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BEST4Hy Closes the loop: final event and achievements on the End-of-life hydrogen fuel cells recycling project

An international partnership developing technologies for the recovery of critical raw materials from hydrogen technologies

12th - 13th of December, Aschaffenburg (Germany) - BEST4Hy Consortium meets for its last General Assembly (GA) and Final Event. Two-day meeting with full agenda and partners at work in the GA and in a workshop for the presentation of the results achieved after three years of project. **BEST4Hy** – SustainaBlE SoluTions FOR recycling of end-of-life Hydrogen technologies – a research project funded by the Fuel Cells and Hydrogen 2 Joint Undertaking (now Clean Hydrogen Partnership) under Grant Agreement No 101007216, developed low-environmental-impact technologies for the recovery and recycling of materials vital to the hydrogen supply chain. Achievements have been showed in this final event, organised by Hensel Recycling and IDO-Lab at their premises in Aschaffenburg and Karlstein am Main (Germany) with the support of project coordinator Environment Park.

Representatives from the hydrogen sector, as well as recycling and metal industries at European level have been invited to attend to the event and the public workshop held on December 13th morning. Some of them, **Toyota Europe Motor, Solvay, Hensel Recycling North America, Hellas CERTH, JRC and Enabled Future Limited** company, followed and supported BEST4Hy project since its beginning as Advisory Board members. The project also collaborated with **IMDEA Energy**, coordinator of eGHOST and SH2E EU projects, with whom BEST4Hy Consortium established a strict collaboration for the common research on hydrogen technologies' sustainability over their life cycle.

During the workshop, challenges and achievements of BEST4Hy project have been presented to the public. The presentation was organised in an interactive way with open discussion finalised to receive feedbacks, exchange experiences and ideas with the attendees to **move forward the sustainability of the hydrogen technologies and understand the current needs of the hydrogen sector with respect to recycling of end-of-life devices and use of recovered materials**.

Relevant achievements have been presented for the recovery material from the EoL PEMFCs, where Hensel Recycling/IDO-Lab and the research centre CEA were mainly involved: **more than 90% of Platinum** has been recovered by hydrometallurgical process after optimisation (TRL5), while Platinum recovery yield reached **up to 95% by using both novel processes developed by BEST4Hy partners**, the alcohol dissolution and the electro leaching/electrodeposition treatment (TRL5).

The recovery of other materials has also been explored, obtaining recovery yields **up to 80% for the Ionomer and to 100% for the membrane.**

In order to close the loop, the recovered materials have been tested in new MEAs by the company EKPO, who also provided aged MEA for the dismantling and recovery processes tested initially. CEA was able to **remanufacture new MEAs comprising of 100% secondary Platinum** to the dimensional requirements of a test short stack. EKPO tested the MEAs with satisfying performance under industrial conditions, with the MEAs reaching about 92% of the voltage of the EKPO commercial material.

A visit to the Hensel Recycling premises and IDO-Lab laboratories completed the overview of the recycling process for the PEM analysis. An end-of-life PEMFC system from automotive application coming from an

authorised wreck yard was used to show the waste to be dealt with and the initial phases of the recovery process. **The Platinum/Ionomer recovery processes were shown by IDO-Lab, who opened its laboratories to the stakeholders with a short training on the hydrometallurgical and alcohol dissolution processes performed in the TRL5 BEST4Hy pilot plants.**

Equally important the results achieved for the material recovery from SOFCs, for which the existing recovery and recycling technologies are currently not enough consolidated. Politecnico di Torino worked with two research teams on EoL solide oxide fuel cells provided by the manufacturer Elcogen. They developed novel processes for the material recovery of both anode (Nichel, Yttria-stabilised-zirconia) and cathode materials (Lanthanum, Cobalt). For the anode material recovery step, a combined process with hydrothermal and hydrometallurgical treatments was optimised from TRL3 up to TRL5. In the meantime, a completely novel process was developed for the materials recovery in the Lanthanum-Strontium-Cobaltite (LSC) cathode, identifying and optimising as best performing process the acid leaching treatment through nitric acid at laboratory scale (TRL3). **More than 80% of materials was recovered. Elcogen took care of the remanufacturing of new SOFC with at least 30% of secondary materials**, achieving the project target and satisfying performance results. During the experimental tests on SOFCs, BEST4Hy project was able to gain knowledge on a new topic, paving the way for further research on material recovery from EoL SOFCs at higher technology level.

Environmental and economic aspects are also key elements for the hydrogen technologies deployment. During BEST4Hy, University of Ljubljana gave an important contribution to the LCA and LCC analysis for hydrogen fuel cells, developing new models and novel inventories for both PEMFC and SOFC technologies, for whom no data is currently available in any database. The modelling of the EoL strategies developed on the basis of BEST4Hy technologies allowed the completion of an LCA: **the innovative recycling processes developed within BEST4Hy are able to reach up to an overall 20% reduction of GHG emissions**, considering the entire hydrogen fuel cells life cycle from production to end-of-life. Overall cost of recycled materials also results comparable (10% range) to the market cost of virgin material in a scenario of industrialised recycling processes.

In this framework, **ecolabelling represents a valuable method to certify and label environmental performance of products**, such as fuel cell technologies. Currently the market is still devoid of ecolabel for FCs. However, EU Ecolabel and EPD International could be voluntary certification systems for potential application. Within BEST4Hy, RINA developed specific guidelines for the industries in order to advance in the procedures of Product Group and Product Category Rule development and proposal to the identified labelling schemes.

At the end of the workshop, ENVIPARK and RINA led a specific discussion on the **standardisation roadmap** for hydrogen fuel cells. An overall analysis of the current hydrogen market reveals an increase of the hydrogen devices demand expect by 2030, considering different applications from stationary to mobility sector. A demand increase was also depicted in the past few years, even if no significant volumes of fuel cell or hydrogen technologies devices have been tracked. Neither specific standard neither regulation is currently available for hydrogen fuel cells and technologies, leaving hydrogen actors with lack of rules in technical management along the supply chain, end-of-life included. BEST4Hy studied the regulation gap and proposed some short-time steps to deal with this issue in the next years in order to be ready for the end-of-life management of hydrogen technologies that will characterise the future market.

Overall, **BEST4Hy final event has proven a fruitful moment of knowledge exchange on the sustainability of hydrogen technologies**. Discussion with the attendees revealed high industrial interest to the topics of recycling and materials recovery from hydrogen technologies. Besides BEST4Hy's fuel cells targets, the need to extend the research to other hydrogen devices, such as electrolysers and ion exchange membrane fuel

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cells, has been also highlighted. Nowadays, sustainability represents a relevant aspect for any products, for which industries are called to answer. During BEST4Hy, **research has made progress on the recovery and recycling of materials from end-of-life hydrogen technologies reaching achievements that represent a first important step and contribution to the research.** However, further research support is required to continue the development of the technologies and approaches and overcome the challenges for their deployment.

Ilaria Schiavi, Project Manager at Environment Park and **BEST4Hy coordinator** states *"During these last three years, BEST4Hy consortium has worked tirelessly to achieve and even go beyond the project targets, demonstrating successfully how important materials can be recovered from EoL fuel cells and how they can be directed both to close loop recycling (remanufacture of cells) and open loop recycling (other value chains, including batteries). Important progress with respect to the state of the art has been achieved, from novel approaches to the dismantling and disassembly of fuel cells, to low environmental impact processes for the recovery of platinum, ionomer and rare earth elements/critical raw materials beside PGMs. Significant progress has been made also in the modelling of the EoL strategies under a life cycle approach. The project has resulted in two patent applications and a number of publications and participations to high level conferences, while the experience gained by the companies participating in BEST4Hy is opening up interesting business opportunities. We believe that BEST4Hy represents an important step towards devising a sustainable hydrogen supply chain but we are aware that there is still much work to be done."*

BEST4Hy Consortium at General Assembly Meeting and Final Event, 12th – 13th of December 2023

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BEST4Hy international consortium is composed by industrial partners and research institutes: Environment Park SpA (Italy), CEA Liten (France), Turin Politecnico (Italy), Hensel Recycling GmbH (Germany), EKPO GmbH (Germany), Aktsiaselts Elcogen (Estonia), RINA Consulting SpA (Italy), University of Ljubljana (Slovenia).

Best4Hy project (*SustainaBlE SoluTions FOR recycling of end-of-life Hydrogen technologies*), is funded by the Fuel Cells and Hydrogen 2 Joint Undertaking within the European Unions' Horizon 2020 research programme.

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