Repository

Section 15 - Hydrogen, Sustainability & Circularity

Topic 103 – Recycling of Components

Dissemination Level: Public

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1. Repository Introduction

This document is part of the H2VE Repository, a structured collection of learning resources and materials developed to support Centres of Vocational Excellence (CoVEs) and training providers in delivering high-quality, up-to-date hydrogen education. The thematic clusters and sub-topics covered in this repository were jointly compiled by all H2VE project partners as part of Deliverable D5.1 - Educational Training Material Specification Document. Each document corresponds to a specific sub-topic within a broader thematic cluster and follows a standardized structure comprising a document header, learning context, core content, curated digital tools, and assessment guidance, where applicable. The aim is to provide trainers and educators with general resources as well as modular content that can be integrated into existing curricula or adapted to specific training contexts. A list of underlying resources and sources is provided at the end of each document to allow for further exploration and verification of the material presented.

2. Topic Overview

Recycling core hydrogen technology components, including electrolyzer and fuel cell stacks, storage tanks, and balance-of-plant equipment, presents distinct technical and logistical challenges. This topic introduces the specific difficulties posed by these components, such as material complexity, hazardous substances, and the need for specialized dismantling processes. Learners are introduced to current industrial recycling pathways and the state of technology readiness for recovering valuable materials from end-of-life hydrogen equipment. Understanding component-level recycling provides a practical grounding for how it fits into the broader circular economy strategy for hydrogen infrastructure, complementing upstream design and secondary-use strategies.

3. Learning Resource Overview

1. Learning Context	Prerequisites: • Completed Topics 99 - 101 • Basic knowledge of PEM fuel cell and electrolyzer stack architecture
2. Content	• **Five End-of-Life Treatment Pathways** PEMFC stacks and PEMWE electrolysers can be processed via five main routes: hydrometallurgy, pyro-hy-

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	drometallurgy, acid dissolution, electrochemical dissolution, or direct reuse of intact components, each with different trade-offs in yield, cost, and environmental impact (detailed further in Topic 105). • **Component-Level Recycling Challenges** The MEA combines a platinum catalyst on a carbon support with a PFSA membrane, requiring careful separation; bipolar plates (stainless steel or titanium) and end plates (aluminum or steel) are comparatively straightforward metal streams; Gas Diffusion Layers (carbon paper) present their own handling challenges. • **Storage Tank Recycling** Type III tanks (aluminum liner with carbon-fiber-reinforced polymer overwrap) and Type IV tanks (HDPE liner with CFRP overwrap) both pose a major recycling challenge in separating and recovering the carbon fiber from the polymer matrix. • **Material Intensity Reference Data** Per MW of PEMWE capacity, NREL (2024) estimates roughly 25 kg iridium, 10 kg platinum, 600 kg titanium, and 200 kg PFSA membrane, figures that illustrate why PEMWE is materially intensive, but also why it is a strong candidate for PGM recovery where proper end-of-life infrastructure exists.
3. Digital Tools	FCH-LCA Tool, End-of-Life Modelling Templates: Model end-of-life recycling scenarios for PEMWE/PEMFC using the FCH-LCA Tool's built-in product system templates.
4. Assessment Guidance	**Assessment Methods** • Material flow exercise: using Table 1 (Uekert et al., 2024), students assign each material stream to a recycling pathway and estimate recovery value at current commodity prices. • Short-answer test: five questions on component identification, recycling challenge explanation, and pathway selection. **Sample Questions**

	1. What are the five end-of-life treatment pathways for PEMWE electrolysers identified by Uekert et al. (2024)? Briefly describe each. 2. Why is the PFSA membrane a particular challenge for fuel cell and electrolyser recycling? What regulatory context is relevant? 3. A Type IV hydrogen storage tank reaches end-of-life. Describe the main materials present and the technical challenge of recycling the carbon fibre reinforced polymer (CFRP) overwrap. **Evaluation Criteria** • Accurate identification of recycling pathways and their characteristics (40%) • Correct technical explanation of at least two recycling challenges (40%) • Quality of regulatory or economic contextualisation (20%)
5. References	• Uekert, T., et al. (2024). Electrolyzer and fuel cell recycling for a circular hydrogen economy. Advanced Sustainable Systems. https://docs.nrel.gov/docs/fy24osti/87146.pdf (Open access via NREL) • DOE/NREL. (2024). OSTI record 2228772. https://www.osti.gov/pages/biblio/2228772 • Clean Hydrogen Partnership. (2020). Life cycle assessment of hydrogen and fuel cell technologies. https://www.clean-hydrogen.europa.eu/media/publications/life-cycle-assessment-hydrogen-and-fuel-cell-technologies_en