

The objective of RESiLEX is to improve the resilience and sustainability of the entire Silicon value chain and reduce EU dependence on critical raw materials for solar panel and battery production. CETAQUA and THARSIS mining have developed a treatment train to recover critical raw materials for their subsequent commercialization. Imperial College London has studied the feasibility of such commercialization

Valorization and Commercialization of Critical Raw Materials from Mining Waste



*Left: Acid waste water at Tharsis Mining
Right: Cobalt and Nickel crystals obtained from the treatment*

From waste to value

A fundamental pillar of the Resilex project is the reduction of EU dependence from imported critical raw materials. For this reason, partners have worked on the development of a truly innovative treatment chain to recover valuable materials from mining waste.

- **The Treatment System:** A "Resource Recovery (RR) treatment train" was designed, consisting of eight modular units. These include physicochemical processes, an anaerobic membrane bioreactor (AnMBR), sulfide precipitation, ion exchange, and evaporation-crystallization
- **Target Materials:** Target Materials: The system aims to recover zinc and copper sulfide (ZnS , CuS), cobalt and nickel sulfate hydrates ($\text{CoSO}_4 \cdot x\text{H}_2\text{O}$, $\text{NiSO}_4 \cdot x\text{H}_2\text{O}$), and Sulfuric Acid (H_2SO_4).
- **Large-Scale Modeling:** An upscaling model was developed capable of treating an inflow of $50 \text{ m}^3/\text{h}$ of acidic wastewater, defining real-world mass balances and energy consumption.
- **Analytical Methodology:** The process followed a four-step approach: chemical characterization, market specification mapping, purification gap analysis, and scenario-based economic assessment.

Commercialization Assessments and Strategic Implications

The commercialization of the described techniques is not merely an environmental remediation strategy; it represents a fundamental industrial opportunity for the technological sovereignty of the European Union.

Economic Scenario Analysis:

- **Scenario I** (Low Intervention): Involves selling the recovered compounds as raw concentrates to intermediate buyers (smelters).
- **Result:** While useful for regulatory compliance, it offers narrow operating margins (approximately €45,540/year).
- **Scenario II** (High Profit): Involves integrating advanced refining stages (such as solvent extraction and precise pH adjustment) to produce "Grade A" products.
- **Result:** Generates a 295% increase in the net operating margin, rising to approximately €179,978/year.

High-Value Markets and Purity Requirements

Shifting to Scenario II opens up access to strategic markets where purity is a critical requirement:

- **Battery Sector:** Purified cobalt sulphate (>99.5%) is an essential precursor for lithium-ion battery cathodes in electric vehicles.
- **Photovoltaic and Optics Sector:** Purified zinc sulphide (>99.99%) finds applications in thin-film solar cells and infrared optical lenses.
- **Sulfuric Acid:** Can be reused internally for metal leaching or sold to the fertilizer industry, establishing a local circular economy.

A component of the wastewater treatment train developed by CETAQUA



Operational Challenges and Cost "Hotspots"

- **Energy Consumption:** The bioreactor utilized is the primary contributor (98%) to the system's total energy demand (3,197 kWh/day), though this can be partially offset by methane production.
- **Chemical Costs:** The use of yeast and organic substrates for nutrient control represents a critical cost "hotspot" that must be optimized using low-cost carbon sources to ensure long-term sustainability.

Regulatory Compliance and European Standards

To achieve End-of-Waste status, recovered materials must comply with strict legislative frameworks adopted in the European Union. **REACH** and **CLP**, for the registration and hazard communication of chemical substances, while the General Product Safety Regulation (GPSR 2025) requires detailed technical documentation and batch traceability.

Strategic opportunity for the EU

The conclusion suggests that manufacturing high-purity materials is not just a technical optimization, but a financial necessity. To justify investments in refining units, it is recommended that European battery and solar panel manufacturers receiving public funding be mandated to source a minimum quota (e.g., 10%) from certified European secondary sources. This approach would directly support the goals of the 2030 Critical Raw Materials Act (CRMA), which aims to obtain 25% of consumption from recycled sources.



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