Conference on
Exploration and Exploitation
of Critical Raw Materials

Pioneering Sustainable CRM Recovery in European Mining

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Institute of Communication and Computer Systems (ICCS)

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European Mining in the Green and Digital Era

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Institute of Communication & Computer Systems (ICCS)

33 years Creating Impact

Founded as the research branch of the School of Electrical and Computer Engineering of the National Technical University of Athens (NTUA).

Advancing Basic and Applied Research

AI and Smart Systems | Hardware and Software | Computer Networks | Mobile Communications | Control and Automation | Power Production, Transport and Distribution | Energy, Transport, Climate Research | Biomedical and Biomechanics | Information Systems | Management and Desicion Support

Promoting Innovation at the intersection of disciplines

By combining our strong disciplines, our research groups develop basic science, explore new scientific areas of interdisciplinary research and enable promising innovations in the light of societal challenges.

Developing the Technologies of the future

ICCS today ranks among the top 3 Research Institutions in Greece and among the first 20 in EU -in terms of research funding.

In numbers

340+

International Partners & Memberships

ICCS has developed an extensive network of partners around the world. Also participates in numerous clusters and association with an aim to advance research.

4450+

R&D projects

Continuously advancing our expertise and knowledge through participation in National and European R&D projects in various scientific fields.

800+

Researchers, Faculty & Staff

More than 800 highly qualified researchers, scientists, faculty members and experts are the main pilar of the institute's successful performance.

30+

Research Units

Scientific Research at ICCS is organized within many cross-cutting thematic groups and labs.

Numerous success stories

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10 Research Divisions

- Cooperative Connected Automated Mobility (CCAM)
- Intelligent Network Systems (INS)
- Multimodal Logistics & Maritime Operations (ML)
- Circular Economy & Tracing (CET)
- **Industry 5.0 & Smart Manufacturing (ISM)**
- Smart Mobility Applied Systems (SMAS)
- **Extended Reality (XR)**
- Health Technologies (HT)
- **Earth Observation & Environmental Monitoring (EOEM)**
- Crisis Management & Secure Societies (CMSS)

Goal OPTIMINER

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➢ Efficient and sustainable recovery of Critical Raw Materials (CRMs) from increasingly complex and low-grade ores

What is the ambition ?

- first European platform and the one-stop-shop to getting efficient, smart, and sustainable processes
- state of the art pilot-scale recovery technologies to accomplish optimised operation
- sustainability and resilience strategies to cover energy efficiency, water and waste valorisation, market resilience and financial sustainability
- go-to-market strategy, openness to the stakeholders and mining community to boost international cooperation

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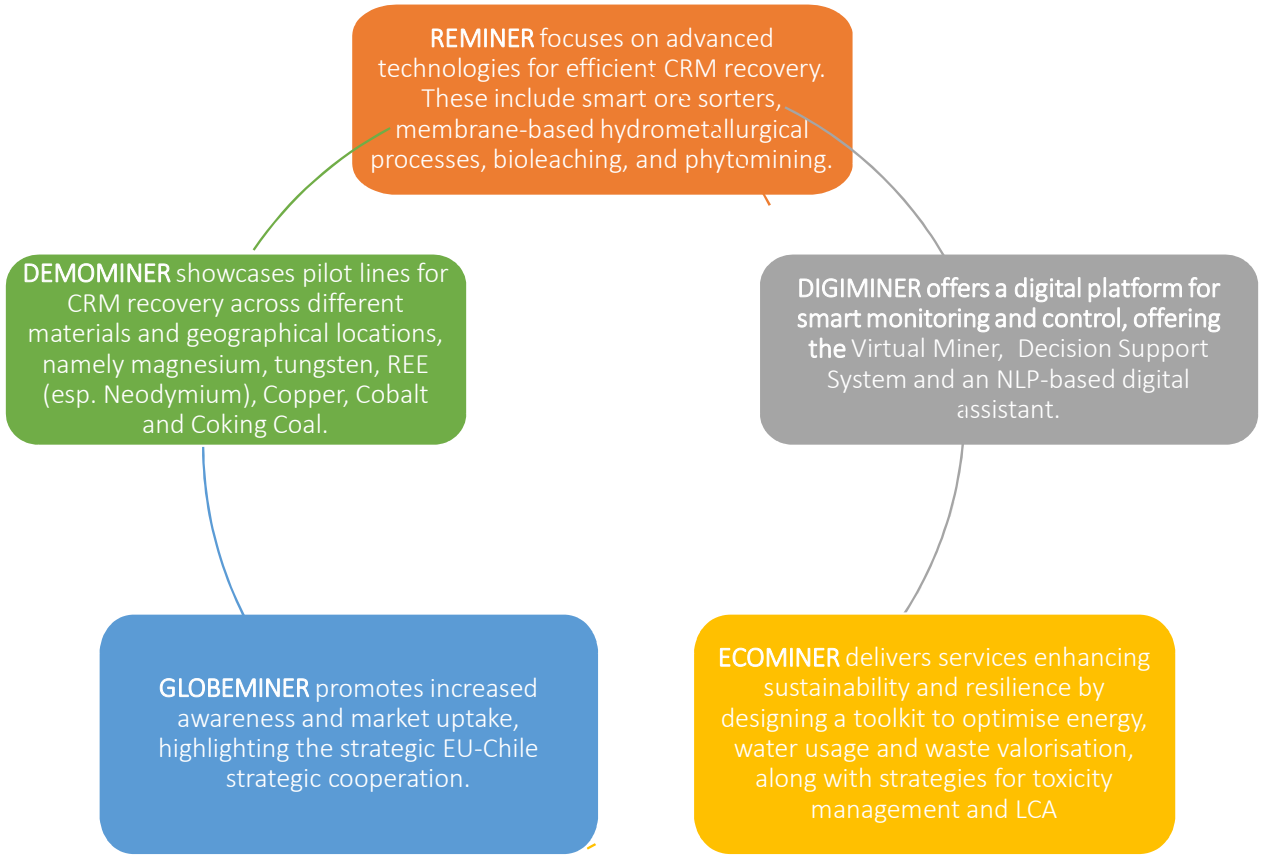
How to solve?



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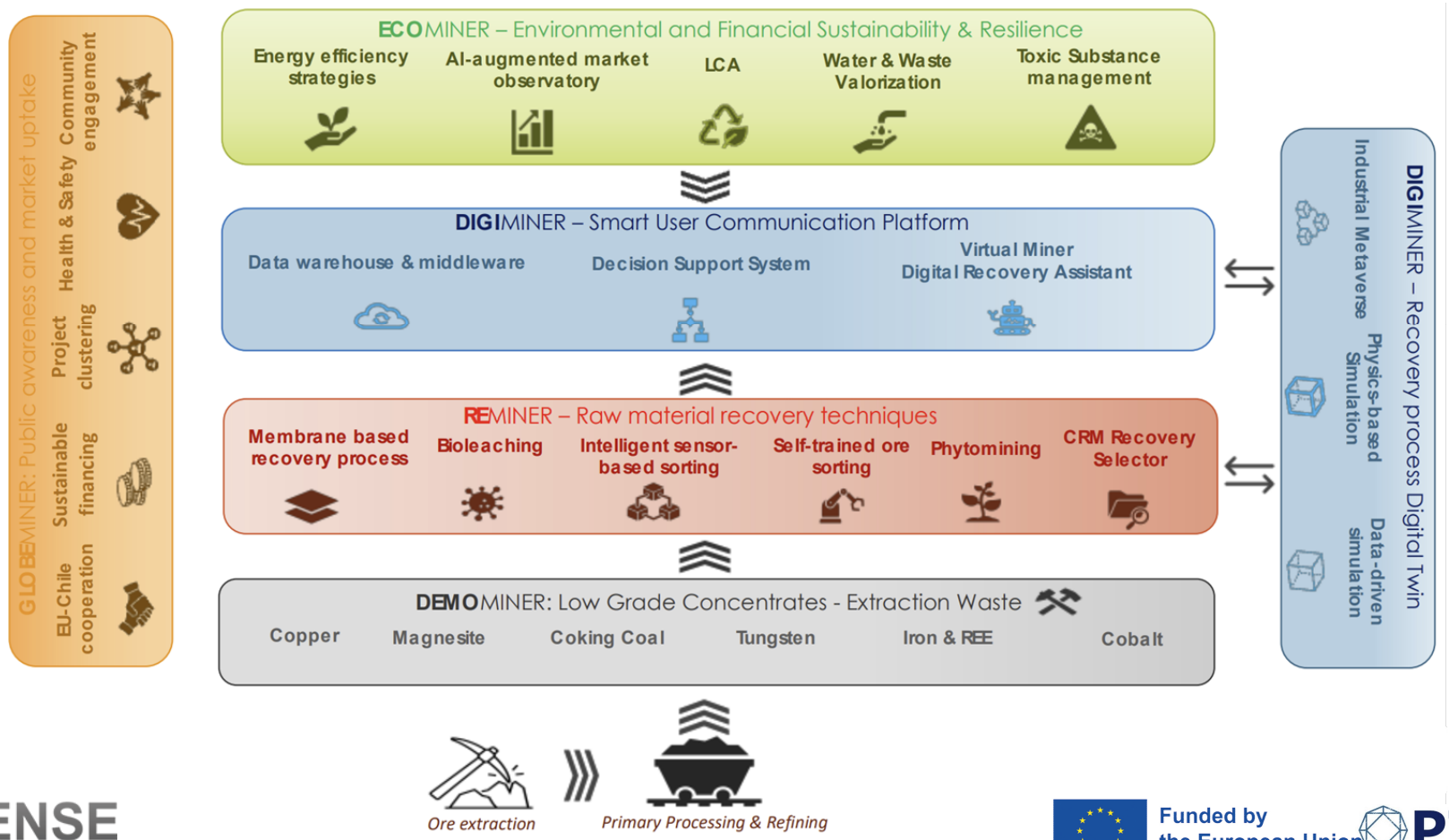
Overall Concept



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Technologies

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REMINER Technologies

- Self-trained ore-sorting mechanism (ICCS)
- Coking coal enrichment technology (GIG/IMN)
- Membrane-based recovery processes for metals, water and chemicals (ISE)
- Bioleaching (BOKU)
- Phytomining (ECO)

DIGIMINER Technologies

- Digital Twin using 3D Visualisation (DTT)
- Physics-based Digital Twins and Reduced Order Models (ROMs) (ITA)
- Data-driven Digital Twins (CORE)
- The Virtual miner module (CORE)
- The OPTIMINER Digital Platform (CORE)
- AI-enabled Decision Support System (LIBRA)

ECOMINER Technologies

- AI-augmented market observatory (LIBRA)
- Life Cycle Analysis (LCA) (ECO)

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Use Case #1: Recovery of Magnesite and Magnesium | TERNA | Greece

Self-trained ore-sorting mechanism to enhance the classification accuracy of non-magnetic sterile minerals (such as dolomite, calcite, and sepiolite), which are the main challenge of the mine company (TERNA).

An innovative bio-leaching process is going to be implemented to recover magnesium from magnesite tailings that are smaller than 10mm.

Focus area	OPTIMINER improvement	Verification/Rationale
Magnesite recovery	Increase of recovery over 20% to current practices, reaching more than 95%	Optimisation of ore sorting process line, using the advanced technologies of the *self-trained ore sorting mechanism*
Magnesium recovery	Over 80% recovery from magnesite concentrate, compared to none that is currently the case	Use of bioleaching in a lab scale to assess recovery rates
Resource management	Reduction in energy consumed and reduction of waste per ton of magnesite end product up to 15%	Exploitation of 3-10mm tailings and use of optimised machinery for smarter energy dissipation

Use Case #2: Recovery of Coking Coal | JSW |Poland

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A pilot-scale study on sorting using an optical/X-ray sorter in order to optimize and calibrate the sorter on lab-scale. This installation will be integrated into the coal processing plant at one of the selected JSW mines to conduct pilot-scale tests.

The self-trained ore sorting mechanism developed for the TERNA use case will be fed with material from the JSW use case and measurement of the respective KPIs will be performed in order to measure the improvement of the recovery rate, and the resource efficiency (energy, water, waste).

Focus area	OPTIMINER improvement	Verification/Rationale
Coking Coal recovery	Recovery of coking coal from raw material reaching 80%	Introduction of coking coal enrichment technology
Water usage	30% reduction in wet beneficiation methods	Replacement of wet methods by dry sorting techniques

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Use Case #3: Recovery of Tungsten| Tailings toxicity management and recovery | SALORO | Spain

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Scaling and implementation of phytocorrection and phytostabilization techniques in mining waste from strategic mining companies in Castilla y León and Spain as a solution to problems of contamination of soil, water and atmosphere by heavy metals.

Focus area	OPTIMINER improvement	Verification/Rationale
Recovery of tungsten	80% recovery from tailing smaller than 45μm using bioleaching; 20% of recovery from tailings using phytomining	
Improvement of sorting	30% improvement in production by using the self-trained mechanism, 20% reduction in energy usage and produced waste	
Heavy metal contamination	15% reduction in the contamination of soil, water, atmosphere, using phytocorrection and phytostabilization techniques in mining waste	

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Use Case #4: Recovery of cobalt and REE | Tapojärvi | Finland

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The recovery of cobalt and REE will take place in a concentrating plant in Rautuvaara. The steps that will be followed are: (1) Market research - Requirements of CRM concentrates; (2) Restudy of CRM mineral resources (Cobalt and REE minerals); (3) Mineralogical study (Cobalt and REE minerals) - Particle size, degree of mineral liberation, mineral association, gangue, and chemical consistency of particles; (4) Laboratory tests - Different methods (bioleaching, leaching, flotation etc.), Chemicals, Enrichment conditions; (5) Pilot test; (6) Effect of the method on water treatment

Focus area	OPTIMINER improvement	Verification/Rationale
Recovery of Cobalt	Over 80% recovery from IOCG concentrate as of none today	
Recovery of REE	Over 80% recovery from IOCG concentrate as of none today	
Resource efficiency	Circular use of water and waste reduction from IOCG concentrate processing. IOCG processing waste will be used to produce Cobalt and REE concentrates. Use of bio-leaching increases environmental KPIs and reduces toxicity	

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Use Case #5: Recovery of REE from Iron concentrate | LEONORE | Spain

Innovative technologies for the extraction of REE from mining byproducts, specifically from the tailings of these iron mines. A Digital Twin of the process line will be built and the digitalisation for the line will take place in parallel with its commissioning. In the meantime, the feasibility study of the REE production will have been completed. In order to assess and optimise the recovery efficiency of the REE, various recovery techniques will be tested using iron ore and iron concentrate samples from the LEONORE production site

Focus area	OPTIMINER improvement	Verification/Rationale
Digital twin	The iron ore process will be digitalised and the digital twin will assist in optimising the operating parameters and process control. Target iron recovery is currently 55%, but with the digital twin the target will increase to 65%	
REE recovery	Recovery of over 80% of REE out of the iron concentrates using REMINER technologies	

Use Case #6: Recovery of Copper and valuable by products | Minera Hasparren SpA | Chile

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The use case will be carried out at a site in Chile, the world's largest copper producer, involving Minera Hasparren, a small-scale mining company that innovates in the processing of copper, gold, and silver minerals. Through the OPTIMINER project, **advanced membrane technologies** will be developed, applied, and tested **in combination with conventional leaching and precipitation processes** to capture high-value materials from the flotation reactor waste. This demonstrator will operate on-site in a bypass, aiming to monitor and analyze byproducts and develop a process scheme for recovery under techno-economic aspects.

Focus area	OPTIMINER improvement	Verification/Rationale
Copper recovery	Increased recovery by 10%	Traditional methods like precipitation and flotation are enhanced by membrane-based technologies
Gold & Silver recovery	Expected 60-80% recovery from extraction waste	
Water usage	5-10% water recovery	

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CRM recovery per Mine

End user	TERNA MAG	JSW	SALORO	TAPO	LEONORE	MINERA
Country	Greece	Poland	Spain	Finland	Spain	Chile
Lead Technology Provider	ICCS	GIG	ECO	BOKU	CORE	CSET
Raw Materials to recover	Magnesium & Magnesite	Coking Coal	Tungsten	Cobalt & REE	Neodymium (REE)	Copper, Gold & Silver
Raw Material classification	CRM	CRM	CRM	CRM	CRM	CRM
Primary ore	Magnesite	Coking Coal	Tungsten	IOCG	Iron	Copper
Stage of production	In production	In production	In production	Design phase	Design phase	In production
Industrial applications	1) **ICT applications**: Smartphones, tablets & laptops 2) **Additive manufacturing (3d printing)**: for automotive, aerospace & defense (drones).	**Steel making process** is the largest application of coking coal in EU.	**1) ICT applications**: Smartphones, tablets & laptops 2) **Automotive & Aerospace applications** through 3d printing techniques 3) **In stainless and hardens tool steels** 4) **turbine blades and vanes.**	1) **Renewables applications**: Li-ion Batteries (LIBs), Fuell cells, 2) Automotive & Aerospace applications through **3d printing techniques**: in various super-alloys, 3) **in gas-turbines, engines**, 4) **dental and medical**.	**Energy-intensive industry applications**: 1) Industrial heat-pumps: Iron is used to make steel for the compressor and heat exchangers & Neodymium is used in permanent magnets	1) **Energy-intensive industry applications**: Industrial heat-pumps, 2) **ICT applications**: Data transmission networks, 3) **Renewables applications**: Solar PVs.
DIGIMINER platform	✓	✓	✓	✓	✓	✓
DSS & Virtual Miner	✓	✓	✓	✓	✓	✓
Digital Twin	✓	✓			✓	✓
Energy efficiency	✓	✓	✓	✓	✓	✓
Water & Waste valorisation	✓	✓	✓	✓	✓	✓
LCA	✓	✓	✓	✓	✓	✓
Toxicity management	✓	✓	✓	✓	✓	✓
Self-trained ore sorting	x	x	x	x	x	x
Coking coal enrichment		x				
Bioleaching	x		x	x	x	
Membrane-based recovery				x	x	x
Phytomining			x			x
CRM Recovery Selector	x	x	x	x	x	x

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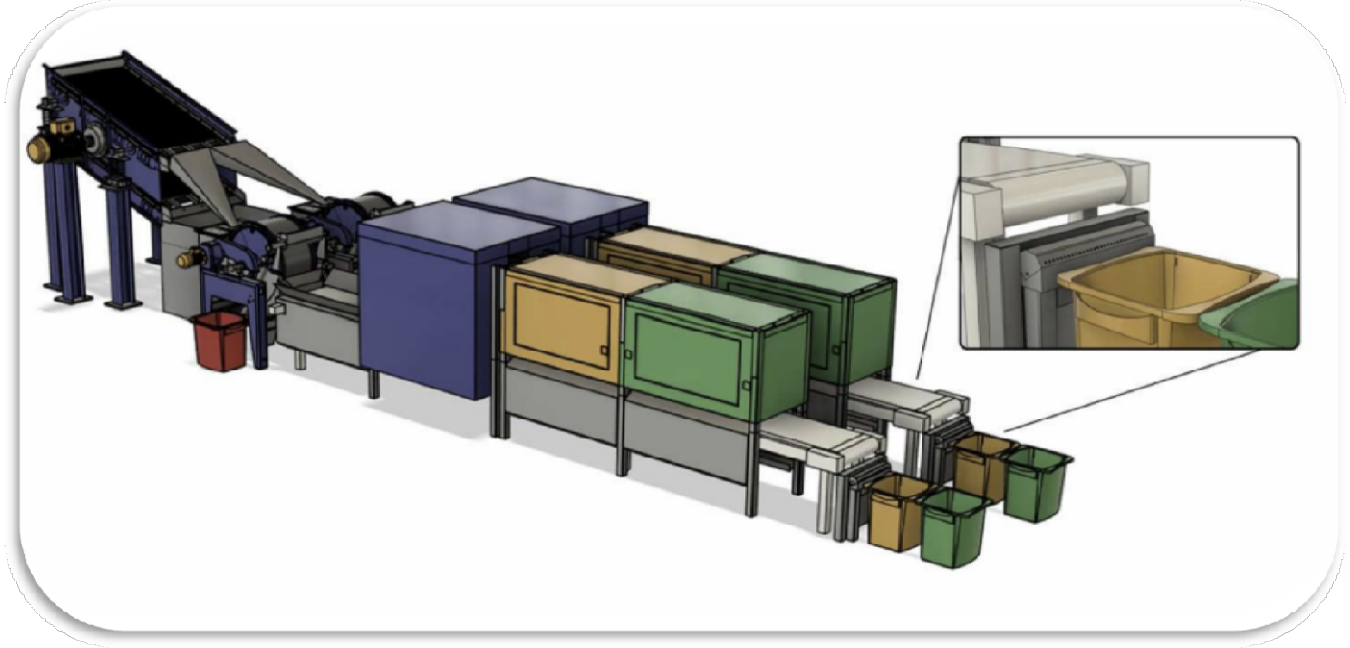
CRM recovery using Sorting Systems (Magnesite extraction)

- Separating the magnesite in two streams, while extracting serpentine and oxidised serpentine from the streams with magnets



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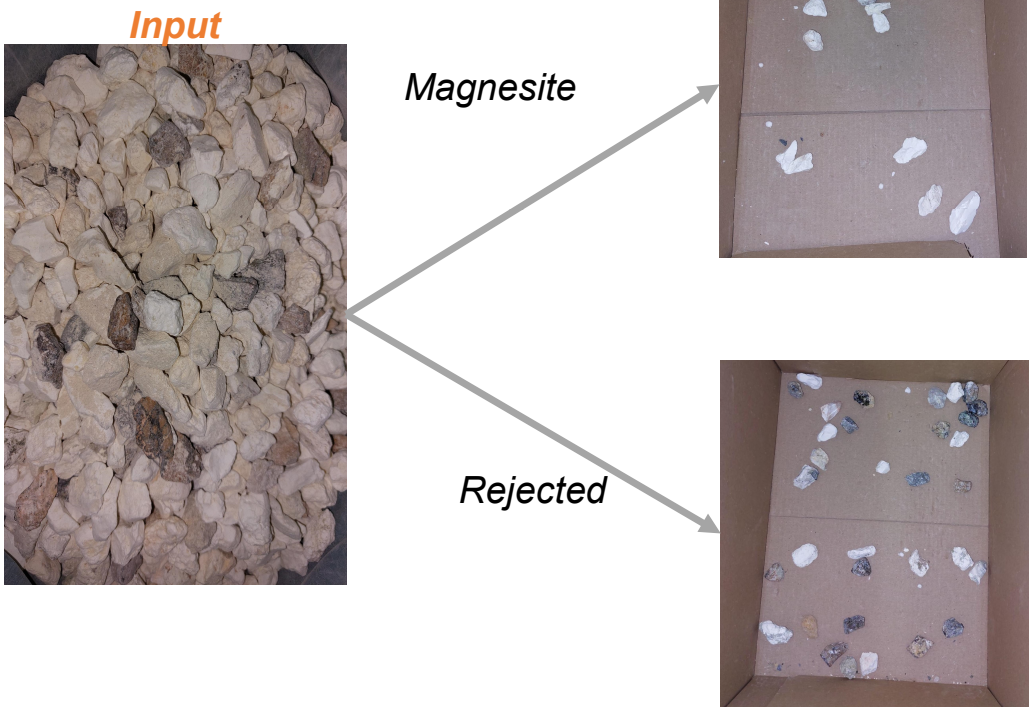
CRM recovery using Sorting Systems (Magnesite extraction)

Size: 10 – 20 mm
Location: TERNA's Gerorema Mine
Ore sorter will be placed after the optical sorter of TERNA.
Categories of the extracted ore samples in Gerorema:

- Magnesite
- Dolomite
- Calcite
- Sepiolite
- Peridotite
- Serpentinite



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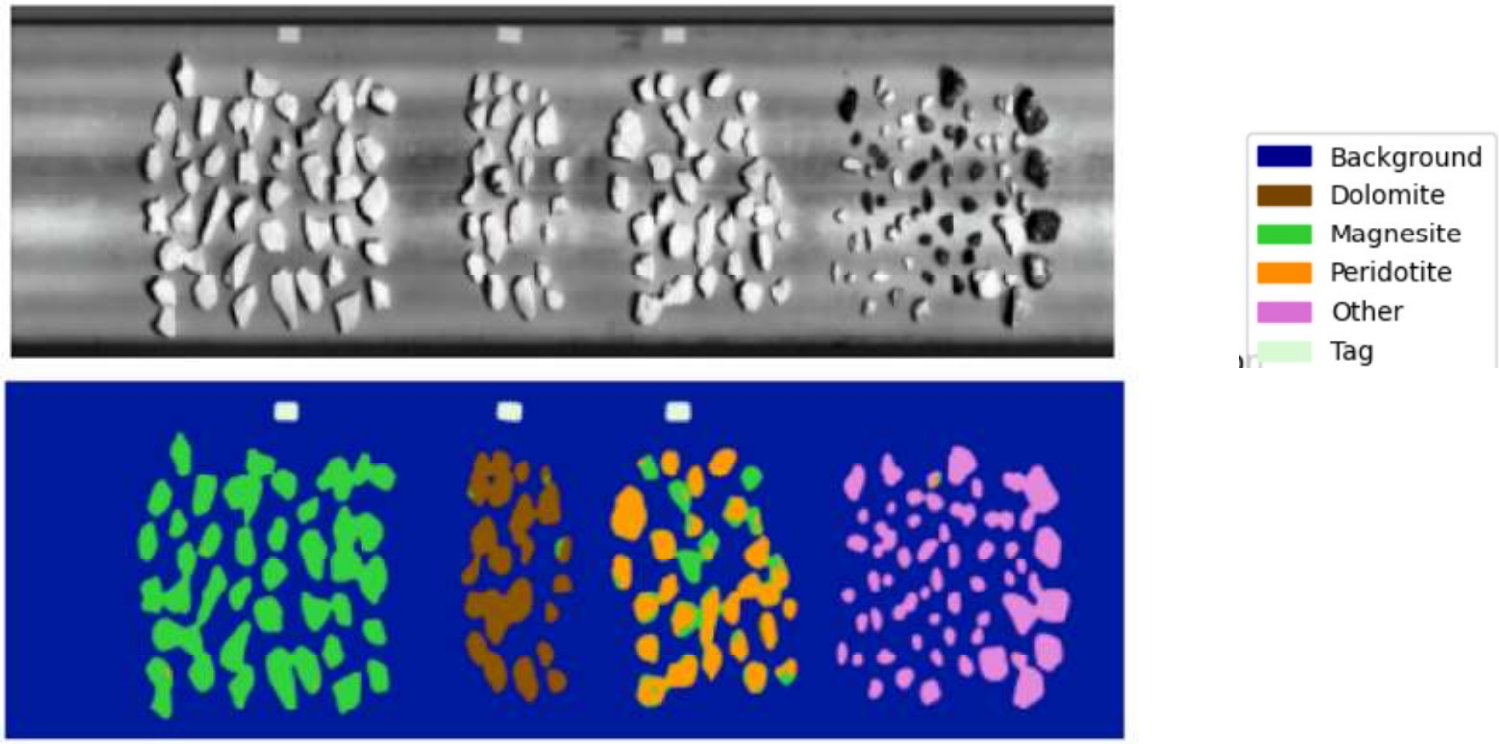
CRM recovery using Sorting Systems (Magnesite extraction)



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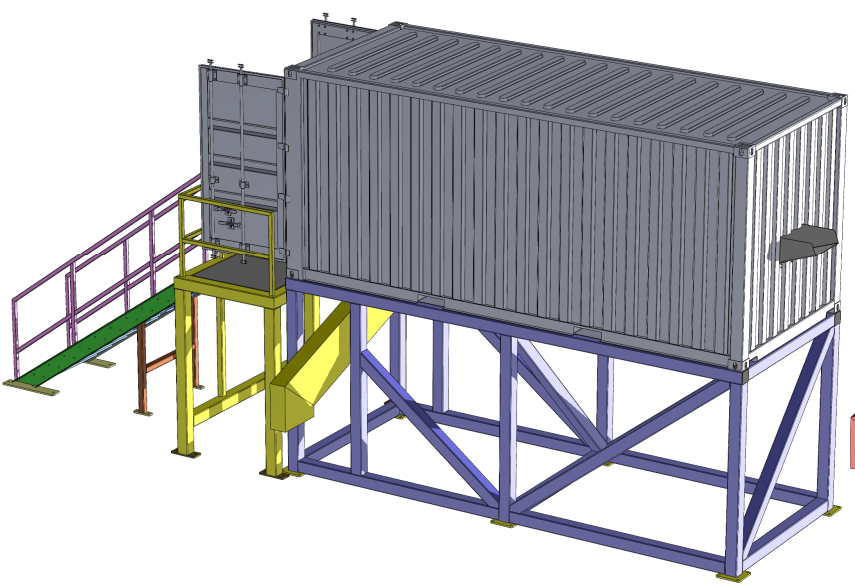

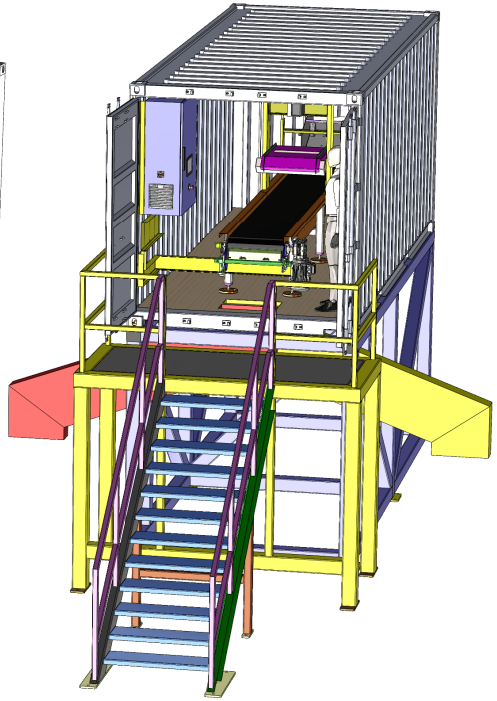

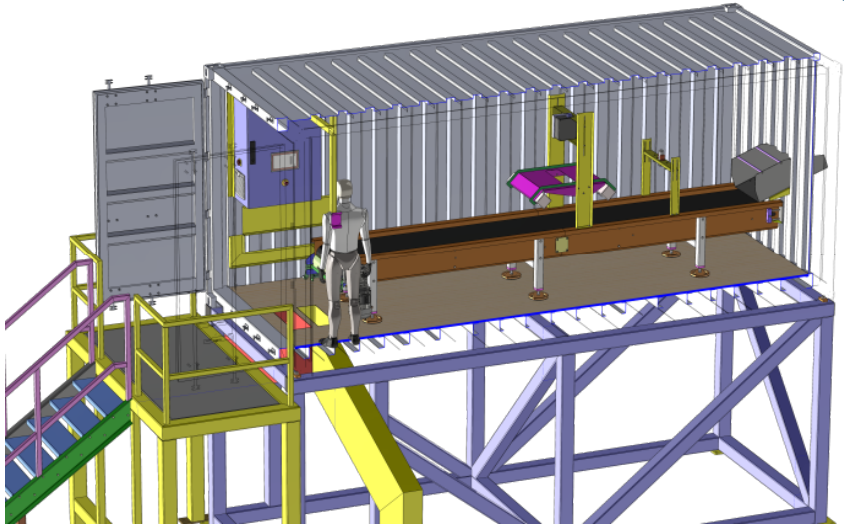

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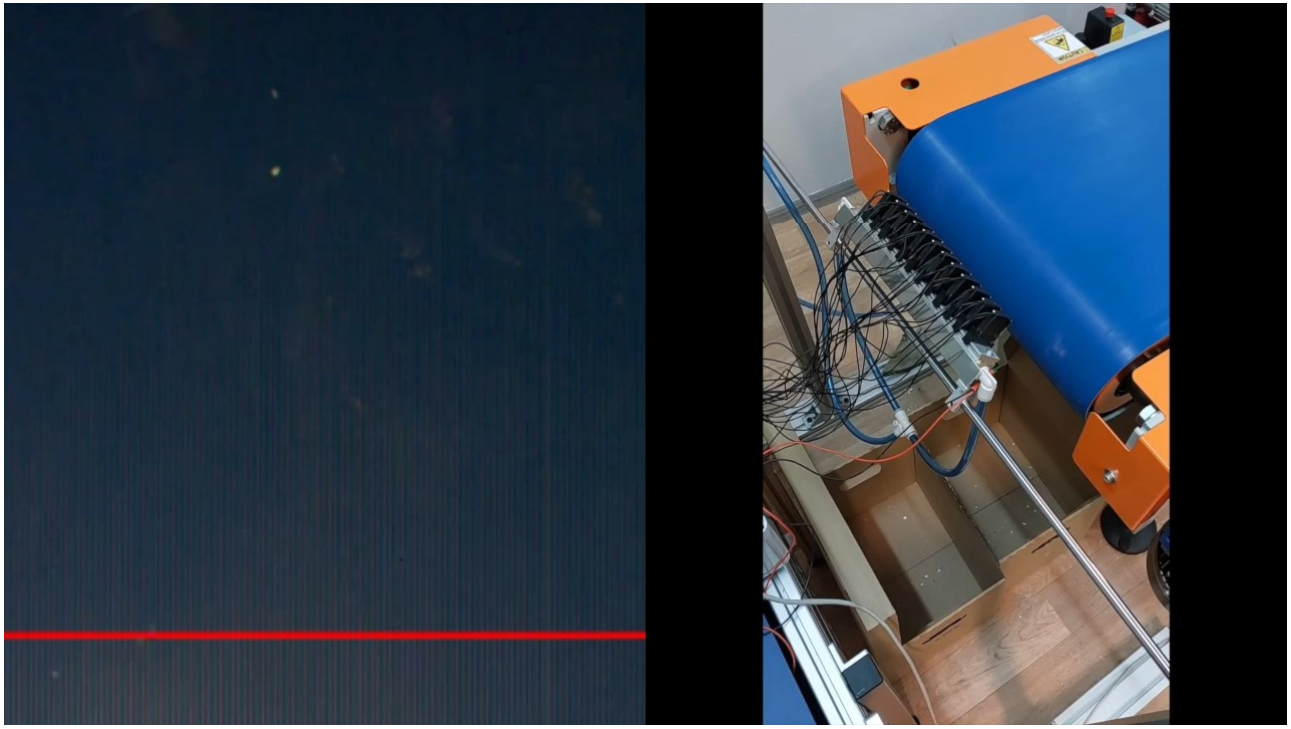

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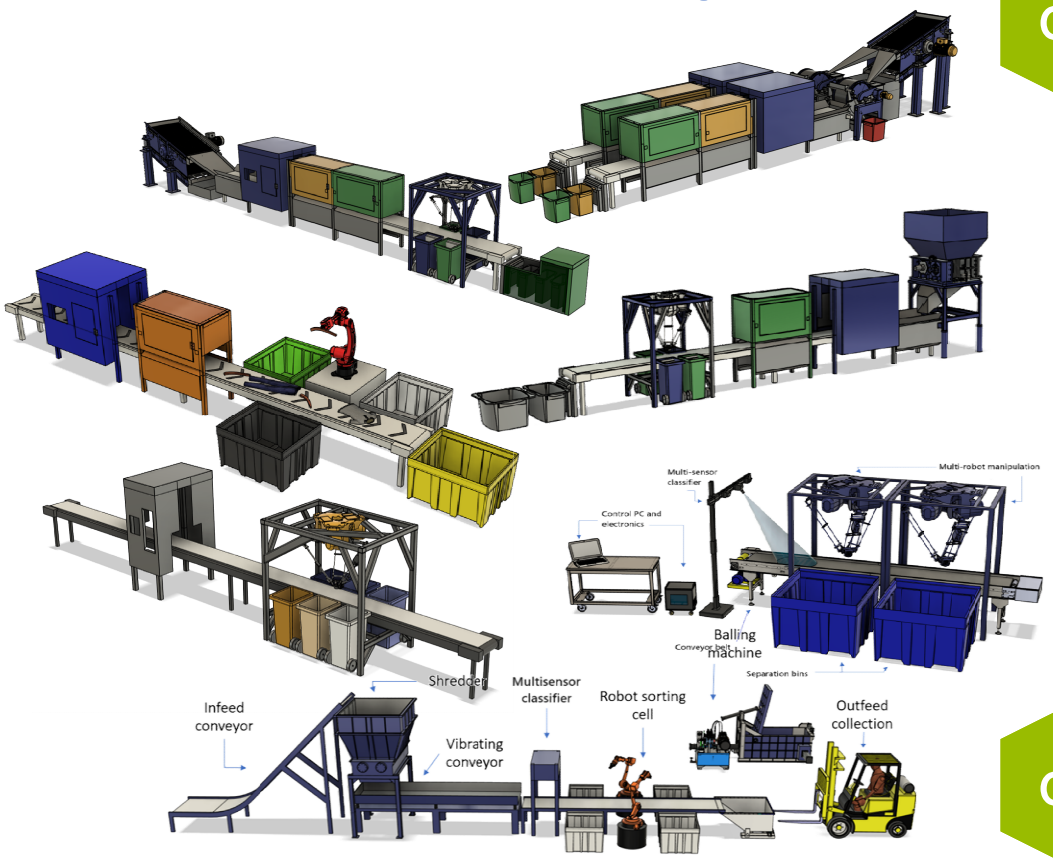
Sister projects in Sorting Activities across Europe



01 PLASTICE

The multi-spectrum sorter is used to separate plastics based on their categories from plastic waste streams. Specifically, **PVC, PP, PET, HDPE, and LDPE** are separated by leveraging multi-spectral data and deep learning models

02 DigInTraCE

The wood scraps sorter, utilizing optical sensors and deep learning, categorizes **wood chips** and **wood scraps** by based on **moisture, shape, size, and color**. The second sorter will be used to characterize and separate plastic wastes and flakes.

03 mastermine
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This sorter can separate different types of **minerals such as dolomite, magnesite and calcite** using optical, near-inferred and X-ray data.

04 REDOL

This sorter can separate different classes of materials such as **plastics, wood, cardboard, cement, metals** from Construction & Demolition Wastes

05 WOOD2WOOD

This mega sorter with human-machine collaboration workstation can separate different classes of **wood and glass** from Construction & Demolition Wastes

06 OPTIMINER

Aims to enhance the sorting of **Magnesite** streams by integrating hyperspectral, optical (RGB), and X-Ray Transmission sensors to analyze spatial, spectral, and 3D molecular properties.

07 PRIM-ROCK

Deploying two AI-assisted sorting systems **for tuneable segregation of mineral ore streams**, utilizing nondestructive vision sensory devices and deep learning models.

08 THESEUS Hub4Circularity

Within Theseus **5 sorters** will be developed in the disciplines of **1) Mixed urban wastes 2) Textile sorting** based on type and quality **3) Metal wastes** categorizing copper & aluminium levels **4) Glass sorting** based on quality and clearness of glasses and **5) Plastics form mixed wastes**

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Contact us for sorting solutions in CRM challenges

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PRIM-ROCK

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