

//EU HYDROGEN

RESEARCH DAYS

15-16 NOVEMBER



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BEST4Hy

sustainaBLE SoluTions FOR recycling of end-of-life Hydrogen technologies

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Project Overview

Call year: 2020

Call topic:

FCH-04-4-2020
Development
and validation of
existing and
novel recycling
technologies for
key FCH products

Project dates:
01/01/2021 - 31/12/2023

Total project budget:
1,586,015.00 €



% stage of implementation
01/11/2023: 90%

**Clean Hydrogen Partnership max.
contribution: 1,586,015.00 €**
Other financial contribution: N/A

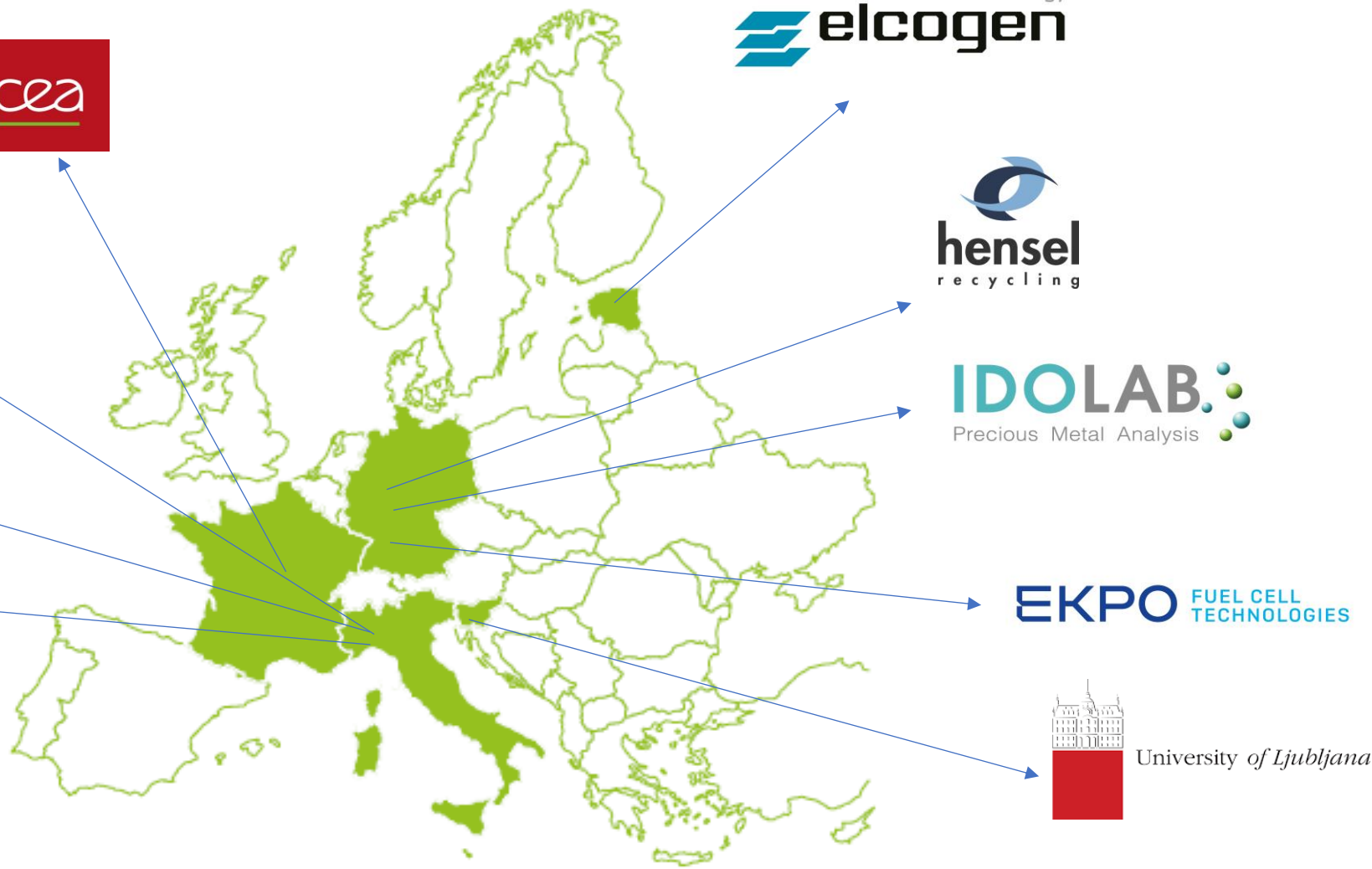


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Partners



Politecnico di Torino



Project concept

Target technologies: PEMFC & SOFC- EoL
Study of disassembly and dismantling (esp. PEMFC):

- Improvement of disassembly procedures to reduce stack material losses and study of possible mechanisation
- PEMFC MEA dismantling: using a gas-based technology to maximise recovery of Pt-containing materials, membrane and GDL

STATE OF THE ART: no dismantling, minimum disassembly to serve downstream processes

- 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

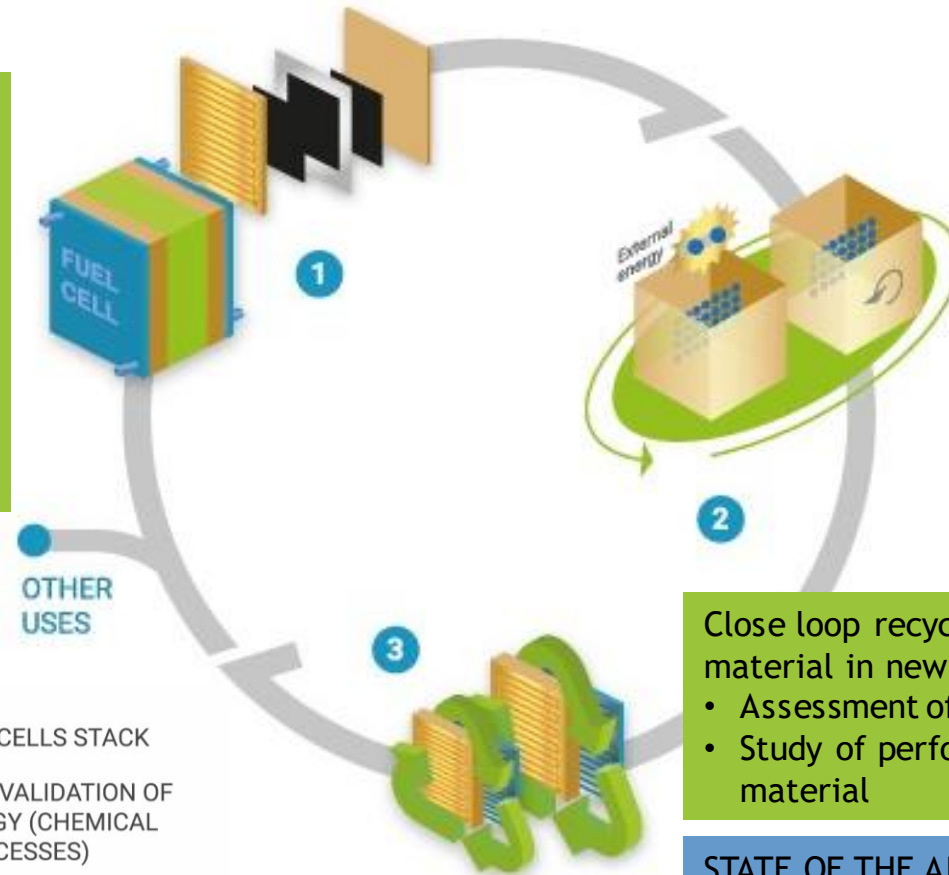


STATE OF THE ART: NO RECOVERY or PYROMETALLURGY to recover Pt only

Four different recovery processes developed up to TRL5: two adaptations of existing technologies + two new ones.

Target materials:

- Pt and ionomer from PEMFCs
 - Ni and YSZ from SOFCs (anode)
- Also a process for the recovery of La and Co from SOFC (cathode) developed at TRL3.
Focus on low impact technologies



Close loop recycling - Integration of recycled material in new cells (both SOFC and PEMFC):

- Assessment of manufacturing methods
- Study of performance vs cells 100% virgin material

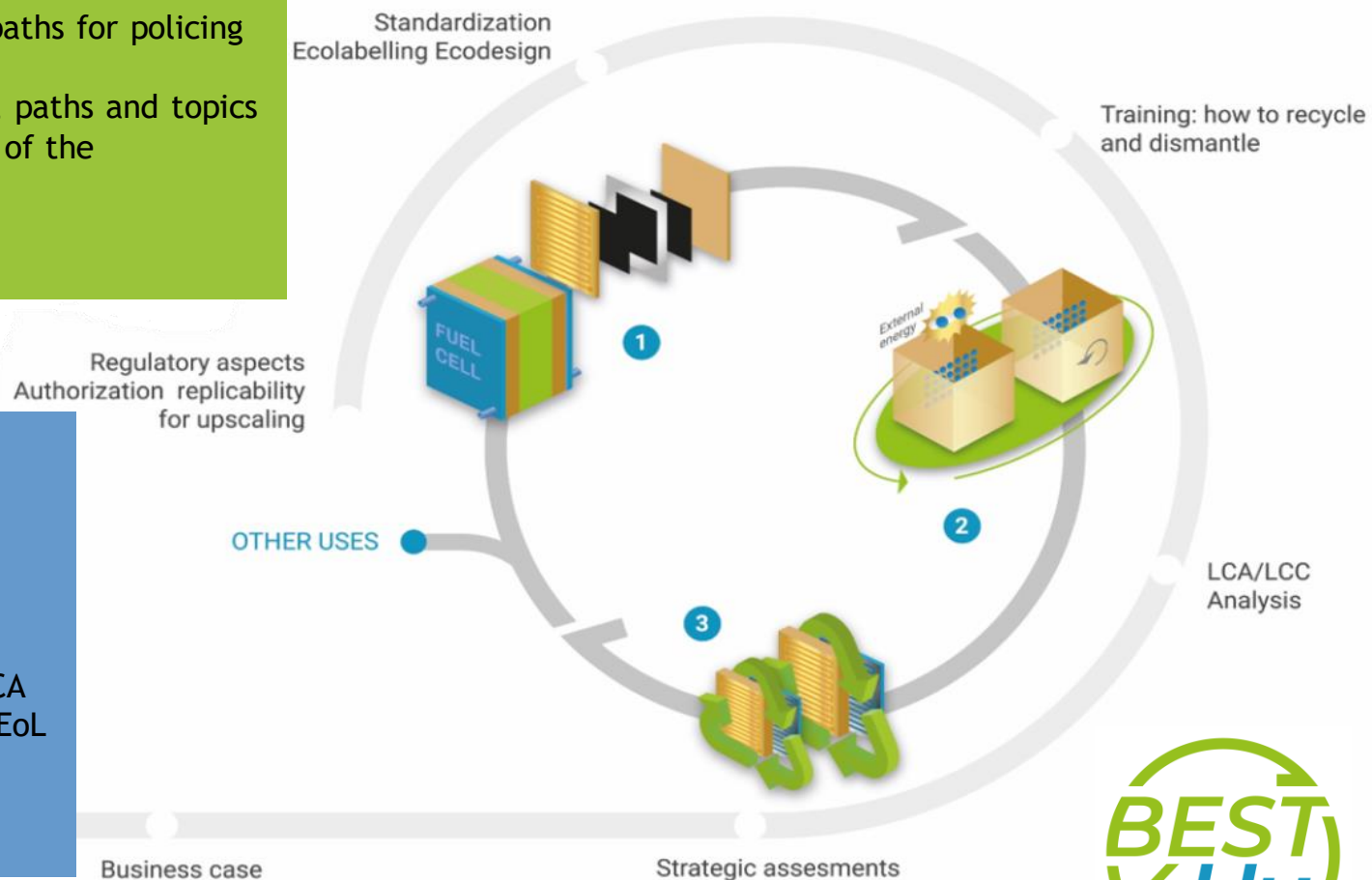
STATE OF THE ART: NO USE of SECONDARY MATERIALS

Project concept

Regulatory aspects: understanding possible paths for policing recovery of precious/critical materials
Standardisation: understanding the potential paths and topics
Training: offer an operational understanding of the approaches/technologies developed
New business opportunities
LCA/LCC analysis of EoL strategies

STATE OF THE ART:

- No specific regulations; Critical Raw Materials Act March 2023
- No specific standards, ecolabelling
- LCA/LCC: only some data and studies on PEMFC technologies for materials and LCA evaluations, no available LCI for SOFCs, no available EoL LCI and LCA models and no LCC data for all (existing and new) EoL technologies.
- Business aspects: supply chain not existing (low volumes)



Some of the key outcomes

ACHIEVED

Proton Exchange Membrane FC

Platinum recovery targets:

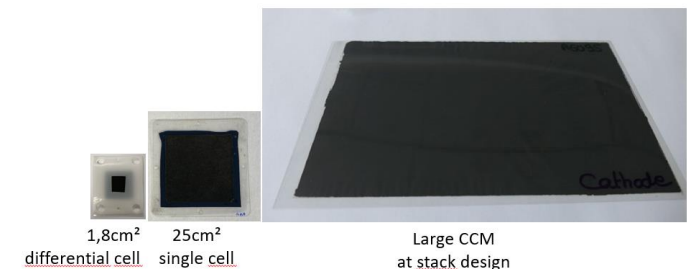
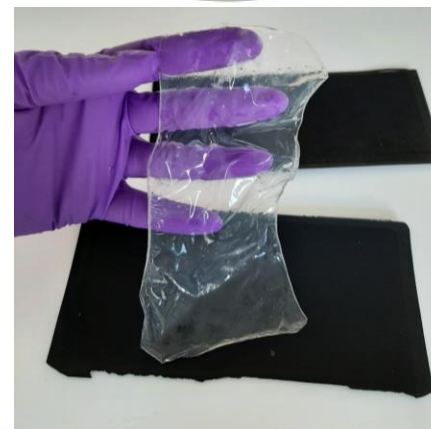
- at least 80% of Pt recovered with hydrometallurgical process at TRL5 -> **ACHIEVED up to 85%;**
- at least 90% of Pt recovered with novel processes (alcohol dissolution & electroleaching/electrodeposition, both at TRL5) -> **ACHIEVED up to 95%**

Other materials recovery targets:

- Recovery of at least 80% ionomer or 100% membrane -> **ACHIEVED membrane recovery**

Closed loop recycling targets:

- New MEAs manufactured with at least 90% of recovered Pt -> **ACHIEVED up to 100%**

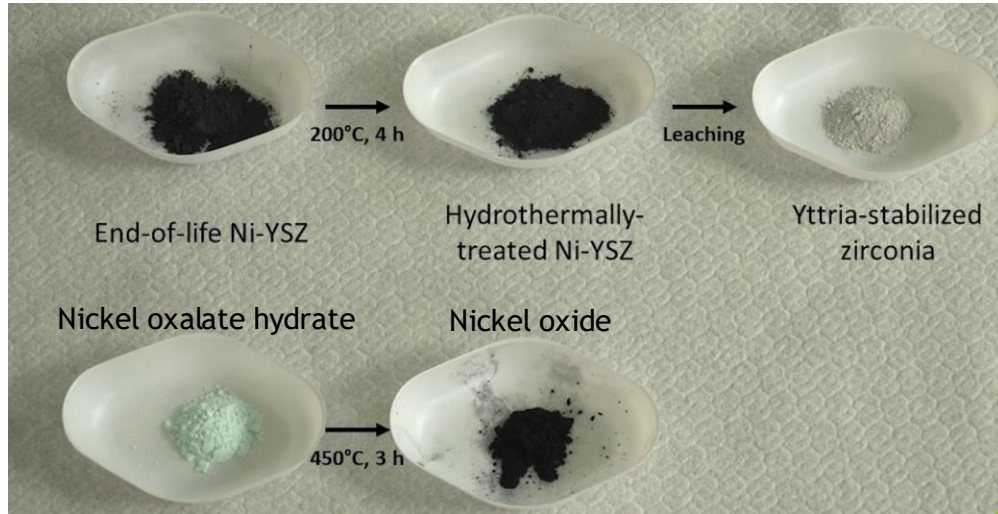


2 PATENTS APPLIED FOR
by BEST4Hy partners



Some of the key outcomes

ACHIEVED



Solid Oxide FC

Anode material targets: at least 80% of materials recovered through combination of hydrothermal and hydrometallurgical processes at TRL5

-> **ACHIEVED**

Cathode material: at least 80% recovery of La and Co

-> **ACHIEVED**

Closed loop recycling: new SOFC manufactured with at least 30% of recovered materials (YSZ, Ni, La, Co)

-> **ACHIEVED**



Some of the key outcomes

WORK IN
PROGRESS

Performance of PEMFC MEAs containing recovered Pt:

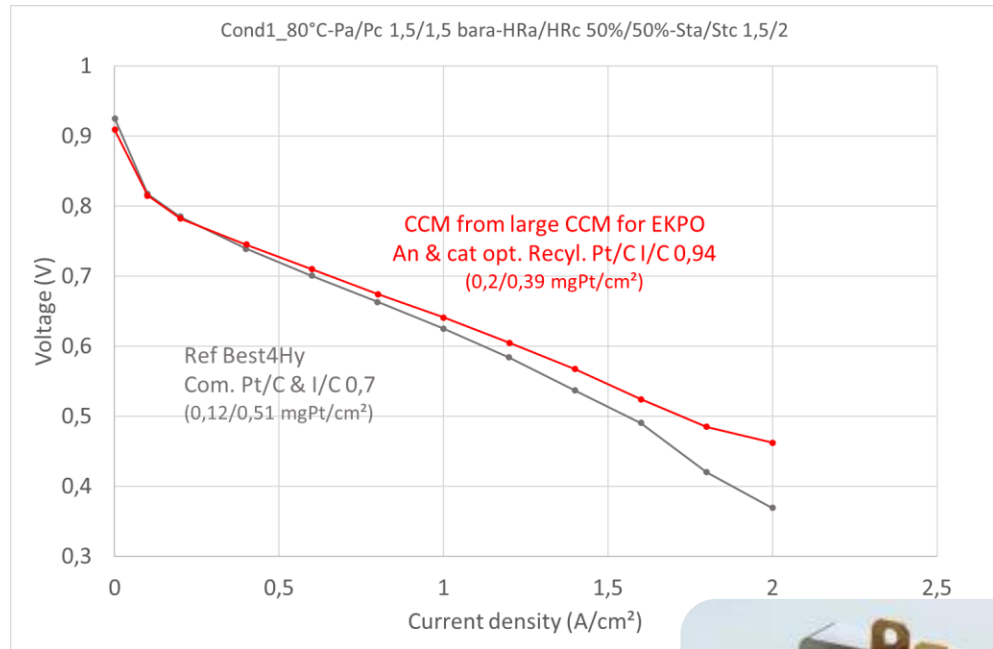
- Single MEAs have reached at least 80% performance (in some configurations, even above) of reference MEAs (=100% virgin materials)
- Performance of MEAs with recovered Pt in stack under evaluation by industrial partner

Performance of SOFC with recovered materials:

- Under evaluation both in lab and by industrial partner

Open loop recycling:

- Evaluation of use of recovered NiO and Co from SOFC for the synthesis of Lithium-Nickel-Manganese-Cobalt-Oxide (NMC) materials



PEMFC polarization curve

25cm² single cell



Some of the key outcomes

WORK IN
PROGRESS

LCA :

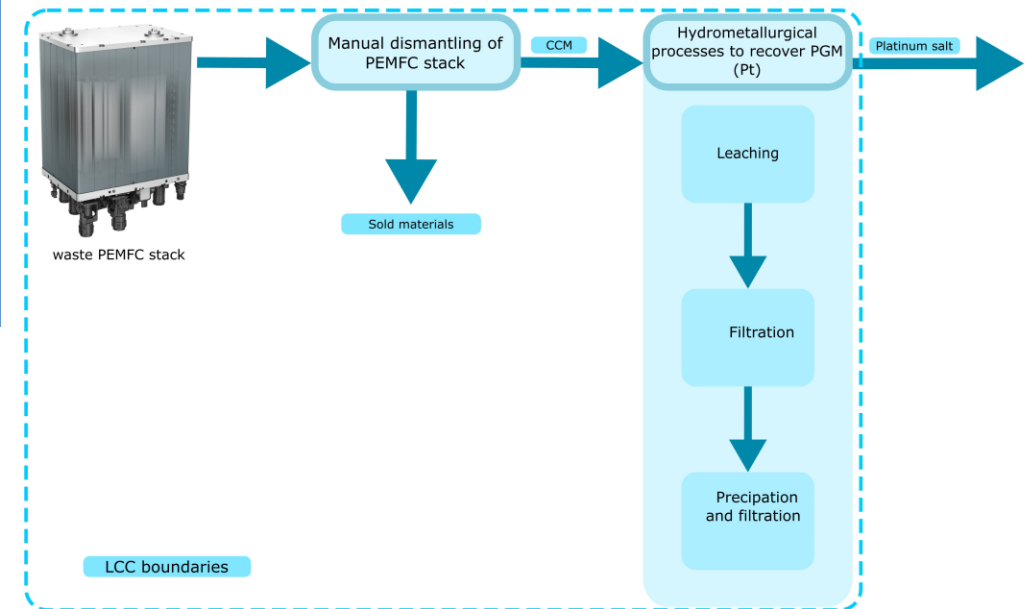
- New innovative LCI for La and Co recovery from SOFC cathode – Low TRL.

LCC Based on LCI and additional inputs from recycling industry:

- **LCC for Pt recovery (HMT) from PEMFC stacks** was performed with promising results for the **recycling industry including Pt recycling from FCH technologies.**

Main CHALLENGES:

- Low TRL processes (EoL of SOFC).
- Results of LCA, LCC are used to highlight hotspots for upscaling of these technologies.
- Implement LCC on novel EoL technologies (data from industry)
- Data on many virgin materials (REE, CRM, esp. for SOFC) are not available (building own innovative LCI)

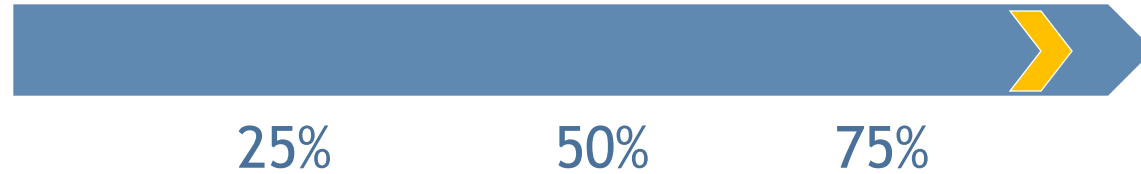


Project Progress/Actions - Aspects



Regulatory and standardisation aspects

Contributing directives, policies; existing standards



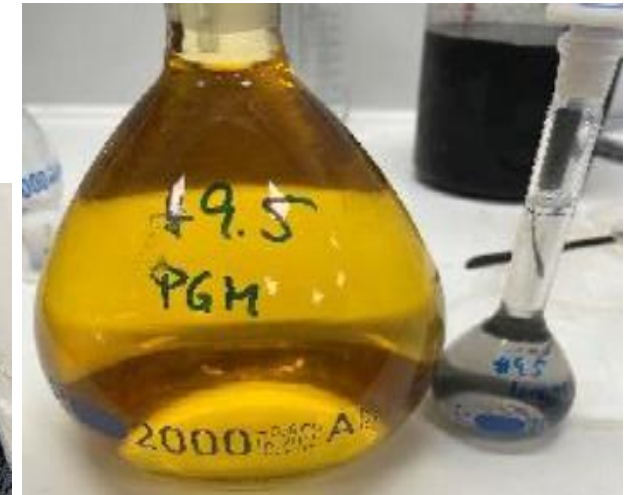
ROADMAP FOR FUTURE POTENTIAL POLICY/STANDARD MAKING

- Critical Materials Act (March 2023) very relevant to the future of policy making of EoL hydrogen technologies
- Many relevant Directives, regulations and Plans analysed (Ecodesign Dir.; End-of-Life Vehicles Dir.; New Circular Economy Plan) -> many are under revision for updating
- What is happening for batteries?
- Standards: identified relevant standardisation committees as no standards related to EoL hydrogen technologies (or their ecodesign) exist as yet



Risks, Challenges and Lessons Learned

- Application of recovery processes to other FC&H technologies: some initial encouraging results but it can be difficult to get hold of EoL materials
- Involvement of the supply chain is FUNDAMENTAL
- Recovery of ionomer: challenges in its characterisation and consequent use in manufacturing of new MEAs



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Exploitation Plan/Expected Impact

Exploitation

Identified 13 Key Exploitable Results

Workshop with the Horizon Results Booster to analyse three different ones and learned how to define an Exploitation Plan for:

- Services
- Further research activities
- (Industrial) exploitation of approaches /patents



Impact

Focus on LCA/LCC:

- Contribute to LCA of SOFC and PEMFCs
- Mapping of EoL strategies - to be used for future assessments (higher TRL)
- Developing a model for LCC of EoL strategies





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