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

TRAINING MODULE 1
Chapter_2

Description and manual to perform the existing disassembling technologies (PEMFC)

Document Details

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Document Details

x PU - Public
CO - Confidential, only for members of the consortium (including the EC)

Clean Hydrogen Partnership
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Abbreviations

CCM	Catalyst Coated Membrane
CL	Catalyst layer
EoL	End-of-Life
GDL	Gas Diffusion Layer
HRD	Hensel Recycling Deutschland
PEMFC	Polymer Electrolyte Membrane Fuel Cell
PGMs	Platinum Group Metals
WP	Work Package

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Contents

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1 Executive Summary

Within project BEST4Hy, a training kit is to be developed. This will be subdivided into 4 Modules with this content:

- Module 1: How to dismantle a fuel cell
- Module 2: Recovery technologies
- Module 3: Technical results and economical aspects
- Module 4: Measures towards to take up.

Module 1 is dedicated to the dismantling technologies of fuel cell stacks and provides information on how to perform and optimize the existing disassembling technologies and how to perform novel dismantling technologies, considering both PEM and SO fuel cells.

Module 1 is organized as follow:

- Chapter 1: Introduction to the FCs: main components and valuable materials in PEM and SOFC;
- Chapter 2: Description and manual to perform the existing disassembling technologies (PEMFC);
- Chapter 3: Description and manual to perform the novel dismantling processes developed within the project (PEMFC).

Video tutorials on how to perform the disassembling and dismantling processes above described are also available.

For more information, users can consult the associated deliverables describing the activities performed in BEST4Hy:

- D1.1: Lab scale optimization results on the 3 PEMFC recycling technologies report
- D1.2 Technical report on adaptation of existing technology (hydrometallurgy process) for PEMFC material recovery: results and design
- D1.5 Pilot-scale plant (TRL5) based on 3 recycling technologies for PEMFCs
- D2.3: Report on the evaluation of MEA including recycled materials in small single cell of PEMFC
- D3.3: Pilot-scale plant (TRL5) based on two integrated existing recycling technologies for SOFCs_PU
- D4.3: Technical report on developed recovery technologies for LSC cathode materials_PU

<u>The present document refers to Chapter 2: Description and manual to perform the existing disassembling technologies (PEMFC)</u>

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2 Introduction

This chapter reports results and achievements linked to WP1 project activity on “Existing and novel technologies of PEMFCs: proof of concept (TRL3 – TRL5).

A first important stage of the recovery and recycling process is the fuel cells disassembly: different methods for PEMFC stacks, cell packages and MEA have been studied by the partners to identify the most convenient way to recover the material, avoiding contamination and pursuing environmental and economic sustainability.

The processes undertaken by the partners are represented below.

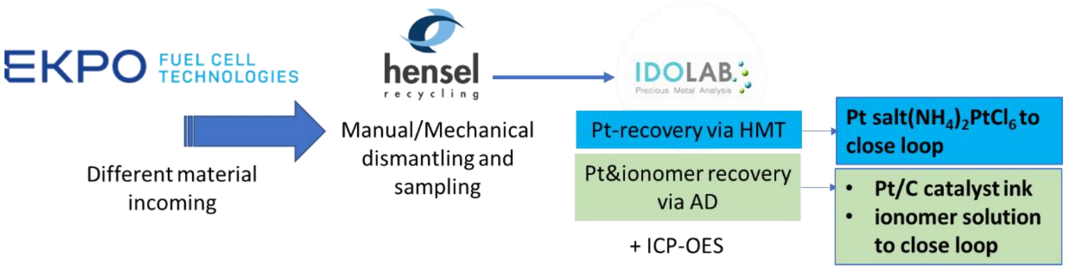

Figure 1 HRD internal processing of incoming material from EKPO

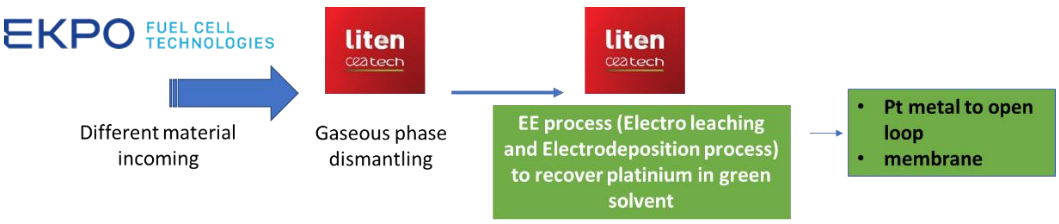

Figure 2 CEA internal processing of incoming material from EKPO

The two processes can interact, as MEAs disassembled from the stacks can then be processed through gaseous phase dismantling. Considering both existing and novel disassembly and dismantling methods, the end-of-life PEM fuel cells might therefore be processed as follows:

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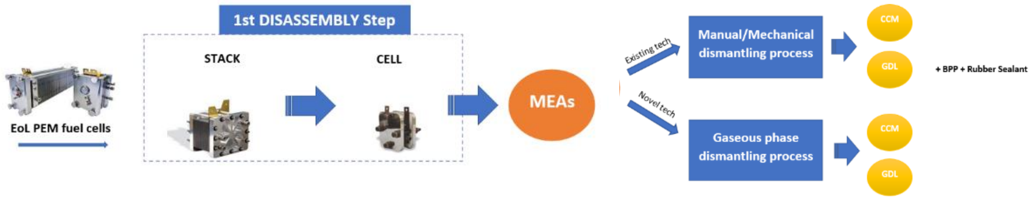

Figure 3 Possible processing of EoL PEMFC adopting the approaches developed within BEST4Hy project

<u>This chapter refers only to the existing technologies for the PEM fuel cells disassembly as analysed by HRD.</u>

Trials reported below have been performed using end-of-life materials (PEMFC stacks, cell packages) with different time of operation (EoL - fresh, 200h, 2800h, 7800h). To go deeper in the research performed in the project, more information is available in the following deliverables:

- D1.1: Lab scale optimization results on the 3 PEMFC recycling technologies report;
- D1.2: Technical report on adaptation of existing technology (hydrometallurgy process) for PEMFC material recovery: results and design.

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3 Disassembling PEM fuel cells: optimization of existing technologies

The disassembling procedures described below are conducted in order to reduce material (mainly Pt) losses, thus making subsequent recovery processes more efficient. They were found suitable for laboratory scale volumes and were mainly based on manual procedures supported by small scale equipment, so they qualify as hybrid disassembly.
Considering the need for scaling up of the processing, some further pieces of equipment were also used to identify possible alternatives to some of the manual steps. Details are provided in section 4. The project had explored initially a full manual disassembly, which is described in section 5 for completeness of information.

3.1 Hybrid Disassembly

This method proved ideal within a laboratory scale environment, since it leads to a clean Catalyst Coated Membrane (CCM) fraction which is the most suited material for subsequent processing finalised to the recovery of platinum.

First step: PEMFC stack disassembly

- Removal of tie rods, cables and casing. The material is mainly made of high-grade steel, which can be recycled or, potentially, reused.
- Removal of endplates
- Layers splitting & removal of sealants & MEAs.

Watch each step in the video realised by HRD: **Disassembling a FCH stack from automotive application**.

The stack disassembly is preliminary to most of the other disassembly methods and might be supported by automation when larger volumes of EoL cells might arise.

Second step: cell package separation

1. Manual separation of the bipolar plate from the MEA (Figure 4)
2. Cutting of rubber sealant by means of a lever cutting machine (Figure 6)
3. Manual separation of the CCM from the GDL (Figure 8)
4. Shredding of the CCM with a regular office paper shredder (Figure 9)

Watch each step in the video realised by HRD:
Manual dismantling process of a PEM fuel cell.

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Figure 4 STEP 1: Separation of the bipolar plate from the MEA manually

Figure 5 BPP detail during manual disassembling

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Figure 6 STEP 2: Cutting of rubber sealant by means of a lever cutting machine

Figure 7 Cut gaskets

Figure 8 STEP 3: Manual separation of the CCM from the GDL

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Figure 9 STEP 4: Paper shredder

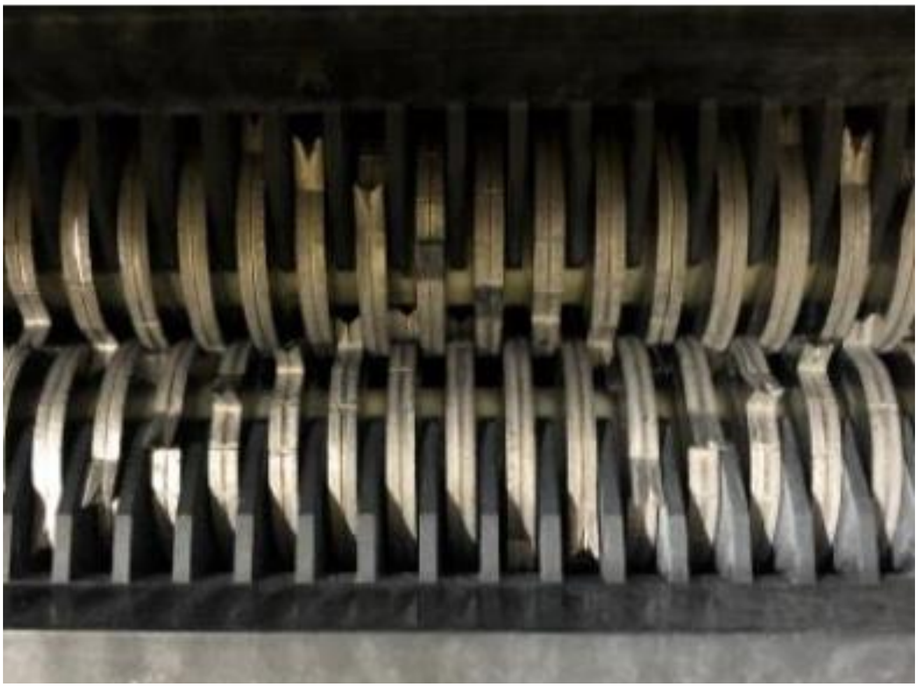

Figure 10 Internal view of paper shredder with CCM fractions traces

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Figure 11 Freshly shredded CCM material

Video on the manual disassembly available in BEST4Hy You Tube channel:

- Manual dismantling process of a PEM fuel cell
- Disassembling a FCH stack from automotive application

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4 Mechanical methods to complement manual disassembly and/or substitute some steps

Some mechanical devices commonly used by waste processors have been trialled to explore scalability of the disassembly process illustrated above. They were applied to the material issued from the manual disassembly of the bipolar plates, i.e. the MEAs, with the aim to understand how different equipment could support the manual disassembly and subsequent phases of the process.
The following piece of equipment were trialled:

- Rotating Knives Shredder;
- Erdwich Shredder;
- Polar Mohr Equipment (no pre-manual disassembly).

Rotating knives (two shaft) shredder did not prove successful. Similarly, paper shredder was applied to MEAs with no satisfying results.

4.1 Erdwich Shredder

This mechanical process applies to the MEAs only. Processing is performed using a single shaft rotor/stator shredder with a Ø20mm pass screen (**Errore. L'origine riferimento non è stata trovata.**). This kind of shredder is a common piece of waste processing equipment available at different scales hence suitable for medium to large volumes also, which is an advantage.

Figure 12 The Erdwich Shredder

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The result of the process is the mix of shredded rubber sealant, GDL, MEA and CCMs that can be seen in **Errore. L'origine riferimento non è stata trovata.**.

Figure 13 Mix of GDL, CCMs and MEAs after the Erdwich shredding

This mix might need further processing for sorting materials for different recovery routes.

4.2 Polar Mohr Guillotine

In this trial a laserwas used to remove the sealant from the MEAs and easily extract the CCM, substituting the manual cut and separation of the layers (anode, membrane and cathode) This operation took place by means of a laser treating CCM and GDL to finally get CCM (delamination) with 2.4 kW power without manual separation of the layers (anode, membrane and cathode).

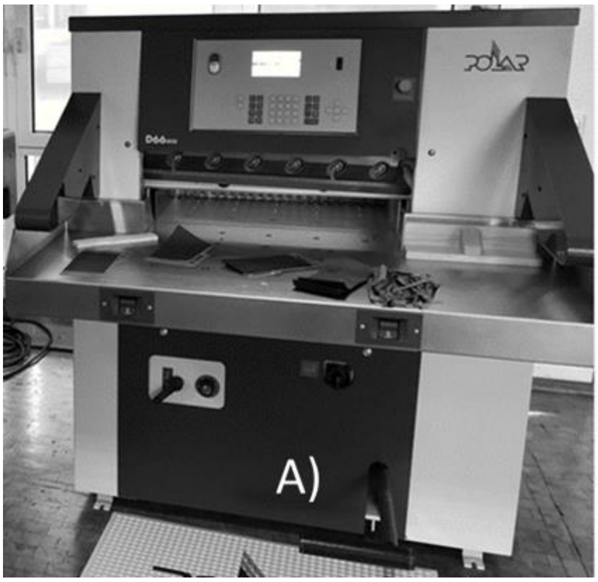

Figure 14 Polar equipment used to dismantle MEA units

With the model illustrated above, three MEAs at a time could be processed. They are placed one on top of the other; subsequently the guillotine is applied to separate neatly the sealant. Cutting time is 3 minutes.

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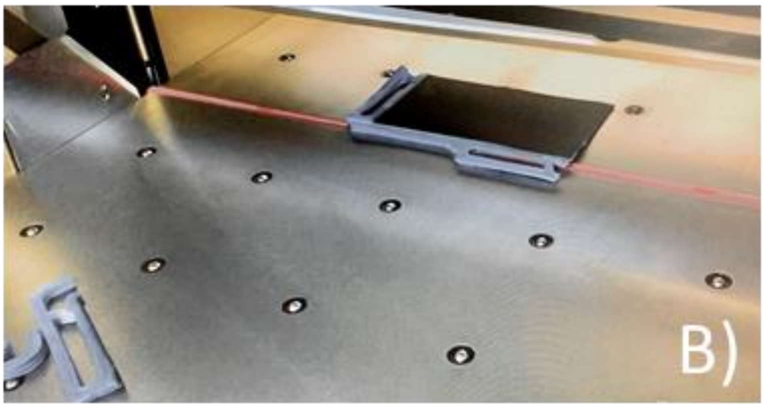

Figure 15 Details of MEA (GDL and gaskets).
Cut off gaskets in the lower left corner

5 Manual disassembly

The preliminary trial of the disassembly of the cells was based on manual processes only, similar to what described for the hybrid disassembly. However, scissors were used for Step2 and 4, the latter resulting in the cutting of the CCM film into 2,5 cm x 4 cm pieces for further physic-chemical processing.

<u>Manual disassembly provides good results in terms of quality of collected sampling, but it is not scalable.</u>

6 Summary of the results

Here a summary of the results for the disassembly trials:

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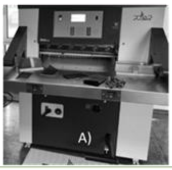
Disassembly	Results	Comments
Manual Dismantling		Ideal sampling. though not scalable
Mechanical Trial 1 (Rotating Knives Shredder)		Contamination inhomogeneous reactive in acid
Mechanical Trial 2 (Erdwich Equipment)		Contamination inhomogeneous
Mechanical Trial 3 (Polar Mohr Equipment)		Inefficient disassembling process
Mechanical Trial 4 (Paper Shredder)		Seem to be promising, but GDL and CCM are difficult to separate

Figure 16 Mechanical trials' results summary.

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