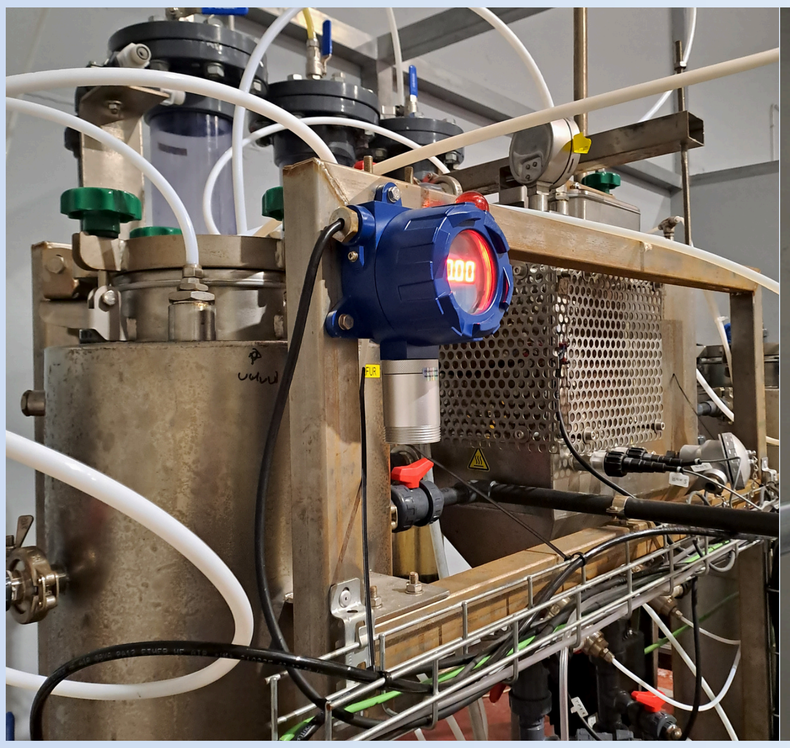
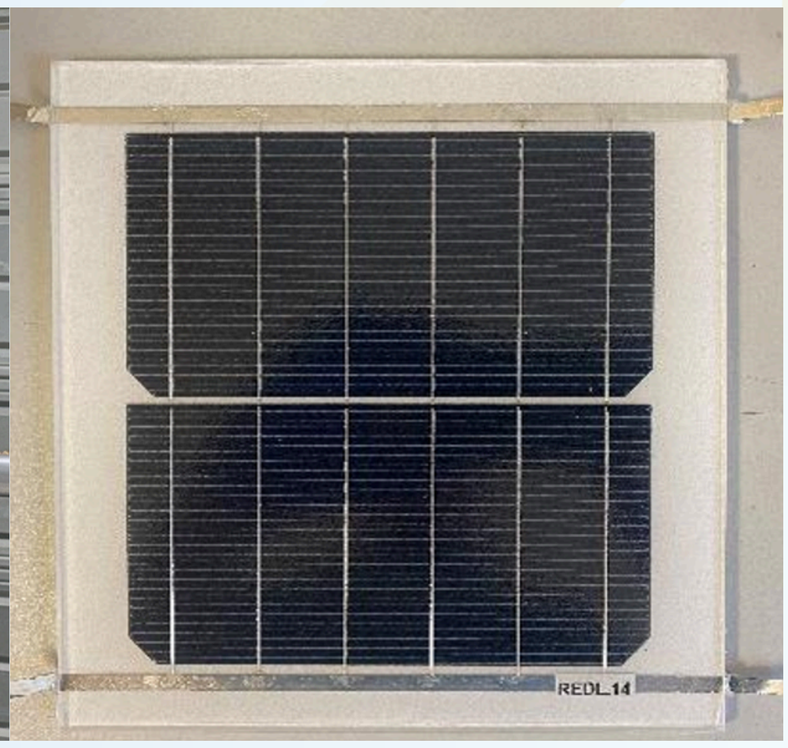
FACTSHEET #16

Critical raw materials, PV and batteries: the results of the RESiLEX project

4 years of joining forces and strong collaboration among 21 partners from 8 EU Countries, have produced key, relevant, and concrete results on different topics addressed as critical for the future of Europe and the energy transition. Here you find a wrap-up of the results coming from the multiple streams of activities implemented by the RESiLEX project since 2022.





Recovery of Critical Raw Materials [Learn more]

Partner organizations successfully designed, built, and operated an innovative resource recovery treatment train that validates the extraction of critical and valuable raw materials (specifically Copper, Zinc, Nickel, and Cobalt concentrates) from toxic mining waste and wastewater. Led by partner **CETAQUA**, this process introduces a cost-effective alternative to conventional lime treatments by utilizing organic waste substrates to reduce chemical consumption, achieving a remarkable ~90% reduction in acidic wastewater discharge on-site.

Supporting this circular model, Imperial College London conducted upscaling, valorization, and replication assessments to identify commercial target markets and suitable global mining sites for the technology, while also mapping social impact hotspots across the broader solar panel supply chain.

On the other hand, **Tharsis mining** focussed on the recovery of materials from the solid waste fraction. Concurrently, **ICAMCYL** foundation executed raw materials supply criticality assessments to define the project's capacity for raw material reduction and market integration. While all baseline goals were accomplished, final steps focus on academic publications and further refining the treatment train—specifically to lower operational costs and maximize metal purity before full industrial upscaling.

Sustainable silicon production [Learn more]

The consortium focused on developing sustainable routes for solar-grade silicon production by utilizing secondary raw materials and low-carbon processing methods. Led by **NTNU**, the primary activity investigated the recycling of industrial silicon kerf through a specialized remelting process using a silicon-aluminum alloy. This alloy was generated via the eco-friendly, aluminothermic SisAl process, which eliminates direct emissions by using aluminum to reduce. Through these combined systems, the team successfully demonstrated technical feasibility by refining the recycled feedstock into a high-purity (99,999%) silicon ingot, which was subsequently passed to **CEA** to evaluate its potential to grow Czochralski ingots for photovoltaics application and then to process high-efficiency silicon solar cells.

Heterojunction solar cells with efficiency up to 23.3% were processed using 12% of recycled feedstock. A critical lesson learned during operations was the strict need to minimize Boron (B) contamination levels within the initial material to maximize the allowable recycling ratio and to achieve solar cell performance and stability in line with industrial standards. Moving forward, the final steps are heavily oriented toward commercialization, with the team initiating strategic dialogues with potential industrial stakeholders to scale up this low-carbon recycling process to a larger manufacturing scale.

Eco-designed PV cells and modules [Learn more]

Partners collaborated to develop and test highly sustainable, eco-designed photovoltaic cells and modules. Driven by **CSEM**, the technical work successfully demonstrated a indium-free and silver-less Silicon Heterojunction (SHJ) Interdigitated Back Contact (IBC) cell achieving up to 25% efficiency alongside an SHJ solar cell process developed and validated at pilot-line scale at **CEA**, with indium and silver content reduced by 72% and 62%, respectively.

Complementing this, **CNRS** focused on removing Indium from Transparent Conductive Oxides (TCOs) by developing a high-throughput Spatial Atomic Layer Deposition (SALD) process for , yielding promising integration data in active cells. Concurrently, **CSEM** developed fluorine-free front sheets, bio-sourced encapsulant formulations, and flax composite backsheets that all successfully passed the rigorous international IEC norms for Damp Heat (DH) and Thermal Cycling (TC) reliability.

These newly engineered module materials were subsequently passed to **CEA**, for further testing and integration alongside selected commercially available bio-sourced materials and an optimized wood frame. This work enables the validation of combined eco-designed components that successfully passed all required reliability tests. Moving forward, the final steps of this work will focus on deeper reliability testing, identifying degradation mitigation solutions, further reducing silver content, and exploring alternative bio-sourced materials, while supporting industrial transfer of the validated processes.

Sourcing and dismantling of End-of-Life PV panels [Learn more]

Consortium established a comprehensive circular value chain for end-of-life (EoL) photovoltaic modules by combining market intelligence, mechanical optimization, and material recovery. Driven by **Envie 2E Occitanie**, the consortium analyzed the European PV market and projected future waste availability to map out key sourcing opportunities and mitigate regional recycling challenges.

On the processing front, **Recma** dramatically increased treatment throughput, worker safety, and ergonomics by upgrading existing infrastructure and commissioning a newly purchased mechanical dismantling machine.

Feeding these dismantled streams into advanced processing, **Comet Traitements** successfully achieved the operational startup of a specialized demonstrator designed to physically recover silicon wafers from the spent modules. With all baseline goals successfully met, the final phases of WP5 focus on upscaling the silicon recovery demonstrator to full industrial production, accelerating processing speeds, adapting dismantling machinery to next-generation panel formats, and establishing a dedicated reuse line to qualify suitable panels for second-life applications.

Battery active materials from solar waste [Learn more]

The consortium successfully developed and optimized a circular processing line to convert silicon recovered from end-of-life photovoltaic panels into high-efficiency silicon-carbon composite anode materials for Li-ion batteries. Spearheaded by the **University of Liege** (**GREEnMat Laboratory**), the technical work scaled up nano-silicon production to 2 kg/day via a semi-pilot milling process and established a pilot-scale spray dryer and a 1.5 kg batch furnace to yield up to 1.2 kg/week of final composite powder, effectively advancing the technology to TRL 6–7.

The electrochemical performance of this recycled material was successfully validated through integration into multilayer Li-ion pouch cells of 2.2 Ah and 247 Wh/kg by partners **CEA** and **CSEM**, demonstrating the viability of utilizing secondary silicon for high-performance energy storage. With no failures reported, next steps focus on transitioning to mass manufacturing, ensuring batch-to-batch consistency despite feedstock variability, and optimizing electrode formulations under industrially relevant conditions like high areal loadings and fast-charging protocols.

Lifecycle assessment & circularity mapping [Learn more]

Here, the consortium conducted multi-dimensional validation analyses encompassing life cycle assessment (LCA), circularity, economic viability, and social impacts of the project's developed technologies. Led by the **University of Gent**, environmental profiling confirmed that the RESiLEX innovation technologies consistently outperform reference scenarios—particularly within the climate change indicator—achieving major impact reductions in acid wastewater, solar-grade silicon production, and cell eco-design while proving the absolute feasibility of the closed silicon loop.

From a financial and operational standpoint, **CEA** verified that these circular advancements successfully reduce the Cost of Ownership (CoO) of a PV module. Concurrently, Imperial College London conducted social impact assessments that successfully mapped global solar panel supply chain hotspots, while also analysing technology upscaling, commercial market integration, and matching target mining sites for replication.

These insights were supplemented by **ICAMCYL's** raw materials supply criticality assessments, which defined recovery and reduction paths for strategic markets, and SolarPower Europe's successful generation of a robust stakeholder network to build EU-wide synergies. Next steps focus on supporting sister-project networks, drafting academic journals, and driving further technological innovations.

Management and outreach [Learn more]

This project, coordinated by **ISMC** and supported with the management and outreach by **Efund**, established a friendly and confident environment among all partners. **ETA** established the online presence, developed multiple dissemination materials, and implemented the communication activities. Together with **SolarPower Europe**, they organized a series of high-level workshops that enabled RESiLEX to deliver a set of policy recommendations that were channeled to the European Commission's DGs.

Tenerrdis spearheaded the project's commercial pathways, successfully delivering two key reports outlining the business plans and exploitation routes for the newly developed RESILEX technologies. The tangible result of this work is a huge amount of reports and video materials available to the European research and industrial sector.

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