Futu RaM

Future availability of secondary raw materials

Providing Data Intelligence & UNFC Methodology for Secondary CRMs

26th March 2025

Funded by the European Union

Schweizerische Eidgenossenschaft
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Swiss Confederation

Federal Department of Economic Affairs, Education and Research EAER
State Secretariat for Education, Research and Innovation SERI

EU Framework Programmes

UK Research and Innovation

Agenda

15:00-15:05 Welcome and introduction | James Horne, Project Manager, WEEE Forum

15:05-15:15 More about FutuRaM | Kirsten Remmen, Group Lead, Empa

15:15-15:30 What have we achieved so far? First results of the project | Kees Baldé, Senior Scientific Specialist, UNITAR SCYCLE

15:30-15:40 Q&A

15:40-15:45 UNFC applied to anthropogenic resources | Soraya Heuss-Aßbichler, Professor of Mineralogy and Petrology, LMU München

15:45-15:50 Mining waste case study | Ronald Arvidsson, Senior Geophysicist, SGU

15:50-16:00 Timber recovery | Jonas Breidenbach, Research Fellow, UCL

16:00-16:10 Phosphorous recovery | Soraya Heuss-Aßbichler, Professor of Mineralogy and Petrology, LMU München

16:10-16:20 Battery recycling | Iman Dorri, Scientific Researcher, LMU München

16:20-16:30 Q&A

16:30-17:00 Panel discussion: How FutuRaM can be useful to observatories and policy makers | Moderated by Erika Ingvald, Economics Affairs Officer, UN | Panellists: Stéphane Bourg, Directeur de l'OFREMI, BRGM; Kieran Campbell-Johnston, Scientific Integrator, TNO; and Minja Marijanski, Environmental Specialist, Proman Management

17:00-17:05 Closing remarks | James Horne, Project Manager, WEEE Forum

DUNCAN KUSHNIR
Data | Science | Engineering

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United Nations Institute for Training and Research

mace

REPIC
WEEE | BATTERIES | PACKAGING

Geoscience for a sustainable Earth
brgm

NEW BOLIDEN

berlin

F

Stiftung GRS Batterien

weeeforum

LOVISAGRUVAN

GeoZS
Geološki zavod Slovenije

emr
METAL RECYCLING REIMAGINED

LMU
LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

Universiteit Leiden
Institute of Environmental Sciences

Erion Weee

WEEECycling

GTK

SGU Geological Survey of Sweden

RECHARGE
ADVANCED RECHARGEABLE & LITHIUM BATTERIES ASSOCIATION

ecosystem
recycler c'est protéger

CHALMERS
UNIVERSITY OF TECHNOLOGY

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Empa
Materials Science and Technology

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Federal Institute for Geosciences and Natural Resources

vito

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More about FutuRaM

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Empa

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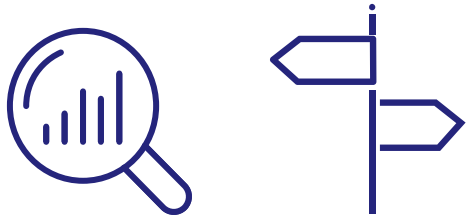
FutuRaM – Main Aim

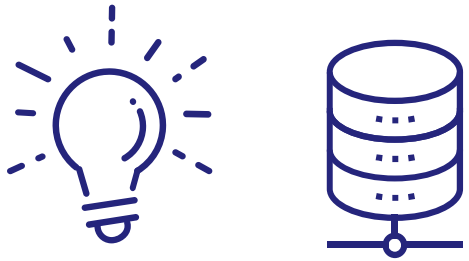
Fact-based decision-making for secondary raw materials management



→ Availability and Recoverability of Secondary Raw Materials (2RMs) in the EU

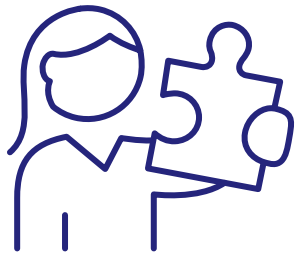
→ Focus on Critical Raw Materials (CRMs)

Easy access and sharing of research insights and data



→ Disseminate information via a systematic and transparent Secondary Raw Materials Platform

Motivation and Challenges



→Emphasize the importance of reliable and complete data

→Model future Secondary Raw Materials stocks and flows

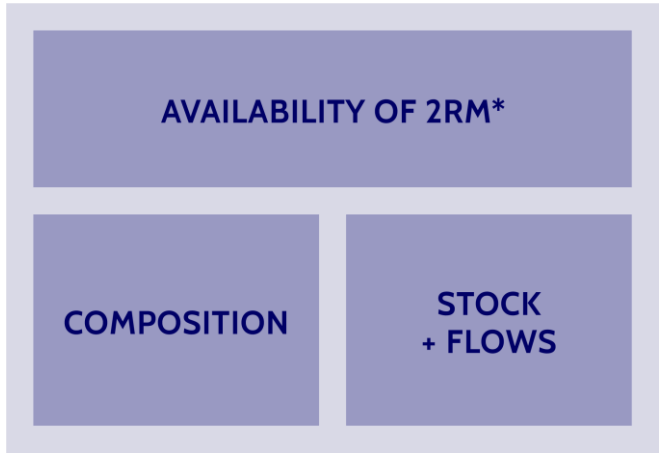
→Support legislation (e.g., CRM Act)

→ Existing models mostly assess availability

→ No harmonized data (very scattered)

→ From multiple sources and databases

FutuRaM: Building on ProSUM

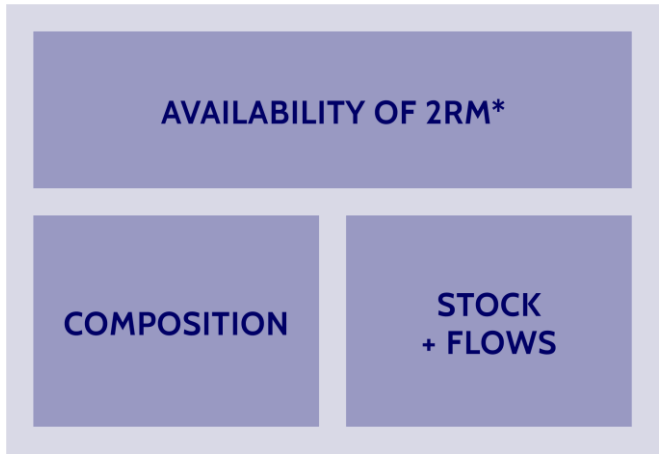


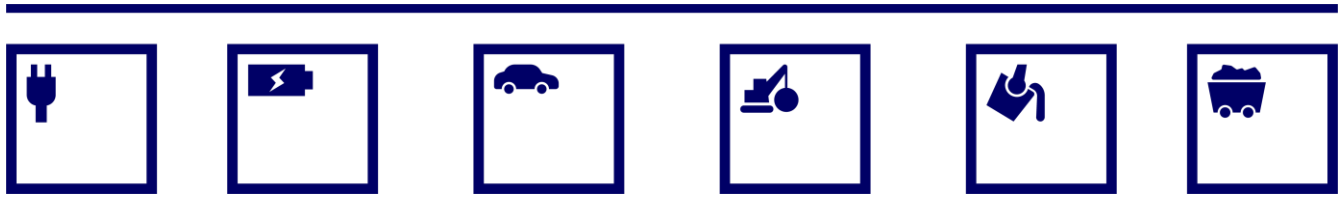
ProSUM 2015 – 2017

www.urbanmineplatform.eu

* 2RM = Secondary Raw Materials

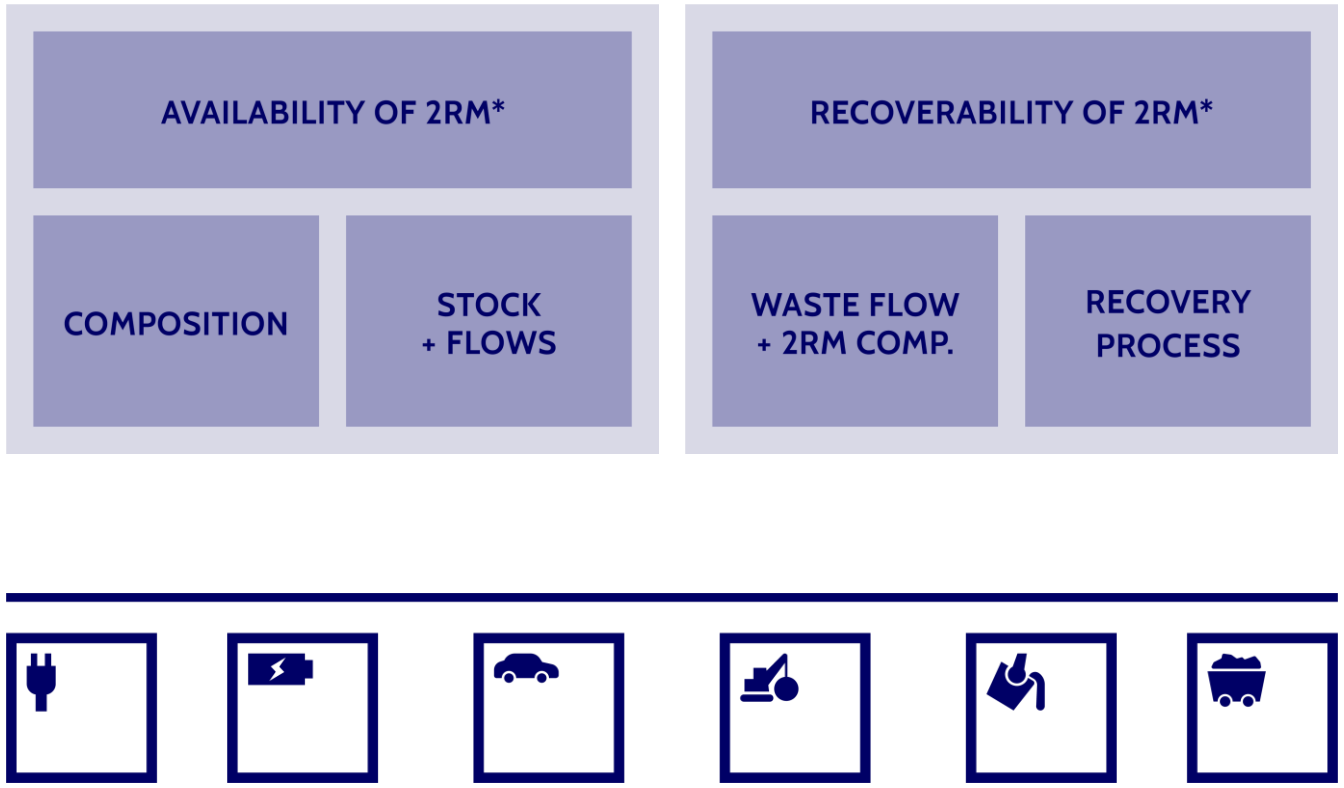
Extension to 6 waste streams





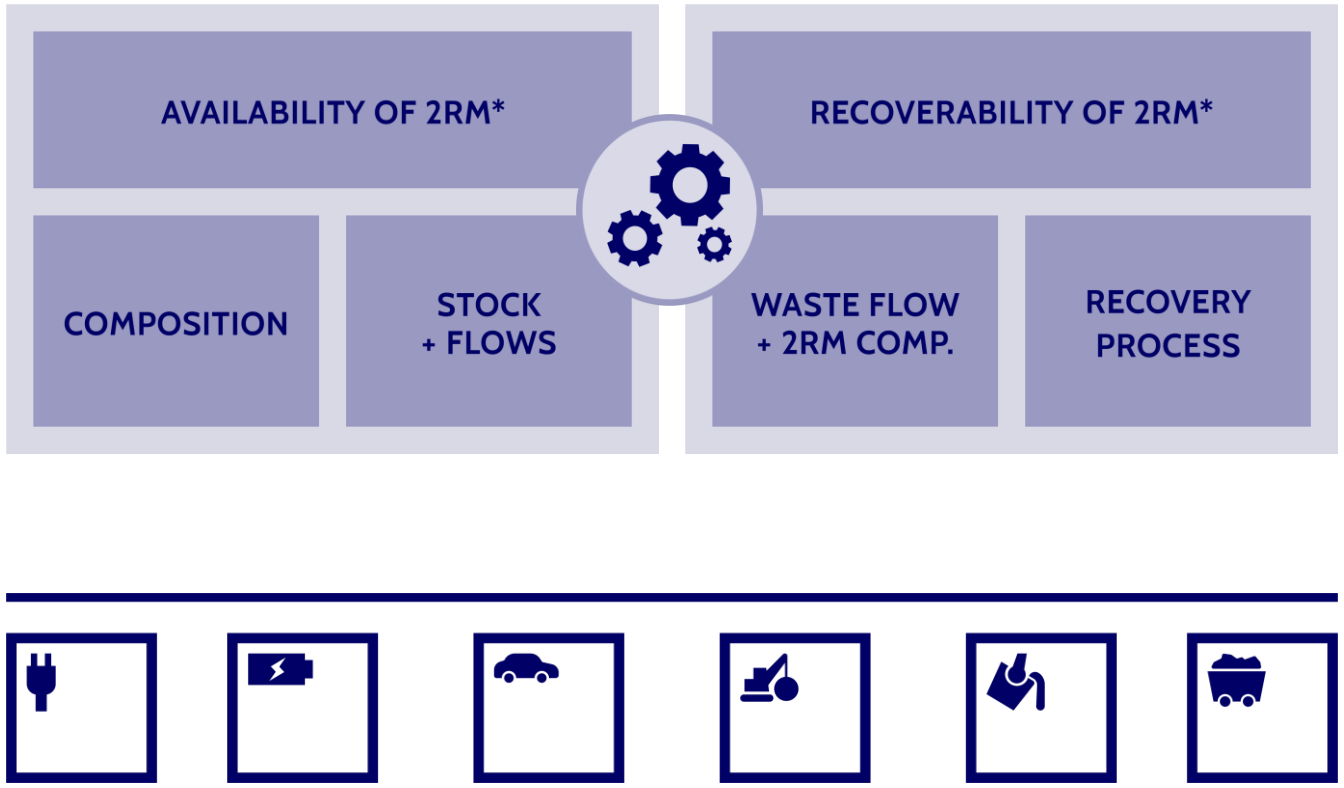
* 2RM = Secondary Raw Materials

Extension to recoverability



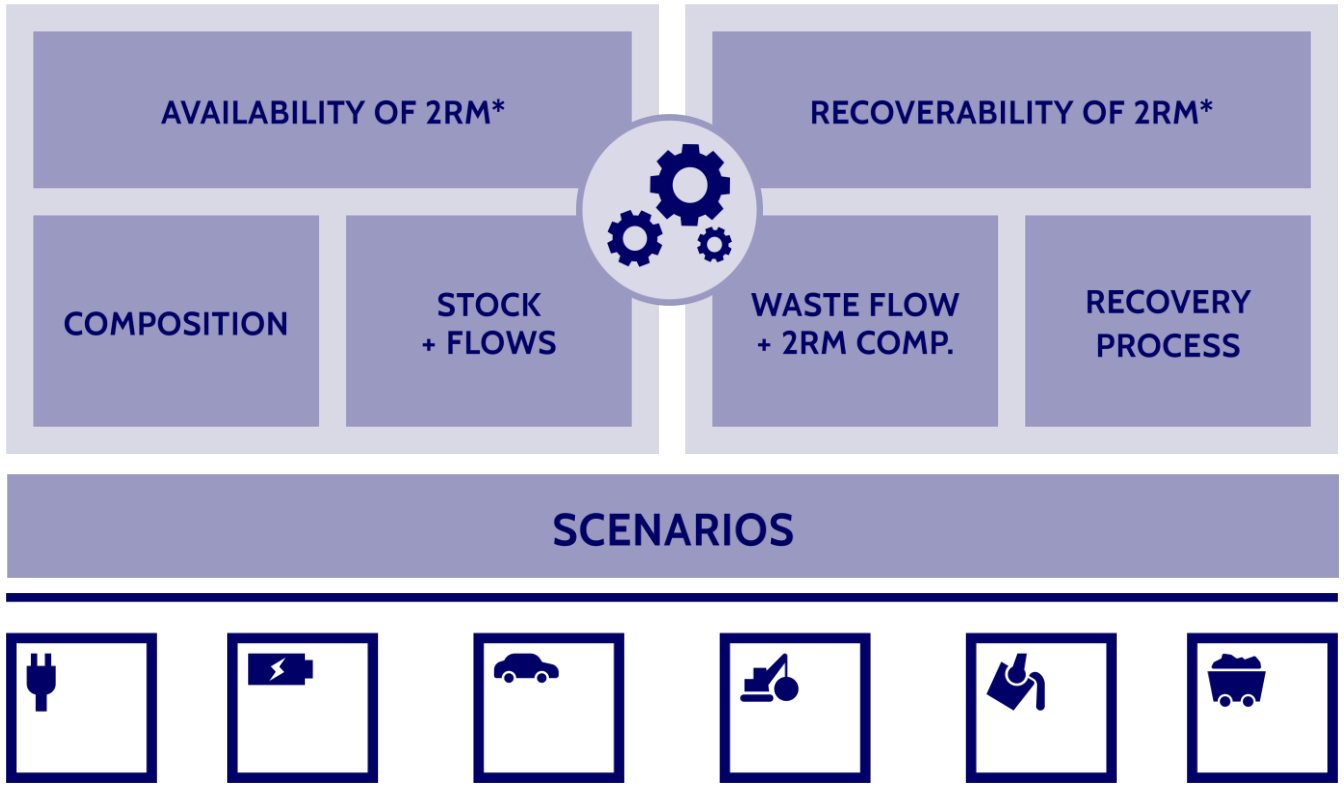
* 2RM = Secondary Raw Materials

Extension to recoverability



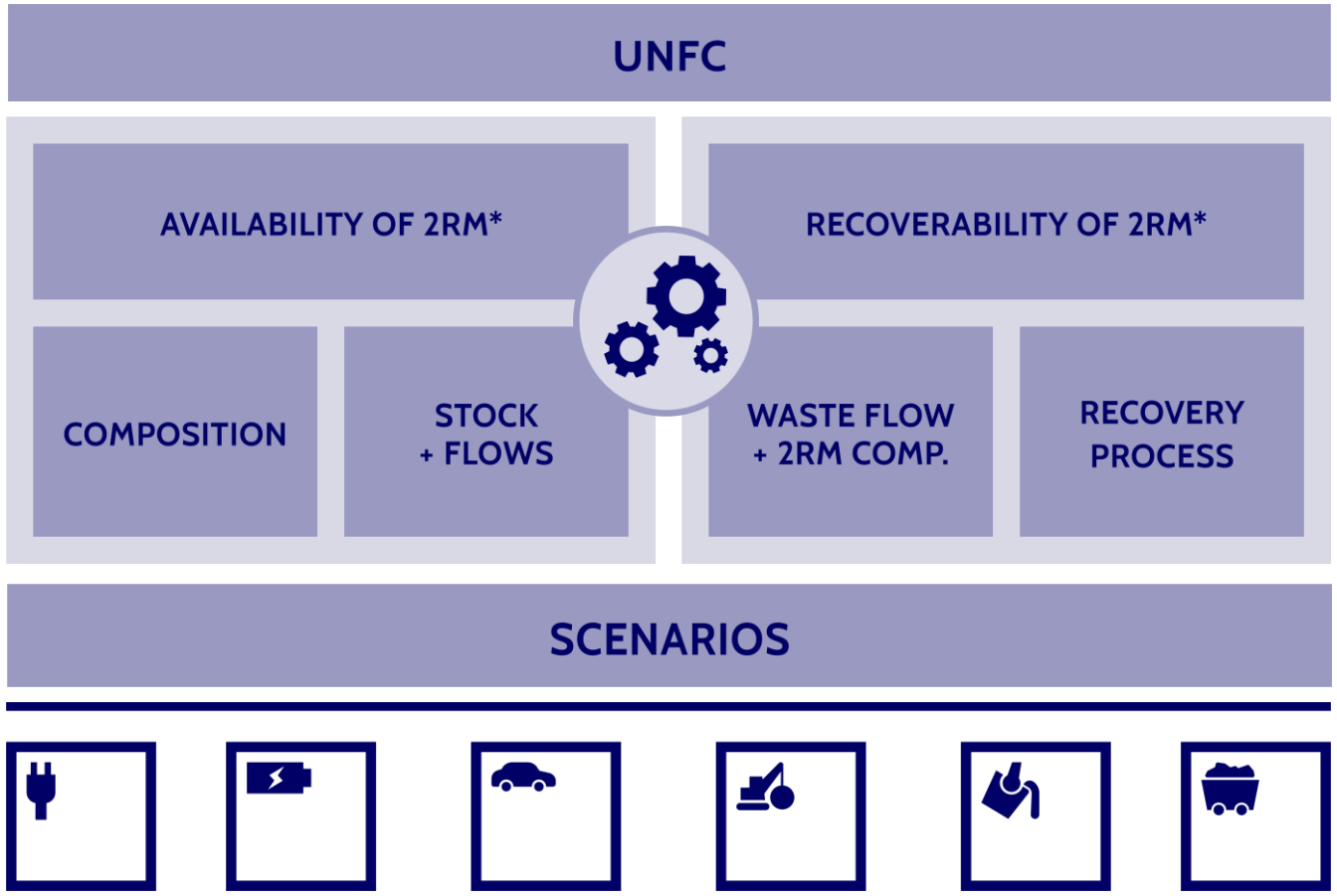
* 2RM = Secondary Raw Materials

Scenarios up to 2050

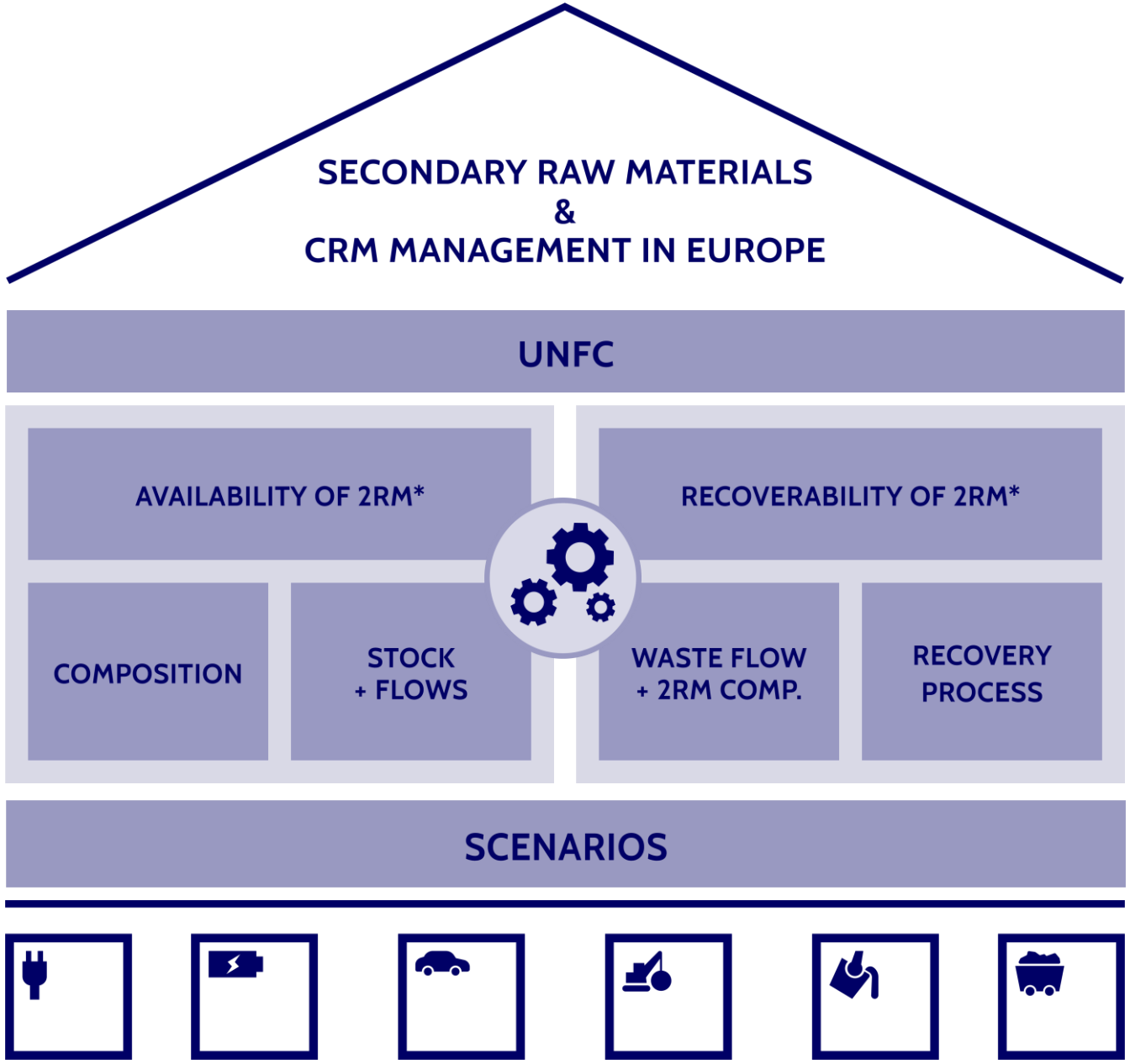


* 2RM = Secondary Raw Materials

UNFC

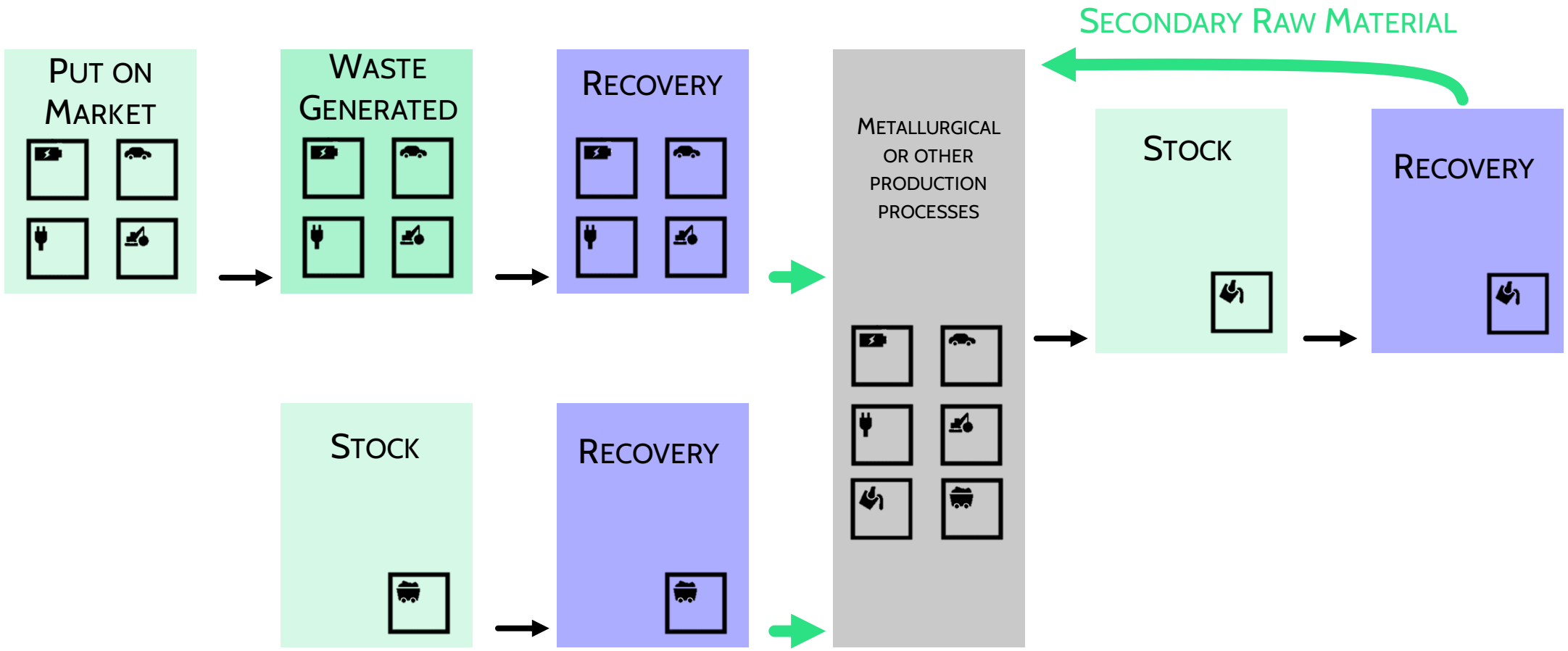


* 2RM = Secondary Raw Materials

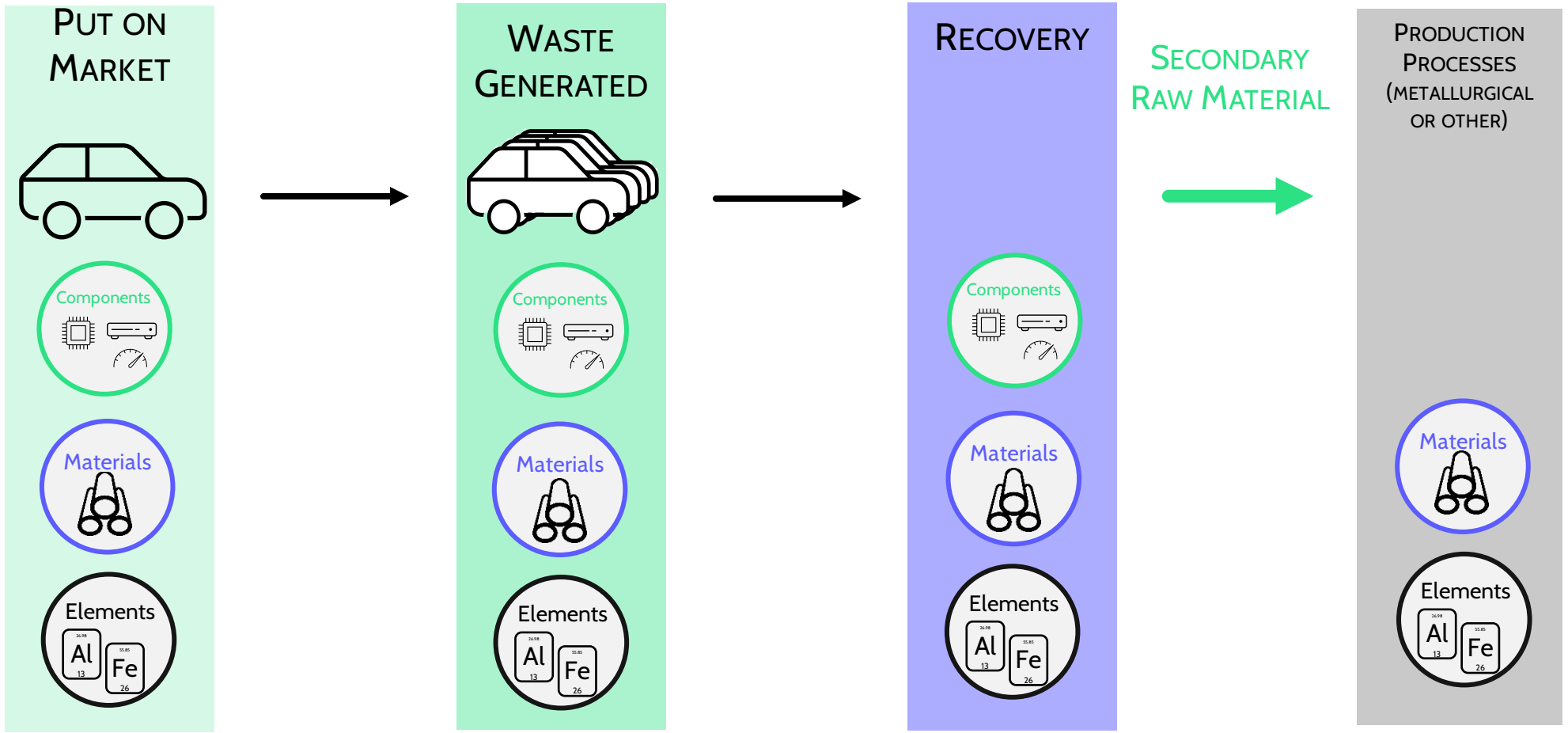


* 2RM = Secondary Raw Materials

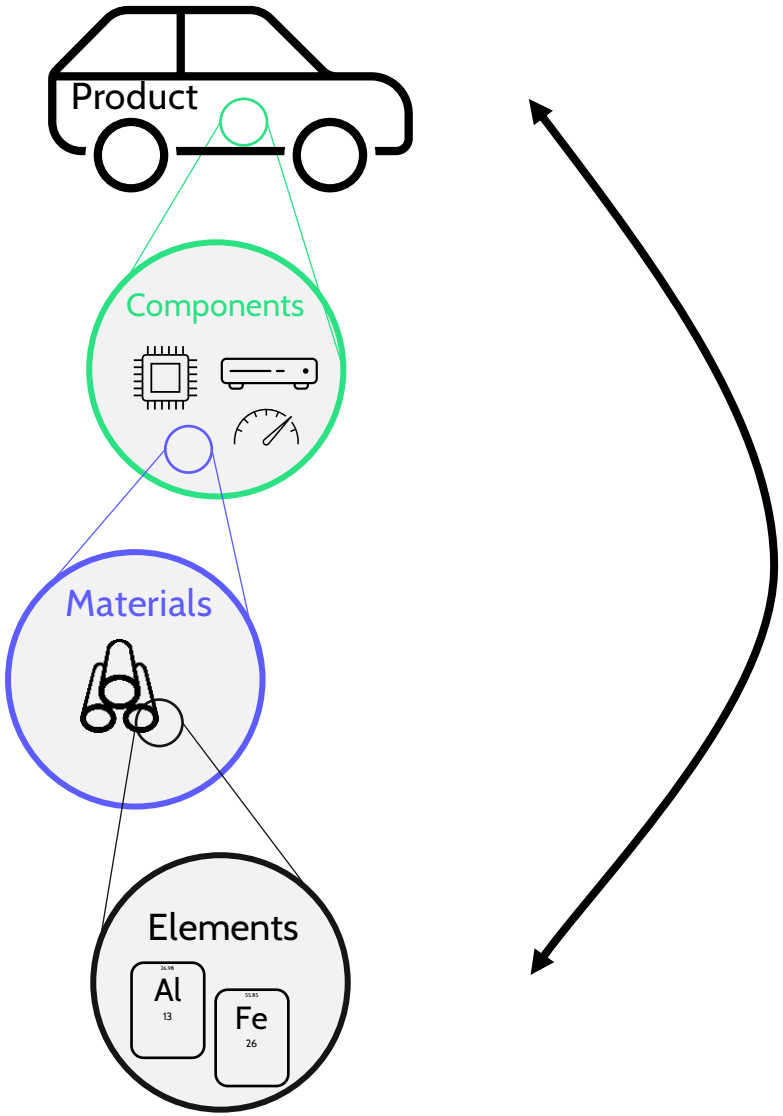
Models in FutuRaM Framework



Composition data

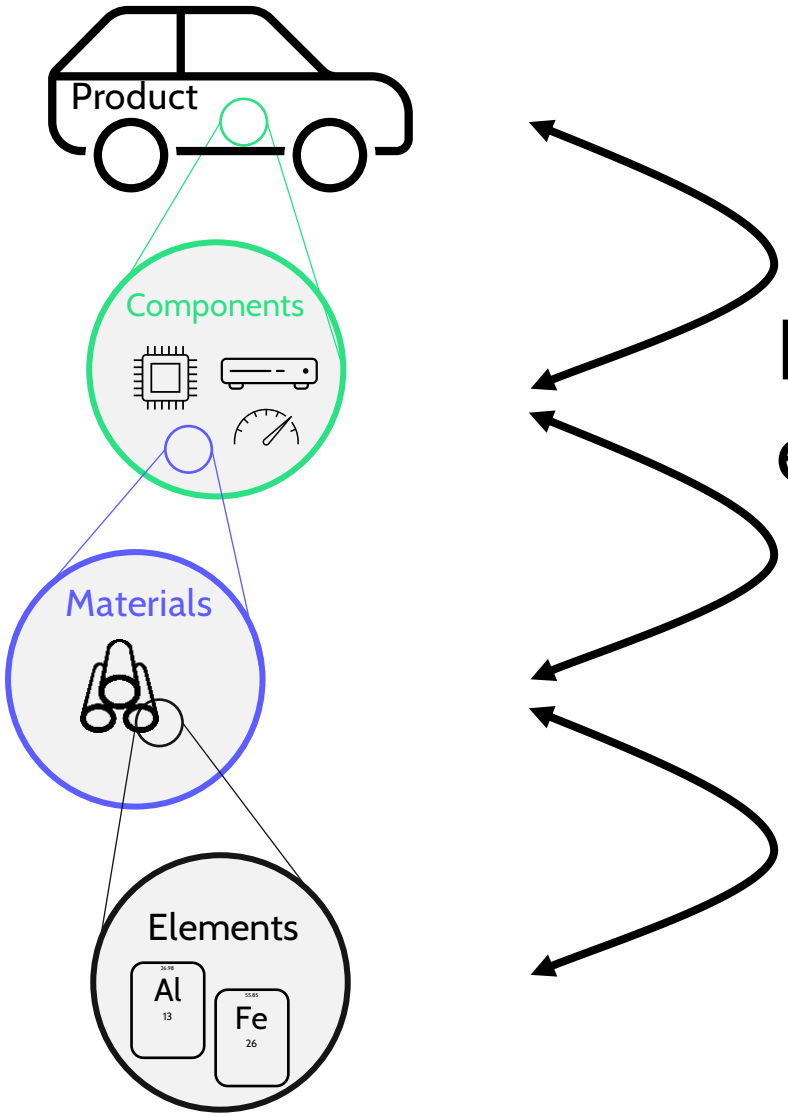


From Availability to Recoverability



Skipping levels will only allow assessment of availability

From Availability to Recoverability



Recoverability assessment is enabled

Harmonization of composition data

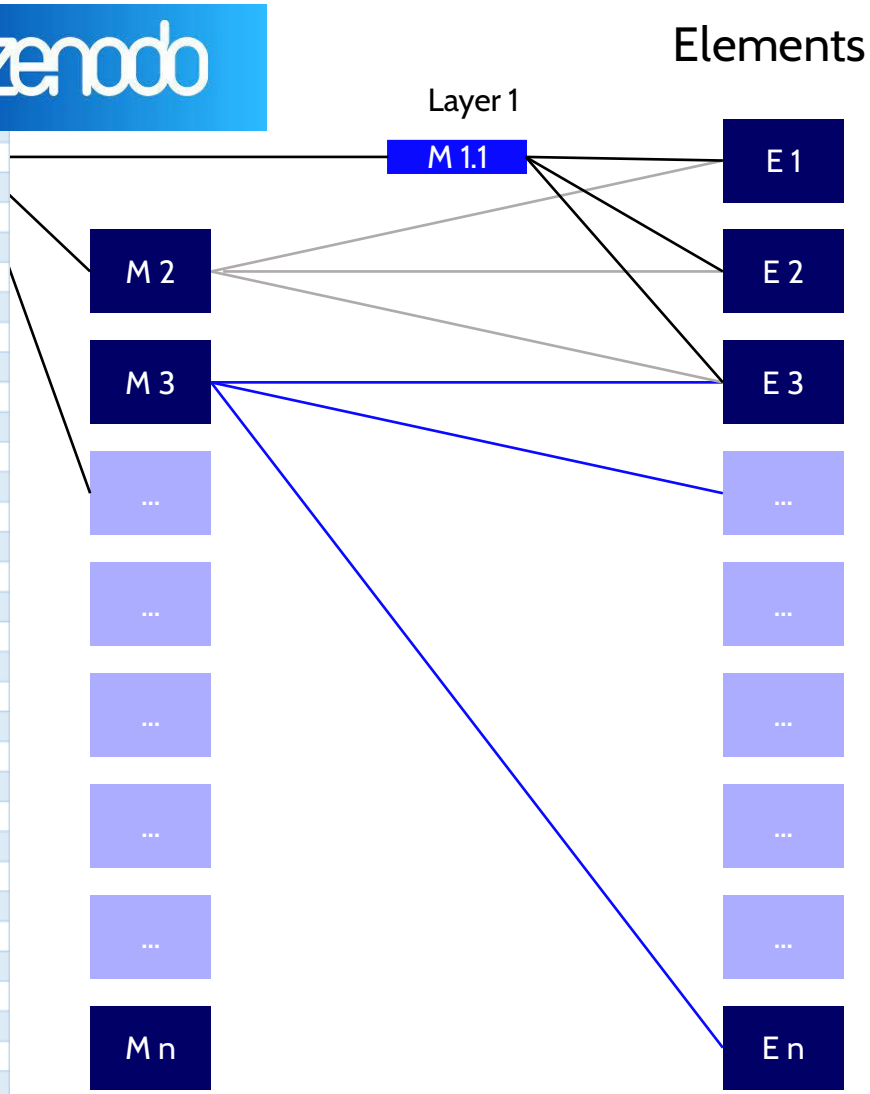
Products

Component

Elements

Waste stream

code	VEHICLEKey	type	fuelType	length	Segment	Description
V01010100	elvPetrol	car	petrol	unkown	Standard	
V01010101	elvPetrol	car	petrol	3.5-3.8	A	Mini cars
V01010102	elvPetrol	car	petrol	3.8-4.2	B	Small cars
V01010103	elvPetrol	car	petrol	4.2-4.7	C	Medium cars
V01010104	elvPetrol	car	petrol	4.6-4.9	D	Large cars
V01010105	elvPetrol	car	petrol	4.8-5.2	E	Executive cars
V01010106	elvPetrol	car	petrol	5.1-5.4	F	Luxury cars
V01010107	elvPetrol	car	petrol	unkown	J	Sport utility cars (including off-road vehicles)
V01010108	elvPetrol	car	petrol	unkown	M	Multi purpose cars
V01010109	elvPetrol	car	petrol	unkown	S	Sport coupes
V02010200	elvDiesel	car	diesel	unkown	Standard	
V02010201	elvDiesel	car	diesel	3.5-3.8	A	Mini cars
V02010202	elvDiesel	car	diesel	3.8-4.2	B	Small cars
V02010203	elvDiesel	car	diesel	4.2-4.7	C	Medium cars
V02010204	elvDiesel	car	diesel	4.6-4.9	D	Large cars
V02010205	elvDiesel	car	diesel	4.8-5.2	E	Executive cars
V02010206	elvDiesel	car	diesel	5.1-5.4	F	Luxury cars
V02010207	elvDiesel	car	diesel	unkown	J	Sport utility cars (including off-road vehicles)
V02010208	elvDiesel	car	diesel	unkown	M	Multi purpose cars
V02010209	elvDiesel	car	diesel	unkown	S	Sport coupes
V03010300	elvBEV	car	electric	unkown	Standard	
V03010301	elvBEV	car	electric	3.5-3.8	A	Mini cars
V03010302	elvBEV	car	electric	3.8-4.2	B	Small cars
V03010303	elvBEV	car	electric	4.2-4.7	C	Medium cars
V03010304	elvBEV	car	electric	4.6-4.9	D	Large cars
V03010305	elvBEV	car	electric	4.8-5.2	E	Executive cars
V03010306	elvBEV	car	electric	5.1-5.4	F	Luxury cars
V03010307	elvBEV	car	electric	unkown	J	Sport utility cars (including off-road vehicles)
V03010308	elvBEV	car	electric	unkown	M	Multi purpose cars
V03010309	elvBEV	car	electric	unkown	S	Sport coupes
V04010100	elvHEV	car	petrol	unkown	Standard	
V04010101	elvHEV	car	petrol	3.5-3.8	A	Mini cars
V04010102	elvHEV	car	petrol	3.8-4.2	B	Small cars



Waste stream specific

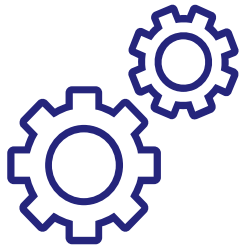
General material information

FutuRaM scenarios until 2050

Business-as-usual

- Little deviation from present consumption, waste production, and recovery rates
- Material demand remains coupled with economic growth (GDP)

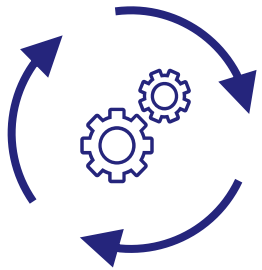
→ Extrapolation of current trends



Recovery

- Use of advanced technologies to increase the recovery of 2RMs from waste
- The EU meets its recycling and recovery targets

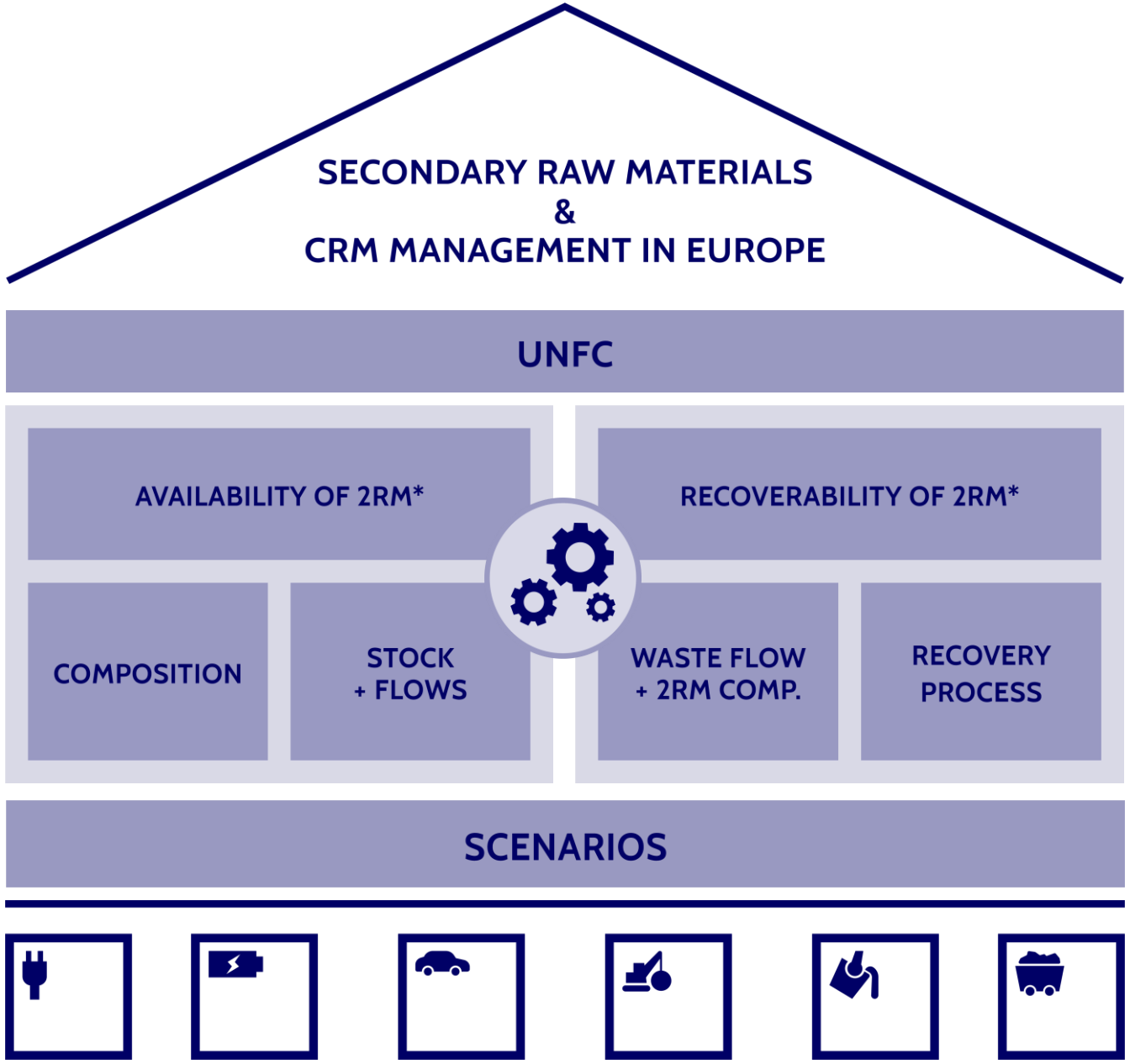
→ Change in the waste treatment



Circularity

- Fully realized circular economy
- Going beyond improved recovery, minimizing waste at the production and consumption stage

→ Changes within stock and flow models (e.g. increase repair) + recovery scenario



- FutuRaM framework allows assessment of recoverability
- Different granularity of scattered data can be addressed in the framework
- Harmonized code table
- Scenarios up to 2050
- UNFC - 19 case studies

* 2RM = Secondary Raw Materials

Thank you

Kirsten Remmen

Group Leader

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Empa

Materials Science and Technology

Futu RaM

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First FutuRaM Results

26th March 2025

Kees Baldé

UNITAR

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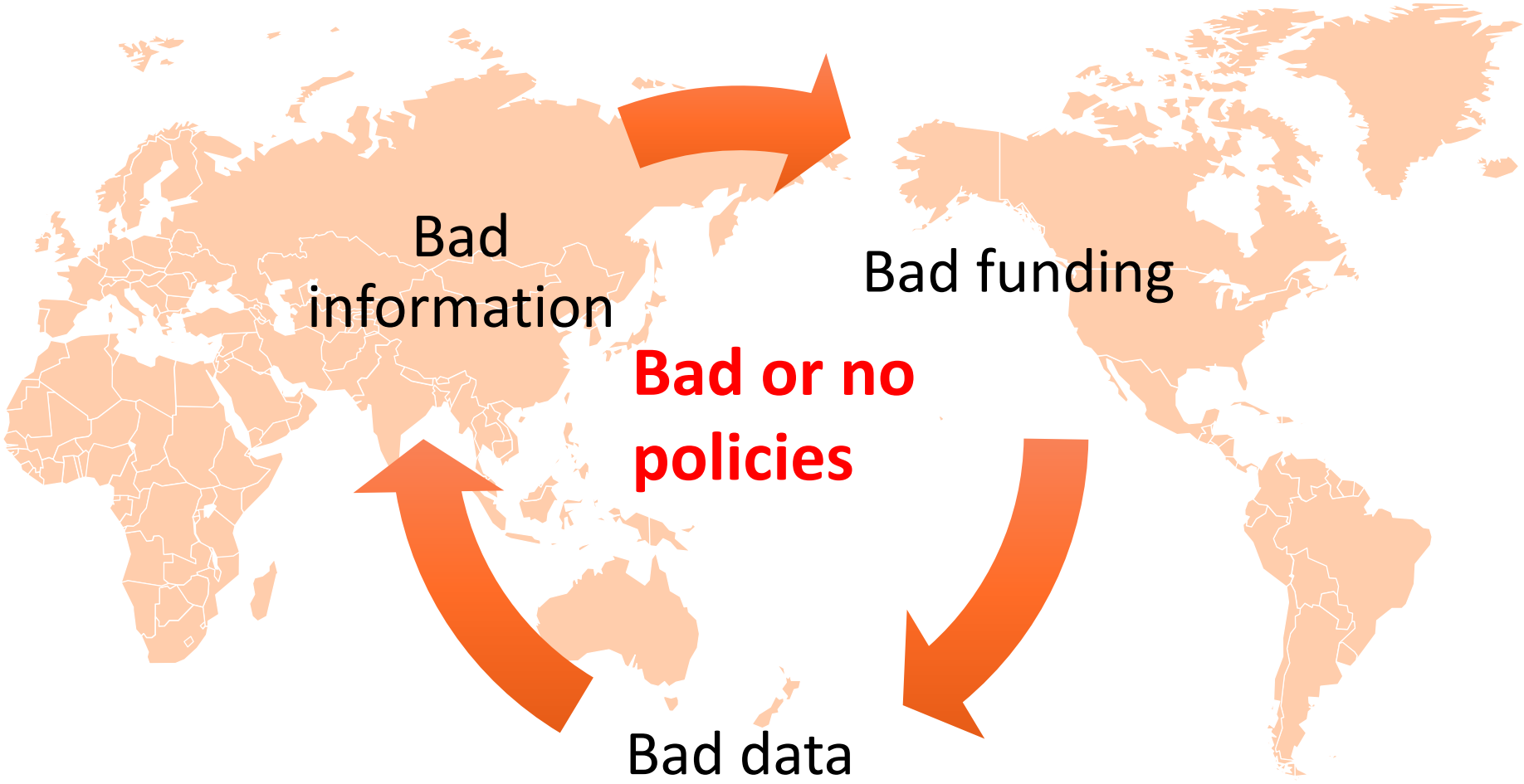
UK Research and Innovation

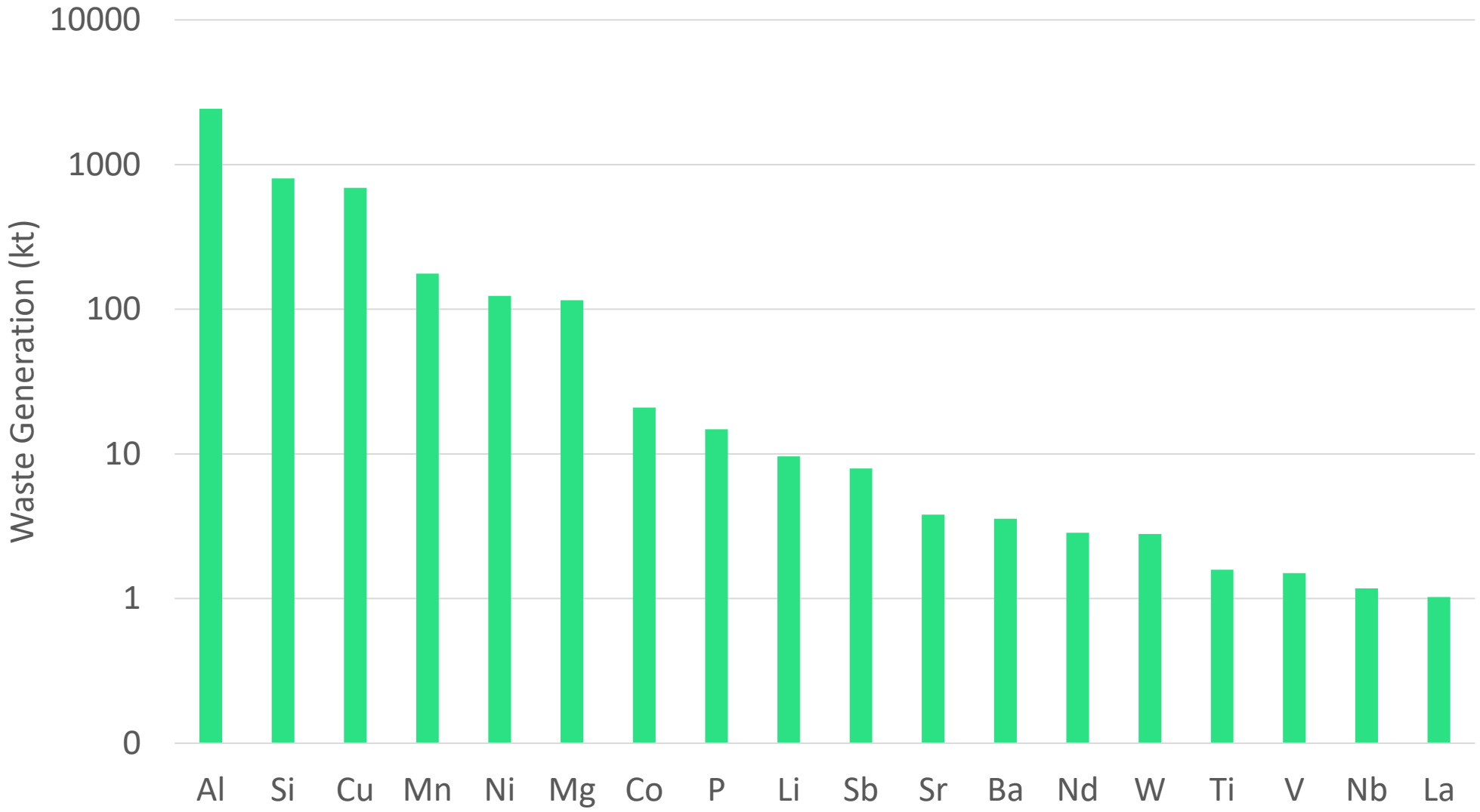
unitar
United Nations Institute for Training and Research

Sustainable Cycles (SCYCLE) Programme

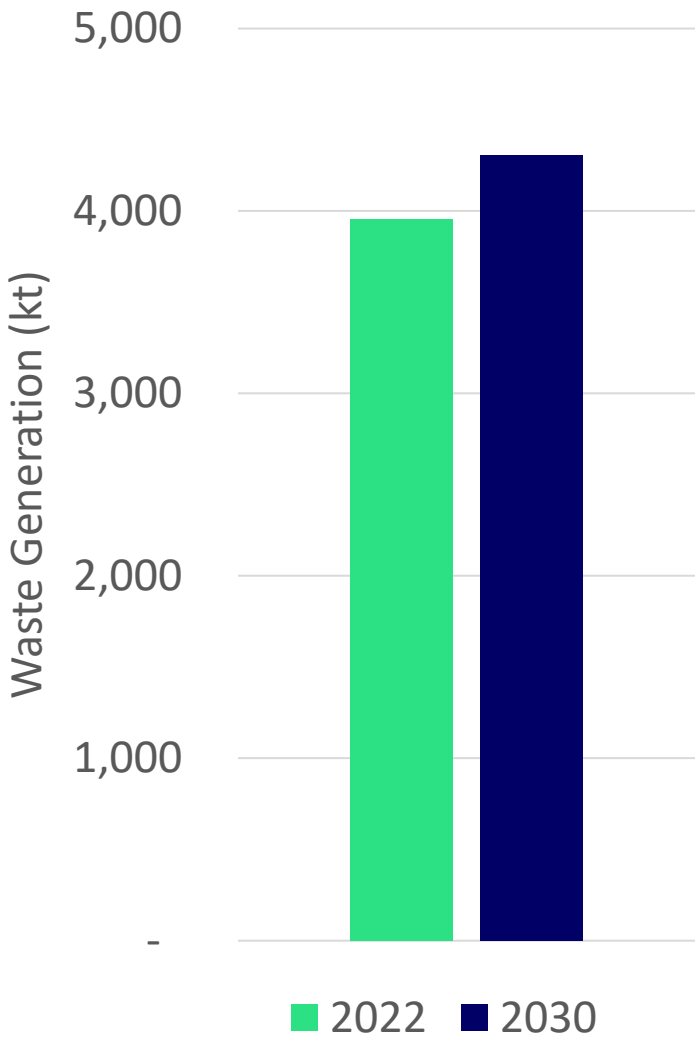
Downward spiral when not having data

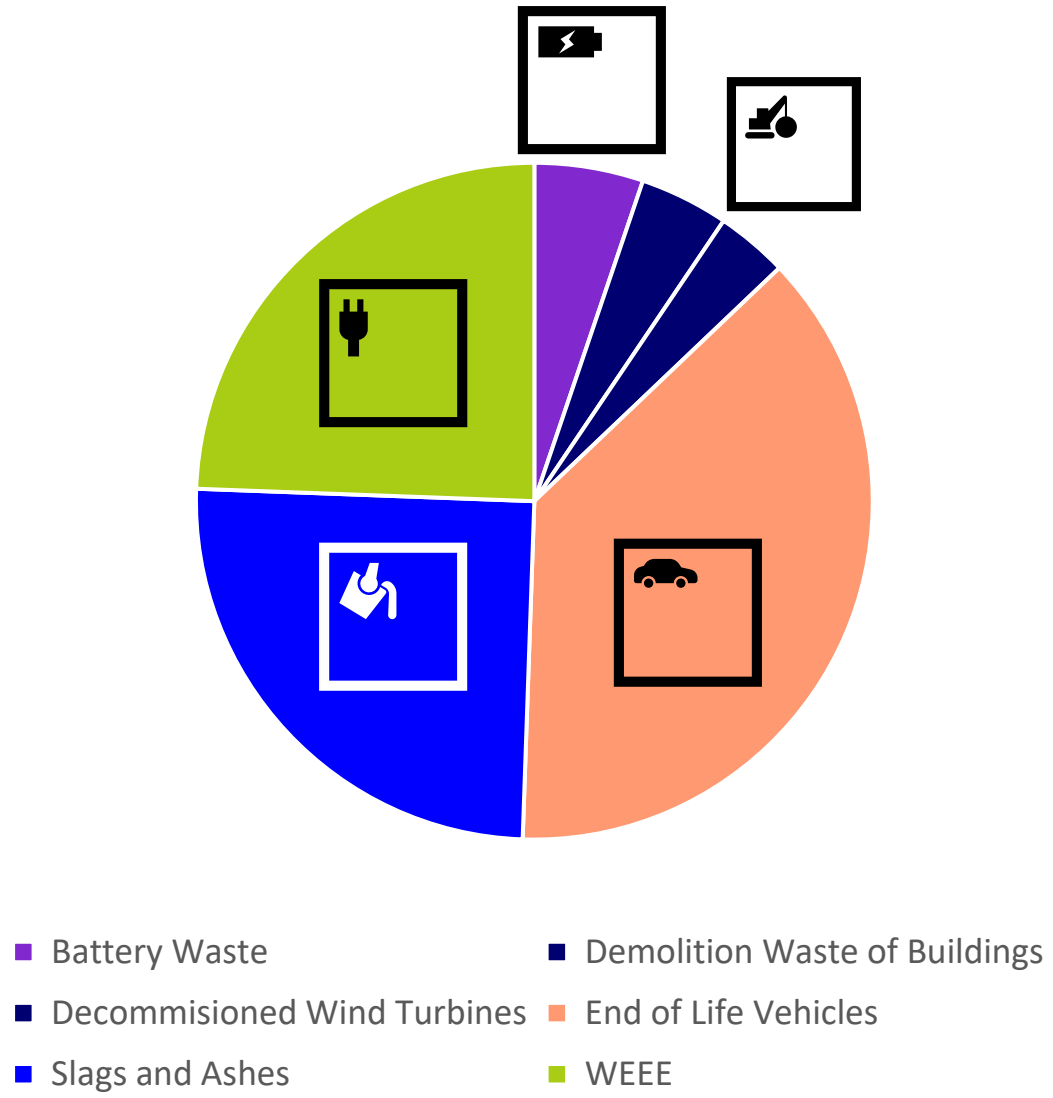


Critical and Strategic Raw Materials in waste streams above 1 kt (2022)

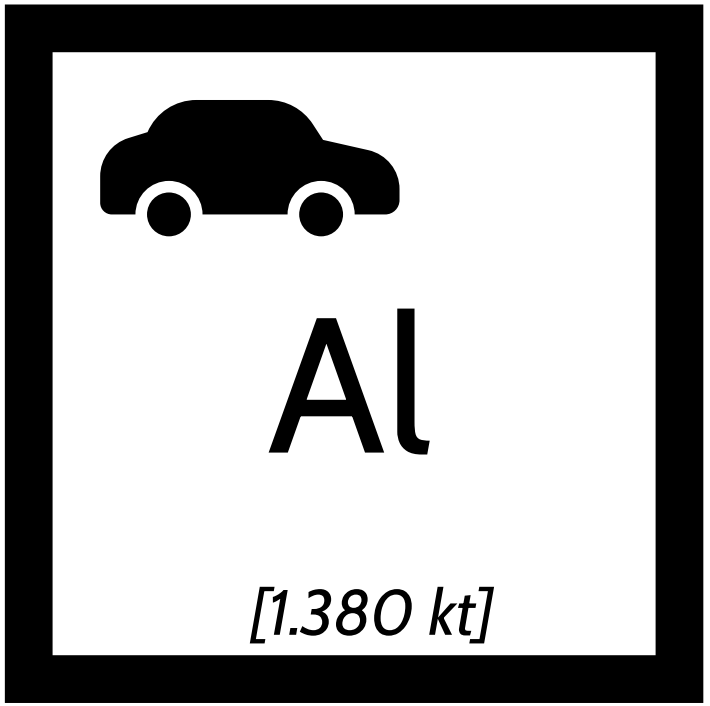


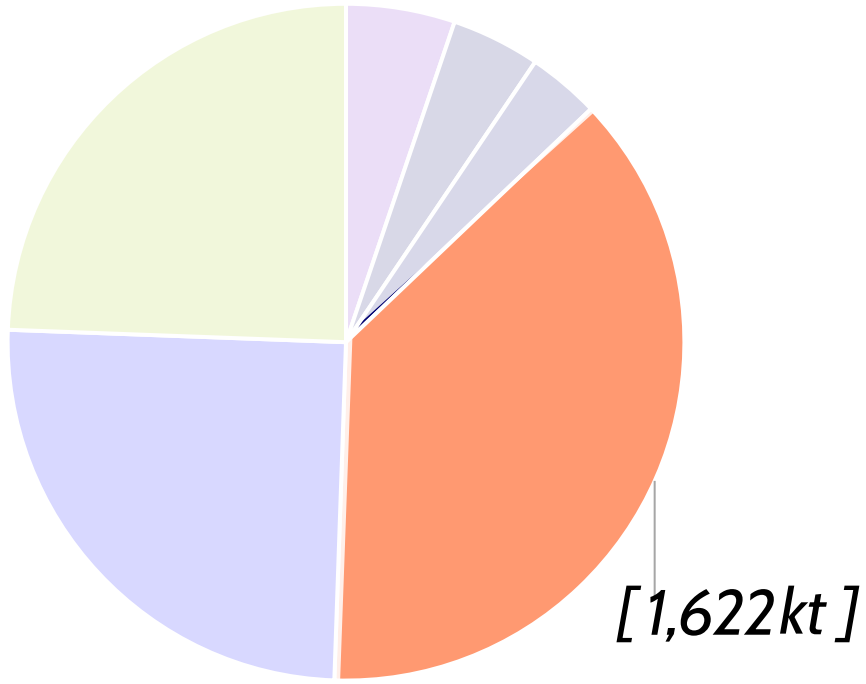
Critical and Strategic Raw Materials in waste streams (kt)





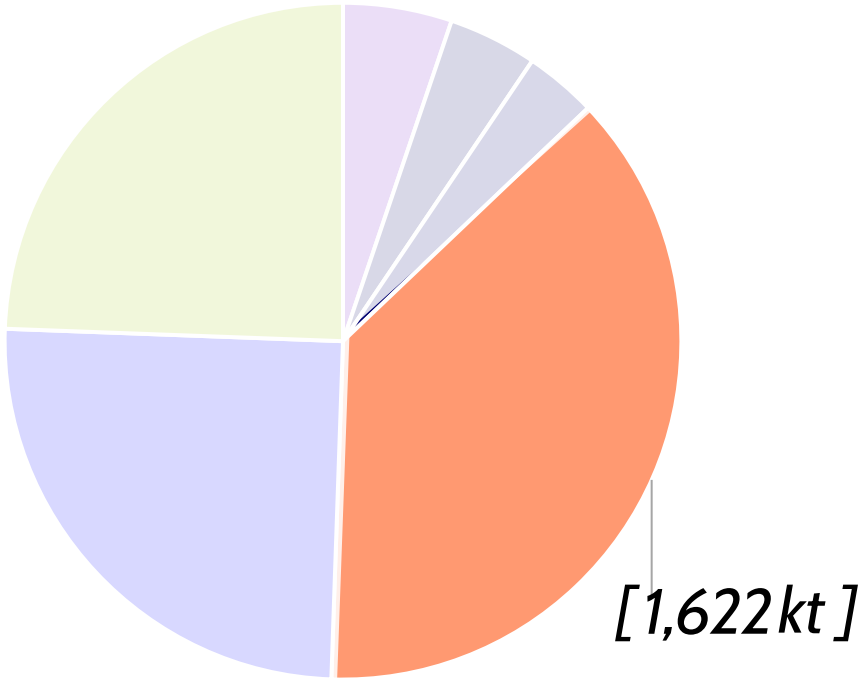
SRMs and CRMs in ELV in 2030 (unit: kt)
Relevant in mass



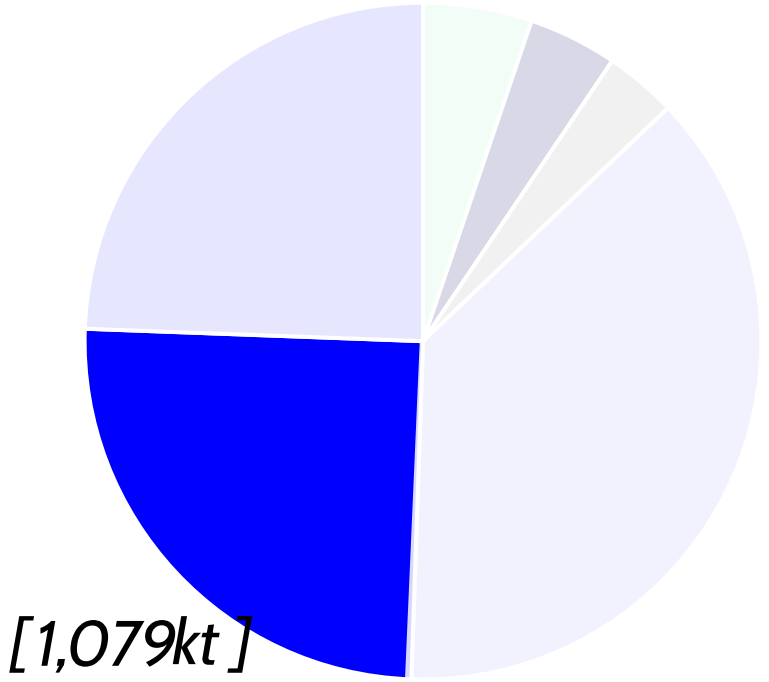


SRMs and CRMs in ELV in 2030 (unit: kt)
Relevant to global extraction

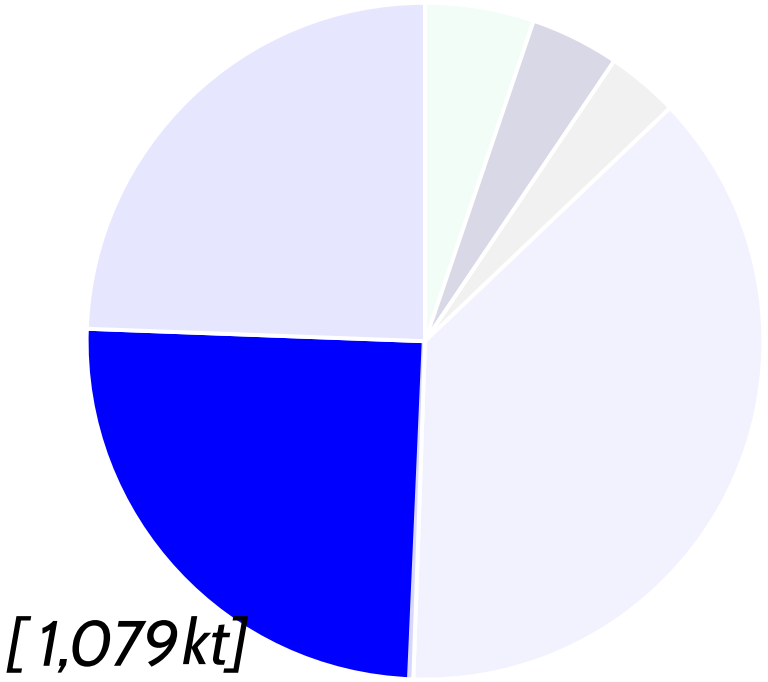
Dy, Pd, Pt *[0,2 kt]*



SRMs and CRMs in Slags and Ashes in 2030 (unit: kt)
Relevant in mass



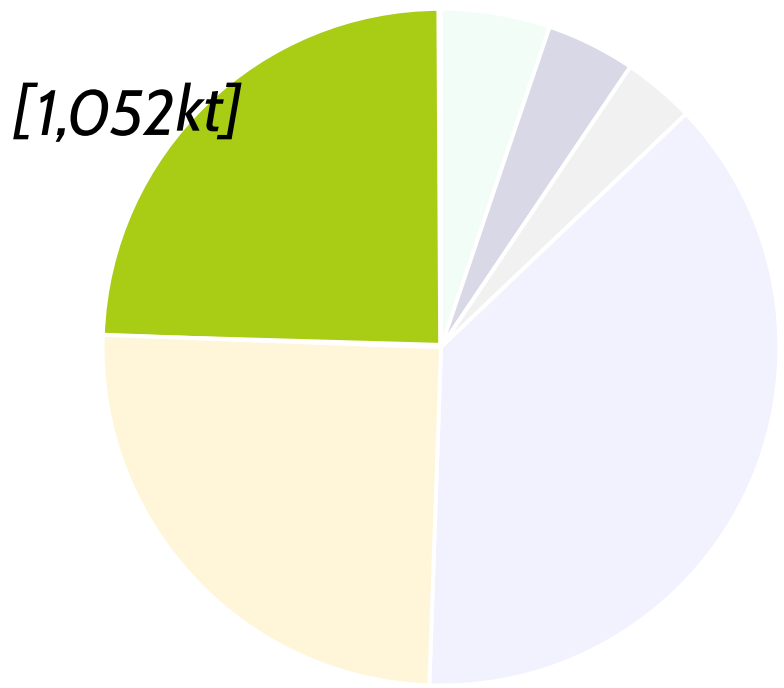
SRMs and CRMs in Slags and Ashes in 2030 (unit: kt)
Relevant to global extraction



SRMs and CRMs in WEEE in 2030 (unit: kt)
Relevant in mass

Al, Cu

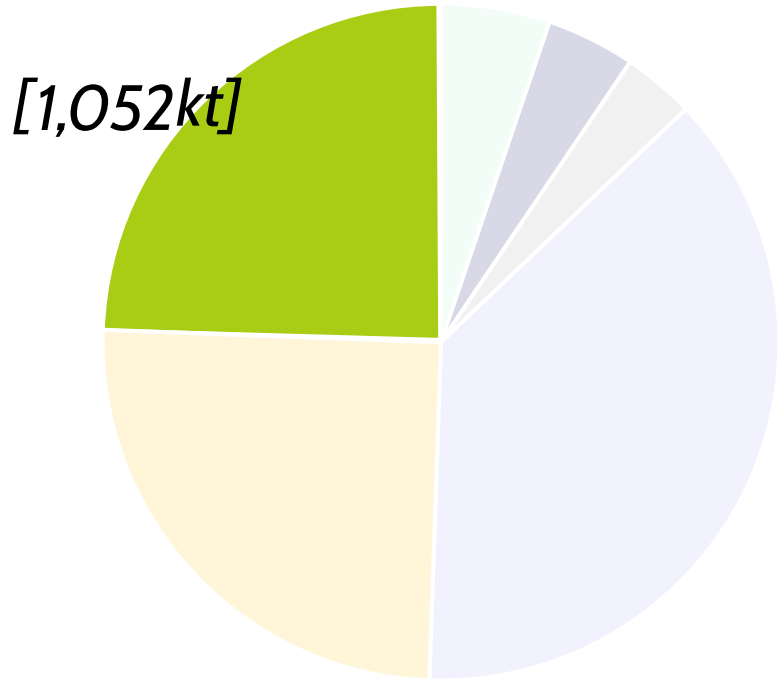
[863 kt]



SRMs and CRMs in WEEE in 2030 (unit: kt)
Relevant to global extraction

Dy, Nd, Pd

[1,3 kt]

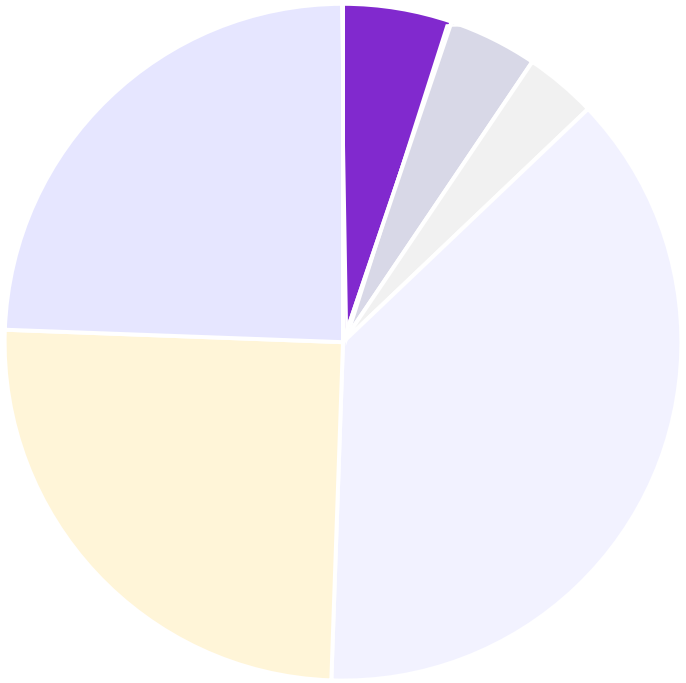


SRMs and CRMs in Battery Waste in 2030 (unit: kt)
Relevant in mass

Mn, Ni, Co

[96 kt]

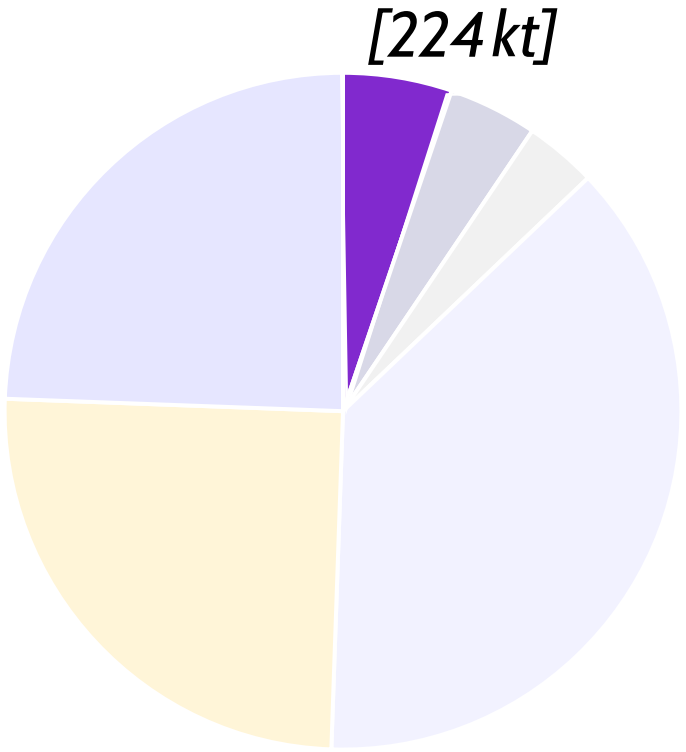
[224 kt]



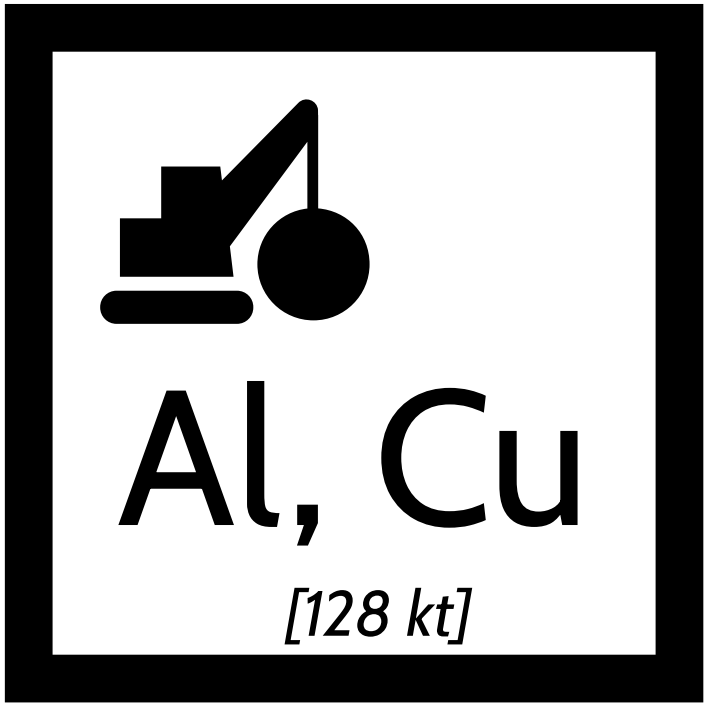
SRMs and CRMs in Battery Waste in 2030 (unit: kt)
Relevant to global extraction

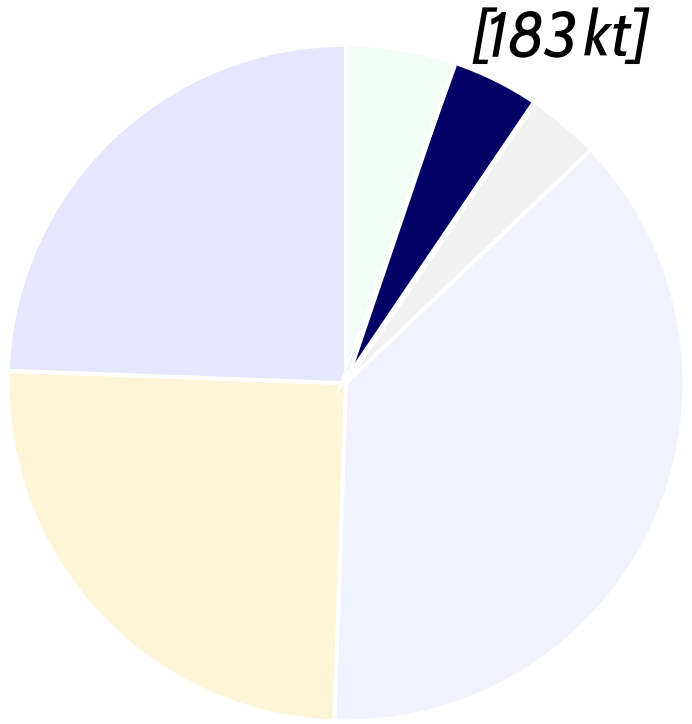
Li, Co, Sb

[34 kt]

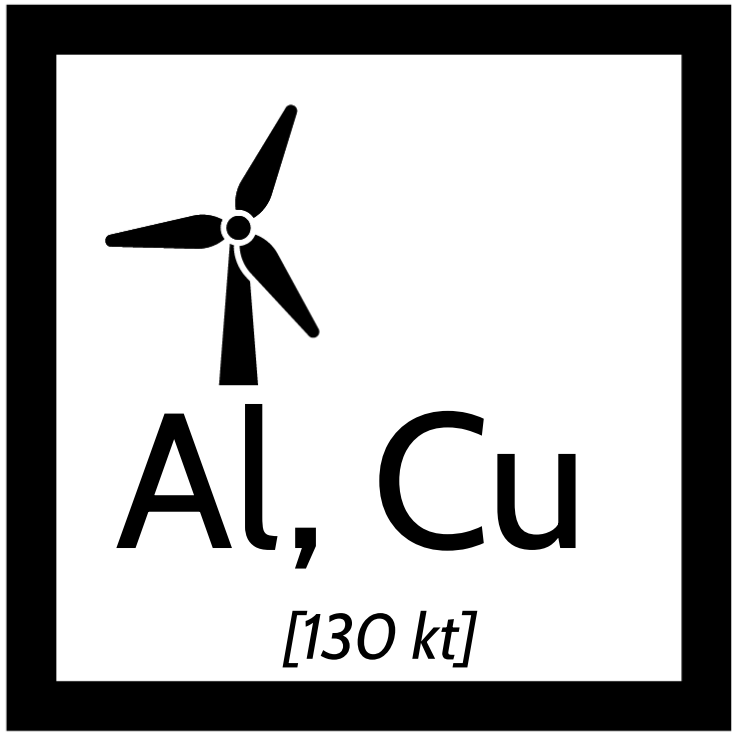


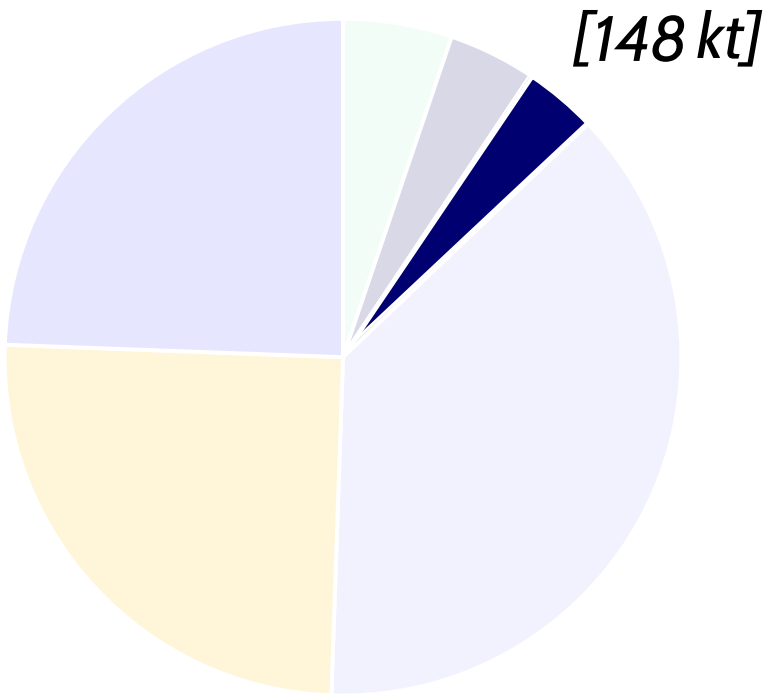
SRMs and CRMs in Construction and Demolition Waste Buildings in 2030
Relevant in mass





SRMs and CRMs in Decommissioned Wind Turbines in 2030 (unit: kt) Relevant in mass

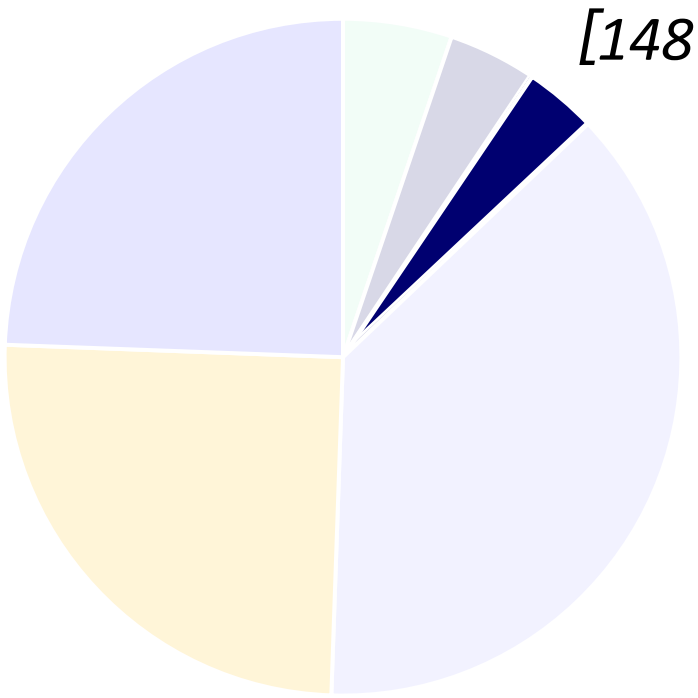




SRMs and CRMs in Decommissioned Wind Turbines in 2030 (unit: kt)
Relevant to global extraction

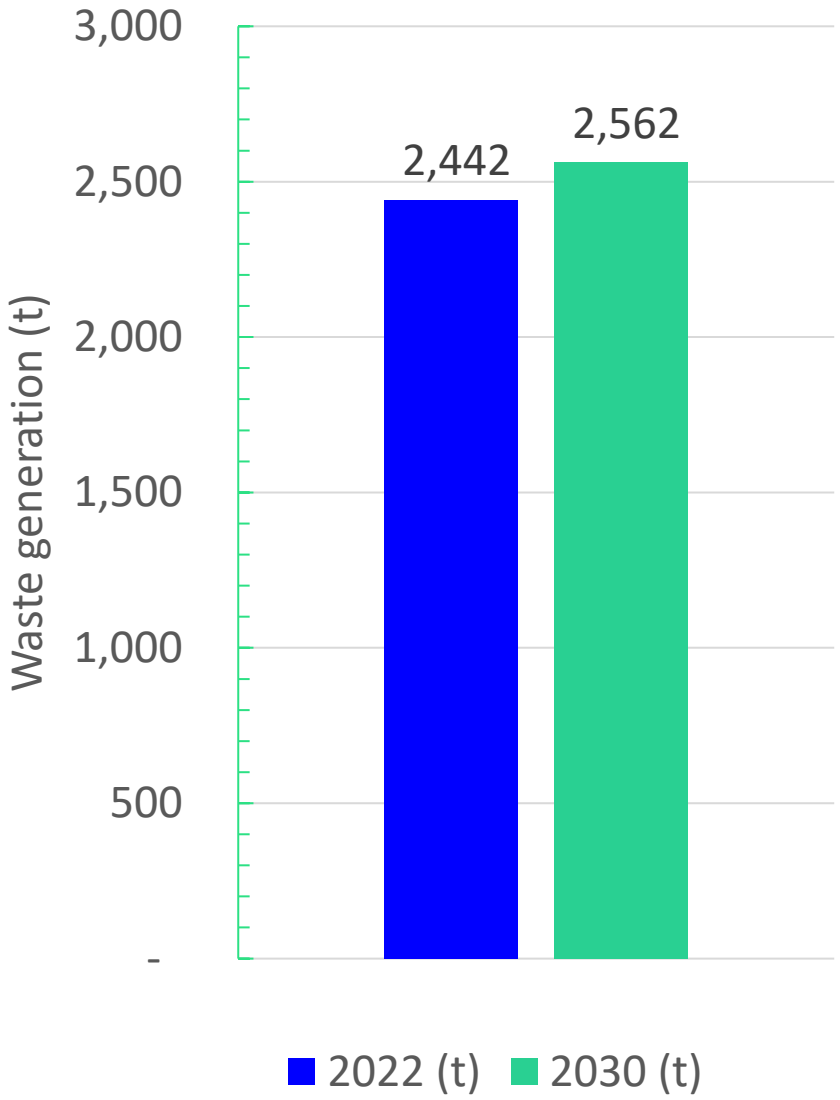
Dy, Tb, Nd

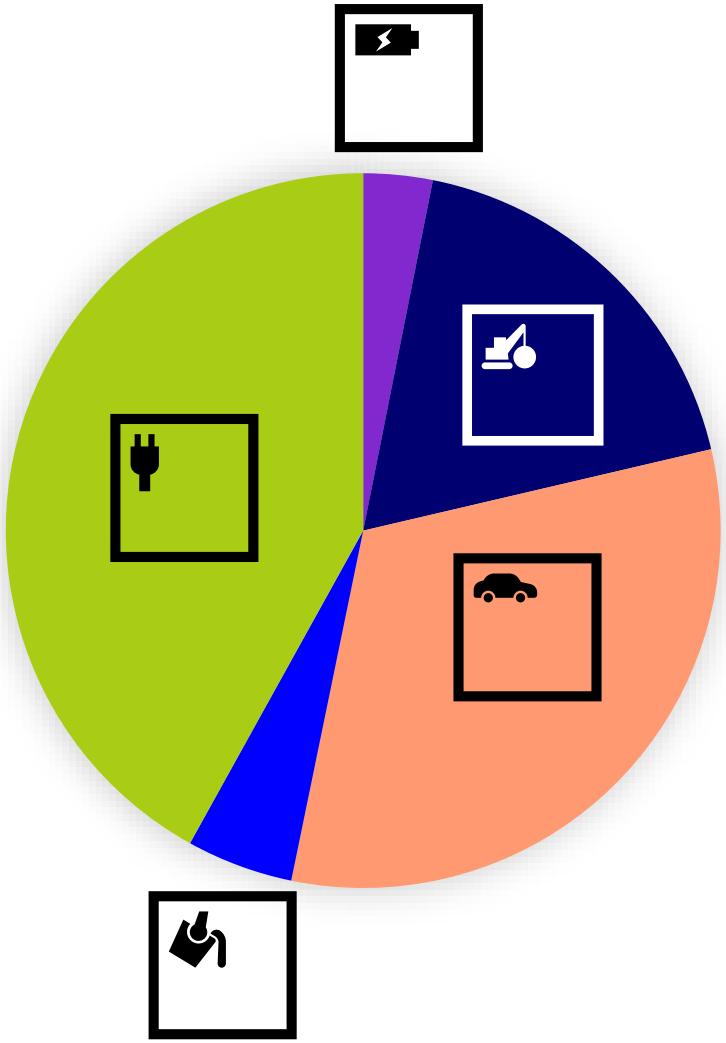
[0,6 kt]



[148 kt]

Neodymium


3,000
2,500
2,000
1,500
1,000
500
-
Waste generation (t)
2,442
2,562
2022 (t)
2030 (t)

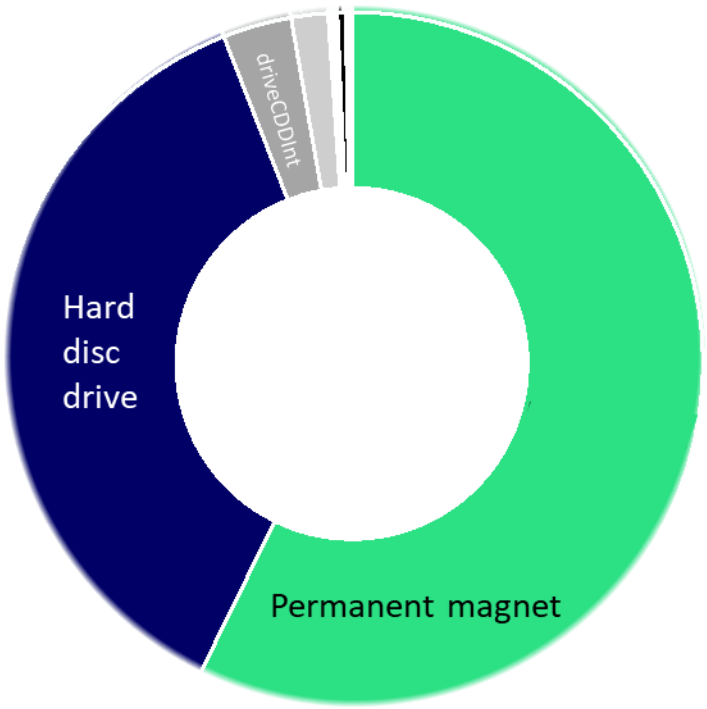


How to find the Neodymium in WEEE in the EU27?

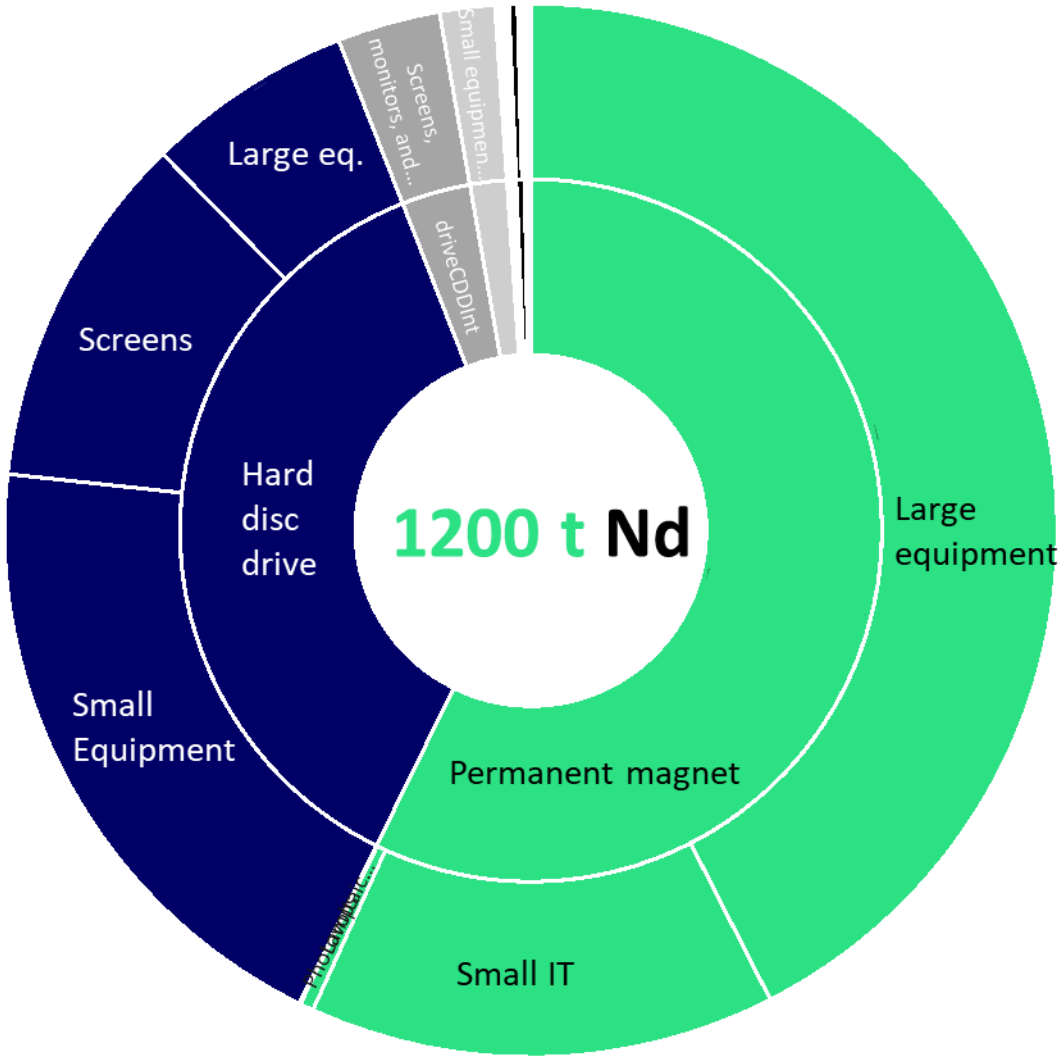
Total: 11 Mt

Where to find Neodynium in WEEE in the EU27 in 2030?

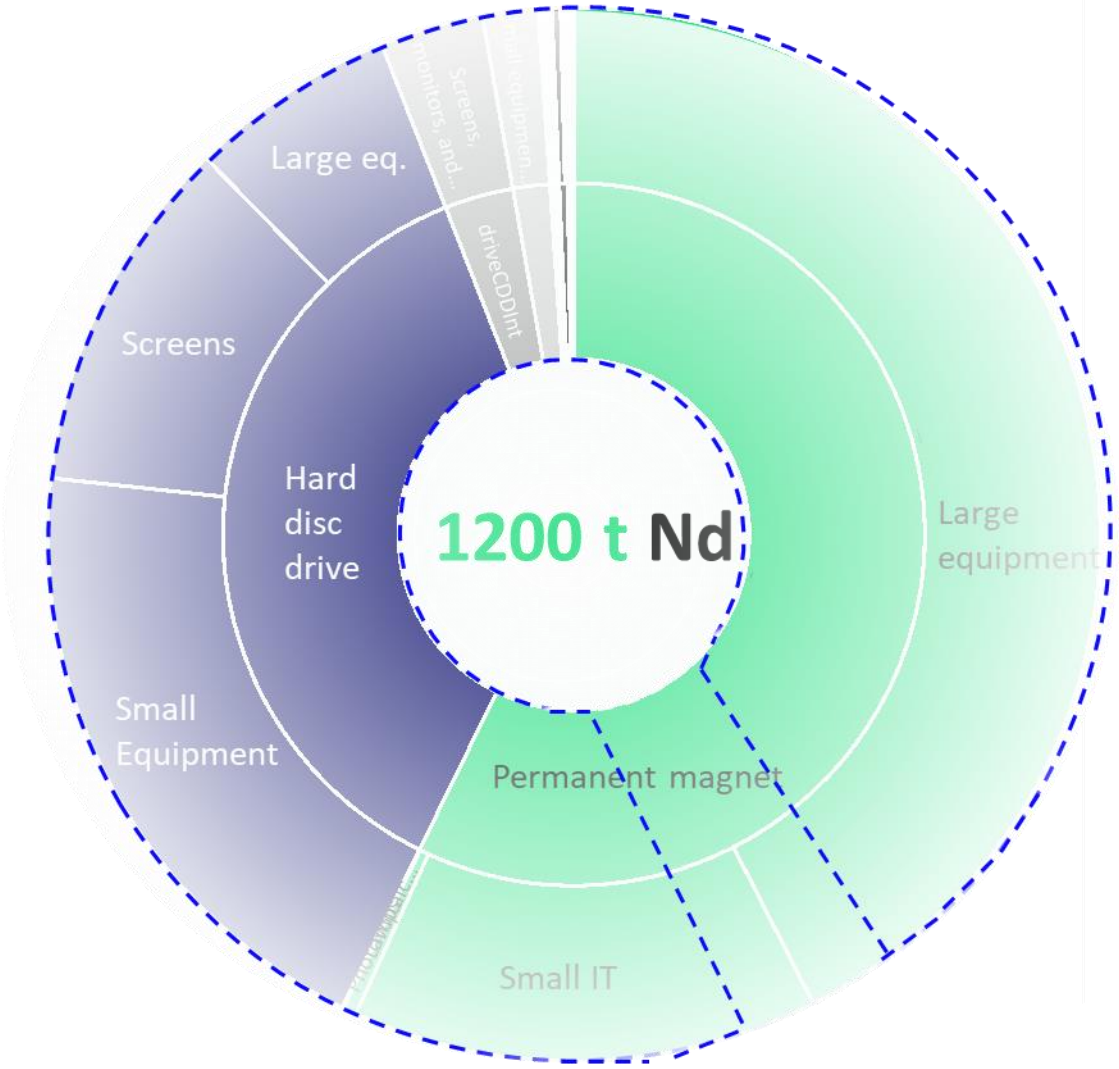
300 kt components containing Nd



How to find Neodynium in WEEE in the EU27 by 2030?



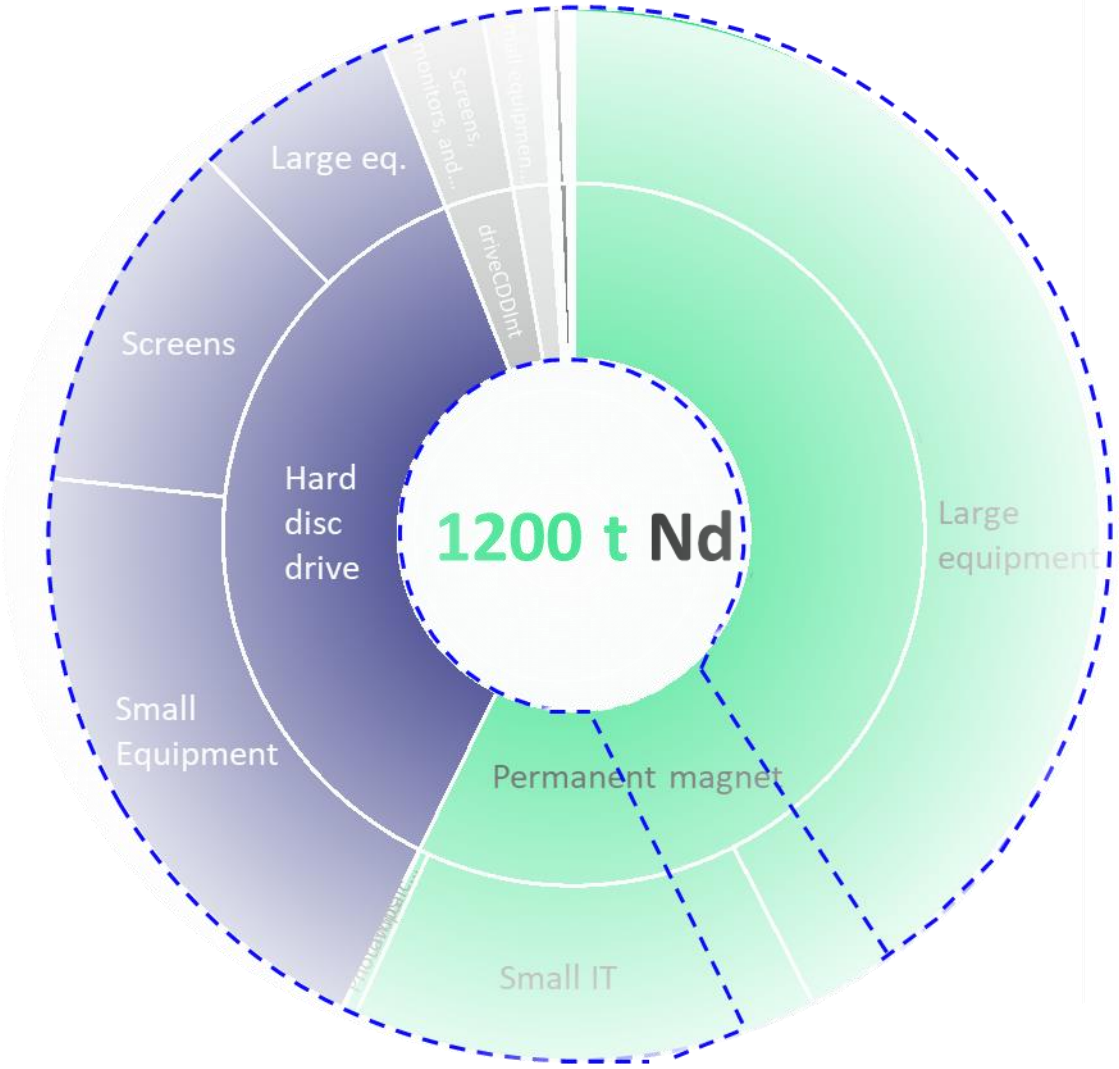
How to recover Neodynium in WEEE in the EU27 by 2030?

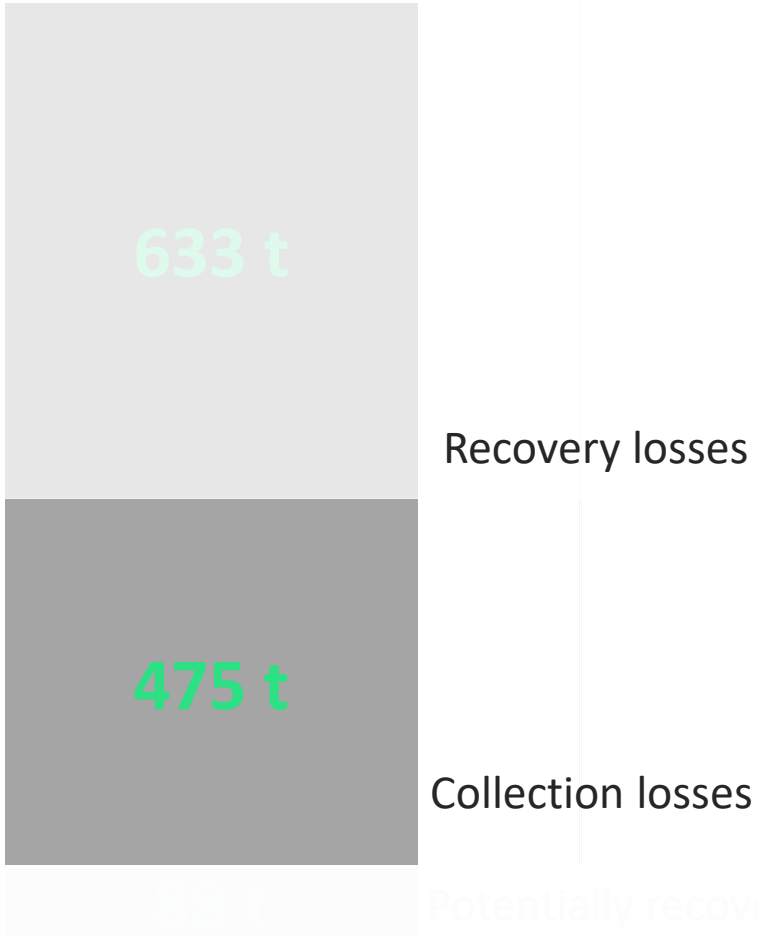


633 t

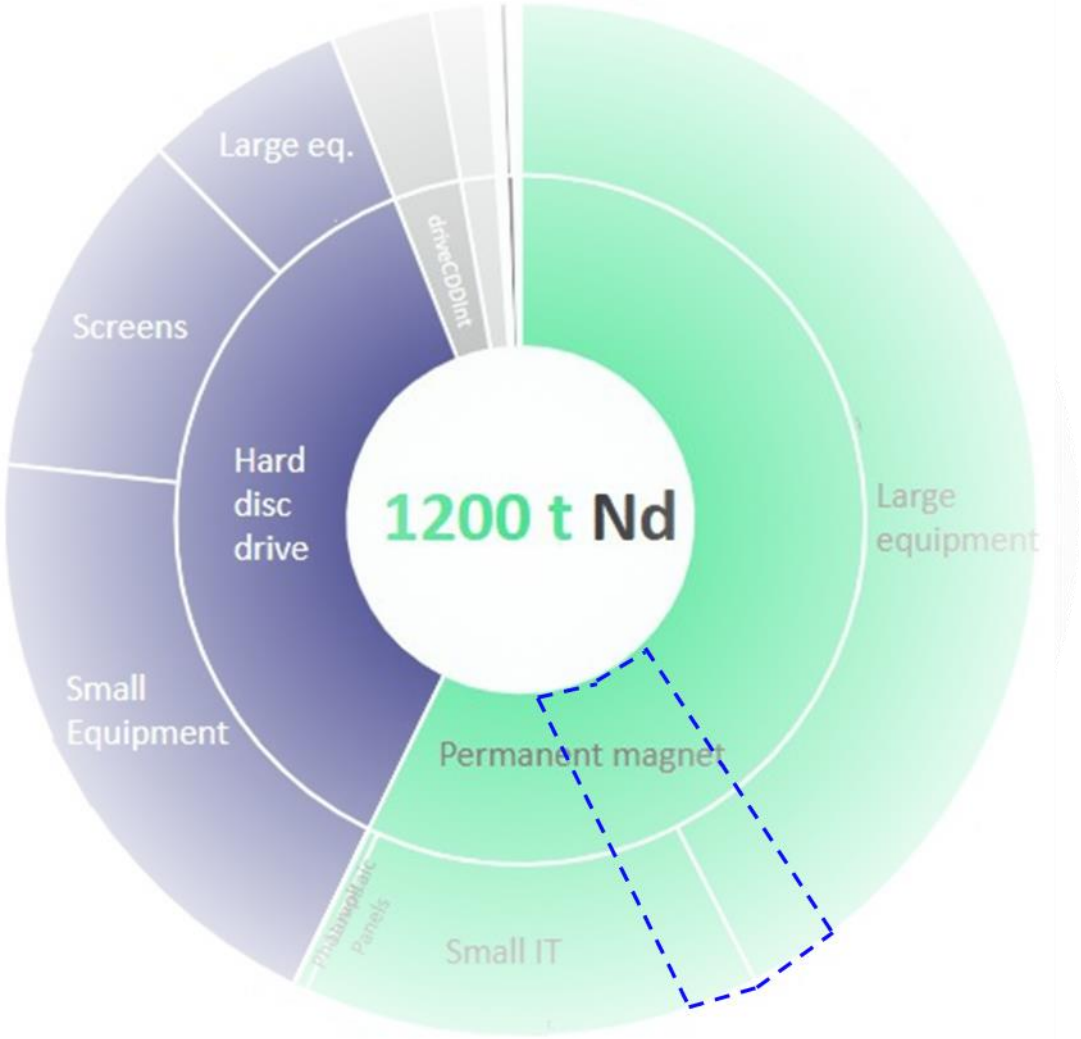
Recovery losses

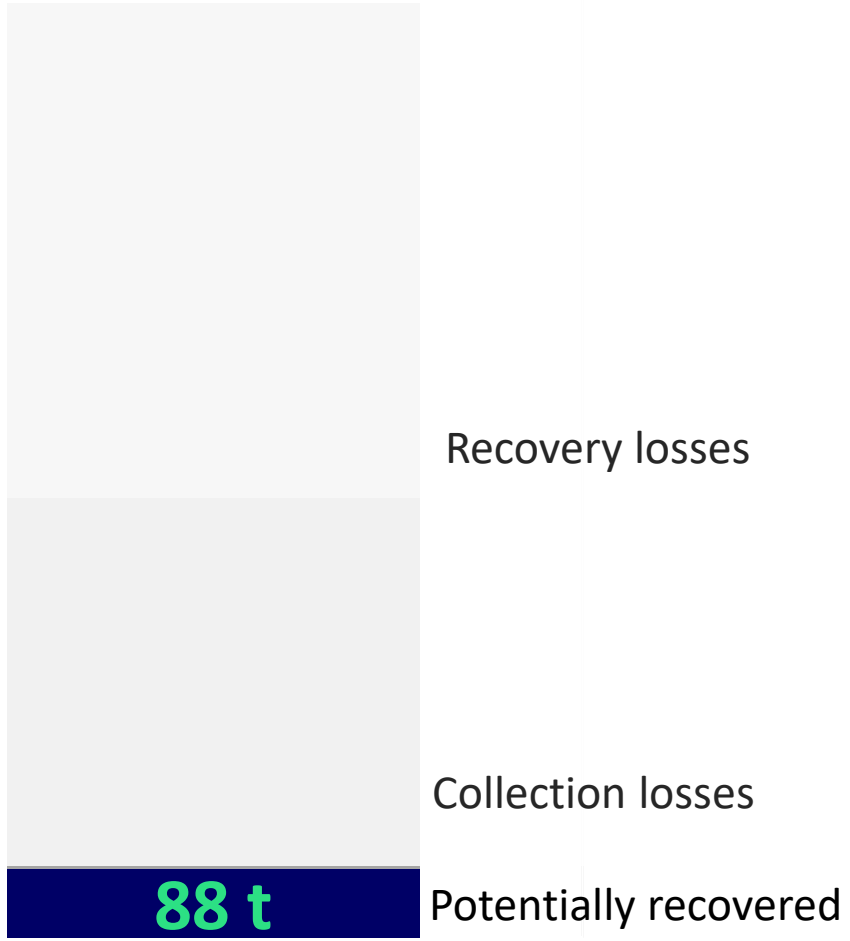
How to recover Neodynium in WEEE in the EU27 by 2030?



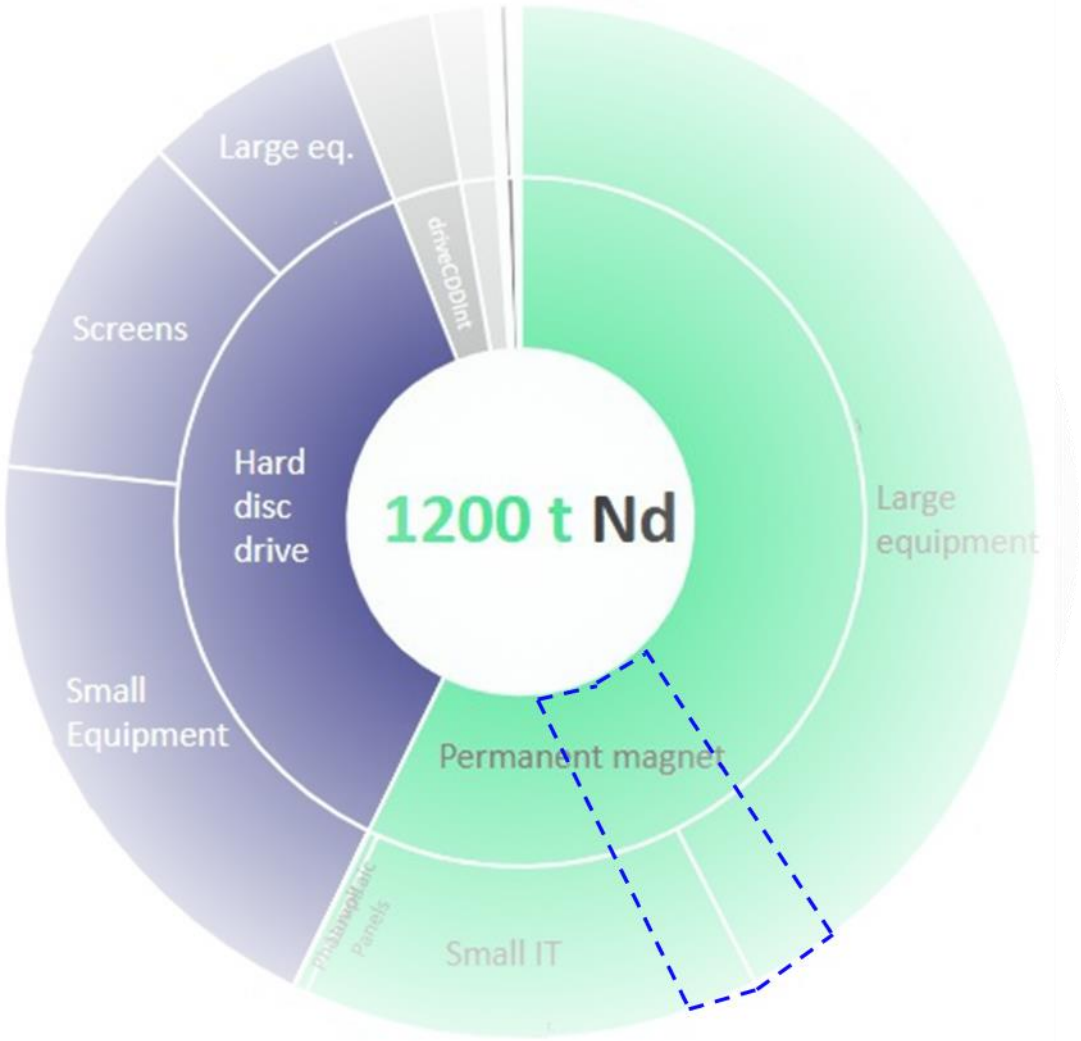


How to recover Neodynium in WEEE in the EU27 by 2030?





How to recover Neodynium in WEEE in the EU27 by 2030?



Direct EU consumption (JRC)

119 t

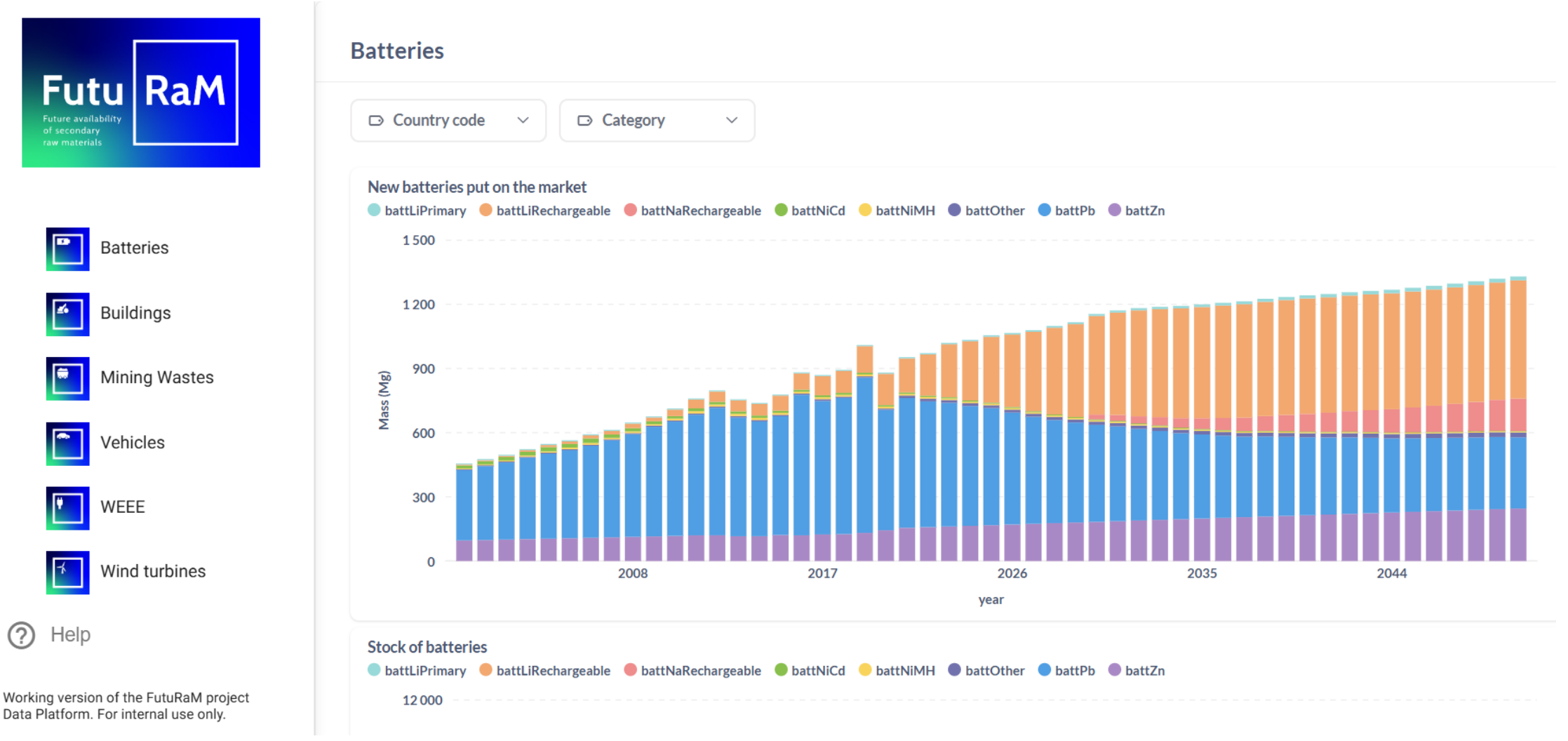
88 t Potentially recovered

Support of Article 26(7) of CRM-Act

- Interim datasets from FutuRaM, amounts of strategic and secondary raw materials, concentrations, waste flows, etc
- Further modelled by Joint Research Center
- List of components, products and waste streams that contain relevant amounts of strategic and critical raw materials
- To be used as an Annex to CRM-Act

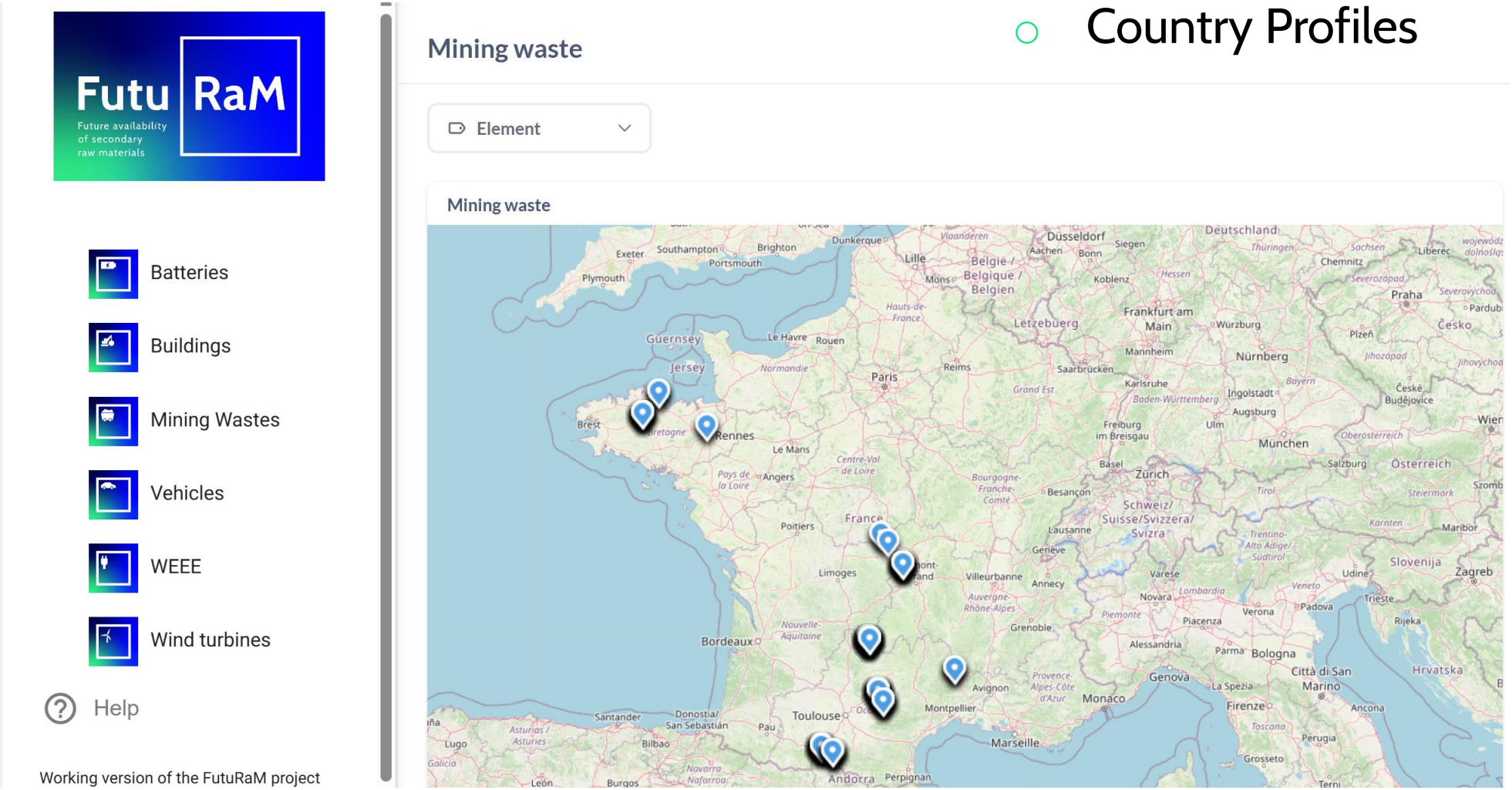
Urban Mine Platform

- Main assets
  - Easy access to download data
  - Data to 2050 in three future scenarios

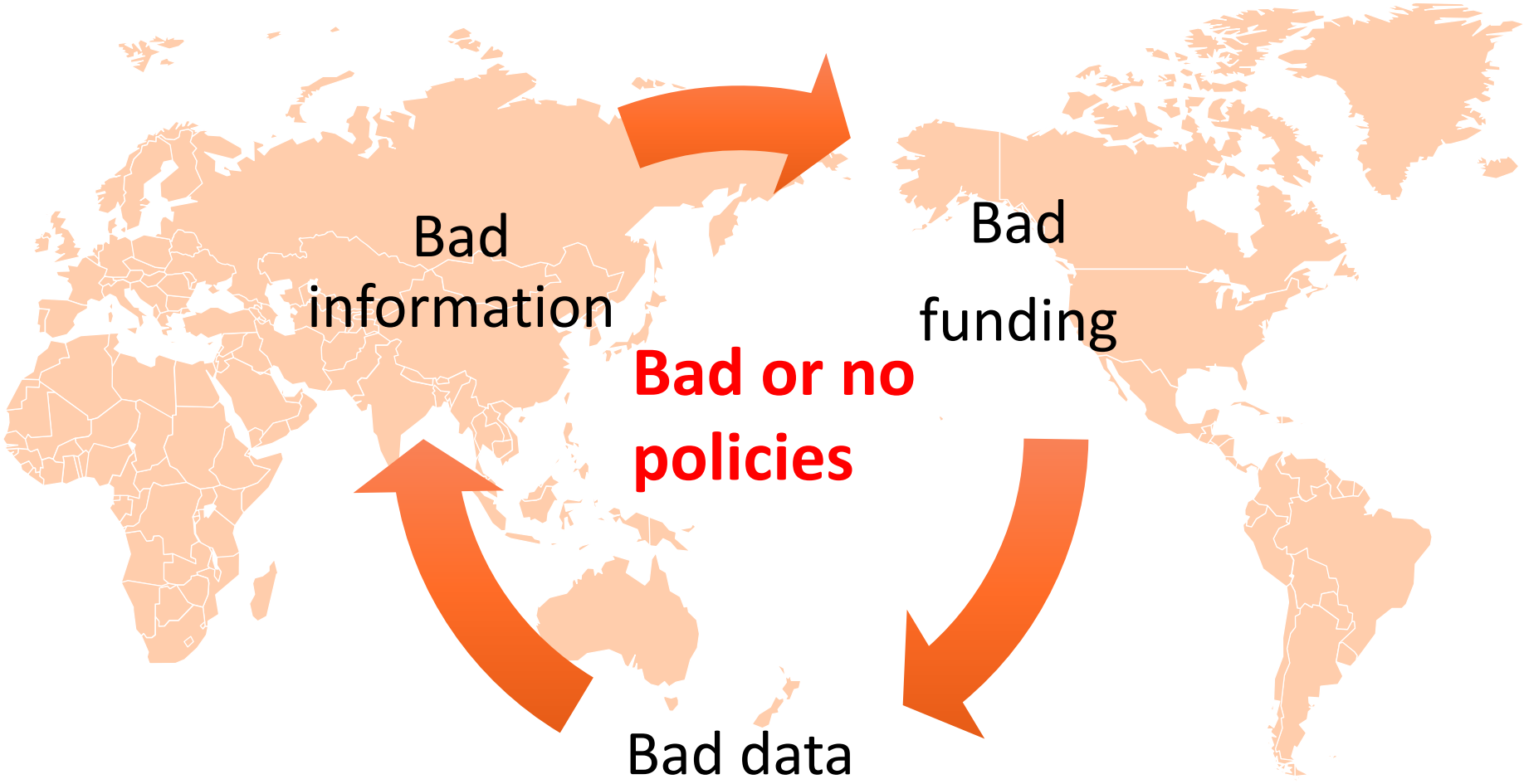


Urban Mine Platform

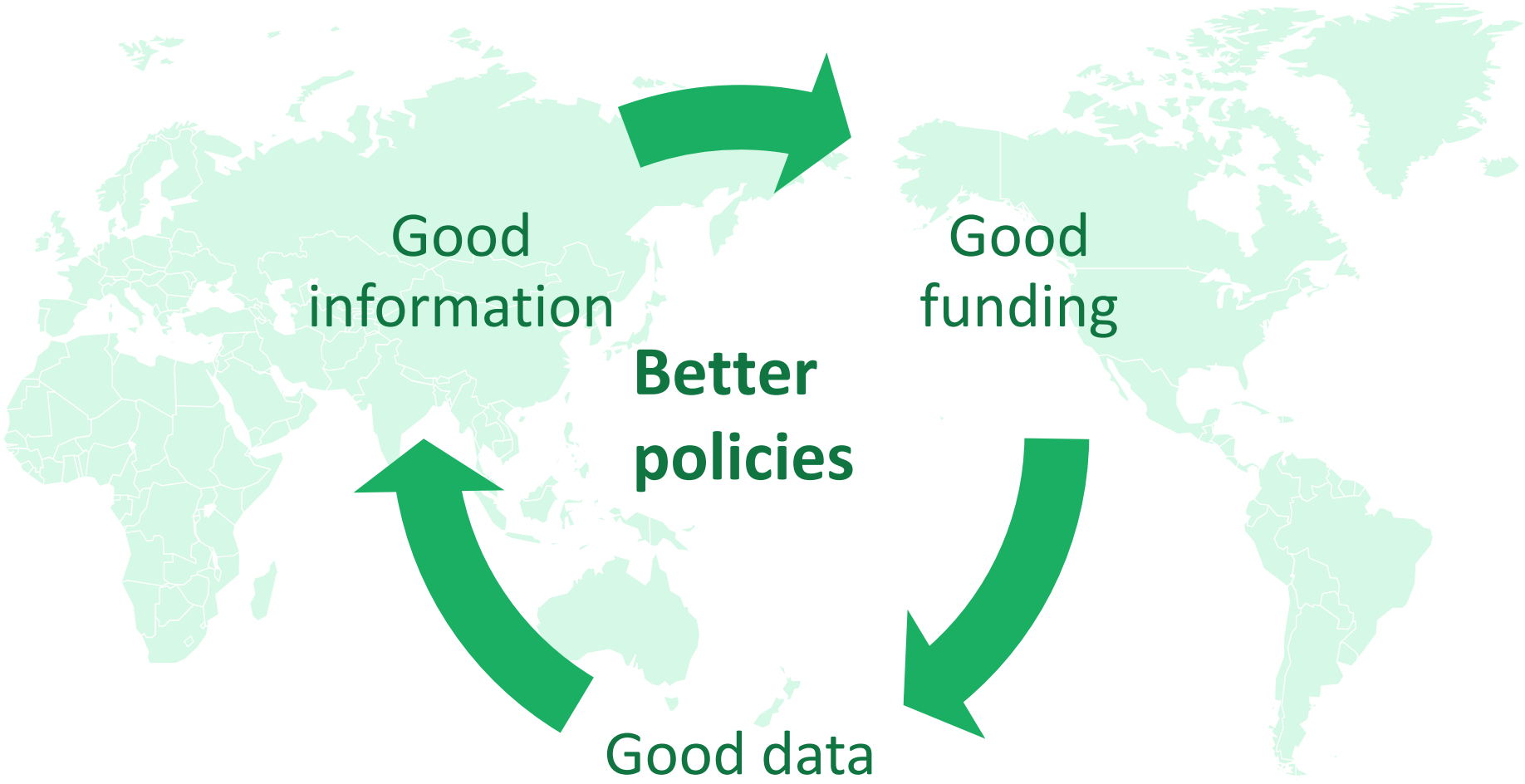
- Main assets
  - Maps with Mining Waste
  - Comparison between waste streams
  - Country Profiles



Downward spiral when not having data



Virtuous cycle – that needs to be sustained



More recovery of secondary raw materials in Europe

Thank you

Kees Baldé

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United Nations Institute for Training and Research

Sustainable Cycles (SCYCLE) Programme

Futu RaM

Future availability of secondary raw materials

UNFC applied to anthropogenic resources

26th March 2025

Soraya Heuss-Aßbichler

University of Munich (LMU)

Funded by the European Union

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

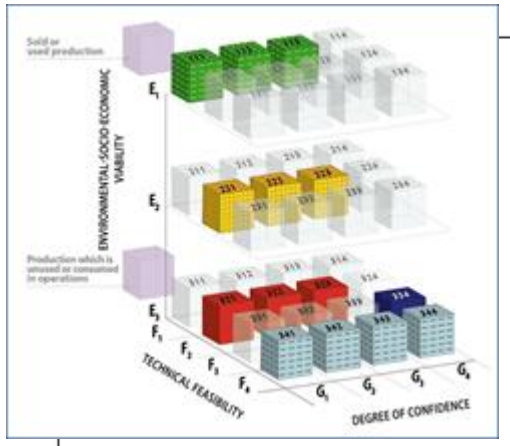
Federal Department of Economic Affairs, Education and Research EAER
State Secretariat for Education, Research and Innovation SERI

EU Framework Programmes

UK Research and Innovation

LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

Phases of project development and UNFC classes



Classification & Decision

Project idea

"Screening"

Prospective project

Remaining products not developed

Pre-feasibility study

Potentially Viable project

Non-viable project

Feasibility study

Viable project

Non-viable project

Implemen-tation

Transparency – Consistency - Comparability

Module definition with specific set of factors for the context of evaluation in the realm of discourse (ROD)

Legislation (Basic - ROD)

→ROD complies with permit requirements

Controlling factors

Circularity (CE - ROD)

→ ROD considering R - types

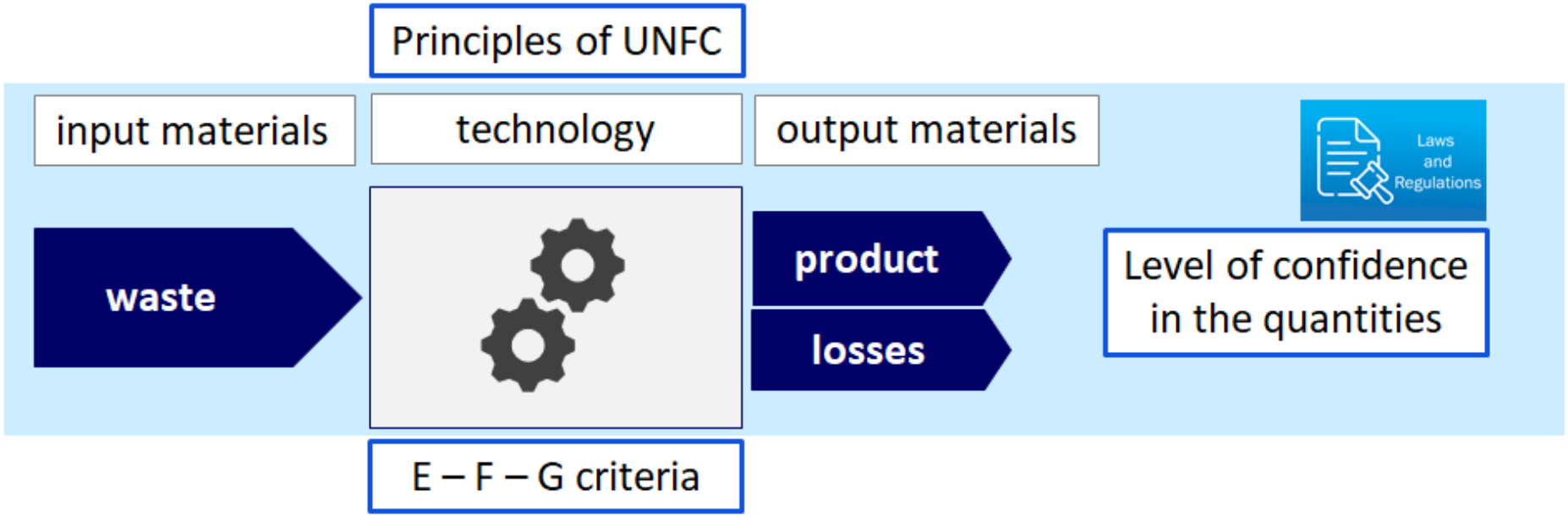
Controlling factors

Sustainability (SDG - ROD)

→ ROD considering the UN SDGs

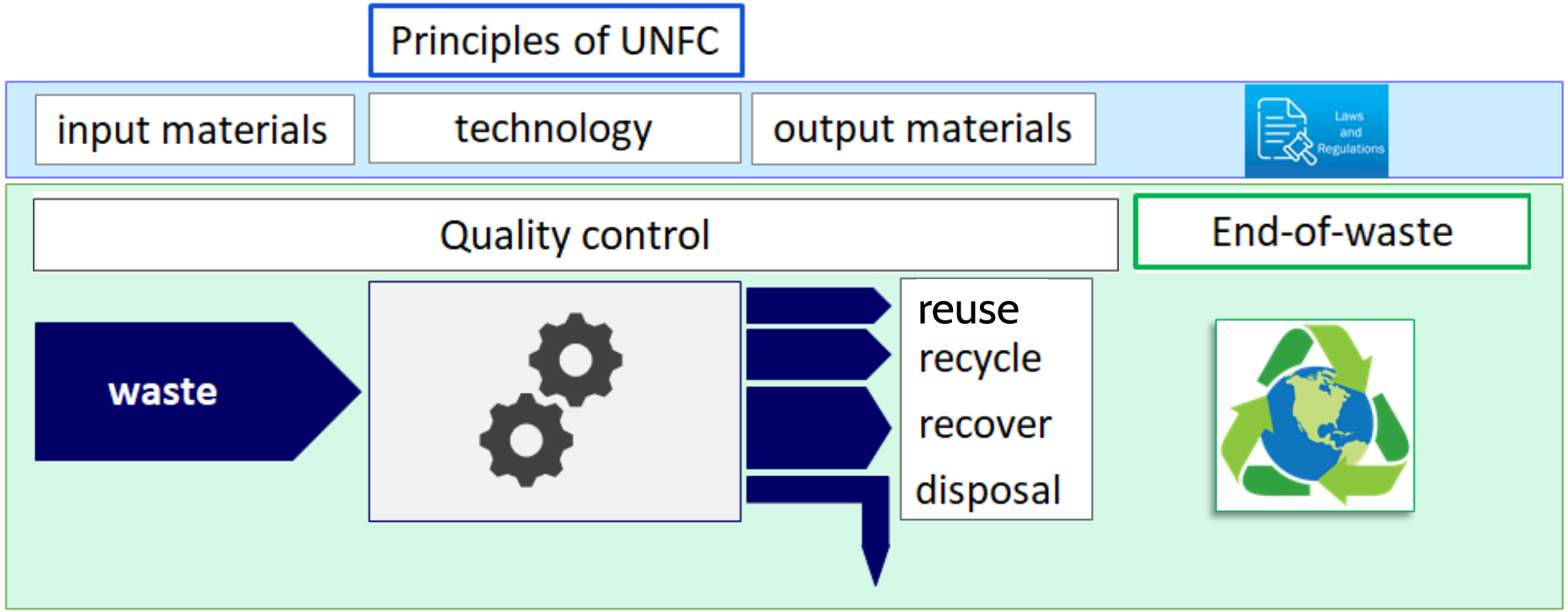
Controlling factors

Basic - ROD



- Requirements for granting approvals for the implementation of the project

CE - ROD

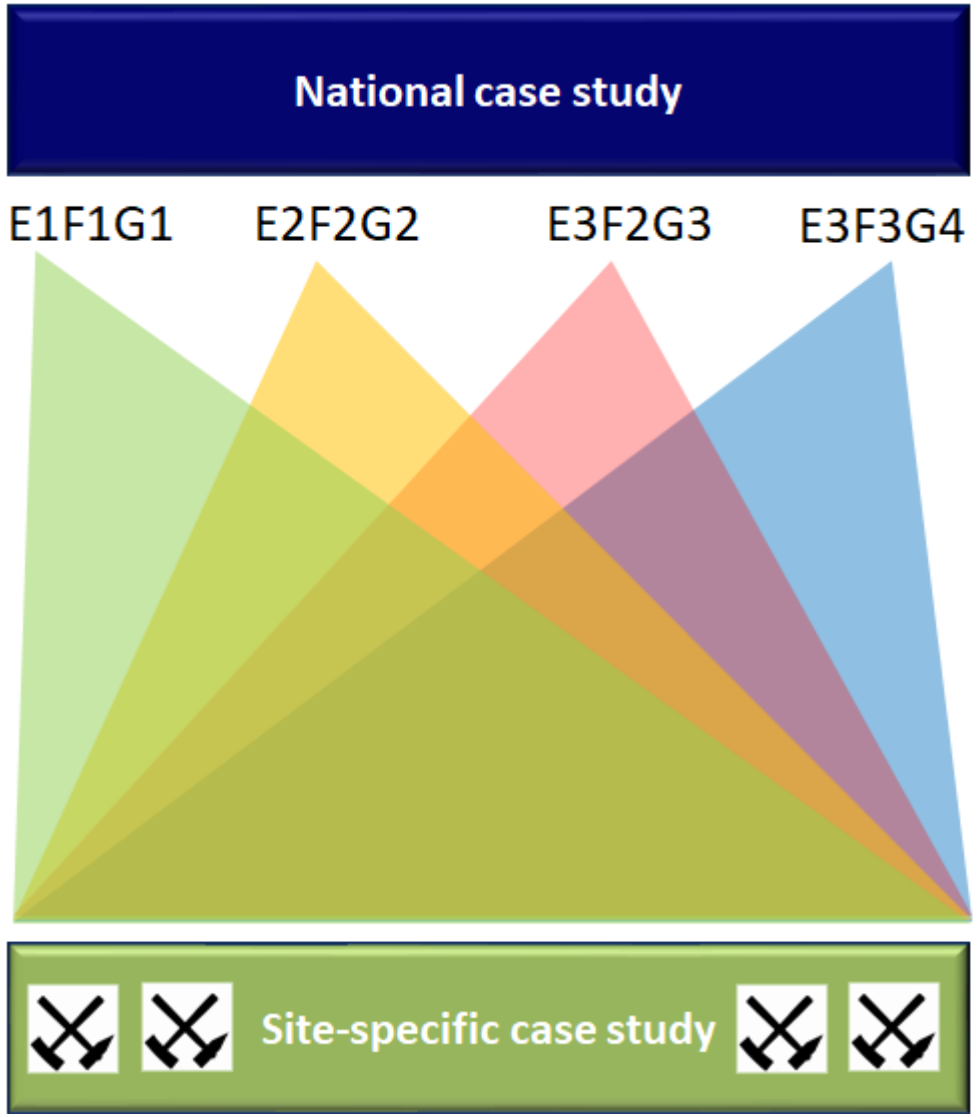


- Differentiation of the products with regard to the closed loop economy
- Contribution to the 'End-of-Waste' assessment

National approach

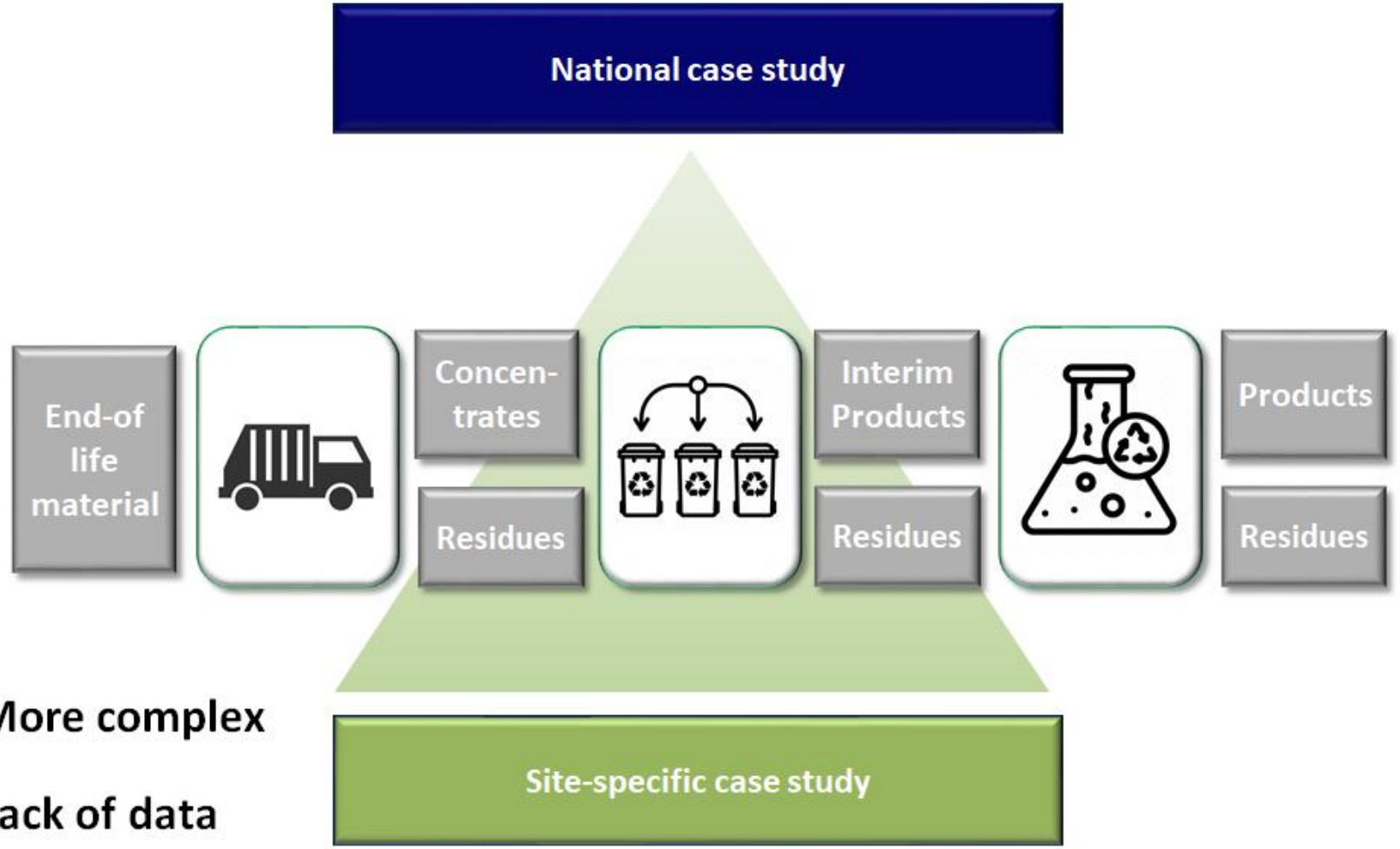
Recovery of 2RMs from Mining Waste

Bottom-up approach



Detailed information
of the projects
Σ (projects)

Recovery of 2RMs in the recycling sector



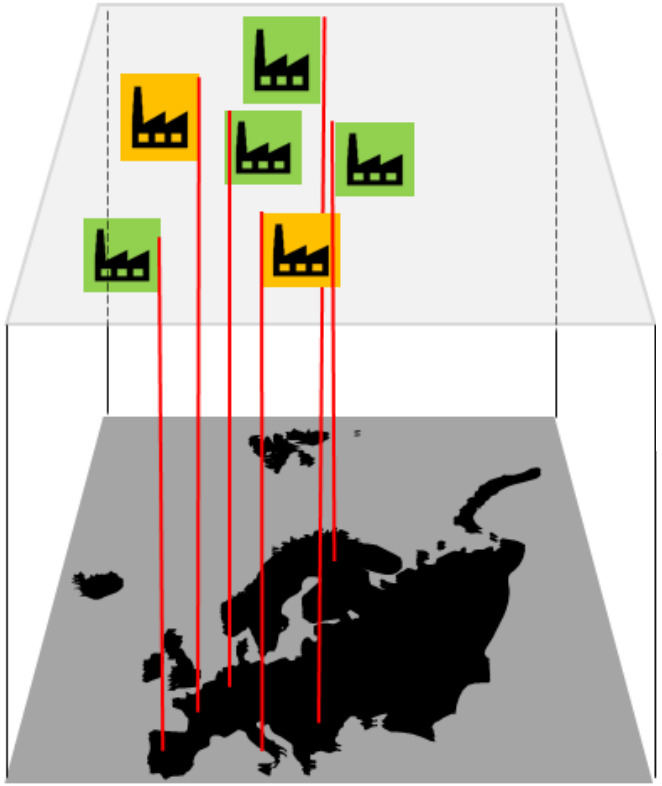
- More complex
- Lack of data

National approach

Map of all the treatment plans

Overview of the total amount of waste produced & its treatment

Summary of stock & flows to create a Material Flow Analysis



Classify the treatment plants according to UNFC terminology

Analyze the MFA for the respective target elements

Assigne the UNFC class to the respective flows

Viable project

Potentially viable project

Application of UNFC

01. Application of UNFC to mining waste
Ronald Arvidsson

02. Timber Recovery - Screening phase
Jonas Breidenbach

03. Phosphorous Recovery - Pre-feasibility phase
Soraya Heuss-Aßbichler

04. LFP- Batteries recycling - National case study
Iman Dorri

Futu RaM

Future availability of secondary raw materials

Mining Waste Case Study

26th March 2025

Ronald Arvidsson

SGU

Funded by the European Union

Schweizerische Eidgenossenschaft
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Confederaziun svizra

Swiss Confederation

Federal Department of Economic Affairs, Education and Research EAER
State Secretariat for Education, Research and Innovation SERI

EU Framework Programmes

UK Research and Innovation

SGU Geological Survey of Sweden

MinW Composition

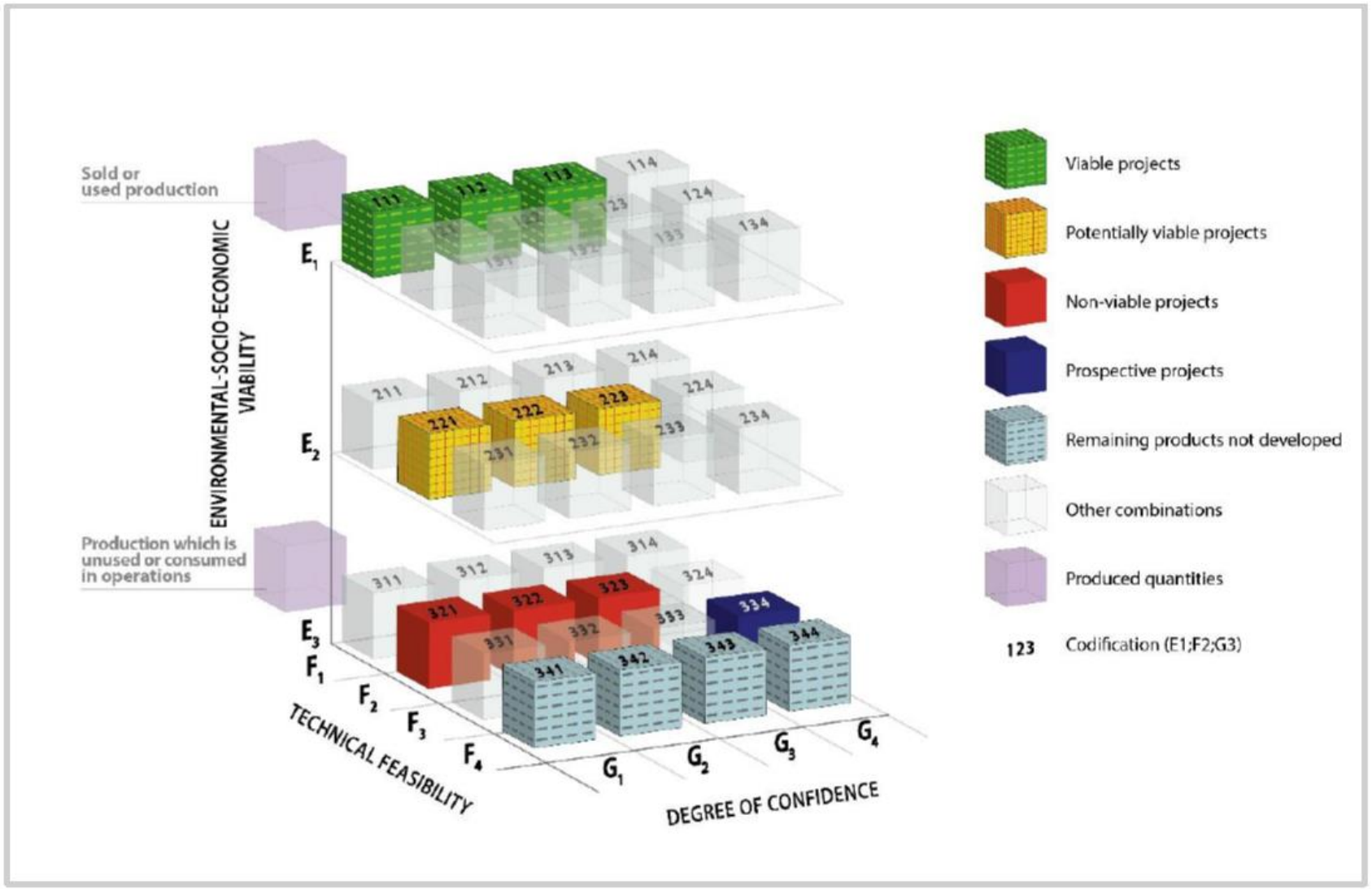
Data
Developed a data base structure fit for CRM Act

Futuram Case studies
- Use sampling protocolls
- Use recognized analysis standards/methods
- Density of sampling determines accuracy/uncertainty of grade, uncertainty tonnage, 3D from maps, photogrammetry, geophysics, onsite observations

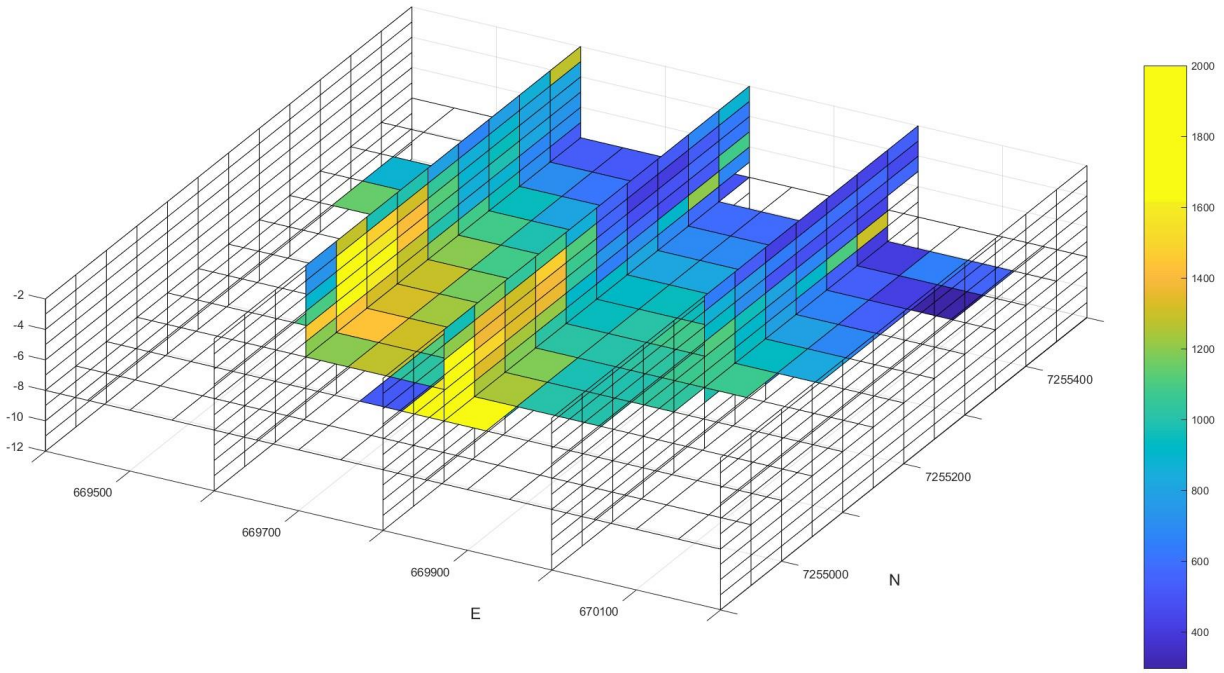
- Examples of high quality cases – composition
- Sweden, Finland, France, Serbia
- National level – Sweden – method development

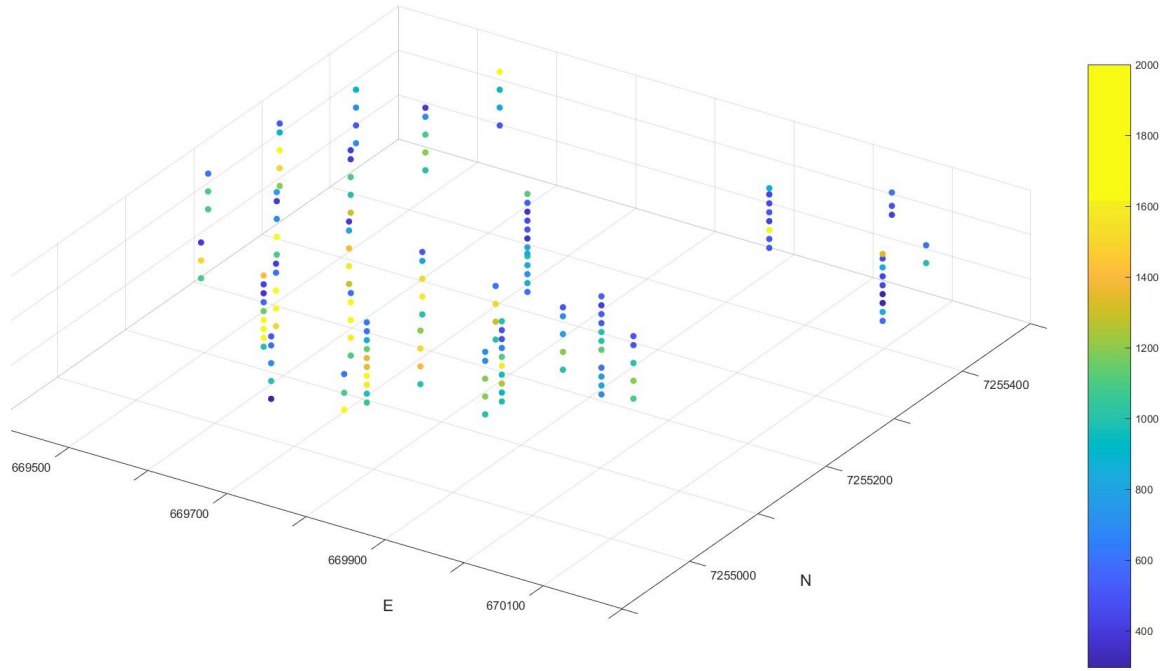
- Composition data
- Grade, tonnage (volume, density,statistics), mineralogy

UNFC Concept

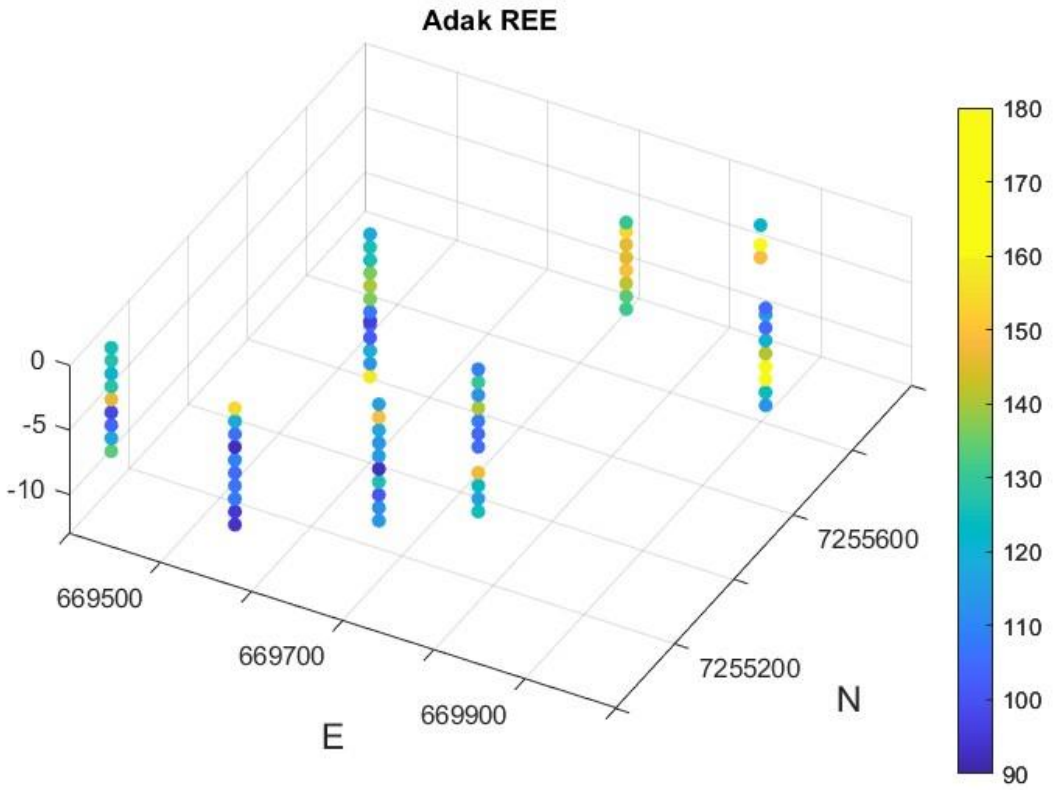


Adak Cu grades within the tailings





Adak REE


Adak REE
0
-5
-10
669500
669700
669900
E
7255600
7255200
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180
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160
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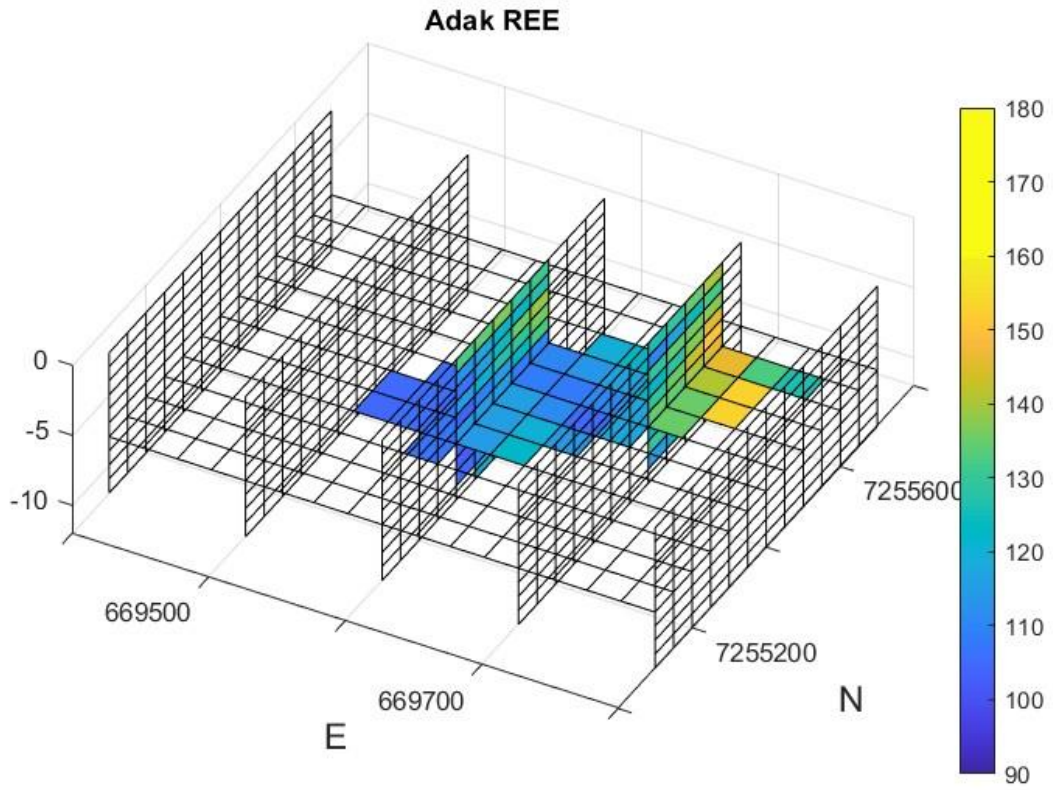
140
130
120
110
100
90


Adak REE
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100
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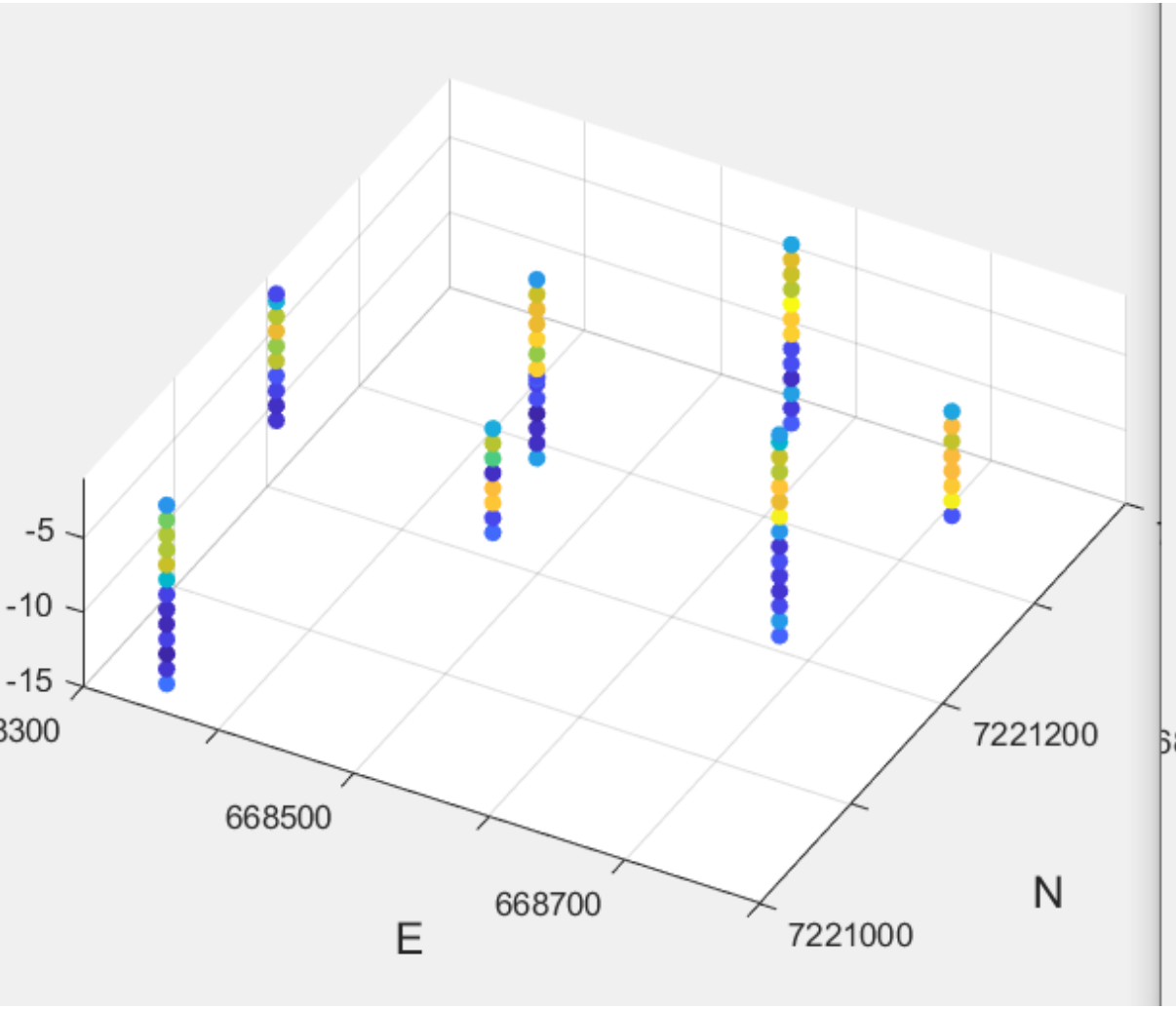
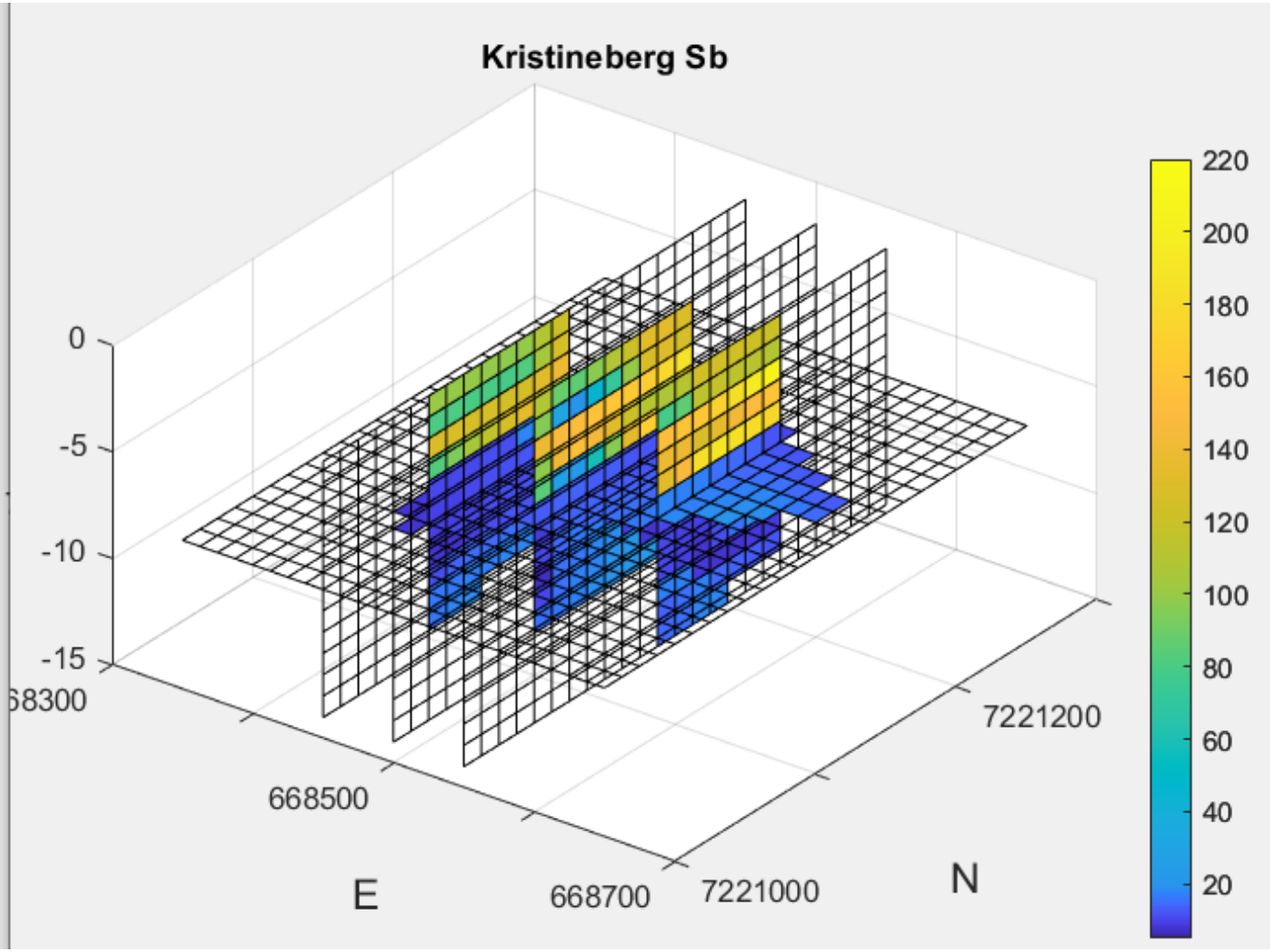
Kristineberg Sb





Example – Håkansboda – rich in Cu, Co

Exploration – dense sampling

Characterization

- Geochemistry – 180 composite samples
- Mineralogy

Beneficiation test

Advanced x-ray sorting => double grade

Photo Ronald Arvidsson

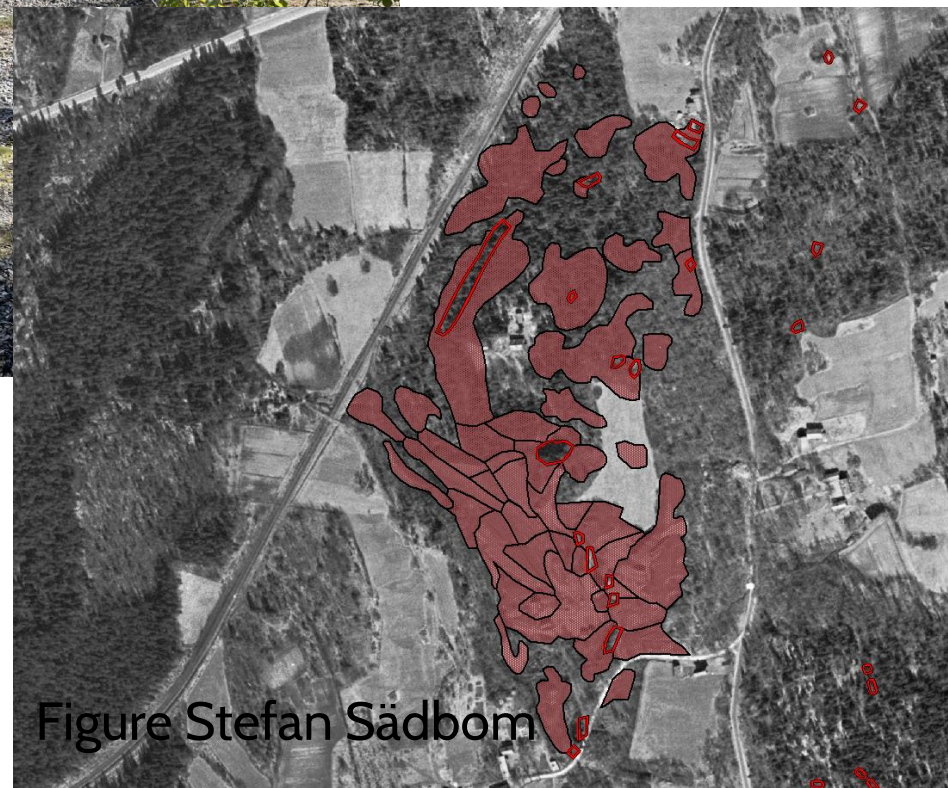
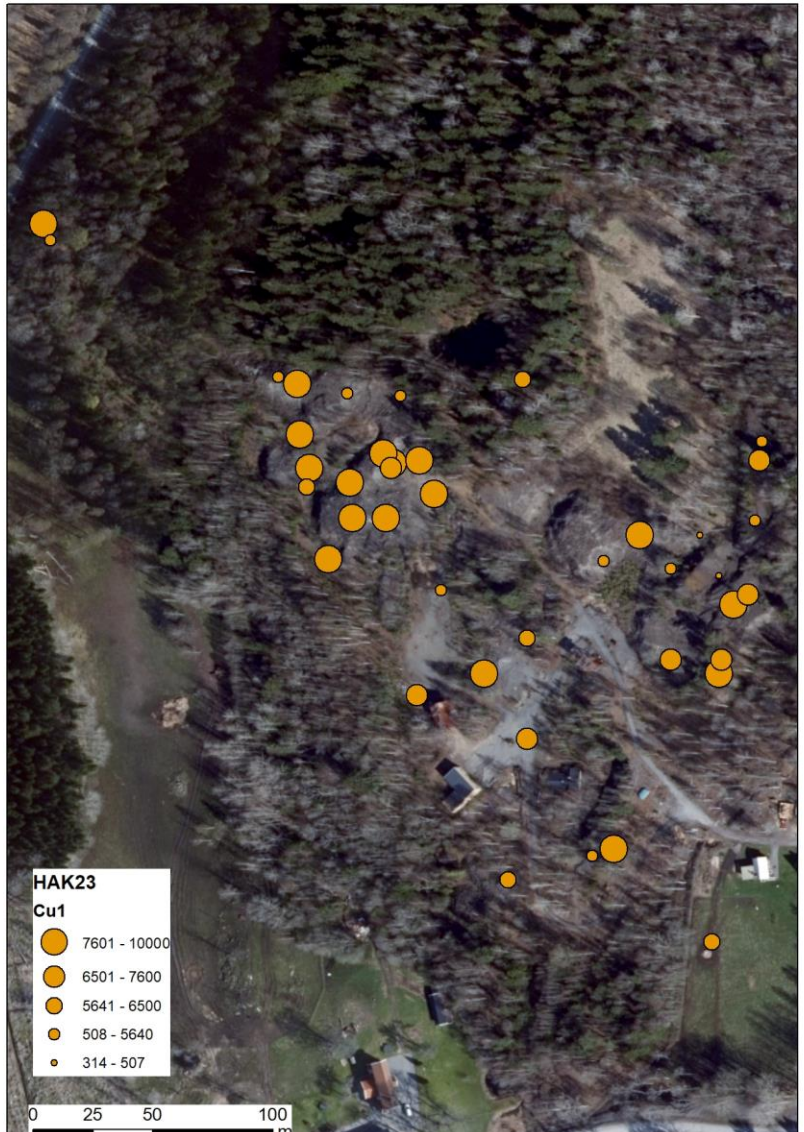


Figure Stefan Sädbom

Håkansboda
Mining waste: ~7,87 ha.
~250 000 t

Resource Cu , Co, Zn



Sensitivity analysis

Necessary with an uncertainty analysis

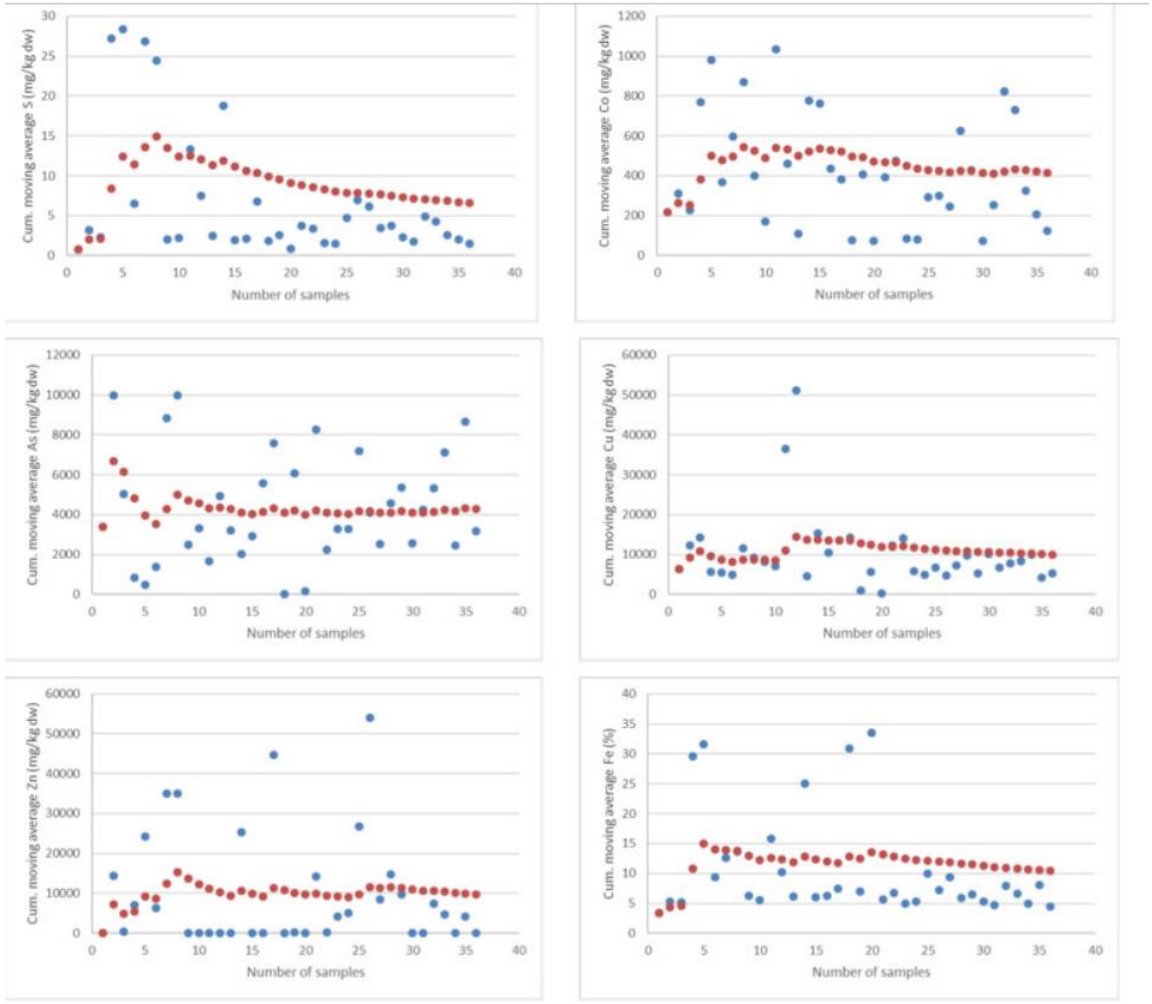


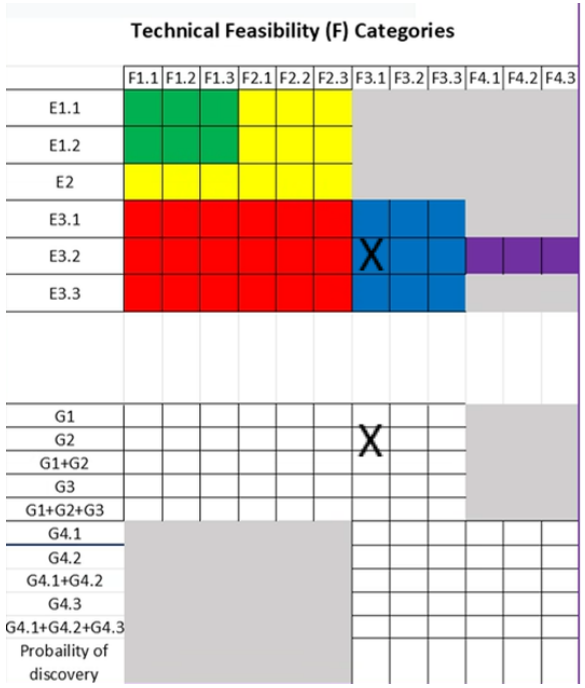
Figure 1 Cumulative moving average concentrations (mg/kg dw) for sulfur, cobalt, arsenic, copper, zinc and iron at Håkansboda historical mining site in Sweden. Average concentrations are calculated using increasing numbers of samples (from 1+n until all samples have been included). Calculated average (n 36) concentrations for sulfur, cobalt, arsenic, copper, zinc and iron are 6.6%, 410 mg/kg dw, 4 300 mg/kg dw, 10 000 mg/kg dw, 9 620 mg/kg dw and 10.4%, respectively.

Development of UNFC – Håkansboda preliminary results

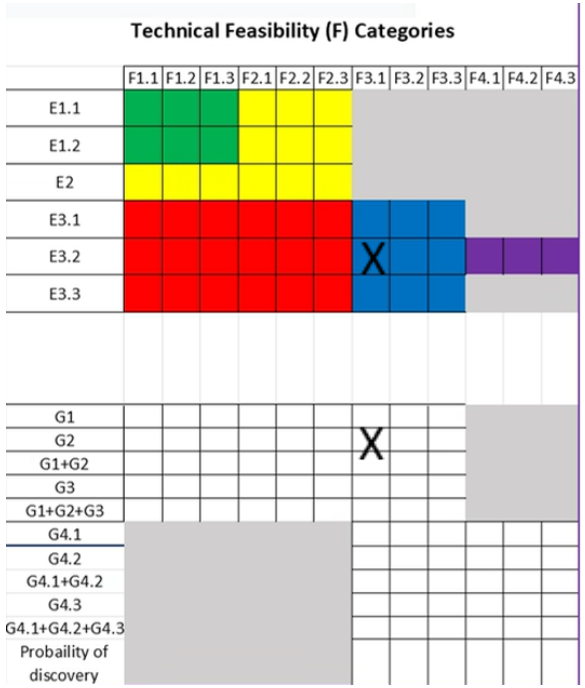
Futuram case – operator Lovisagruvan

- Resources
  - 250 000 tonnes
  - Cu 0.7%
  - Zn 1.2%
  - Co Areas >500 ppm
  - Ag 15 ppm
  - Au .2 ppm
- Beneficiation test – 2nd step, but ongoing
- Permitting has not started for recovery/EIA

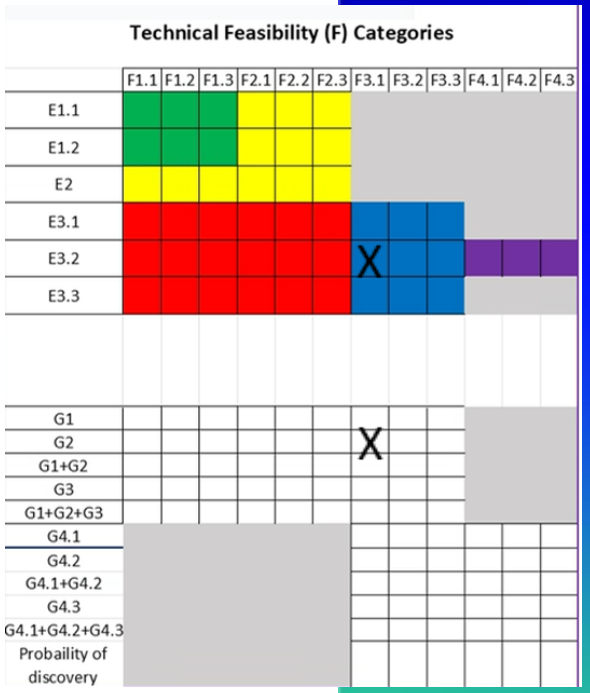
Cu



Zn



Co



Conclusions

Primary mining UNFC fit for mining waste

UNFC by surveys –
- sampling procedures
- uncertainty analysis
- products not consumed or exploration

Howto select for UNFC
- understanding of what grade of interest
- OPEX and CAPEX study – Futuram project

Industry
- viable projects

Database fit for CRM Act

Thank you

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Futu RaM

Future availability of secondary raw materials

Timber Recovery Case Study

Mass timber product manufacturing from wood recovered from construction and demolition

Jonas Breidenbach[1,2,3], Julia Stegemann[1,2,3], Colin Rose[1,2,3]

[1] University College London (UCL)
[2] UK CLT LLP
[3] International Centre of Excellence on Sustainable Resource Management in a Circular Economy (ICE-SRM/CE)

26. March 2025

Funded by the European Union

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UCL

Introduction: Secondary timber in the UK (1/3)

4.5 million tonnes wood ‘waste’ annually in the UK – 50% from CDW

2.5% ‘solid’ reuse

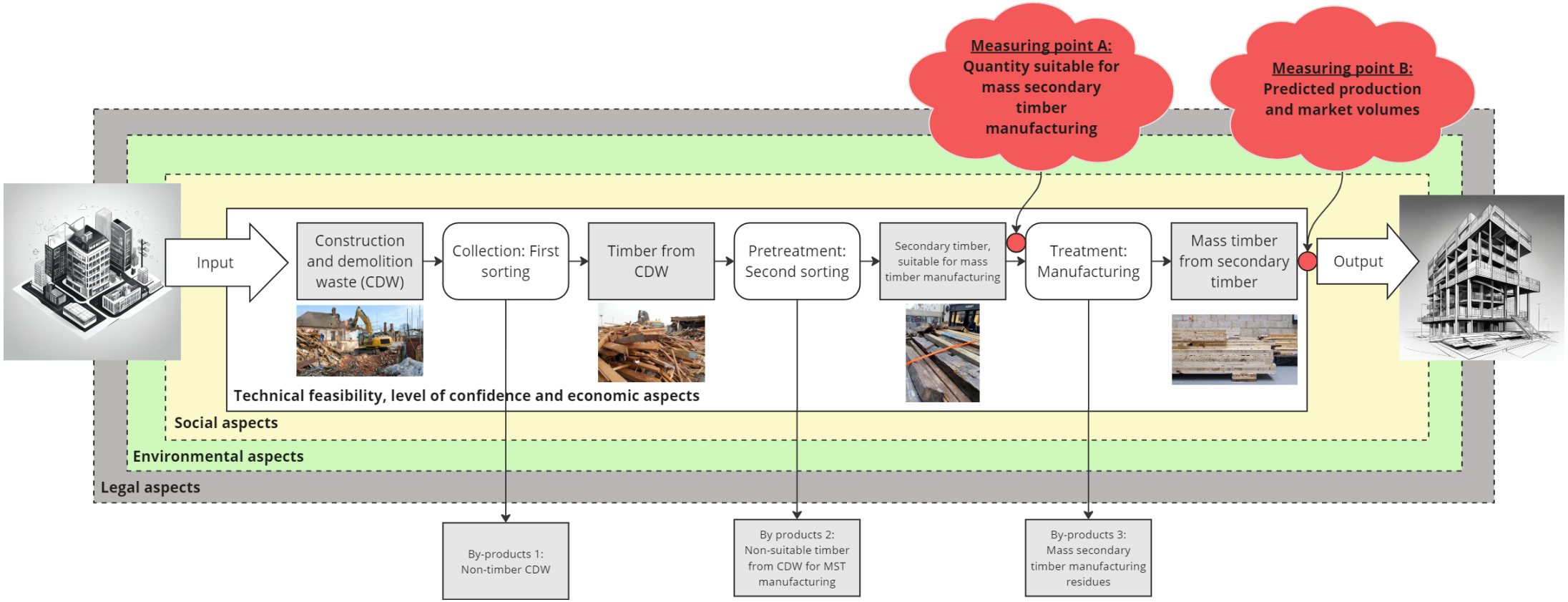
90%+ chipping for biomass energy or other ‘downcycling’ products

Is there potential for an industrial upcycling project to manufacture mass timber products from recovered wood from construction and demolition in England?

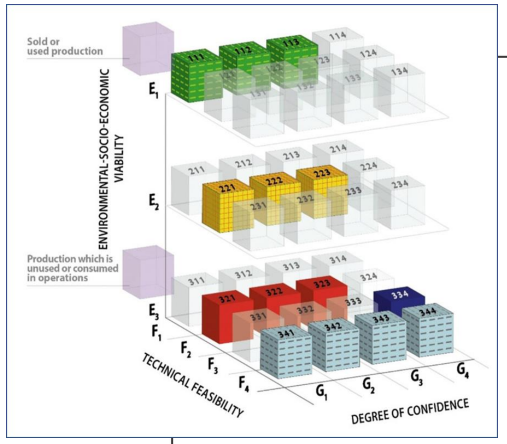
Data: InFutURe Wood (2018) Assessment of what happens to recovered timber in the UK

Introduction: Waste stream (2/4)

Waste Stream: Recovered wood from Construction and Demolition Waste

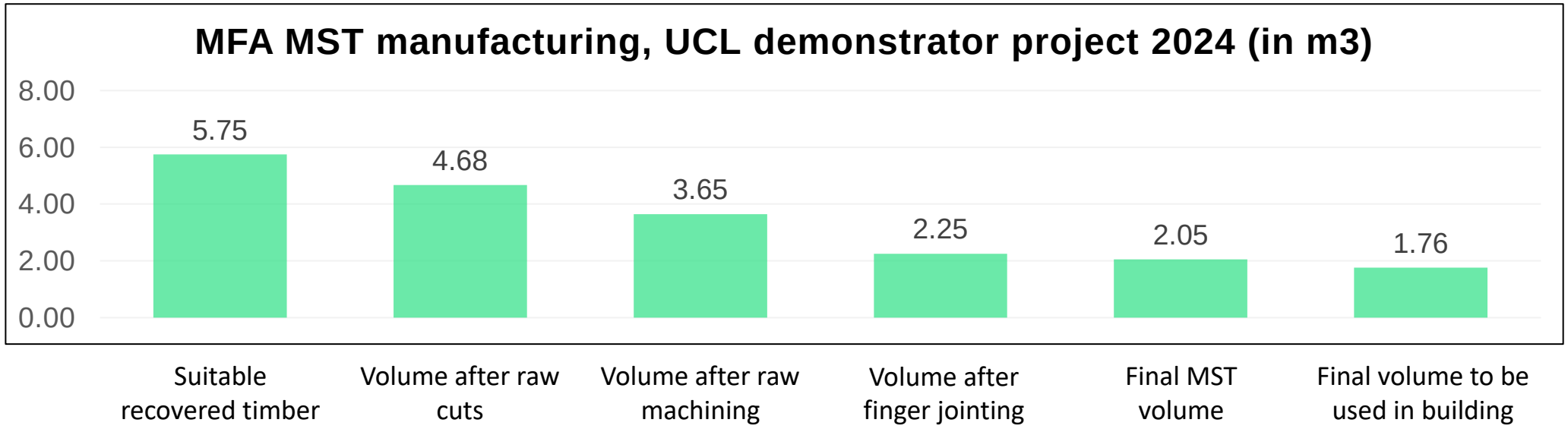


Introduction: Phase of project development (3/4)



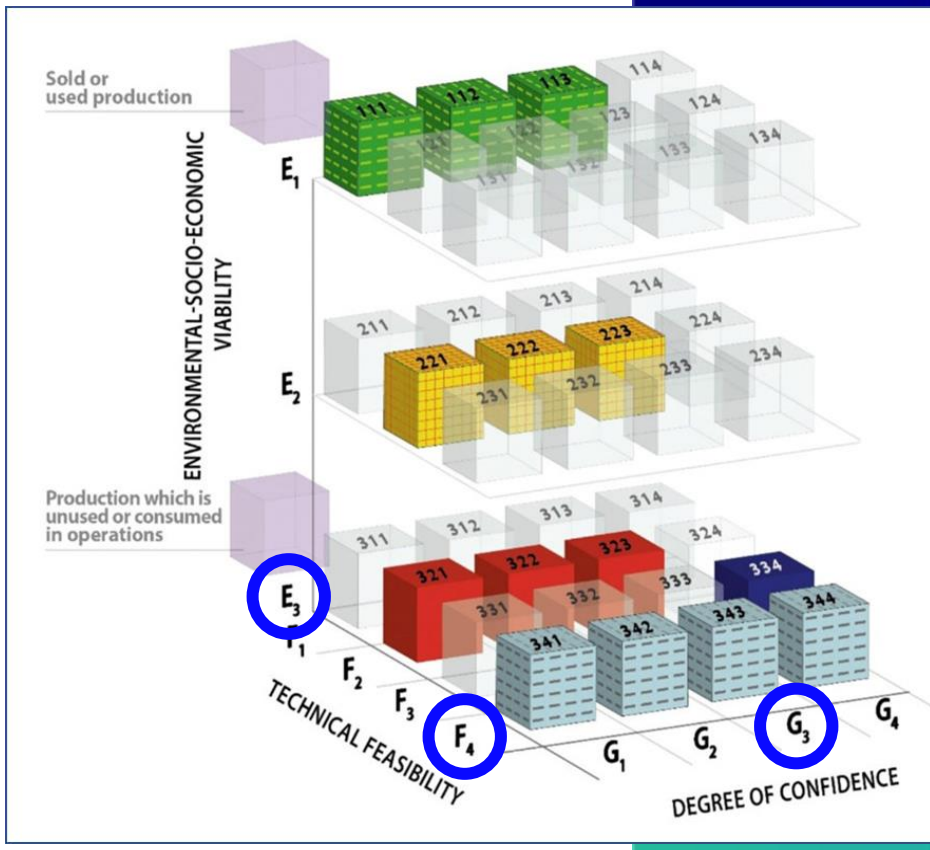
Procedure

1. Compilation of basic information
2. Evaluation of the preconditions
3. Preliminary technical feasibility assessment
4. Stakeholder assessment
5. UNFC-compliant categorisation



UNFC categorisation

1. **Environmental-socio-economic viability – E3.2**
   Environmental-socio-economic viability cannot yet be determined due to insufficient information.
2. **Technical feasibility – F4.1**
   The technology necessary is under active development, following successful pilot studies, but has yet to be demonstrated to be technically feasible for this project.
3. **Degree of confidence – G3**
   Product quantity associated with a project that can be estimated with a low level of confidence.



Final UNFC Classification

E3.2 F4.1 G3

Remaining products not developed from prospective projects

Discussion

- Need to evaluate the pre-treatment technologies regarding the environmental-socio-economic viability
  - Process efficiency
  - Manual labour vs. automation
  - Scaling
- Legal uncertainty due to lack of industry standards
- Lack of data on secondary timber quality (species, dimensions, contamination, etc.)
- CE-ROD helps to take a more differentiated view of recycling projects

Summary

- Apply the UNFC for secondary timber on a Screening phase level helped
  - ...to better understand and characterise the project;
  - ...the application is depending on material characteristics and technology development levels;
  - ...and to better understand the UNFC in terms of application for anthropogenic resources.
- The result of the Screening phase showed positive signs for MST product manufacturing potential in the UK
- Identification of knowledge gaps

Outlook

- Progress to pre-feasibility project development phase with a special focus on
  - economic assessment;
  - location and layout planning;
  - and technology

Thank you

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Futu RaM

Future availability of secondary raw materials

Phosphorus Recovery Case Study

26th March 2025

Soraya Heuss-Aßbichler[1], Ludwig Herrmann[2], Juan Antonio Munizaga Plaza[1]

[1] University of Munich (LMU), [2]Proman GmbH

Funded by the European Union

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Phosphorus recovery from sewage sludge in Germany

- **Sewage sludge** 1.629.897 Mg dry matter/year with about 1,5 – 3,5% P

  source: German Statistics Office

- → about 56.026 – 130,728 Mg P_2O_5/year
  18 % is recycled in agriculture and land use

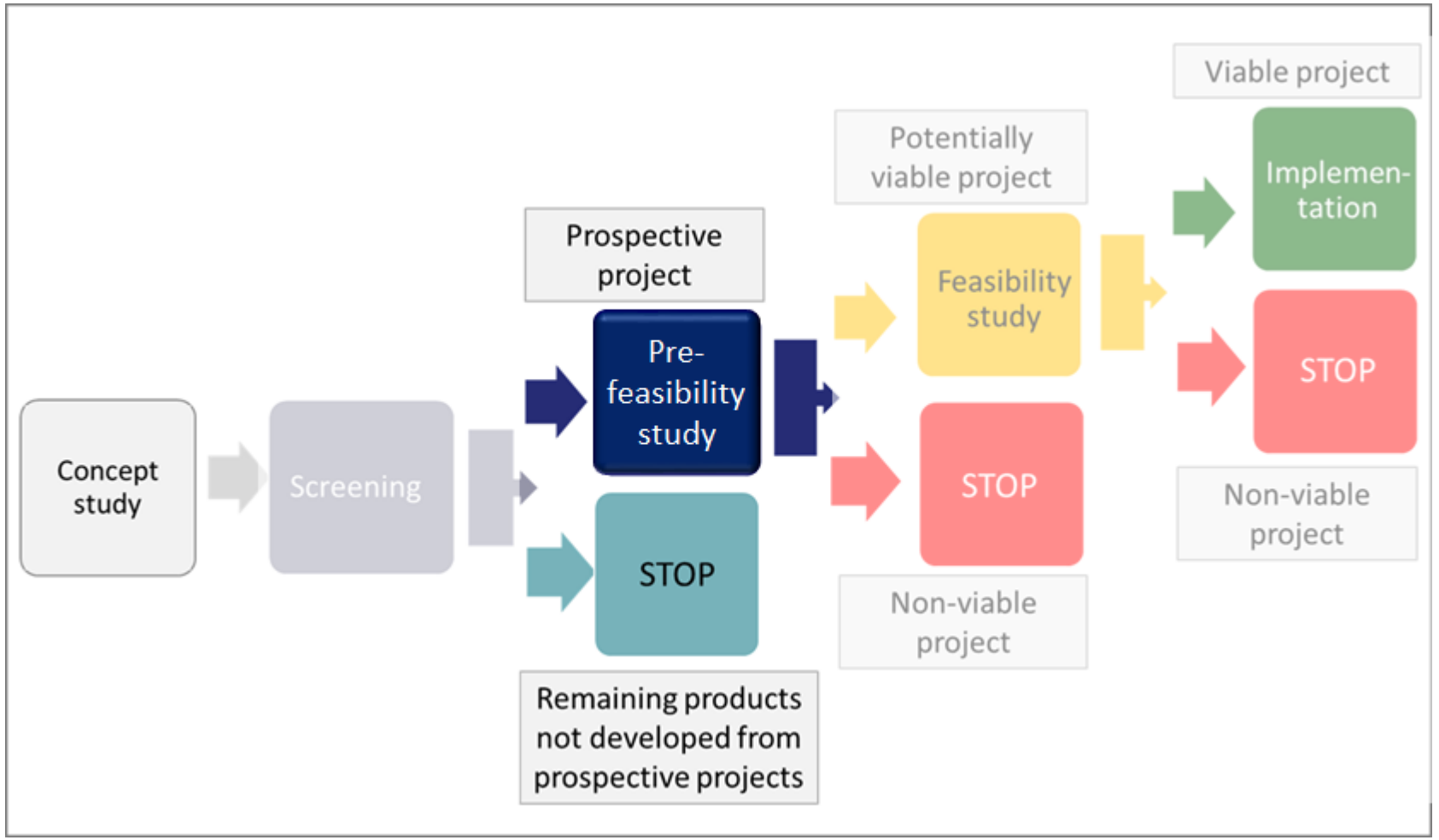
- **P_2O_5 in mineral fertiliser sales** in the season 2022/2023:
  → **116.000 Mg/year**

  source: www.IVA.de

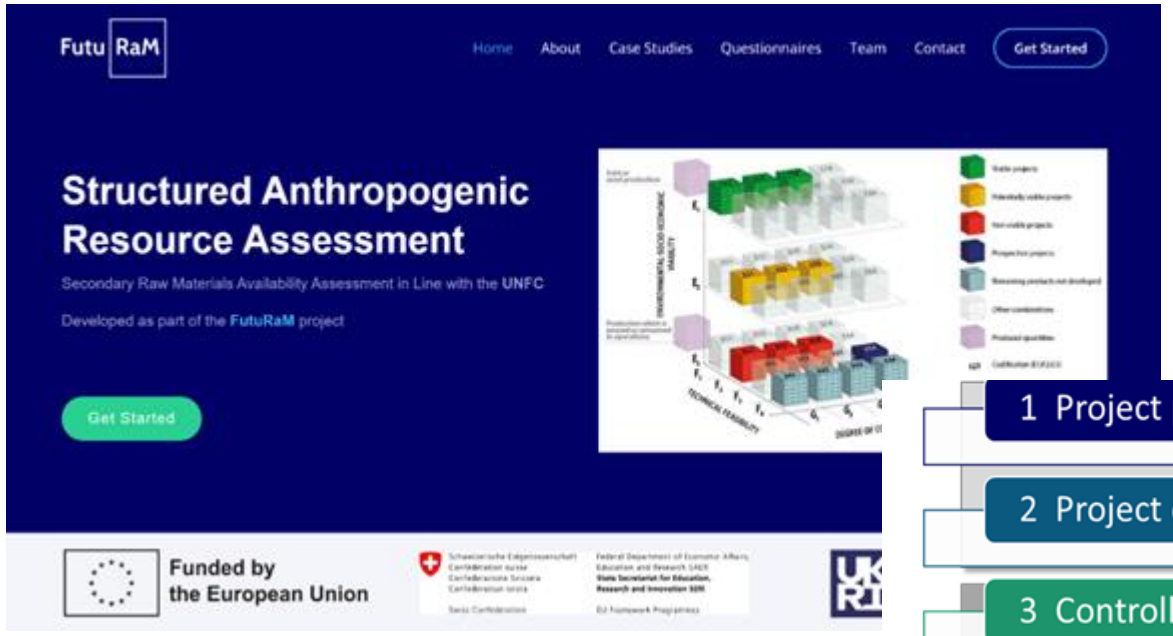
§§ From 2029, the recovery of phosphorus from sewage sludge required by law

- Those responsible for wastewater treatment need a suitable solution to recover phosphorous. What is the best solution for them?

Phosphorus recovery – pre-feasibility study



Application of the 7 stage procedure through SARA



1 Project profile - main information

2 Project definition and settings

Definition of the project

3 Controlling factors for project classification

4 Project assessment and used methodology

Evaluation of the project

5 Result categorization

6 UNFC Classification

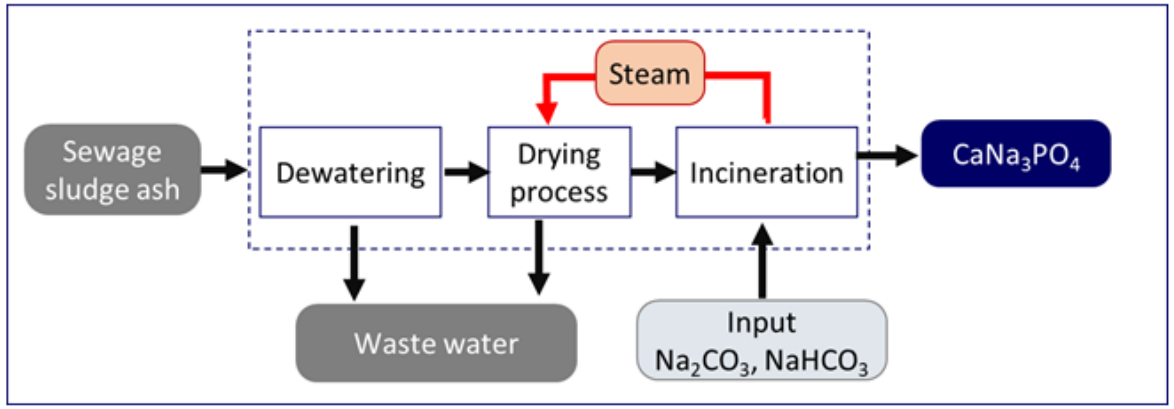
7 UNFC Reporting

Classification and reporting

Comparison of two technologies

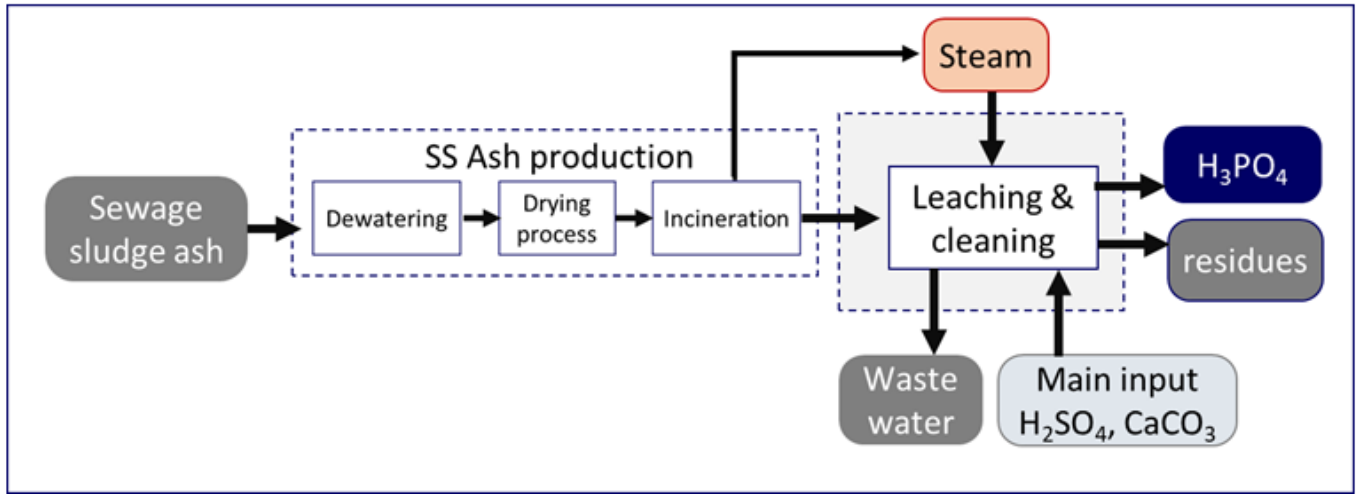
Ash-Dec

Altenstadt
Germany



Phos4Life

Solothurn
Switzerland



Comparison of the controlling factors (CFs)

G-axis	Ash Dec (incineration of sewage sludge)	Phos4 Life (leaching of sewage sludge ashes)
Input	50,000 Mg/a (SS)	40,000 Mg/a (SS ash)
Output	15,000 Mg/a (R-Rhenania Phosphate)	12,000 Mg/a (phosphoric acid – 75%, technical grade)
Waste	No solid waste	50,000 Mg/a leaching residue 26,000 Mg/a sludge from waste water treatment
Level of confidence	G1	G1

F-axis	Ash Dec (incineration of sewage sludge)	Phos4 Life (leaching of sewage sludge ashes)
TRL	TRL 9 (tested and approved in full scale)	TRL 6
Infra-structure	Ready for implementation	Available
Categorie	F1.3	F2.1

SWOT analysis - AshDec

Strengths

- In combination with grate incinerator, almost negligible **investment**
- **Operations cost** below the market price of comparable phosphate fertilisers

Weaknesses

- Only P can be recovered
- Unknown product, not within the normal scope of farmers‘ fertiliser selection
- Farmers do not pay a fair price, due to knowing the origin of the resource

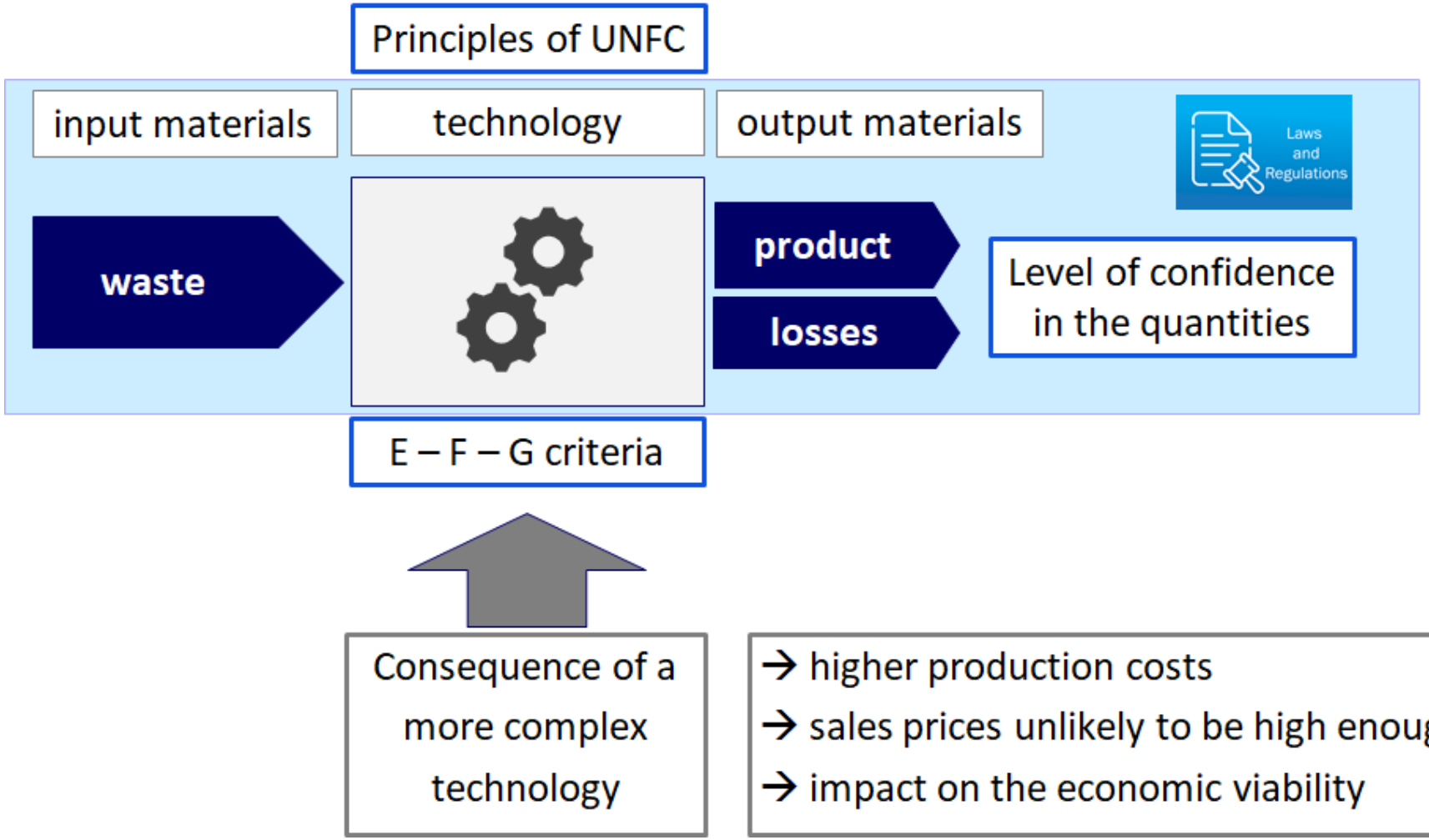
Opportunities

- If farmers pay the market price for fertiliser (P) replacement value, the process is profitable
- Product recommended for use in organic farming, but not yet licensed
- Removal of organic contaminants

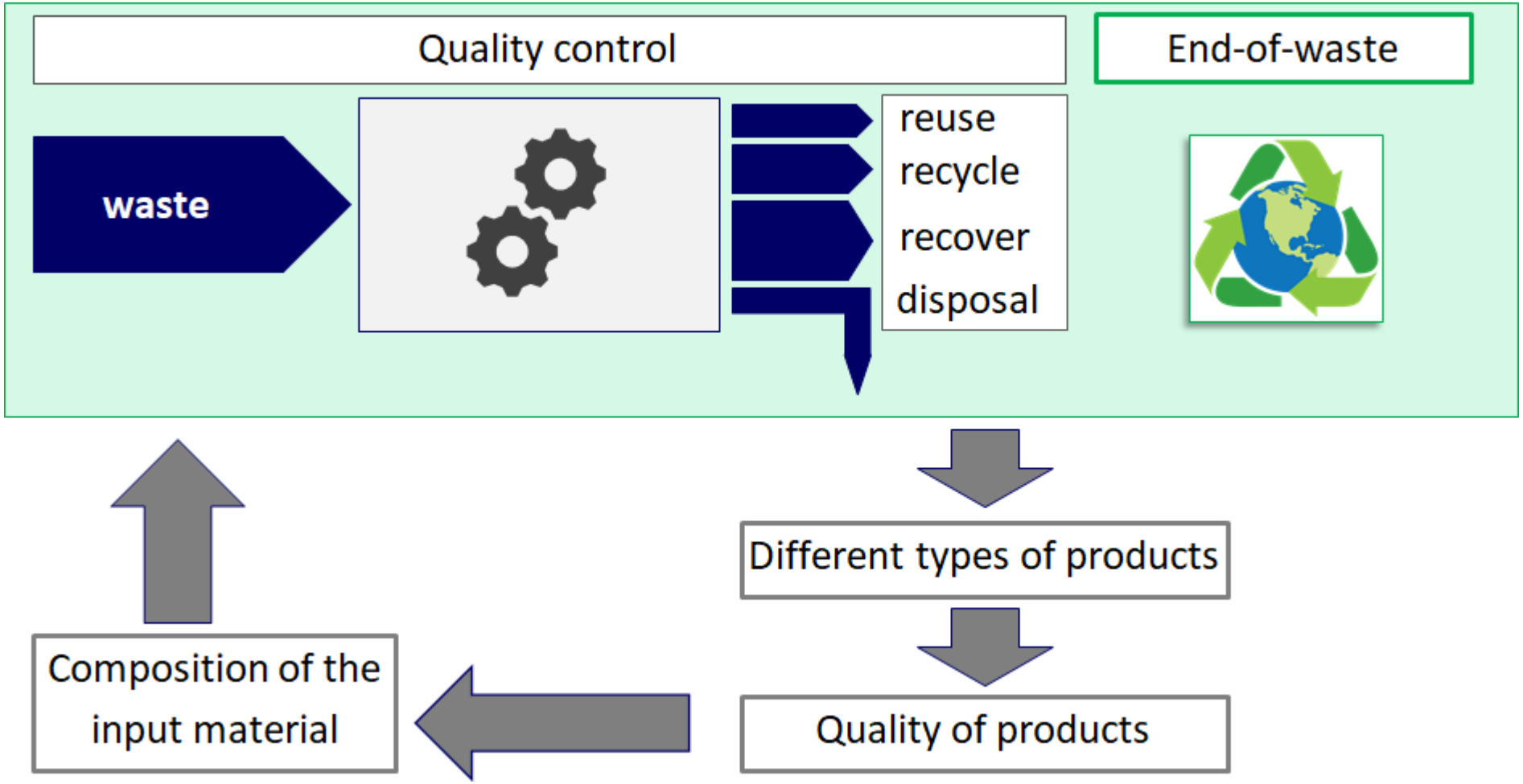
Threats

- Most inorganic contaminants transferred to the soil
- Strict regulation of inorganic contaminants in fertilisers
- Grate incinerators unusual for sludge incineration

AshDec vs. Phos4Life - Basic-ROD



AshDec vs. Phos4Life - CE-ROD



Impact of CE-ROD

Ash Dec

Phos4Life

Controlling Factor	INPUT	OUTPUT
Type of product	Should have high P - content	Ashes with Calcined Phosphate as a fertilizer
	Should have high P - content	Phosphoric acid for production, including fertilizer
Quality of the product	Quality of the sewage sludge	Limitation due to the content of heavy metals
		No limitation

Conclusion

- The prefeasibility study reflects the maturity of the projects and ensures transparency, consistency and comparability
- The structure provided by the UNFC makes it easier to compare projects
- Basic-ROD is not sufficient for decision making, as shown with two different projects to treat sewage sludge

- CE-ROD enables a cost-benefit analysis of the different technologies
- It provides an overview of the information required to find the best solution for each location

Thank you

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Futu RaM

Future availability of secondary raw materials

UNFC National Case Study: LFP Battery Recycling in Germany

26th March 2025

Iman Dorri | Franziska Maisel

LMU | TUB

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Schweizerische Eidgenossenschaft
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Swiss Confederation

Federal Department of Economic Affairs, Education and Research EAER
State Secretariat for Education, Research and Innovation SERI

EU Framework Programmes

UK Research and Innovation

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UNFC on National Level

1) Bottom-up approach:

- Classification of all projects in the region or country in question related to the target sector (e.g., mining)
- Reporting the UNFC classes of all projects along with estimated quantities in a table
- Detailed information is required for each project.

Example: UNFC by National Geological Surveys, a case study from the UK by Tom Bide

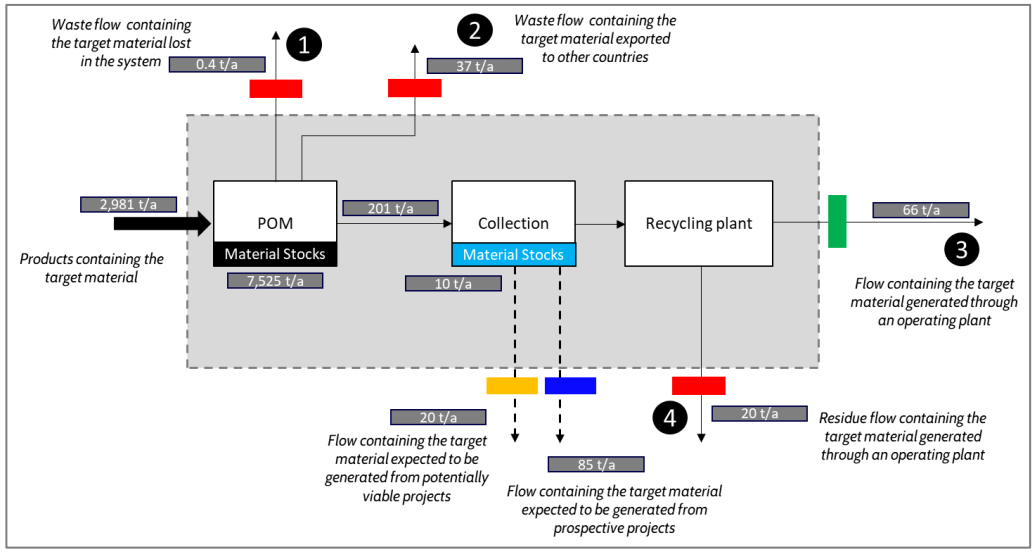
Main output	E	F	G	Quantity	UNFC class
Commodity	1 | 2 | 3	1 | 2 | 3 | 4	1 | 1+2 | 1+2+3 | 2 | 2+3 | 3 | 4	Quantity (tonnes)	UNFC class
Ball clay				46 200 000	111
Ball clay				54 100 000	221
Ball clay				2 000 000	221+2
Ball clay				132 000 000	222+3
Ball clay				4 500 000	223
Barytes				9 000 000	111
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

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

UNFC on National Level

2) Top-down approach (developed in FutuRaM)

- Developing an MFA for the whole recycling value chain for the specific waste stream and the target material with regard to the status quo
- Assigning the UNFC-compliant classes on the flows and stocks based on the table.



"UNFC-complaint classes for MFA"

Class		Definition	Adapted definition
	E1F1.1 G(1,2,3)	Viable projects	Flows related to operating plants that produce the target material
	E2 F2 G(1,2,3) E2 F(1.2,1.3) G(1,2,3)	Potentially viable projects	Flows containing target material expected to be generated through plants under construction or expected to become operational soon
	E3 F2 G(1,2,3)	Non-viable projects	a) Waste flows containing the target material that leaves the system boundary (i.e., Export) before recycling the target material b) Flows containing the target material that cannot be recovered to get the target material
	E3 F3 G4	Prospective projects	Flows containing the target material expected to be generated through future projects
	E3 F4 G(1,2,3) E3 F4 G4	Remaining products not developed from identified projects or prospective projects	a) A stock containing the target material for which the quantity and quality of the target material is available (E3 F4 G1,2,3). b) A stock containing the target material, but with not much information about the quantity and quality of the target material (E3 F4 G4).

MFA for LFP Battery recycling in Germany :

Mapping current and future national LFP Battery material flows and assessment of the recycling potential of secondary SRMs and CRMs

(1) Investigation of battery stocks and flows for 2024 and 2030 (ELV, LMT, portable and industrial batteries)

(2) Calculating compositional data based on LFP battery cell composition

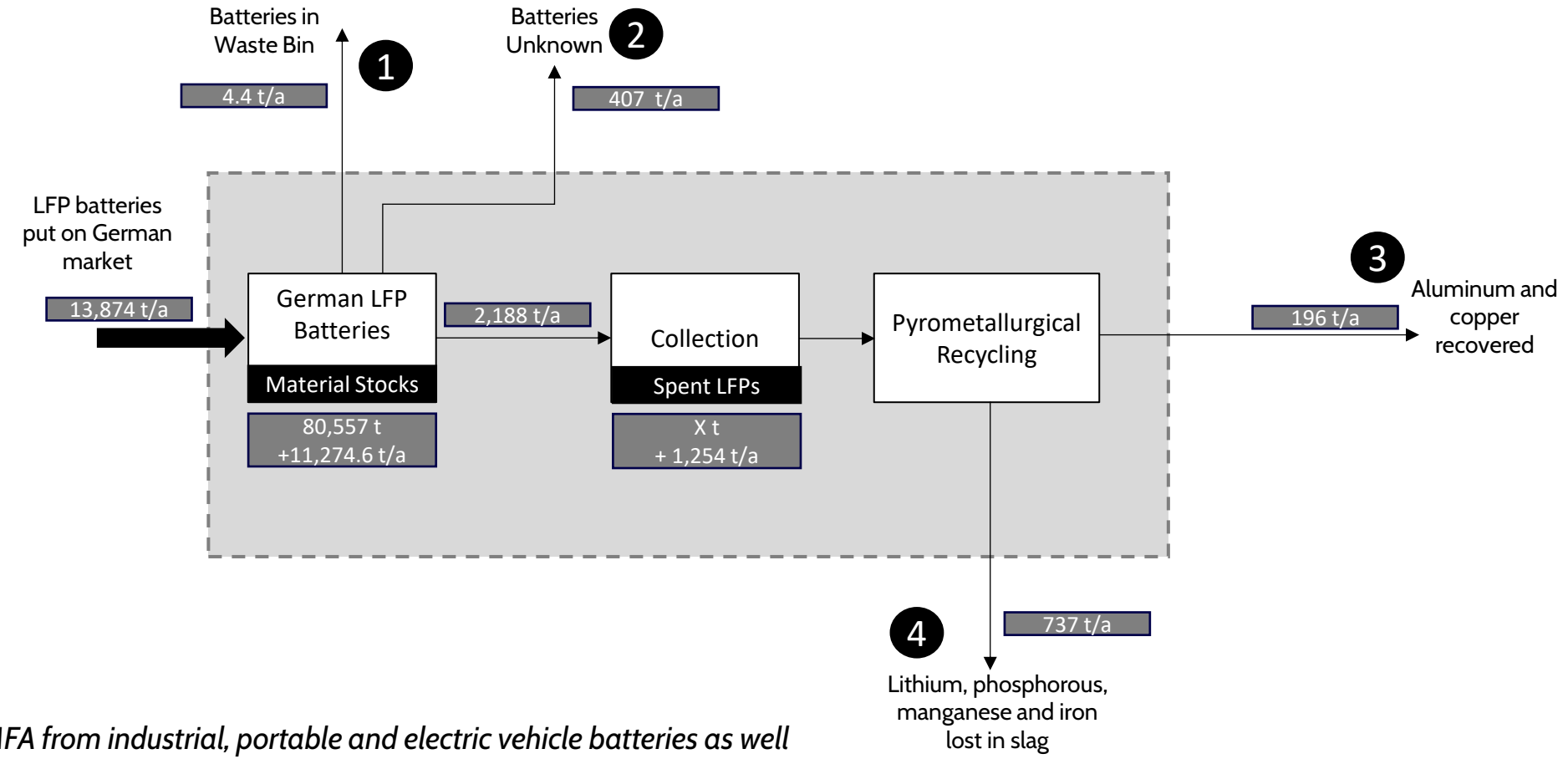
(3) Mapping the recycling infrastructure in Germany and their current and future capacities

(4) Investigation of possible recycling technologies for LFP batteries and recovery rates for certain materials

(5) Classification of MFA for recycling value chain of LFP batteries in Germany

LFP Battery Recycling MFA for Germany

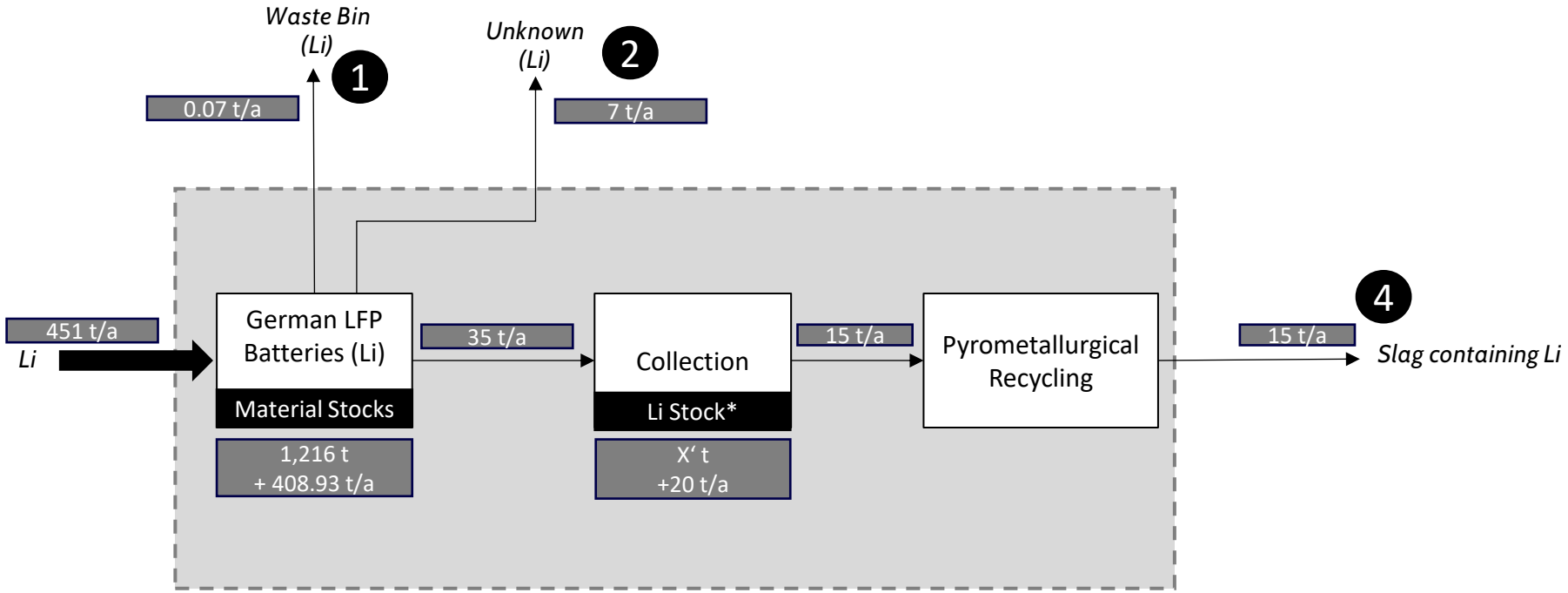
2024



LFP battery MFA from industrial, portable and electric vehicle batteries as well as batteries from light means of transport in Germany in 2024

LFP Battery Recycling MFA for Lithium

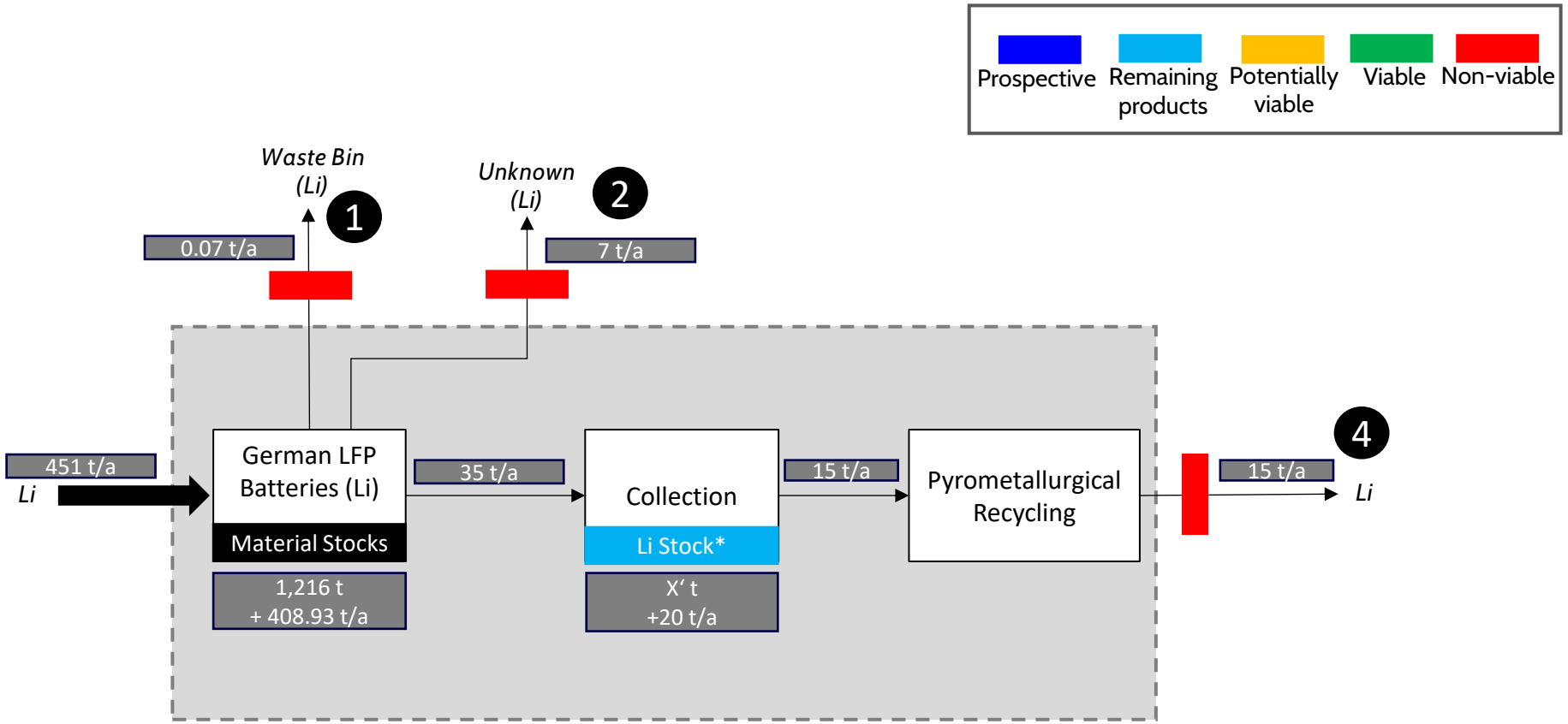
2024



*based on LFP battery recycling capacity in 2024

Application of UNFC to MFA for Lithium

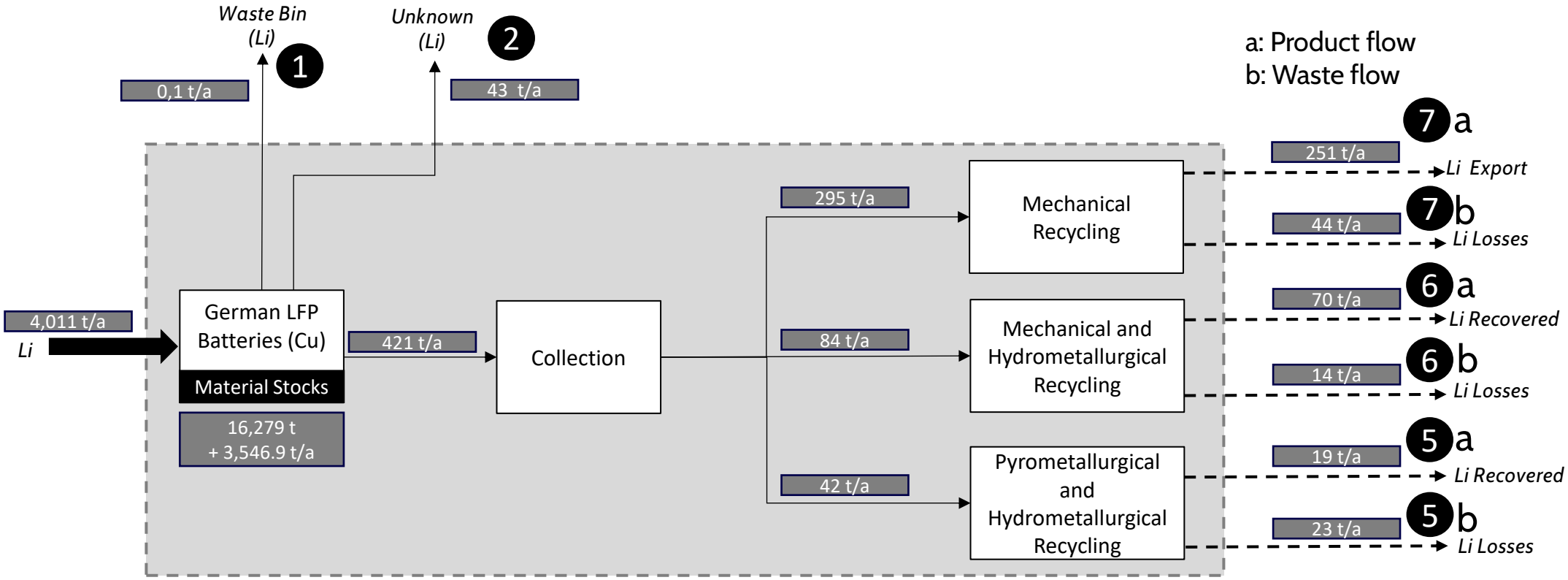
2024



*based on LFP battery recycling capacity in 2024

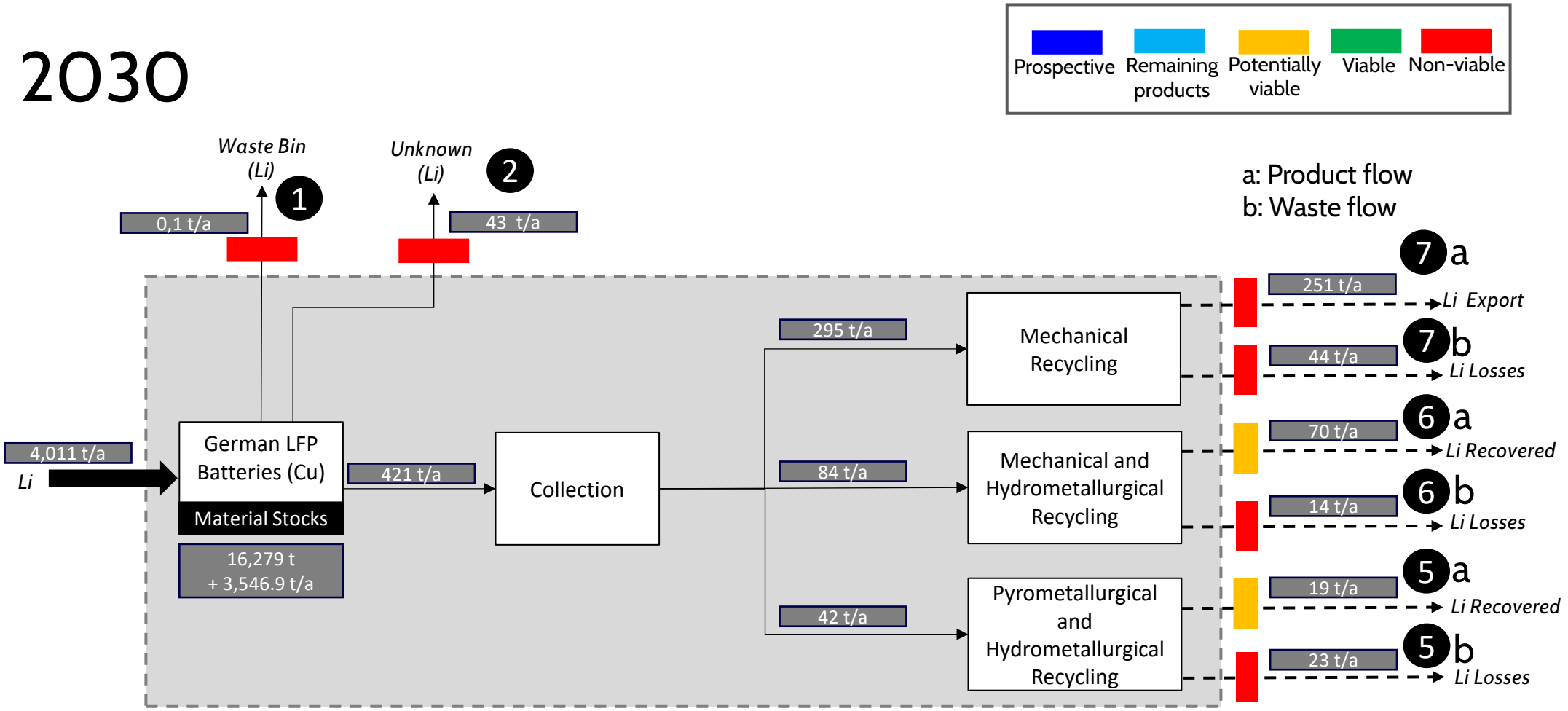
LFP Battery Recycling MFA for Lithium

2030



Application of UNFC to MFA for Lithium

2030



Summary

Recovery of Li from LFP Batteries in Germany

Li	t/a	2024	2030
Li	INPUT LFP to the market	451	4,011
Li	Collected spent LFP	35	421
1	LFP (Li content) in Waste bin (before collection)	0,07	0,1
2	LFP (Li content) unknown (before collection)	7	43
3	Slag (Li, P, Mn, Fe)	15	
4	Remaining stock (Li content in collection)	20	
5	Recovery (Li) – Pyro-/Hydrometal.		19
6	Recovery (Al, Cu, Li) – Mechn/Hydrometal.		70
7	Black mass – Mechan. (Li content exported)		251
8	Losses of Li during the recycling		81

Thank you

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Thank you for attending

Further information and to join the FutuRaM Network via the QR code