

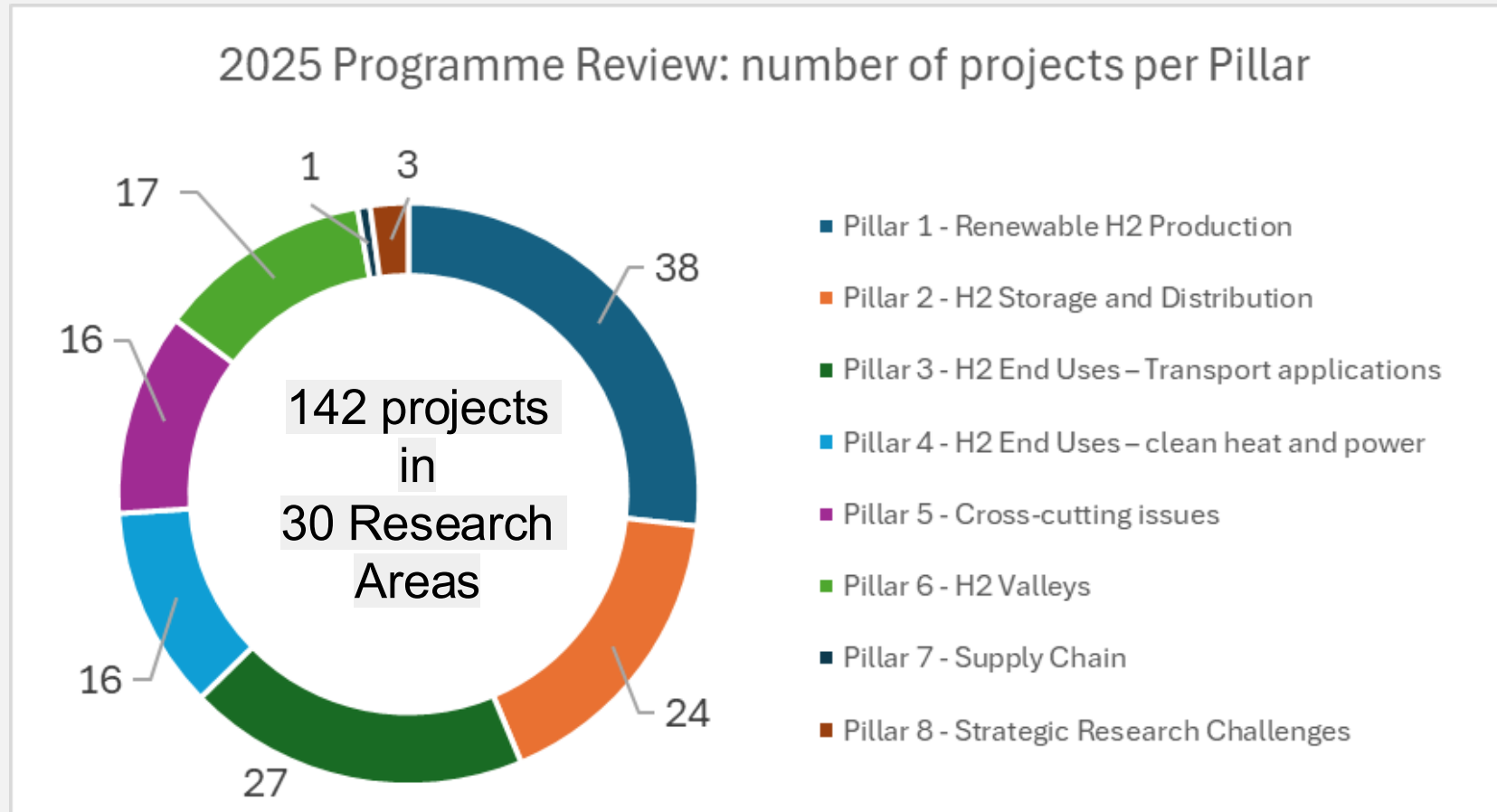
Annual Programme Review 2025

JRC assessment

Darina Blagoeva
Hydrogen Research and Innovation Days

24-25/11/2025

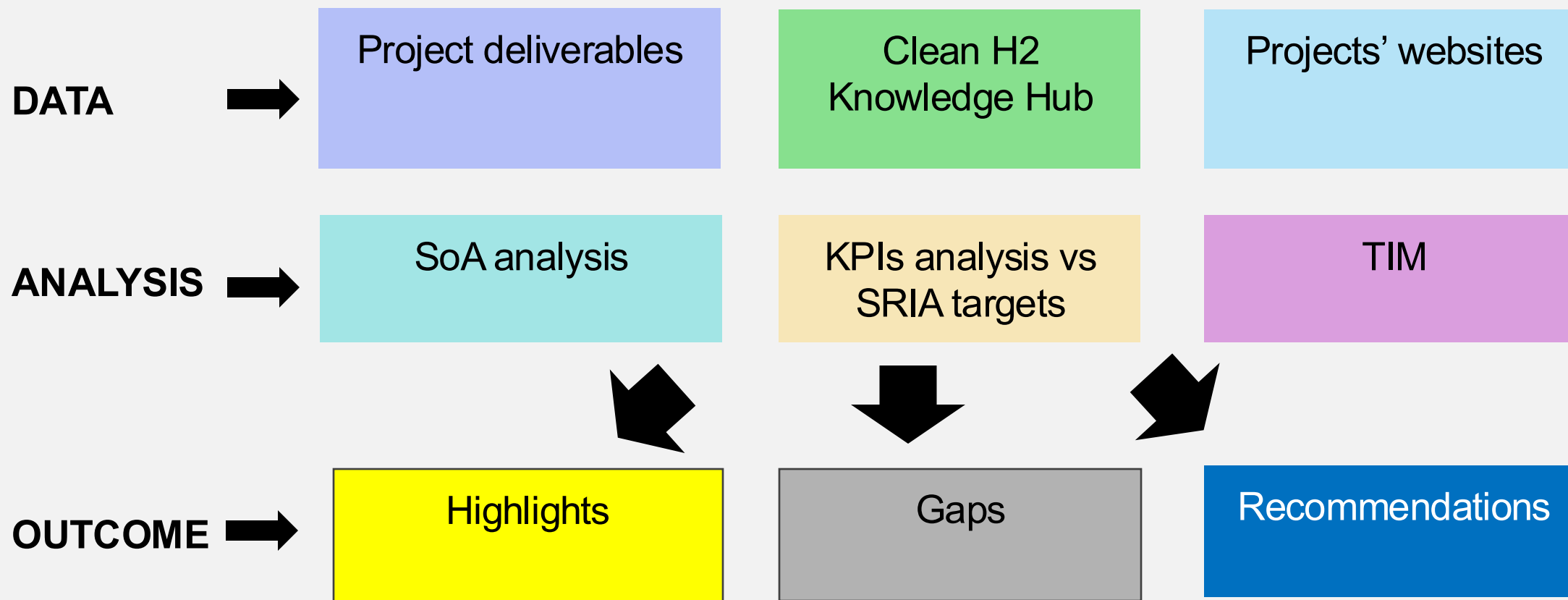
Projects considered for the 2025 Assessment



Source: JRC with info from Clean H2 JU



Assessment Methodology



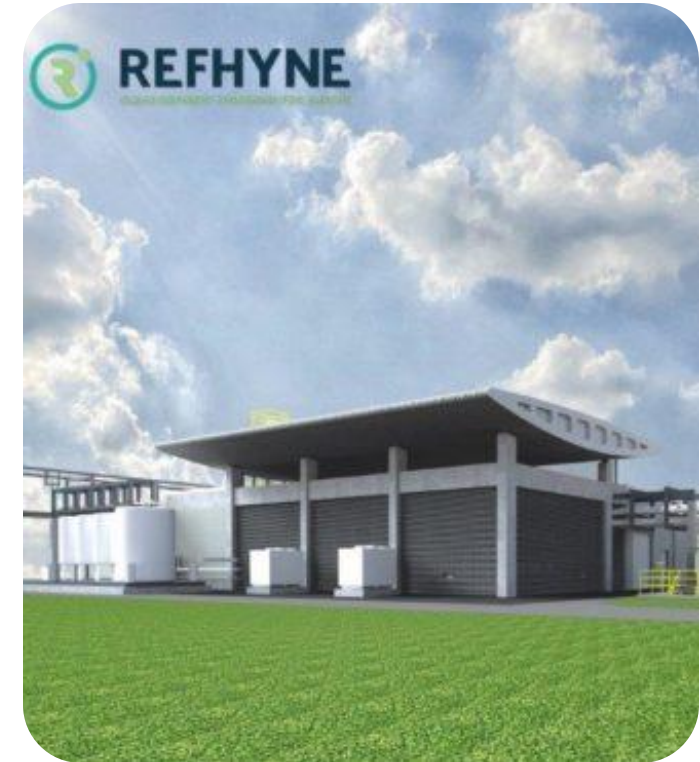
Source: JRC



Pillar 1 Renewable hydrogen production

Highlights:

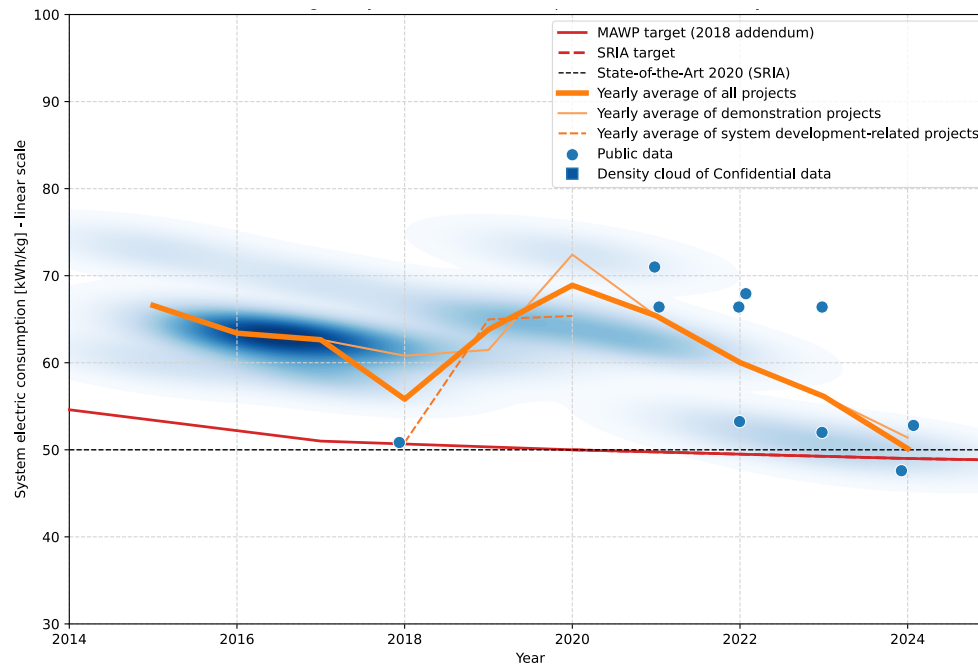
- 10 MW PEM EL at Shell's Rheinland refinery in Wesseling, Germany (REFHYNE); 1200 hours operation; 21 tonnes H₂
- 2.6 MW SO EL at Neste refinery Rotterdam (MultiPHLY)
- Improvement in performance and degradation issues (DJEWELS, HOPE);
- 2000 hours of MEA testing (ADVANCEPEM)
- Progress in AEM (e.g. dimensionally stable electrodes) (HYPRAEL)



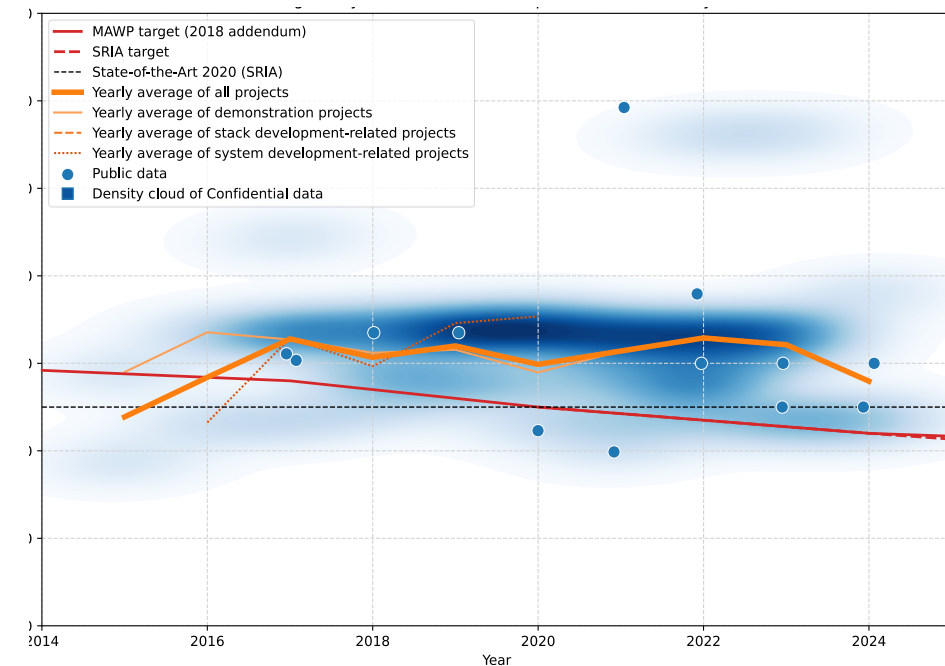
Installation site of a 10 MW PEMWE by ITM Power at Shell's Rheinland refinery in Wesseling, Germany
Source: <https://www.refhyne.eu/de/homepage-2>

Pillar 1 Renewable hydrogen production

Average of system electric consumption Alkaline electrolyzers



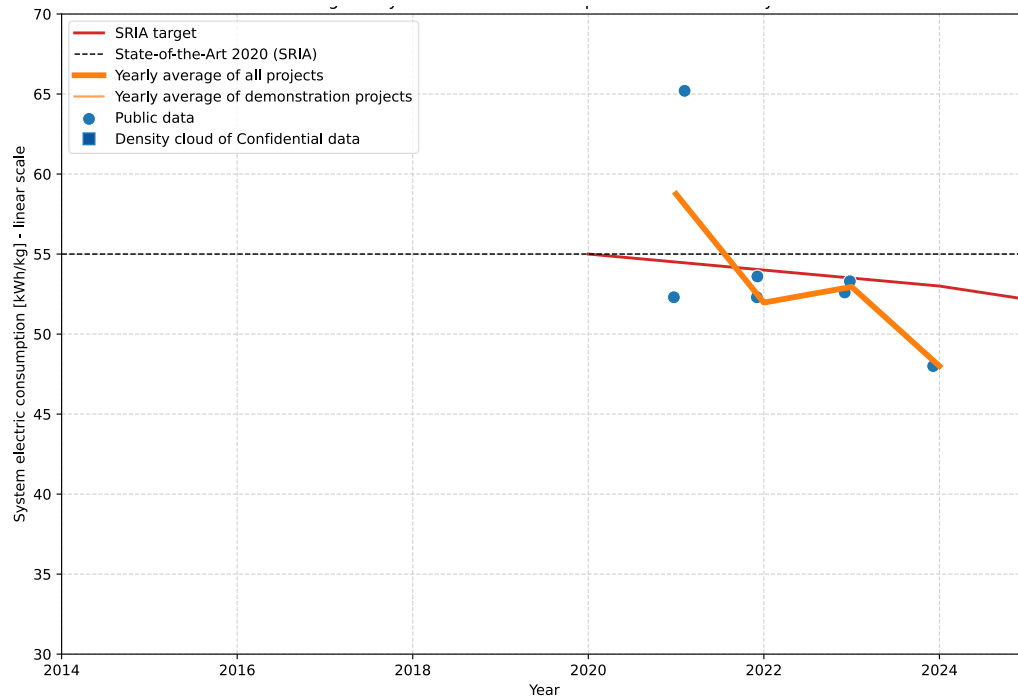
Average of system electric consumption PEM electrolyzers



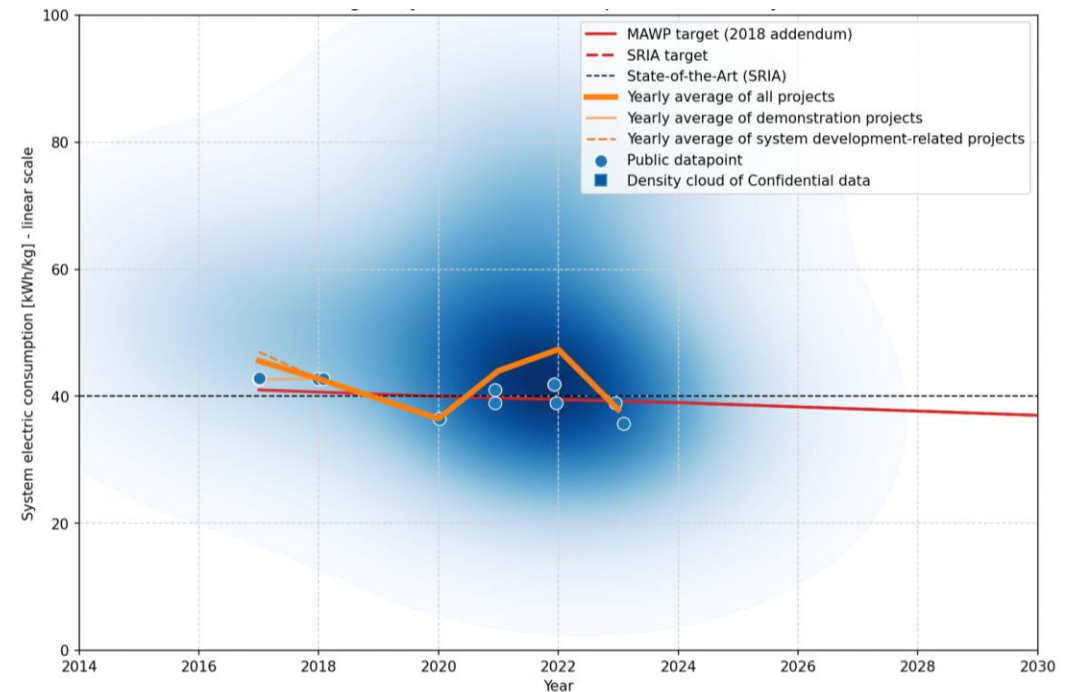
The majority of **alkaline** electrolyser deployed in projects (2018 – 2024) are on average **above the SRIA targets for system electric energy consumption**, measured in kWh/kg of H₂ produced

Pillar 1 Renewable hydrogen production

Average of system electric consumption of AEM electrolyzers



Average of system electric consumption of SO electrolyzers



Projects deploying PEM, AEM & SO (2017-2024) electrolyzers have predominantly met or nearly met the SRIA targets!
Downward trend in energy consumption across all four types of electrolyser, with the most significant improvements observed in projects using AEM electrolyser.

Pillar 1 Renewable hydrogen production

Gaps & Recommendations:

- **Testing Protocols & Standardisation**: the EU harmonised test methods and protocols & protocols developed in JU projects (Hy-Spire for O-SOE and P-SOE cells) leveraged in international standardisation efforts; contribution to committees such as IEC TC 105 MT 206 and WG 107.
- Addressing **optimisation challenges** in terms of material, electrochemical screening, manufacturing processes, reducing CRMs and PFAS;
- Promoting a more unified **European design and configuration of WEL stacks**, BoP and/or systems to eventually enhance existing European supply chain;
- **Developed Diagnostic and Monitoring tools** (REACTT project) to be applied by projects for stack degradation monitoring;
- **Synergies with ongoing certification efforts**, such as CertifHy;



Pillar 2 Hydrogen storage and distribution

Distribution challenges, including storage, compression, purification, separation, transportation, HRS

Highlights

- Research on [porous rock storage](#) generating extensive knowledge (HYUSPRE).
- Development of proton ceramic electrochemical reactors for [ammonia cracking](#) and hydrogen purification (SINGLE, WINNER).
- Safety research on distributing large volumes of hydrogen via pipelines, targeting [material compatibility and advanced leak detection](#) (CANDHY, PILGRHYM).
- Working towards a membrane containment system for [large-scale liquid hydrogen transportation](#) (LH2CRAFT).



Source: HD KSOE

Pillar 2 Hydrogen storage and distribution

Gaps & recommendations

- Recalibrate research objectives to reflect budgets and TRL levels.
- Focus on higher TRL activities for tangible results. Targeted support for projects that address engineering and scale-up challenges.
- Clarify market opportunities and potential impact of technologies, particularly for areas like ammonia cracking.
- LH₂ refuelling has high boil-off rates, no SRIA KPI currently addresses this.



Pillar 3 Hydrogen end-uses: transport applications

Highlights

- As of February 2025, **242 hydrogen FC buses in real-world operation** in 16 European cities.
- **Hybrid hydrogen FC train operated across 7 rail lines** in the Iberian peninsula, completing 10,000 km in hydrogen mode during a 37-day campaign without incidents.
- **Class approval of different hydrogen-powered vessel types** for maritime and inland navigation.
- Operation of several **hydrogen FC vessels for European inland navigation**.



H2 Barge 2 operating on the Rhine river

Source: <https://flagships.eu/>



Pillar 3 Hydrogen end-uses: transport applications

Gaps & recommendations

- **Field data and operational lessons** from demonstrations should be more channelled into regulatory and standardisation processes.
- Financial support mechanisms, such as subsidies or tax incentives, should be enhanced to offset higher operational costs and to **strengthen the business case** for hydrogen vehicles.
- A **robust European supply chain** for hydrogen mobility components should be further developed to ensure flexibility, reliability, and availability of spare parts.
- **Training of personnel** should be improved all along the hydrogen supply chain for hydrogen mobility
- The **liquid hydrogen supply chain** should be expanded for large-scale marine demonstration projects.



Pillar 4 Hydrogen end-uses: clean heat and power

Highlights

- Support broader **sustainability objectives**, including zero-emission heating and power solutions;
- **Decarbonisation of maritime** (AMON) and **digital** (E2P2) sectors.
- Contribution to **standardisation** efforts (SO-FREE, E2P2), Enhance resilience in regions with **limited electrical grid infrastructure** (E2P2); **grid balancing** services (24/7 ZEN);
- 6 new projects on gas turbines, boilers, and burners; **HELIOS** - high-pressure experimental test campaign on a full-scale burner, demonstrating promising performance;
- **SWITCH**: 1,000 operational hours and demonstrating near HHV efficiency in SOFC mode, aligning with the 2024 SRIA CAPEX targets under mass production conditions.



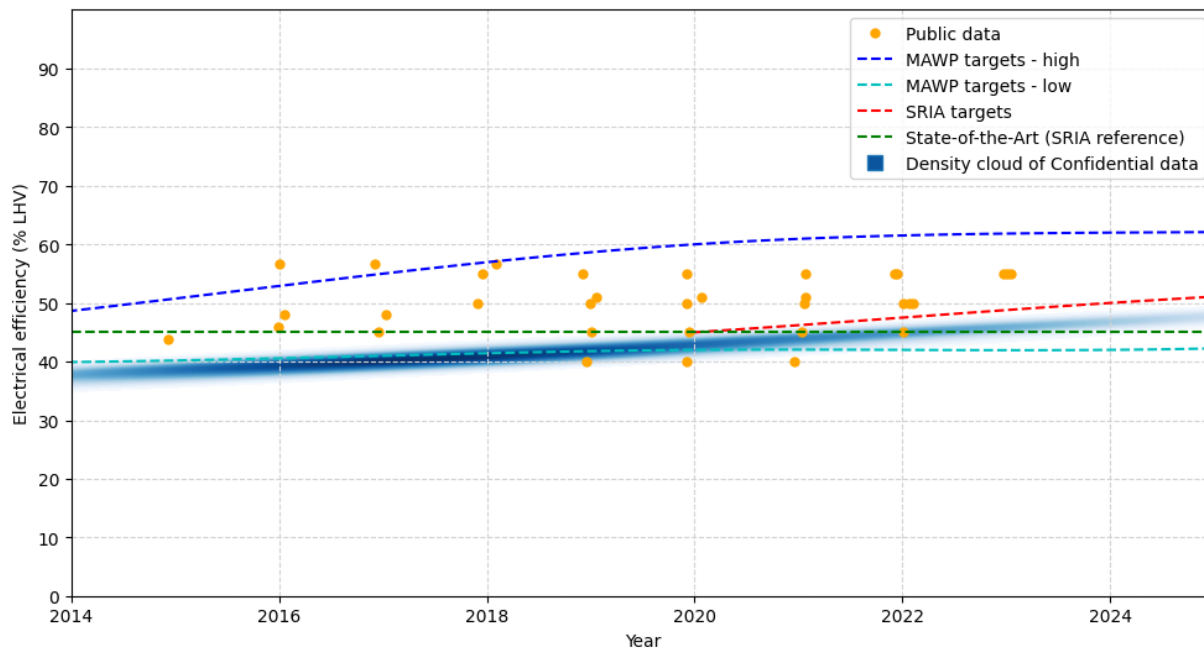
SWITCH project won the Energy Globe Award 2023 as the best Italian initiative in the field of energy sustainability.

Source: <https://www.investintrentino.it/>

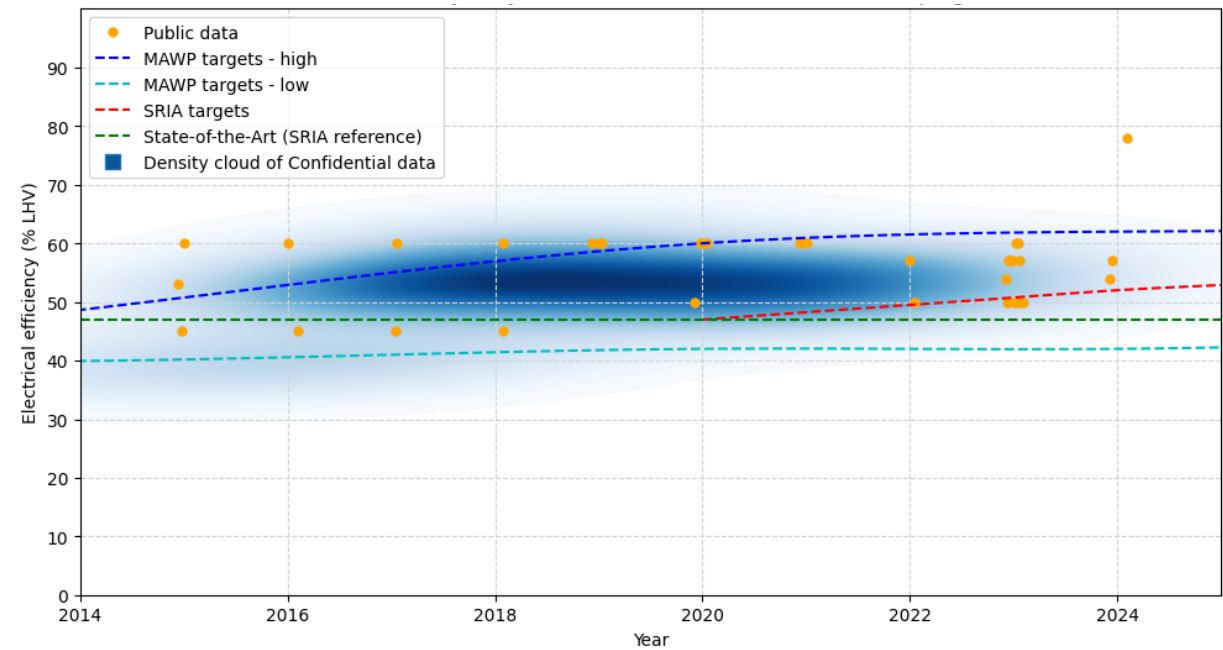


Pillar 4 Hydrogen end-uses: clean heat and power

Electrical efficiency Mid-size PEM FC



Electrical efficiency Mid-size SOFC



Mid-size PEM FC electrical efficiency exceeds 2024 SRIA target (red line).
Mid-size SOFC electrical efficiency: since 2020 all projects have exceeded 2024 SRIA target.

Pillar 4 Hydrogen end-uses: clean heat and power

Gaps & Recommendations

- Further technological refinement and increased production scale for SOFC CHP;
- Need of systematic risk assessment & availability of skilled labour for operation and maintenance;
- 'Better Use of Generated Knowledge,': assessing the viability of current systems for further testing and refinement & extending field testing; transparency and public sharing of data to maximise its usefulness.
- Hybrid and tri-generation systems for increased efficiency, cost-effectiveness, sustainability, and energy resilience (learning from Bio-HyPP and FlexiFuel-SOFC is to identifying the right sectors for these systems, ensuring successful implementation)



Pillar 5 Cross-cutting issues

EDUCATION

Highlight: development of education materials and create awareness

Gaps and recommendations: continuity & awareness outside of EU

SAFETY

Highlights: inter-project collaborations & knowledge sharing; clear strategy aiming at filling urgent gaps in policy priorities; advancements in knowledge of liquid hydrogen behaviour; engagement in various standardisation bodies;

Gaps and recommendations: sharing lessons learned; Increasing synergy with other institutes; reducing permission times

SUSTAINABILITY

Highlight: first hydrogen specific life cycle sustainability assessment (LCSA) and eco-design guidelines, sustainability panel

Gaps and recommendations: data collection, benchmark definition, monitor sustainability



Source: <https://sh2e.eu/>

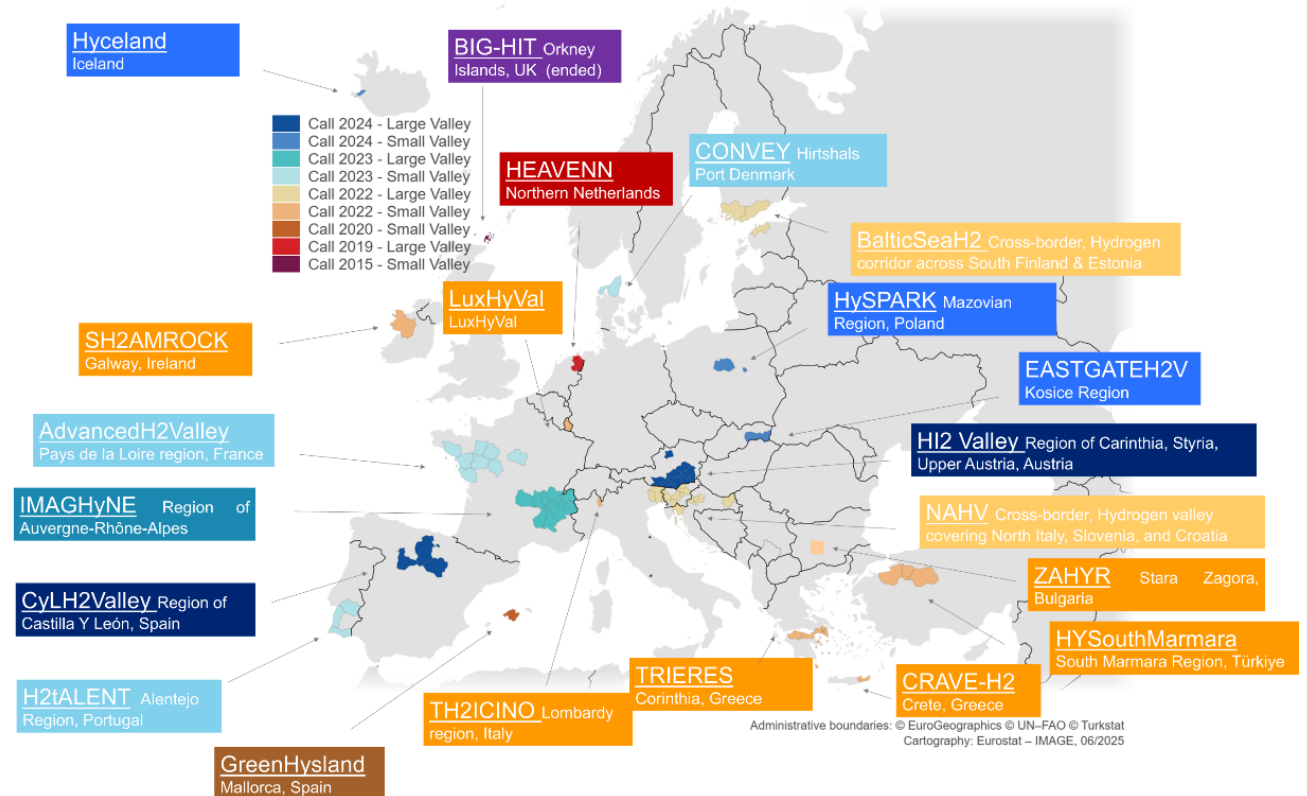


Pillar 6 Hydrogen valleys

Highlights

Hydrogen valleys **advancing & being deployed** in EU; wide variety of approaches and technologies;

Challenges: **integration with larger off-takers**; drove away by market evolution and delay in the **development of a larger H2 infrastructure** (backbone, capillary distribution of HRS), **technical & permitting issues**.



Excludes Hydrogen Valleys included in the [Mission Innovation H2VP](#) (100 Valleys worldwide, 67 European)

Map of deployed valleys funded by the Clean H2 JU expected by 2025

Source: Clean H2 JU



Pillar 6 Hydrogen valleys

Gaps & Recommendations

- Beneficial effect from the [new tools to help H2 valleys](#) navigating through various large landscape of regulations, funding schemes and permitting frameworks;
- [Harmonization of the different requirements](#) would help the valley to avoid inefficiencies or overlapping initiative;
- More research needed to address the [integration of H2 valleys](#) with existing energy systems;
- Key research areas include [grid interconnection](#), [system flexibility](#), and the [role of hydrogen as a storage medium](#) to complement variable renewable energy.



Pillar 7 Supply chain

Highlights

- Supply chain aspects addressed in > 20 projects across different pillars (ongoing and completed).
- Pillar 7 promotes sustainable competitiveness.
- AMPS aims not only to reduce the cost through automated mass manufacturing, but to do it in a sustainable way (cradle-to-gate life cycle assessments (LCA), aligning scalability with environmental & sustainability objectives).
- AMPS project – progress done towards conceptional design for stack assembly station, development of a digital twin of the production facility, lab-scale demonstrations of automated stack component handling.

Gaps & Recommendations

- Supply chain challenges are a persistent issue in hydrogen R&I. A forward-looking approach to identifying vulnerabilities can be strengthened by a retrospective analysis of past project lessons learned.



Pillar 8 Strategic research challenges

Highlight

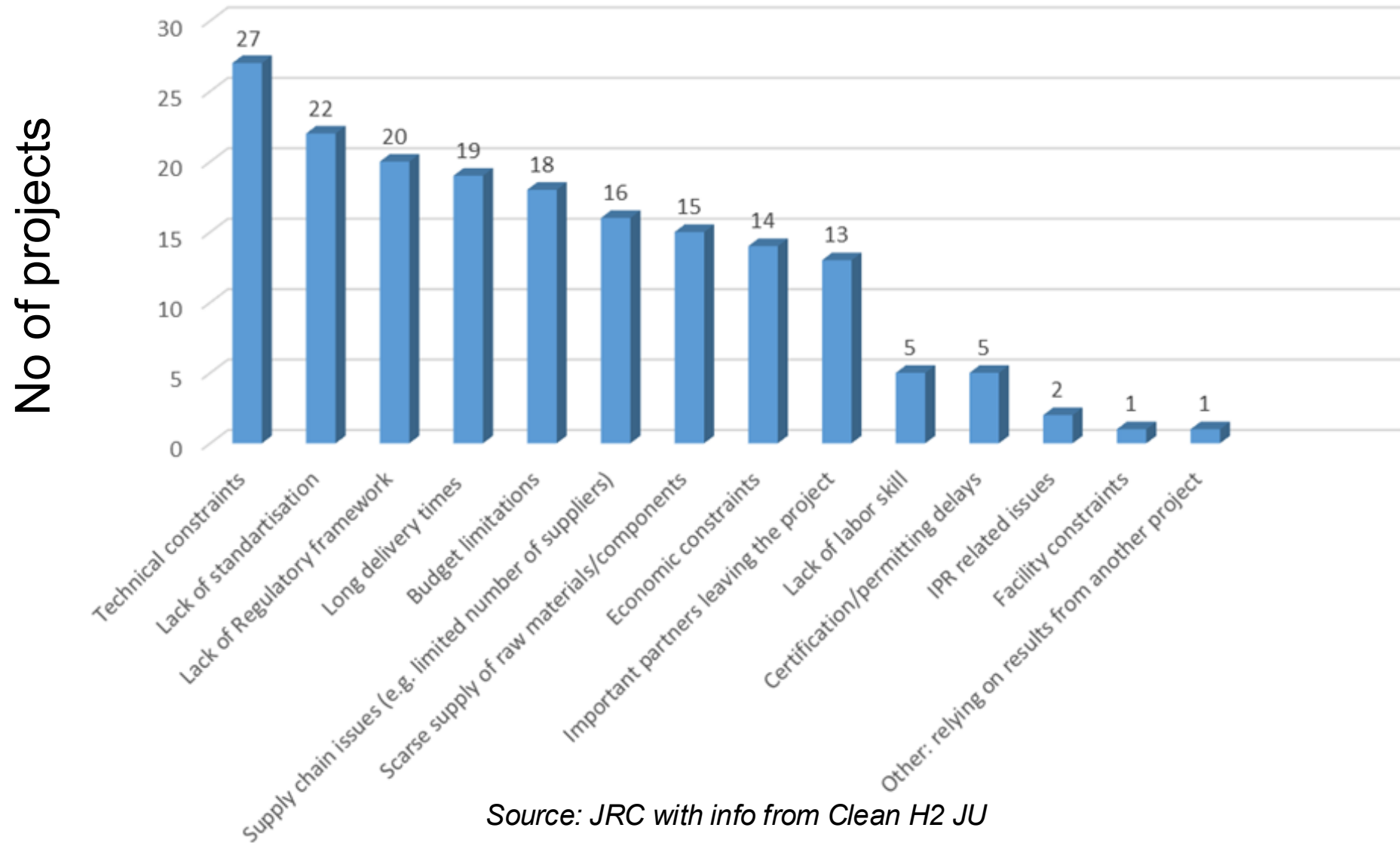
- Technical progress in the development of CRM-free/lean catalysts and PFAS-free/lean ionomers.

Gaps and recommendations

- CRM: Quantify CRMs materials usage; Harmonization of CRM targets; Enhanced recycling and reprocessing of CRMs; Banning the export of CRM-containing waste outside the EU.
- Monitor PFAS emissions;
- Develop a reuse and recycle roadmap for hydrogen technologies
- Ensure eco-design standards for all fuel cell and hydrogen technologies mandate dismantlability.



Common challenges and bottlenecks reported by projects



Source: JRC with info from Clean H2 JU



General Recommendations

Effective collaboration and knowledge sharing are essential for advancing hydrogen technologies, particularly through comprehensive data management.

Operational and Experimental Data are vital for developing comprehensive datasets that facilitate long-term technology deployment.

Comprehensive risk assessments with realistic timelines and contingency planning involving all stakeholders, third parties, and subcontractors.

Promoting wider use of the developed diagnostic tools (e.g. REACTT, RUBY).

Lessons Learned & best practices: not missing opportunities for valuable knowledge sharing and growth; Upon completion, each project should produce a dedicated deliverable that documents the lessons learned.



Thank you



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