SUSTAINABLE SOLUTIONS FOR RECYCLING OF END-OF-LIFE HYDROGEN TECHNOLOGIES

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BEST4Hy coordinator

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 101007216. This Joint Undertaking receives support from the European Union's Horizon 2020 research and innovation programme, Hydrogen Europe and Hydrogen Europe research

FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

EMIRI ENERGY MATERIALS INDUSTRIAL RESEARCH INITIATIVE

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THE CONTEXT: WHY BEST4Hy PROJECT

Hydrogen is becoming more and more a realistic solution contributing to the **decarbonization** of our economy**.**

A **correct disposal path** within a clear regulatory context and the full **recovery of the critical materials** used is needed.

This is crucial for supporting the new hydrogen systems, as lower environmental impact technologies, and the **whole hydrogen economy delivery.**

What are the critical issues related to the recovery and recycling of critical raw materials from fuel cells (FCs) and electrolysers?:

- complexity and cost
- issues with emissions and hazardous materials
- low level of technology readiness
- insufficient recycling contribution to meet high demand in various growing sectors.

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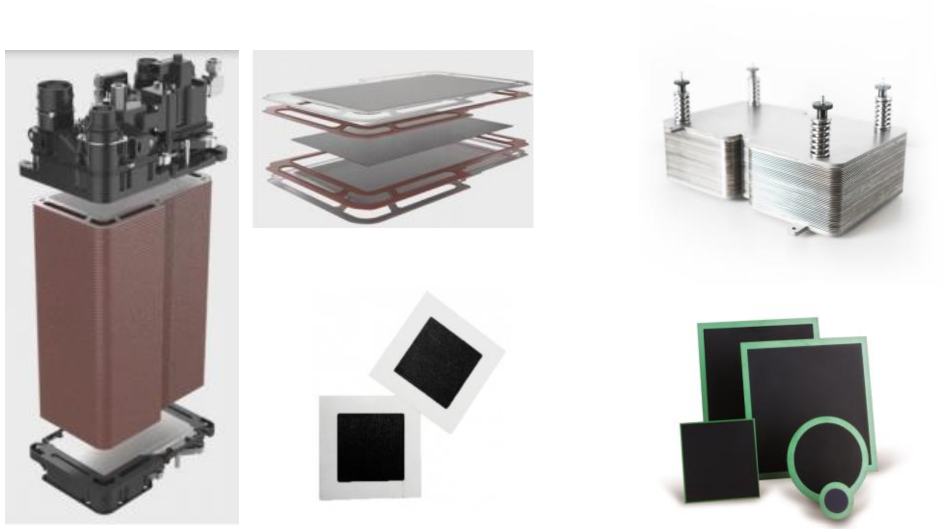
THE PROJECT

BEST4Hy is a research project funded under FCHJU2 in the framework of Horizon 2020 research and innovation programme.
Duration: M36, starting January 2021
Maximum JU contribution: 1, 586 M€
Maximum grant amount: 1, 586 M€

It focuses on the **development and validation of existing and novel recycling processes** for 2 key FCH products: **PEMFC and SOFC.**

The End of Life (EoL) strategy supported is accompanied by **LCC** and **LCA** evaluations to ensure it delivers the best material for **closed loop** and **open loop recycling.**



Materials are evaluated for **quality** and **performance** in remanufactured PEMFC & stacks and SOFC.

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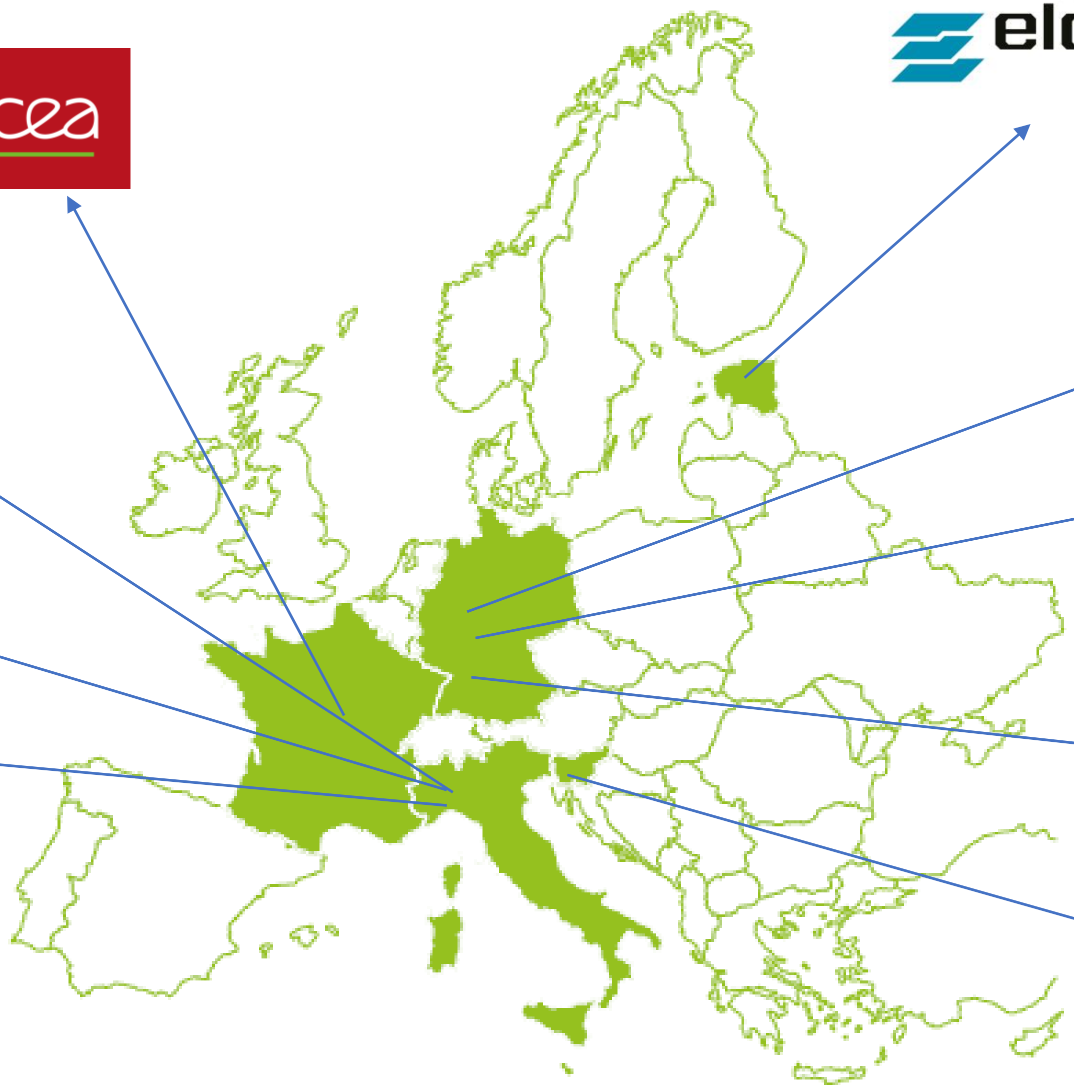
THE CONSORTIUM



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OBJECTIVES

- **ADAPTATION of ONE existing technology** for the **recycling of PEMs** (at least 80% of incoming Pt recovered)
- **COMBINATION of TWO existing for the recycling of SOFCs** (at least 80% of incoming anode material recovered overall, all to reach TRL5)
- **Validation at TRL 5 of two novel technologies for the recycling of PEMs** (at least 90% of incoming Pt recovered and 100% of membrane or 80% ionomer recovered)
- **DEMONSTRATION at TRL3 of ONE** novel technology for the recycling of SOFCs (>80% of La and Co recovery).
- **LCA and LCC of the processes for sustainability** (-20% GHG in the overall production)
- **Assessment of quality of materials** and components in closed and open loop recycling.

30% Recycled critical raw materials in SOFC cells manufacturing.

70% Ionomer in the manufacturing of PEMs stacks.

95% Platinum in the manufacturing of PEMs stacks.

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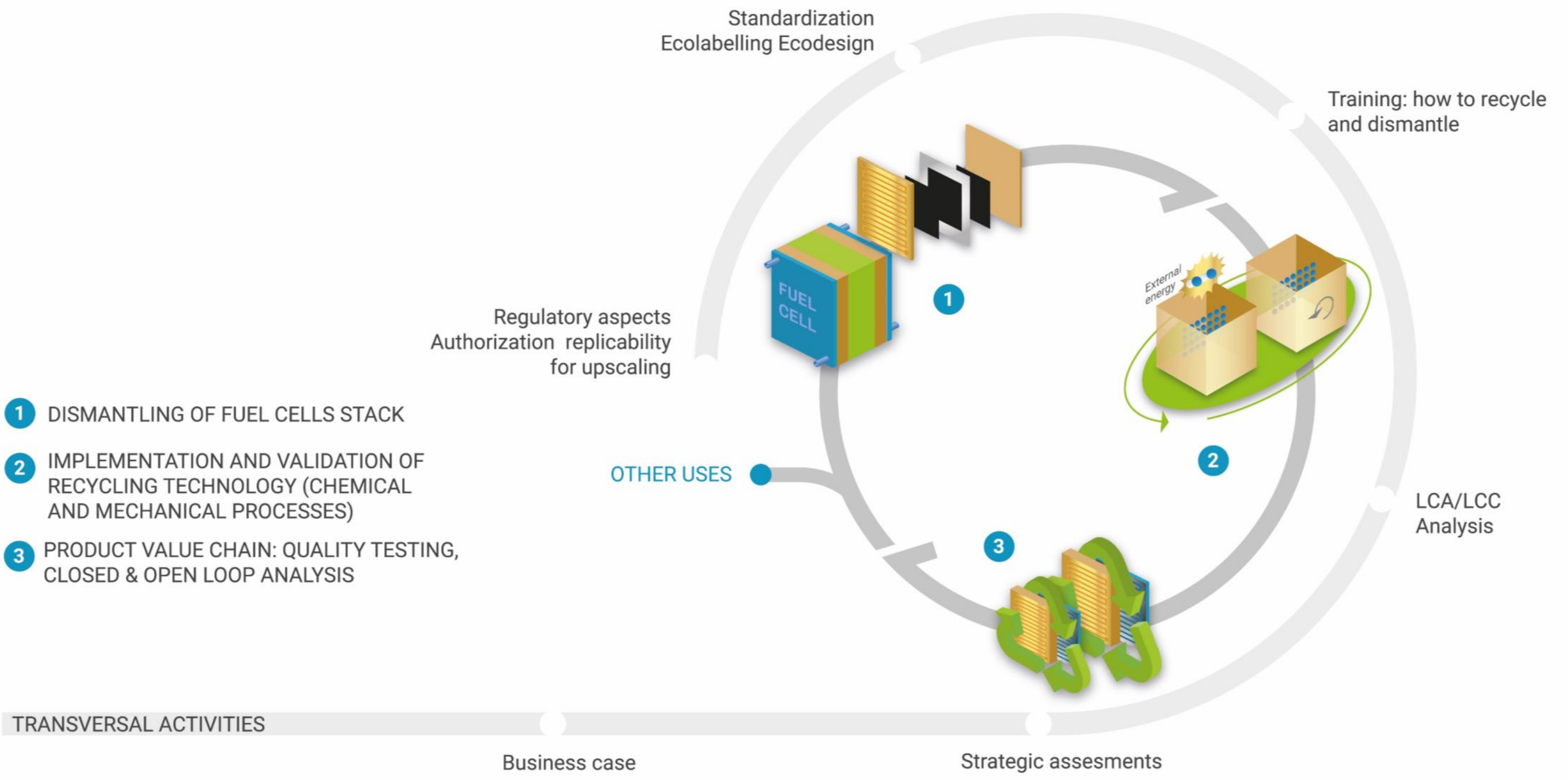
PROJECT CONCEPT

1 DISMANTLING OF FUEL CELLS STACK

2 IMPLEMENTATION AND VALIDATION OF RECYCLING TECHNOLOGY (CHEMICAL AND MECHANICAL PROCESSES)

3 PRODUCT VALUE CHAIN: QUALITY TESTING, CLOSED & OPEN LOOP ANALYSIS



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DISMANTLING OF FUELL CELLS STACK

PEMFC recovery process:
Development of a manual dismantling for EoL and new PEMFC components and entire stacks.

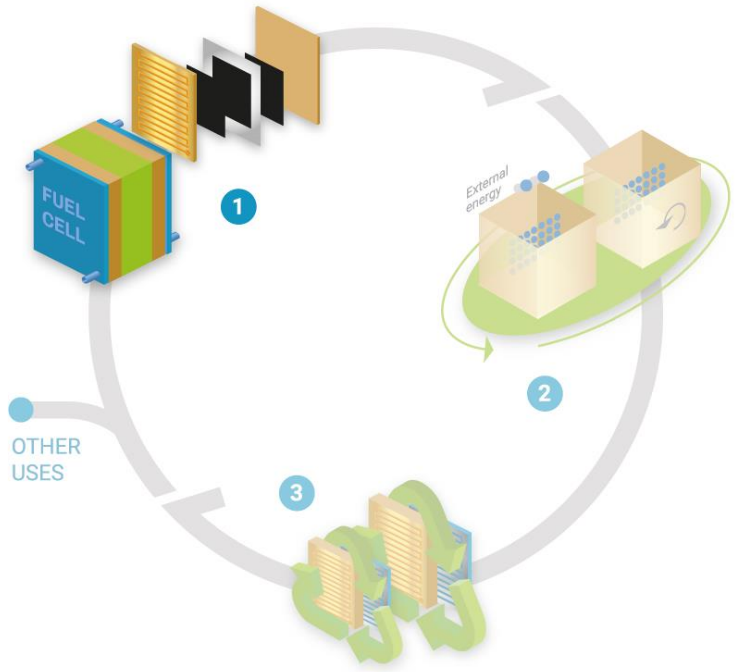
Novel gaseous approach for the membrane electrode assembly (MEA).

SOFC recovery process:
Development of a manual dismantling of the SOFC stacks and trial to dismantle stacks mechanically with ad hoc equipment.

Partners

PEMFC - EKPO, Hensel Recycling, CEA

SOFC – Elcogen, POLITO



1 DISMANTLING OF FUEL CELLS STACK

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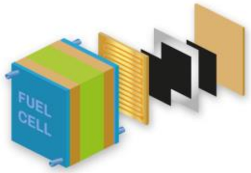
MAIN RESULTS ON DISMANTLING OF PEM FUELL CELLS STACK



•**Manual Approach** with removal of layers, sealings, CCM/electrodes.
•Moreover, a **mechanical dismantling** was performed **with an ad hoc equipment (rotating knives shredder);** this machine is typically used to shred metallic and composite materials and is ideal to reduce volume and separate fractions smoothly.
→Hensel Recycling plan to deepen this topic and continue to explore possibilities of **a more efficient mechanical shredding and separation, changing boundary conditions, working towards automation of the dismantling process.**

Challenges
•Maximization of material recovery, including improvement of dismantling procedures to reduce stack material losses of 5-10% (especially Pt)

Gaseous dismantling of MEA
•As an alternative to the alcoholic solution soaking.
•Gaseous media will allow **quick penetration of green solvents inside the different components, facilitating their separation.**
•The gaseous approach will allow the recovery of solvent.
•**Very efficient dismantling** whatever the aging of the MEA's
•High pressure process makes dismantling easier for MEA's with sealing

Challenges
•High gas recovery efficiency (>95%), fast process (<30min), use of low environmental impact chemicals.

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RECYCLING TECHNOLOGY

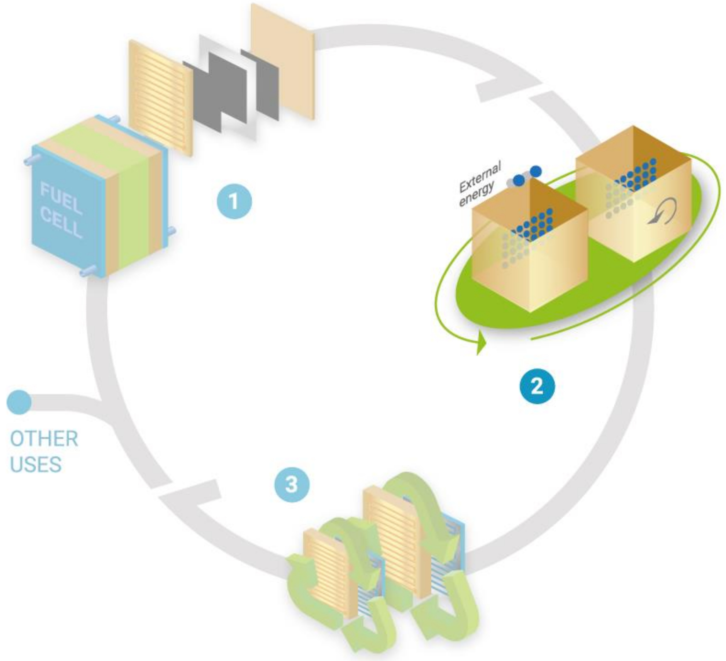
BEST4Hy will validate **four recovery processes** currently at lab scale (TRL3), with the view to develop them up to TRL5.

The technologies concerned allow recovery of critical raw and precious materials such as:
- **Pt** and **ionomer** from PEMFCs (Hensel Recycling and CEA),
- **Ni** and **YSZ** from SOFCs anode (PoliTO).

All materials recovered will be fully characterized to maximize closed loop recycling.

Additionally, a process flow for obtaining recycled La- and Co- precursors for LSC manufacturing will be experimented at TRL 3 (PoliTO).

A first evaluation of the energy, resource use and emissions, amongst other, will inform the LCI/LCA under development by UL.



2 IMPLEMENTATION AND VALIDATION OF RECYCLING TECHNOLOGY (CHEMICAL AND MECHANICAL PROCESSES)

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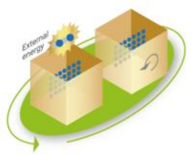
MAIN RESULTS ON RECYCLING TECHNOLOGY



Hydrometallurgical process

•recover by Hensel Recycling of Pt as a solid [NH4]2PtCl6 salt, ammonium-hexachloroplatinate on different aged materials

•**Optimization at TRL3 to obtain the best Pt recovery with quality analysis of Pt solution with ICP-OES**

•First salts sent to CEA for characterization

•Ongoing characterization and Pt/C Catalyst synthesis with first materials (Hensel Recycling and CEA)

Challenges

•Obtaining Platinum salt for reuse it in a closed-loop-recycling with a **final efficiency of Pt recovered of » 80%.**

•Demonstrating **high recovery capacity** (> 80%) of ionomer and Pt/C for reintroduction in closed-loop recycling (catalyst recycling yield »90%).

•Demonstrating more **environmentally friendly treatment routes**, which do not require the use of organic solvents or strong acids and avoid the emission of toxic gases.

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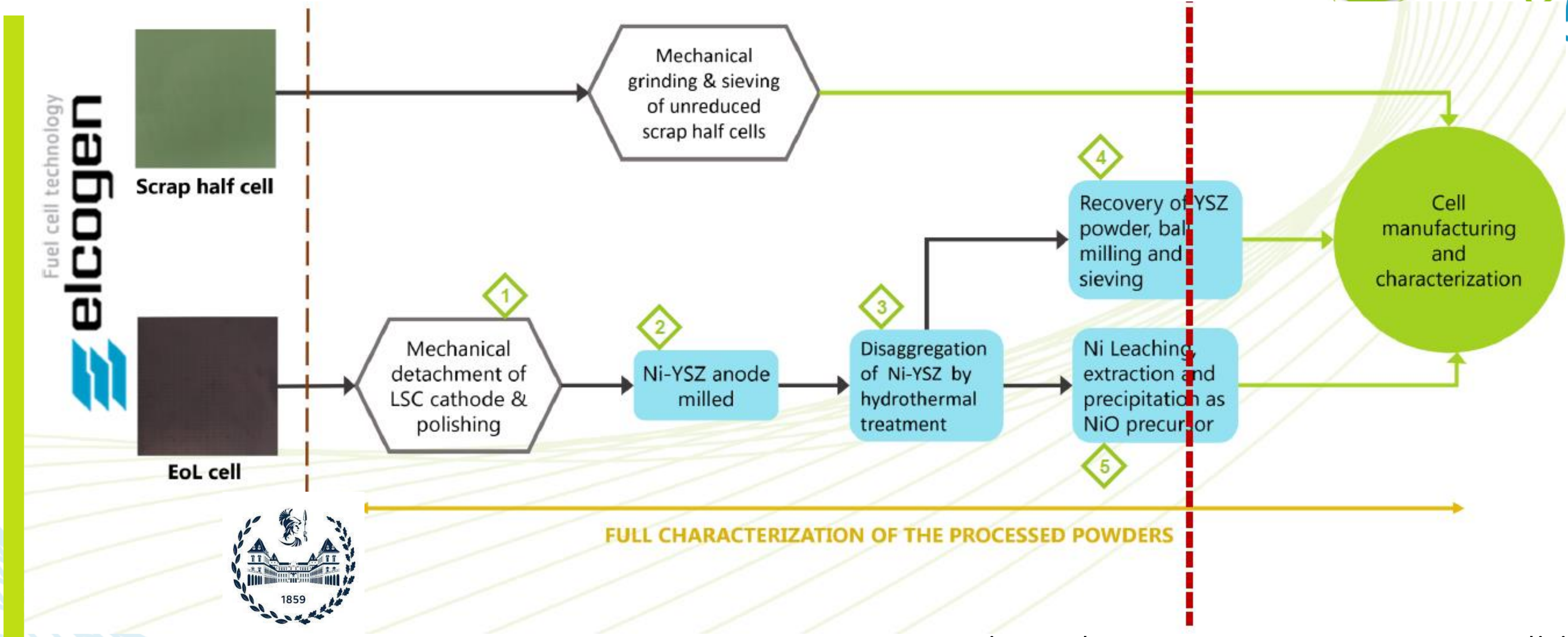
MAIN RESULTS ON RECYCLING TECHNOLOGY



Challenge. scaling-up (TRL 5) a process that allows **more than 80% recovery of both Ni (in the form of NiO) and YSZ according to the manufacturer's requirements.**

Given the current treatment conditions, **leaching with HNO_3 results the most promising strategy to extract Ni**

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Focusing on Advanced Materials: Further Gaps

- **Current dependency from critical raw materials and future increasing demand.**

Best4Hy focuses on maximizing the recovery of platinum, yttria stabilized zirconia, lanthanum and cobalt (PGM and, for Yttrium, HREE groups respectively within the 2017 EU list of CRM; in addition, concerns regarding the social implications of cobalt mining are rising) establishing the degree of reusability back into FCH components (closed loop recycling) but also exploring redirection to the market for other applications (open loop recycling).

- **Costs of the recycling.**

The cost of recycling of the total volume of PEMFC produced has been evaluated by project Hytechcycling to be around 800k€ in 2026 rising with the number of PEMFCs sold to over 2ml€ in 2050, while total costs for SOFCs are estimated to be around a third of that. These first findings suggest that PEMFC recycling, due mostly to the value of the PGMs, would be therefore a revenue generating activity. Whether it would be the recycling center to benefit from the whole amount will depend on the organisation of the value chain. SOFCs are currently not being recycled with value production, hence Best4Hy will be the first to analyse the conditions making this recycling economically attractive either for SOFCs manufacturers or for recycling centres. BEST4Hy will identify these aspects via LCC.

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Focusing on Advanced Materials: Further Gaps

- **Environmental and social impact.**

Alongside the direct economic aspects, which also have consequences in terms of who should be bearing the cost of the recycling, are also some environmental considerations: producing just 1 kg of primary platinum (from virgin sources) emits 40 tons of CO2 and consumes 200 gigajoules (GJ) of energy. In comparison, producing 1 kg of platinum from secondary (recycled) sources emits one twentieth of the emissions (2 tons of CO2) and consumes 10 GJ of energy. BEST4Hy will identify these aspects via LCA.

- **Barriers on existing regulations.**

(i) How to declare rare/precious/hazardous material that compose FCH technologies in technical datasheet; (ii) How to treat at the end of life rare/precious/hazardous material that compose FCH technologies (not necessarily looking at FCH technologies regulation but more in general looking at material regulatory framework); (iii) How to recycle/convey to waste landfill/dismantle at the end of life FCH Technologies (and or similar technologies containing similar rare/precious/hazardous material). BEST4HY will overcome barriers, creating new "innovation agreements" and "working groups" on FCH, involving stakeholders in the sector, policy makers, universities via also AB involvement. Guidelines on ECO-Labeling/ECODESIGN will be crated. An Extended Producer Responsibility (EPR) scheme will be analysed also for FCHs and compared with existing ones (WEEEs, batteries, automotive industries).

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Q&As

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Thank you

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https://best4hy-project.eu/

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