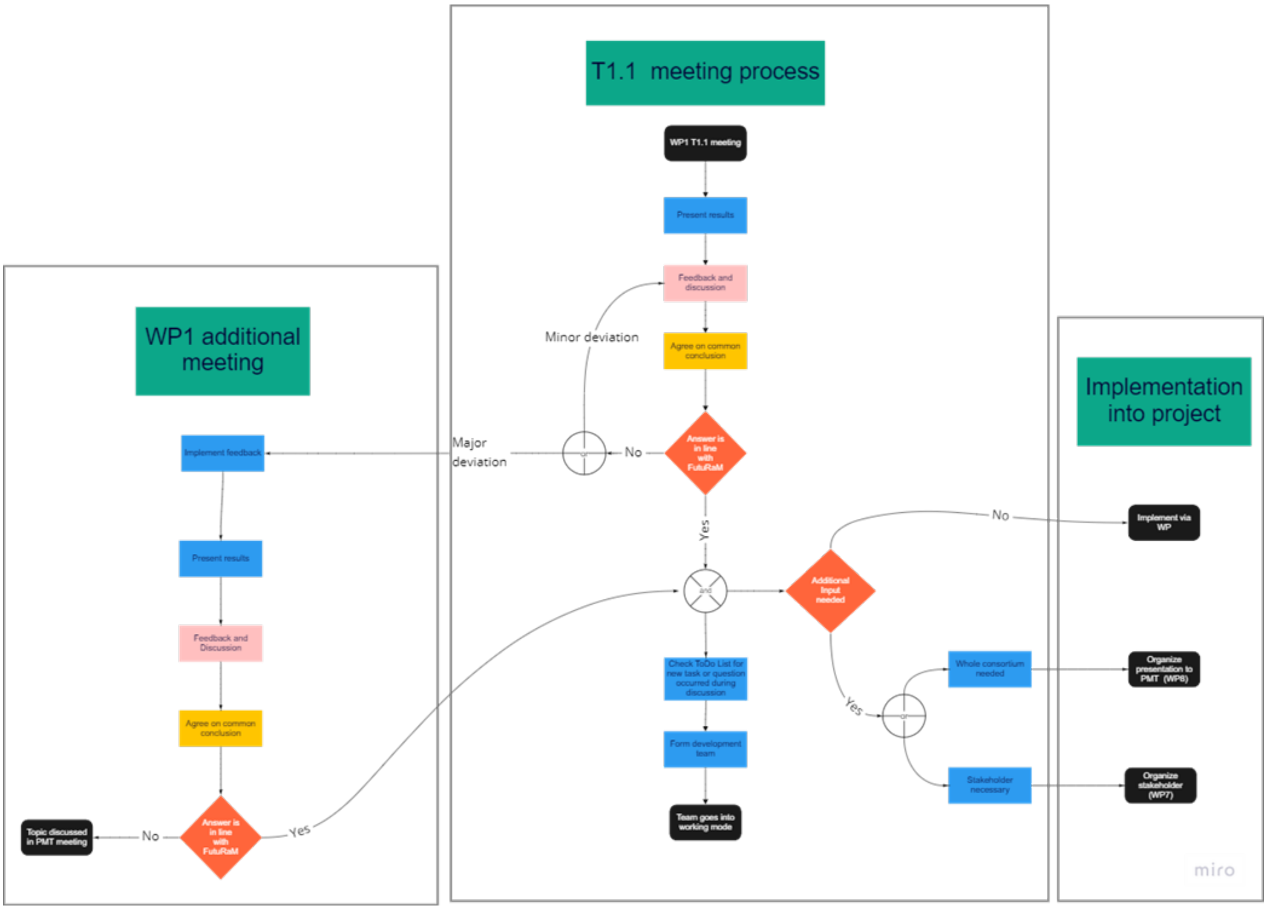
6.2 Recommendations and next steps

In order to achieve the goals set forth in FutuRaM, the next steps as outlined by the WP and task leader in the respective next step chapters need to be addressed. These steps will be closely followed up by Work Package 1 as part of the waste stream leader meeting to ensure their successful implementation.

In order to reach our goal, several key actions must be implemented. First and foremost, we need to design the concepts and methods in a way that closely mirrors the real world, ensuring practicality and relevance. It is crucial to increase efficient communication across the consortium members and further enhance our a forward-thinking approach, actively seeking innovative solutions and staying ahead of emerging trends by leveraging the multi- and interdisciplinary structure of FutuRaM. By fostering open discussion and encouraging creative thinking, we can address challenges proactively, quickly adapt to changes and harmonize this across the WP and WS. Finally, enhancing as well as stream lining effective collaboration across the FutuRaM consortium is key. Encouraging interdisciplinary teamwork and fostering a culture of cooperation will promote the exchange of ideas, expertise, and resources, ultimately leading to more robust and comprehensive framework and hence a successful overall project.

7 Annex

7.1 Annex 1 - Process



7.1.1 Description of Work

1. **Present results**

Task leader:

- Ensures time frame is kept

Development groups:

- Results from Development group is presented in an organized way answering the research questions (Template)
- Results already need to be presented to allow easy exploitation, communication and dissemination

Output: Organized results, leading to a decision document

2. **Feedback and discussion**

Task leader:

- Moderates feedback and discussion
- Ensures time frame is kept

Development team/leader:

- Documentation of the feedback and direct adjustment of the results

All meeting participants:

- Provide input and knowledge to Development group in a result orientated manner
- Feedback focuses on the results and research question
- Check if results are in line with FutuRaM approach
- Avoid repetition

Output: Knowledge and input needed to answer the research question are available

3. **Agree on common conclusion**

Tools will be used such as SWAT to make sure the best decision is being taken
Task leader:

- Moderates
- Ensures time frame is kept

Development Group:

- Used the feedback from the discussion to present a conclusion

Output: Conclusion

4. **Answer is in line with FutuRaM**

Yes: All answers are in line with the FutuRaM approach, and all questions are answered
No:

- Minor deviation and uncertainties that can be solved within the time frame go back to Step 2
- Major deviation and uncertainties --> Additional meetings needed

Task leader:

- Documents the decision

5. **Additional Input needed**

Yes: Decide on who needs to give impact and contact WP leads of WP 8 and WP 7 respectively
No: Implement output in WPs --> Development lead to make sure output is communicated, Task lead is supporting

6. **Check to-do list for new tasks or questions arising during discussion**

Group to-dos in concepts, methods, models and procedures

Task lead:

- Present to-do list

- Document final decision on next question

All meeting participant:

- Decide and agree on next tasks and questions

7. **Form Development team**

All meeting participants:

- Provide input on who could be part of the team
- Decide on team

Task lead:

- Documentation
- Support new Development team

7.2 Annex 2 - ODF Template

Key Exploitable Result: Secondary Raw Material – Knowledge Base

F

FutuRaM SRM-KB aspires to be an updated and user-friendly platform to guide all stakeholders searching for SRM and CRM information. The platform aims to present harmonised and consolidated data about SRM and CRM quantity and quality and predict future material use in the economy (EU27+4).

BACKGROUND KNOWLEDGE

Nowadays FutuRaM stakeholders find SRM available sources in portal with reports and data services like EU references portal (i.e. RMIS) or at research projects portals like UMP Panorama. Regarding to reference, documents or publications, our stakeholders find information at UNEP, JRC or in Geological surveys (i.e. researchers, industry associations and consultants). Others popular sources of data are Eurostat and National stats.

Despite lots of projects analyzing SRM availability, for most of them, the data collected doesn't considerably SRM availability, for most of them, the data collected doesn't take into consideration common classification (UNFC) and non uniformed statistical analysis. Moreover, the existing data/information is dispersed making it difficult for stakeholders, Data needs to be regularly updated and no worldwide references dataset for SRM like USGS for CRM.

DISCUSSION POINTS

1. Who could be in charge of updates, maintenance, and associated costs?
2. What type of data to provide – raw data, statistical analysis, or reports?
3. As a stakeholder what kind of services would you need? Would you be willing to pay a customised service with a specific report?

ROADMAP

Short-term - get the involvement of stakeholders representatives. Consider their suggestions into account.

Mid-term – prepare a short sample of data to be tested by stakeholders.

Long term – be a recognized KB that centalize the data on SRM to facilitate commercial exploitation.

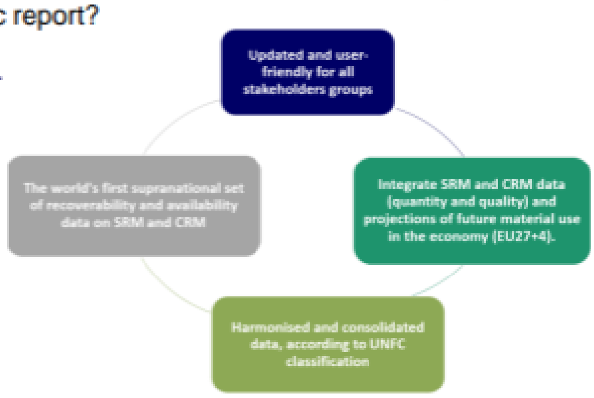


Figure: SRM-KB – unique value proposition

USEFUL LINKS

[Raw materials information RMIS Portal] [OECD material resources]

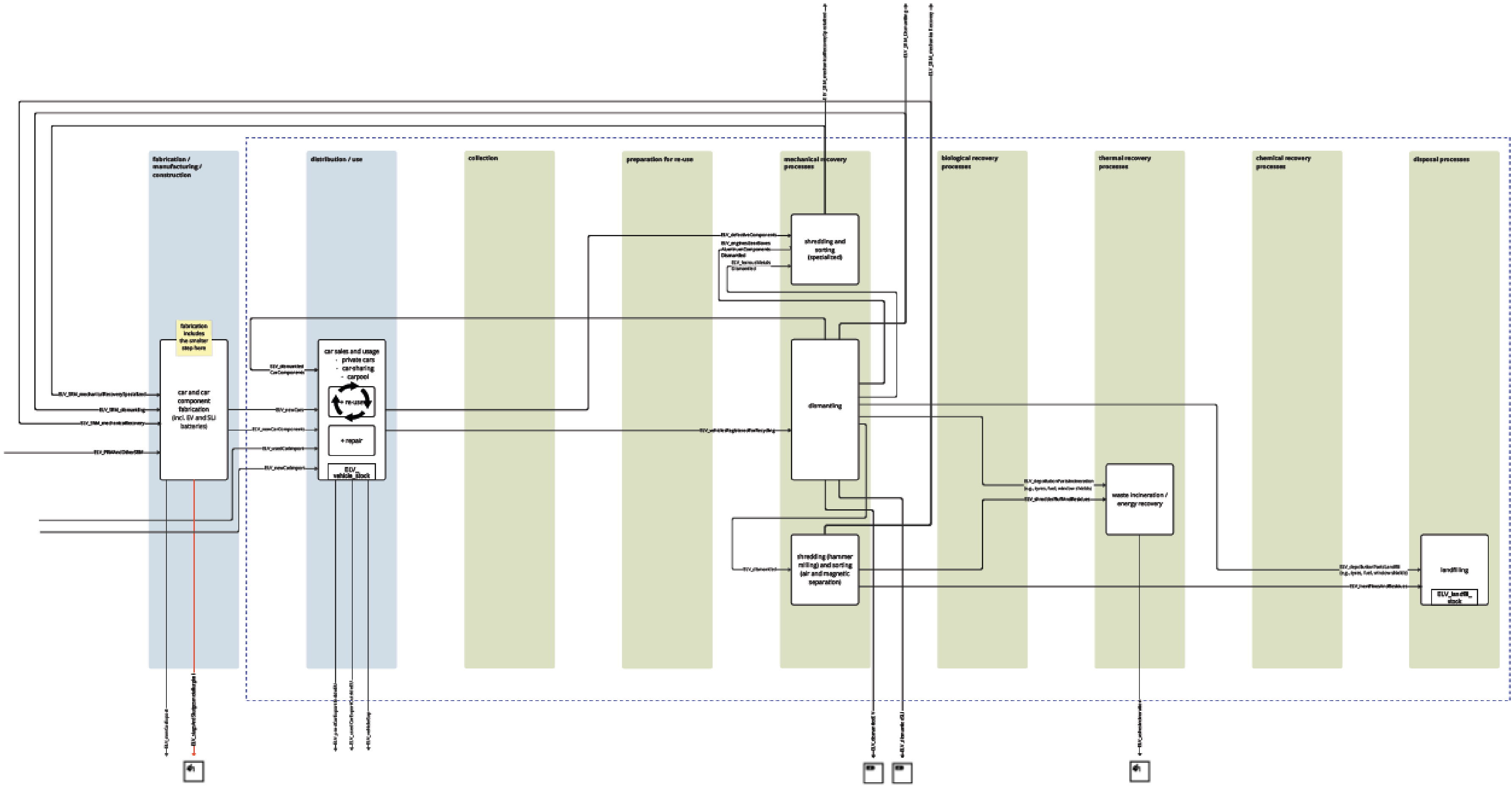
[Intraw]

ODF – 28.03.2023 WP 7

7.3 Annex 3 - Classifications

See Excel file "FutuRaM_WP1_M6_Annex_Classifications"

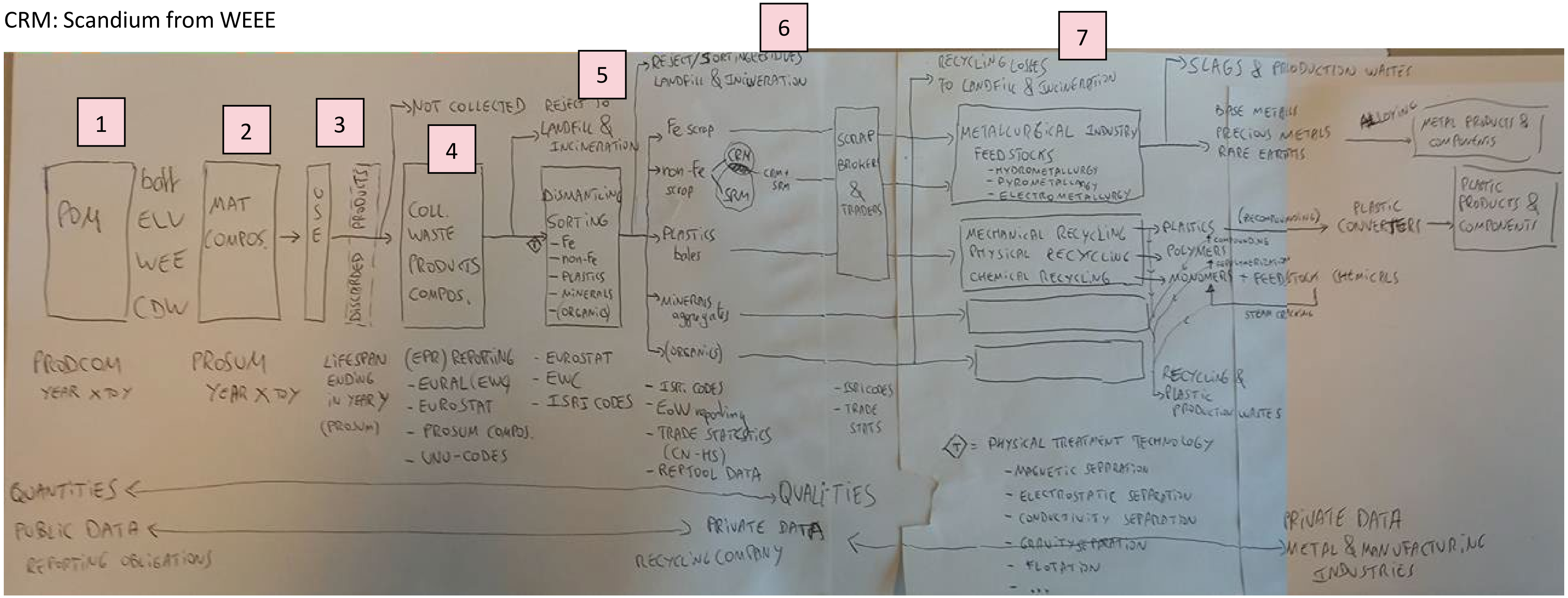
7.4 Annex 4 - Example Flowchart ELV



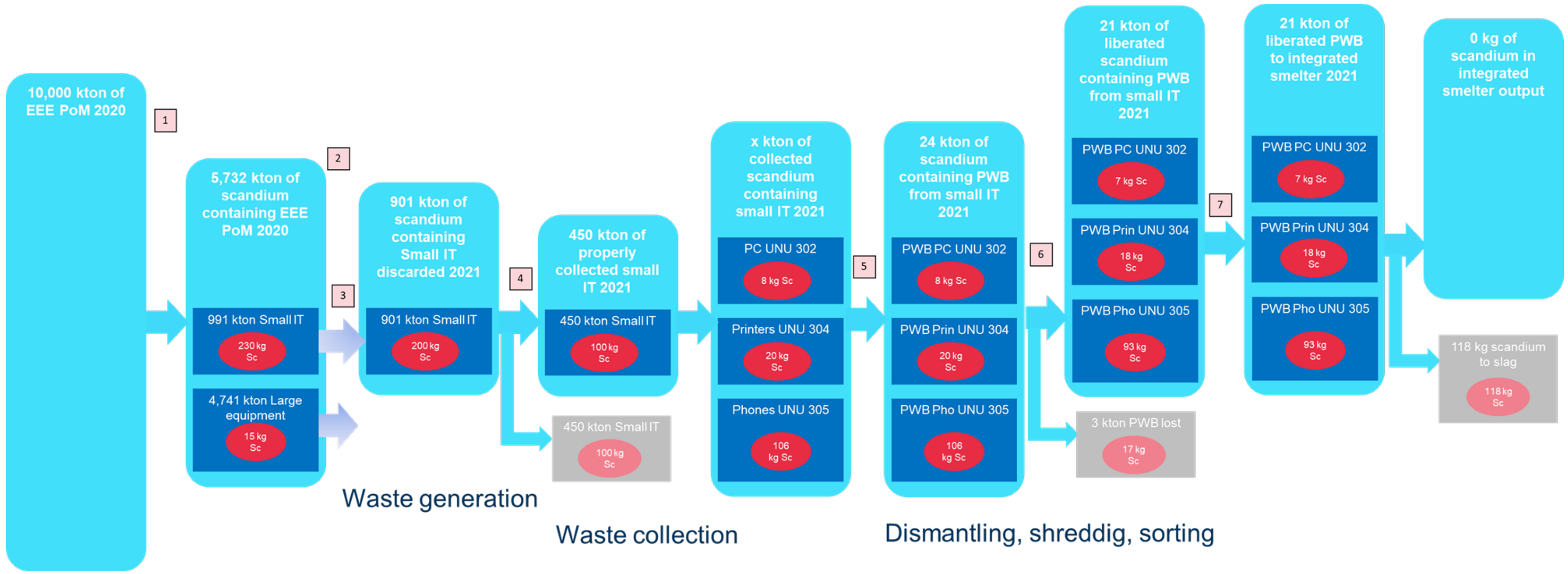
Annex 5 - Example Model Scandium

Demo exercise FutuRaM WP1

CRM: Scandium from WEEE



Note that the numbers refer to the sections here below!



10,000 kton of EEE PoM 2020
1
5,732 kton of scandium containing EEE PoM 2020
2
991 kton Small IT
230 kg Sc
4,741 kton Large equipment
15 kg Sc
3
901 kton of scandium containing Small IT discarded 2021
901 kton Small IT
200 kg Sc
4
450 kton of properly collected small IT 2021
450 kton Small IT
100 kg Sc
450 kton Small IT
100 kg Sc
x kton of collected scandium containing small IT 2021
PC UNU 302
8 kg Sc
Printers UNU 304
20 kg Sc
Phones UNU 305
106 kg Sc
5
24 kton of scandium containing PWB from small IT 2021
PWB PC UNU 302
8 kg Sc
PWB Prin UNU 304
20 kg Sc
PWB Pho UNU 305
106 kg Sc
6
3 kton PWB lost
17 kg Sc
21 kton of liberated scandium containing PWB from small IT 2021
PWB PC UNU 302
7 kg Sc
PWB Prin UNU 304
18 kg Sc
PWB Pho UNU 305
93 kg Sc
7
21 kton of liberated PWB to integrated smelter 2021
PWB PC UNU 302
7 kg Sc
PWB Prin UNU 304
18 kg Sc
PWB Pho UNU 305
93 kg Sc
0 kg of scandium in integrated smelter output
118 kg scandium to slag
118 kg Sc
Waste generation
Waste collection
Dismantling, shreddig, sorting

7.4.1 Put on Market (PoM) in 2020 – EEE with scandium embedded

EEE Put on Market

- In 2020, more than 10 million ton of EEE was put on market in the EU27.
- In 2020, scandium containing EEE that was put on market in the EU-28 + Norway and Switzerland consisted of about 991 kton of small IT and 4,741 kton of large equipment

(From ProSum publicly available data - Procom + Eurostat (CN) + composition data of various sources.)

1. DATA & INFORMATION ISSUE: It is not clear whether PRODCOM or other (combinations of) datasets are used as primary data source at

7.4.2 Material composition of PoM in 2020 – EEE with scandium embedded

Material composition of PoM

- In 2020, it was projected that about 230 kg of Scandium would be placed on the market in the EU27, contained in 'VI Small IT'; 15 kg contained in 'IV Large equipment'; and about 275 kg in total through EEE
- Between 2010 and 2020, about 2.5 Ton of scandium (250 x 10), mainly embedded in small IT and large equipment, was placed on the EU market

7.4.3 In summary, available data allow to conclude that in 2020 about 245 kg of scandium were PoM for use in the EU-27, contained in about 5,732 kton of EEE.

(From ProSum publicly available data - Various data sources from ProSUM project. There are variations of component (PCB) composition over time. Element embedded in component/materials is fixed, but we can still build a time series based on the variations of component/material)

2. DATA & INFORMATION ISSUE: It is unclear which data sources are used and/or available for material compositions of EEE and their

7.4.4 Discarded products in 2020 – Discarded EEE with scandium embedded

Discarding of scandium containing EEE

- In 2020, 901 kton of small IT was projected to be discarded in the EU-28 + Norway and Switzerland

Material composition of Waste Generated

- In 2020, it was projected that about 200 kg of Scandium would become available through EEE discarding in the EU-27, contained in 'VI Small IT (and with 14 kg contained in 'IV Large equipment'; and about 250 kg in total through EEE)

7.4.5 In summary, available data allow to conclude that in 2020, about <u>200 kg of scandium</u> became available in the EU-27 under the form of waste from discarding <u>901 kton of small IT.</u>

(From ProSum publicly available data - It is included in UNITAR's internal model. This internal model outputs the waste that is fed into the recovery model.

> 3. DATA & INFORMATION ISSUE:
>
> The statistical lifetime-based relation between the weight of small IT PoM in the years prior to 2020 (2.500 kg in the period 2010 to 2020) and the generated small IT waste in 2020, if any, is unclear. Will this relation be included in the modeling exercise?

7.4.6 Collected discarded products – Collected WEEE with scandium embedded

Collected small IT becoming available for recycling - We aim to use country level all the way to the collection (or incineration). But for recovery process, this should be done at EU level. Corresponding years will be used.

- In 2021, about 46% of the about 901 kton discarded small IT (and the about 200 kg of scandium contained in it) was collected compliantly wit EU regulation. This corresponds to roughly 414 kton of small IT, with 92 kg of embedded scandium
- In 2021, about 4% of the discarded small IT was collected as metal scrap. This corresponds to roughly 8 kg of embedded scandium.

7.4.7 In summary, available data allow to conclude that in 2021, about <u>100 kg of scandium</u> was made available in the EU-27 under the form of <u>450 kton of properly collected small IT (WEEE category 6).</u>

> 4. DATA & INFORMATION ISSUE:
>
> The available data on collection are at country level. Will all other data points use country level or EU level data? Discarded EEE tonnages above refer to 2020 and not to 2021, year to which the collection

(ProSum data, combined with information and data from mail Giulia Iattoni 26th of April 2023)

7.4.8 Dismantled, shredded and sorted collected waste products – Collected and treated WEEE with scandium embedded

Not all small IT subcategories seem to contain scandium (*See mail Giulia Iattoni 26th of April 2023). We don't have granular information of how much is collected of each subcategory. It is assumed that it is the same rate as the main collection category (6 in this case).*

Instead, scandium was reported to be contained in the following small IT UNU

- 0302 Desktop PCs (excl. monitors, accessoires)
- 0304 Printers (e.g. scanners, multi functionals, faxes)
- 0305 Telecom (e.g. (cordless) phones, answering machines)

(Description of UNU categories taken from: *Magalini, F., Wang, F., Huisman, J., Kuehr, R., Baldé, K., van Straalen, V., ... & Akpulat, O. (2014). Study on collection rates of waste electrical and electronic equipment (WEEE). European Commission*)

5. DATA & INFORMATION ISSUE:

In 2021, 450 kton of small IT (WEEE category 6) was properly collected. It is not clear how much of this

On the other hand, we know which components of the desktops, printers and telecom devices contain most (if not all) of the product-embedded scandium at the moment of PoM, namely the Printed Wiring Boards (PWB). In order to trace the destination of the scandium over the WEEE recycling process, our analysis will focus on the destination of PWB over the consecutive processing steps.

UNU cat.	Description	PCBunspecified (ton) PoM 2021 (?)	Scandium (kg) PoM 2021 (?)
302	Computers	14.473	15
304	Printers	21.485	40
305	Phones, videophones…	11.308	211

(Mail Giulia Iattoni 26th of April 2023 We provided discarded waste (not PoM). Product composition is not constant (see point 2).

6. DATA & INFORMATION ISSUE:

It is unclear whether volumes of PCBunspecified and of scandium refer to PoM in 2021 data, or to

In 2021 however, only half of the devices that were discarded by the users were collected in a way that allows for PWB recovery in the Member State (see section 4).

UNU cat.	Description	PCBunspecified (ton) Collected properly 2021	Scandium (kg) Collected properly 2021

302	Computers	7.237	8
304	Printers	10.743	20
305	Phones, videophones…	5.654	106

Collected discarded desktop PC's, printers and telecom devices are sent to pretreatment facilities. Pretreatment can include a depollution and one or more manual sorting and dismantling steps, and size reduction by shredding. In Europe, different WEEE pretreatments are applied with relevance to the Printed Wiring Board (PWB) recovery:

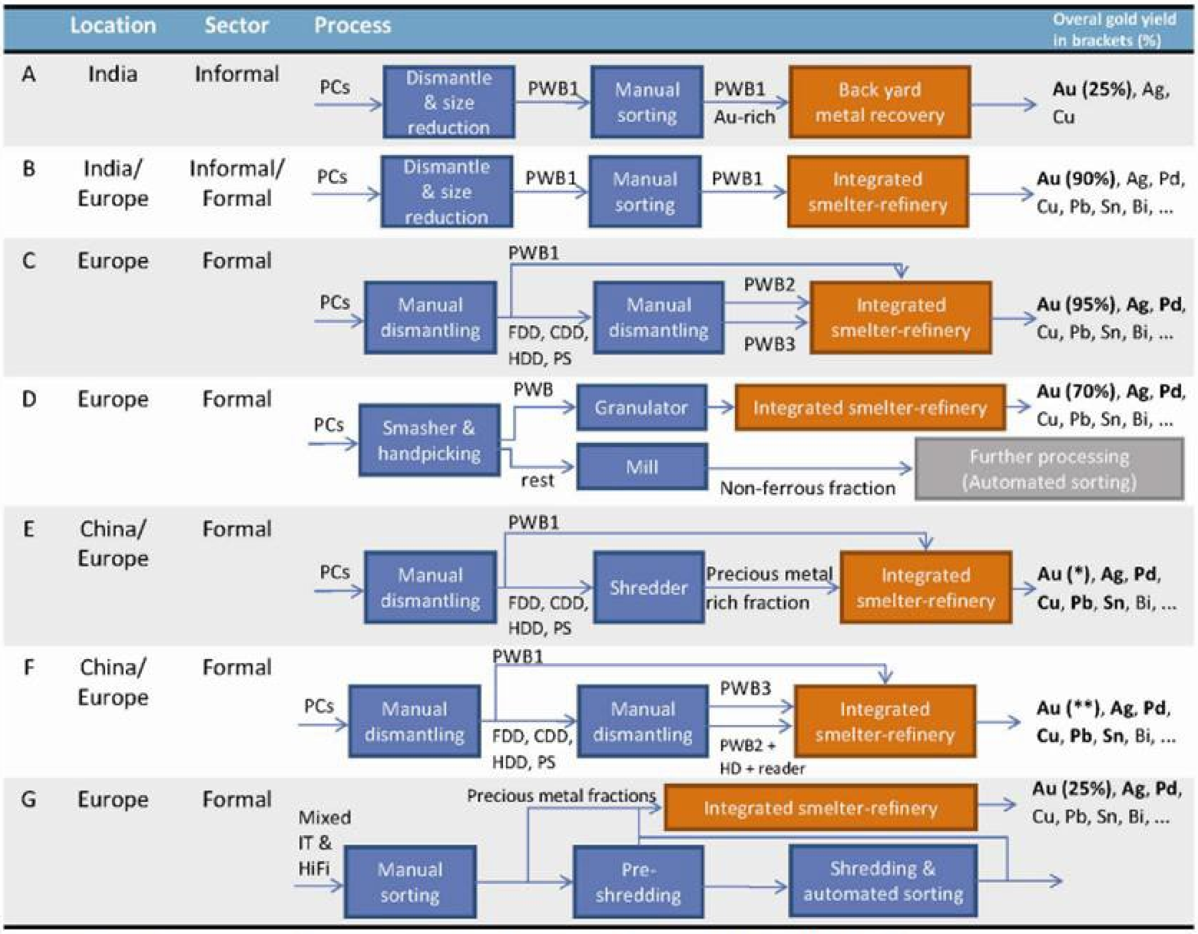


Figure 1: *Pre-processing and end-processing routes investigated in the projects.*
PWB1 = motherboards, video cards. PWB2 = from floppy disk drive (FDD), hard disk (HDD) and CD/DVD drive (CDD). PWB3 = from power supply (PS).
A and B: Rochat et al. 2007, Keller 2006. C and D: Salhofer 2009, Meskers et al. 2009. E and F: Gmünder 2007. G: Chancerel et al. 2008.
** overall gold yield similar to process D. ** overall gold yield similar to process C.*

The different PWB recoveries are largely determined by the manual dismantling depth. Thereto, PWB in WEEE are categorized in different grades, based on their expected precious metal content. PWB that are more rich in precious metals include motherboards and video cards are categorized as PWB1.

The more PWB that are manually removed before shredding a device, the less the (precious) metals contained in PWB will be dispersed over post-shredder material fractions from which they cannot be recovered.

(From: *Chancerel, P., Meskers, C. E., Hagelüken, C., & Rotter, V. S. (2009). Assessment of precious metal flows during preprocessing of waste electrical and electronic equipment. Journal of industrial ecology, 13(5), 791-810*)

WEEE treatment facilities in Belgium and several other Member states will manually dismantle the high grade PWB1 or hand pick PWB after smashing. PWBs that are not removed by manual dismantling or handpicking are shredded and further treated in an automated sorting process. This process will yield a PWB fraction that will contain part of the, now size reduced PWB. The other part will be lost as contaminant in other material fractions, or as dust.

(From: *Meskers, C., & Hagelüken, C. (2009). The impact of different pre-processing routes on the metal recovery from PCs. URL: http://www. preciousmetals. umicore. com/PMR/Media/escrap/impactOfDifferentPreprocessing. pdf (дата обращения 01.10. 2012)*

In summary, it was estimated that in 2021, 134 kg of scandium, contained in about 24 ktons of PWBs as components of properly collected small IT (WEEE category 6) devices belonging to the UNU categories 302, 304 and 305, were supplied to pre-processing facilities for treatments including dismantling, shredding and sorting.

7. DATA & INFORMATION ISSUE:

It is observed that scandium weight estimated from material composition data of properly collected category 6 small IT (i.e. 100 kg of scandium for the EU27) differs from the scandium weight derived from the supplied for processing share of the scandium containing components from UNU product category volumes that were properly collected for further processing (i.e. 134 kg). This issue is yet to be tackled.

7.4.9 Non-ferrous metal fraction with scandium-containing components from treated WEEE

Based on the insights with respect to the most common treatment routes for UNU categories 302, 304 and 305, it is possible to conclude that the scandium containing components, in particular the PWBs, will give rise to a specific non-ferrous fraction, Eural waste code (EWC) '***16 02 15* hazardous components removed from discarded equipment***', that is sold and traded under the ISRI code '***EM3 – Circuitboards and Shredded Circuitboards from the Processing of End-of-Life Electronics***'.

We assume that in Belgium and some other Member States, half of the PWB will be removed by manual dismantling or handpicking after smashing, and half of the unliberated PWB will enter a mechanical process that, among other material fractions, will yield a PWB-fraction. We further estimate that 75% of the unliberated PWB content can be recovered as EwC 16 02 15* or EM3 by this mechanical treatment. This way, it is expected that the preprocessing of devices that contain scandium in the PWB, will yield 87,5% of the original content of PWBs. This assumption allows us to estimate the weight of the scandium embedded in small IT that will result from the processing of the properly collected small IT devices that belong to the UNU categories 203, 304 and 305.

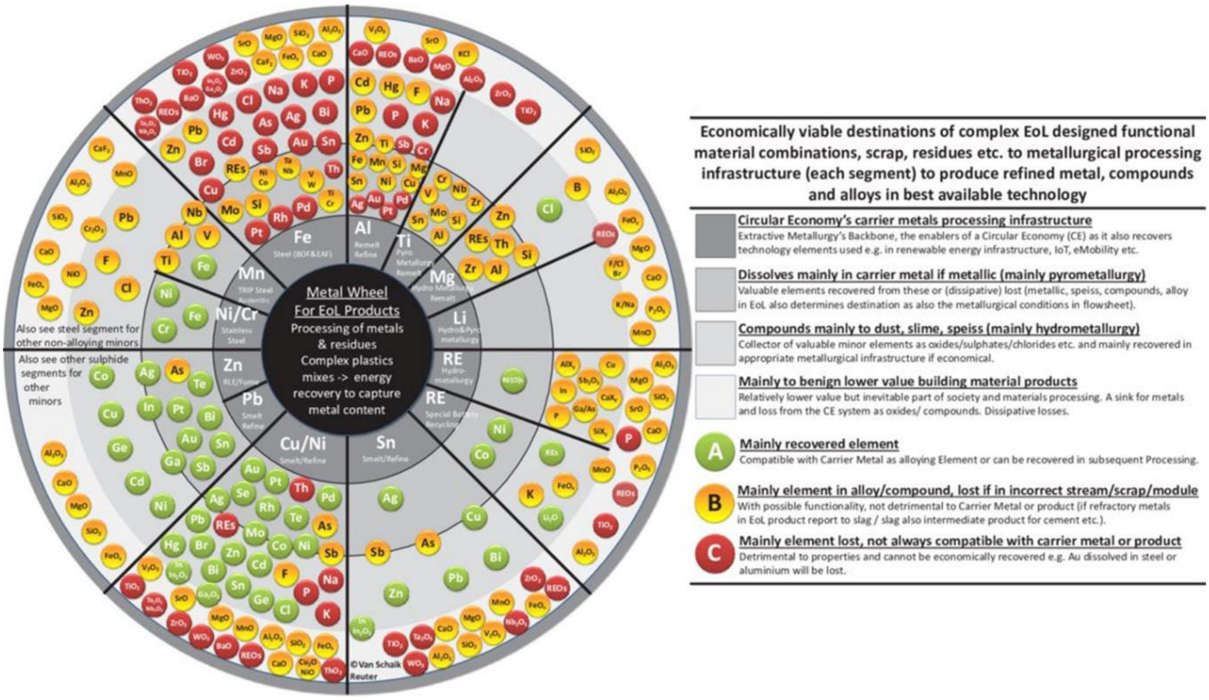
UNU cat.	Description	PCBunspecified (ton) Collected properly 2021	Scandium (kg) Collected properly 2021	Scandium (kg) in recovered PWB 2021
302	Computers	7.237	8	7
304	Printers	10.743	20	18
305	Phones, videophones...	5.654	106	93

In summary, it was estimated that in 2021, <u>118 kg of scandium</u> was recovered under the form of about <u>21 ktons of PWBs</u> liberated from properly collected small IT (WEEE category 6) devices belonging to the UNU categories 302, 304 and 305.

7.4.10 Non-ferrous metal fraction with scandium-containing components from treated WEEE

In Europe, both the manually removed PWB and the PWB-fraction from mechanical preprocessing will be sent to an integrated smelter that targets the recovery of copper and precious metals.

According to the metal wheel, no scandium can be recovered from processing PWBs in an integrating smelter.



(From: *M.A. Reuter, A. van Schaik, J. Gutzmer, N. Bartie, A. Abadías Llamas: Challenges of the Circular Economy - A material, metallurgical and product design perspective. In: Annual Review of Materials Research. Band 49, 2019, S. 253–274*)