Repository

Section 15 - Hydrogen, Sustainability & Circularity

Topic 101 - Circularity Engineering, Modularity & Design for Disassembly

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

Embedding circularity into hydrogen technologies starts at the engineering and design stage, long before a component reaches end-of-life. This topic covers modularity and Design for Disassembly (DfD) as key strategies that facilitate maintenance, component replacement, and end-of-life recovery, thereby extending equipment lifespan and easing recycling processes. Learners explore how design choices made at the manufacturing stage, such as standardized connectors, accessible fastenings, and material separability, directly influence the feasibility and cost of later circular interventions. These engineering practices are situated within the broader context of hydrogen infrastructure (electrolyzers, fuel cells, storage systems), providing a technical grounding for understanding how circularity is designed in rather than added on afterward.

3. Learning Resource Overview

1. Learning Context	**Prerequisites:** • Completed Topics 99 - 100 or equivalent knowledge of sustainability criteria and R-strategies • Basic knowledge of electrolyser and fuel cell component architecture (MEA, bipolar plates, end plates)
2. Content	• **From Linear to Circular Product Logic** Circular design shifts hydrogen equipment away from a

	"take-make-dispose" model toward a "design-use-recover-redesign" cycle, embedding circularity considerations at the engineering stage rather than treating them as an end-of-life afterthought. • **Modularity** Designing electrolysers, fuel cells, and storage systems so individual stacks or cells can be replaced without decommissioning the entire system extends equipment lifespan and reduces the scale of material loss at end-of-life. • **Design for Disassembly (DfD)** Practical DfD measures include minimising the number of different fastener types, clearly labelling materials, and enabling non-destructive separation of MEA layers, bipolar plates, and membranes — all of which make later repair, refurbishment, or recycling technically and economically feasible. • **Design for Recycling (DfR)** DfR focuses on material compatibility: avoiding contamination of metal streams by PFSA membrane material, and enabling hydrometallurgical platinum recovery without requiring incineration (linking directly to the recycling processes covered in Topic 105). • **EU Ecodesign for Sustainable Products Regulation (ESPR)** Regulation (EU) 2024/1781 is the legal driver behind DfD and DfR requirements for hydrogen equipment, including the mandatory Digital Product Passport, which will require manufacturers to document material composition and disassembly information for each product. • **Case Study: eGHOST Project** The EU eGHOST project applied ecodesign methodology to PEMFC systems, presented at EHEC 2024 alongside SH2E, offering a concrete worked example of how DfD principles translate into real component design.
3. Digital Tools	-
4. Assessment Guidance	**Assessment Methods**

	• Design critique exercise: provide students with a schematic of an existing electrolyser stack. Ask them to mark it with DfD improvements (max. 5 changes) and justify each using Ecodesign for Sustainable Products Regulation (ESPR) principles. • Case study report (750 words): analyse how modularity in one named commercial electrolyser product supports circularity goals. **Sample Questions** 4. Explain the difference between Design for Disassembly (DfD) and Design for Recycling (DfR), using an example from H_2 technology. 5. What is the EU - ESPR and what obligations does it place on H_2 equipment manufacturers? 6. Why is PFSA membrane handling a challenge for both DfD and DfR in PEM fuel cells? **Evaluation Criteria** • Accurate definition and distinction of DfD vs. DfR (25%) • Quality of design critique with technically plausible improvements (50%) • Correct reference to ESPR obligations and Digital Product Passport (25%)
5. References	European Parliament & Council. (2024). Regulation (EU) 2024/1781 — Ecodesign for Sustainable Products. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32024R1781 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 IEA. (2024). EU Ecodesign Regulation — Policy summary. https://www.iea.org/policies/25028-eu-ecodesign-regulation