FUEL CELL AND HYDROGEN JOINT UNDERTAKING: A EUROPEAN R&I SUCCESS STORY

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Fuel Cells and Hydrogen Joint Undertaking

FCH JU (hereafter covering both FCH JU and FCH 2 JU) is a public private partnership supporting research, technological development and demonstration activities in fuel cell and hydrogen energy technologies in Europe. Its aim is to accelerate the market introduction of these technologies, realising their potential as an instrument in achieving a carbon-clean energy system. Its members are: (1) the European Commission, (2) the fuel cell and hydrogen industries, represented currently by Hydrogen Europe, and (3) the research community, represented currently by Hydrogen Europe Research.

FCH JU was setup in May 2008 under FP7 in order to accelerate the development and deployment of fuel cell and hydrogen technologies and ensure a world leading, competitive European FCH industry while increasing jobs. The programme entered its second phase, with FCH 2 JU, in Horizon 2020.

FCH 2 JU has a total budget of €1.33 billion (€665 million from Horizon 2020) provided on a matched basis between the EU (represented by the European Commission) and the private members (industry and research).

In November 2021 the Council Regulation establishing the Joint Undertakings under Horizon Europe should be adopted, naming the Clean Hydrogen JU as the successor of FCH JU. The EU will support the Clean Hydrogen JU with €1 billion euro for the period 2021-2027, complemented by at least an equivalent amount of private investment (from the private members of the partnership).

The Clean Hydrogen JU will contribute to the European climate neutrality goal by producing noticeable, quantifiable results towards the development and scaling up of hydrogen applications. This will help develop a number of hydrogen technologies, which are currently either not competitive or have a low technology readiness level but are expected to contribute to the 2030 energy and climate targets and most importantly make possible climate neutrality by 2050.

The focus of the research and innovation activities of the Clean Hydrogen JU will have a different scope compared to FCH 2 JU, shifting to areas related primarily to the production of clean hydrogen, as well as the distribution, storage and end use applications of clean hydrogen in hard to abate sectors. They will be guided to a large extent by EU's Hydrogen

Strategy and the policy developments in this context, contributing to its implementation.

ROLE OF HYDROGEN TECHNOLOGIES AND CONTRIBUTION OF FCH JU

Fuel cells, as an efficient conversion technology, and hydrogen, as a clean energy carrier, have great potential to help reduce CO2 emissions, to reduce dependence on fossil fuels and to contribute to economic growth.

Hydrogen is an energy carrier that can play a critical role in EU's energy transformation. It can be used as a feedstock, a fuel or an energy carrier and storage, and has many possible applications across industry, transport, power and buildings sectors. Together with other storage applications, like hydro pumps and batteries, as well as smart grid applications, it can act as a vector for seasonal storage of renewable energy. At the same time, clean hydrogen can be used to replace fossil fuels in the hard to abate sectors and complement renewable energy sources in the effort to transform our economy.

Most importantly, it does not emit CO2 and does not pollute the air when used. It is therefore an important part of the overall solution to meet the 2050 climate neutrality goal of the European Green Deal. In its strategic vision for a climate-neutral EU published in November 2018, the share of hydrogen in Europe's energy mix is projected to grow from the current less than 2% to 13-14% by 2050.

For hydrogen to claim this position in the energy mix, it will require among others the improvement of its competitiveness against other energy carriers, research and innovation into breakthrough technologies and an infrastructure network that can bring it to the market.

The Fuel Cells and Hydrogen Joint Undertakings played an important role in structuring and mobilising an otherwise fragmented landscape of different sectors and industries. Its efforts have enabled several technologies to come close to maturity, and to achieve EU global leadership for some hydrogen technologies, notably on electrolysers, fuel cell buses, hydrogen refuelling stations and megawatt-scale fuel cells.

These innovative technologies will allow Europe to integrate the use of renewable electricity in many sectors that up to now were difficult to decarbonise, in particular heavy-duty transport and energy-intensive industries.

Moreover, FCH JU pre-normative research activities allowed improvement in the applicable regulations, codes and standards, supporting the increased production and utilisation of hydrogen in the EU.

With hydrogen gaining an increasing role in the energy transition, especially in decarbonising hard to abate sectors like heavy industry and heavy transport, the Clean Hydrogen Partnership will have an even more important role in promoting hydrogen technologies and helping them realising their potential.

PROGRAMME STATUS

Since its setup in 2008, FCH JU has funded a total of 287 projects with a total funding exceeding EUR 1 billion. This has been complemented by more than EUR 1 billion from other sources (regional, national, private), leading to a portfolio of projects exceeding EUR 2 billion budget. (see figure 1)

Focusing on the current Programme, it comprised 758 beneficiaries from the industry (66%), research organisations (11%), public sector (6%), education establishments (12%) and other categories (4%). These beneficiaries come from 32 different countries, including most EU27 countries.

The FCH 2 JU Programme of research and innovation is structured as follows:

- A research and innovation Pillars on Energy, accounting for about 45% of the budget;
- A research and innovation Pillars on Transport, accounting for about 41.5% of the budget;
- Overarching projects, integrating both transport and energy technologies to demonstrate the inter-operability and the sectoral integration aspects, accounting for about 6% of the budget; and
- Cross-cutting research activities supporting the transition to market for FCH technologies, absorbing the final 7% of the FCH JU budget.

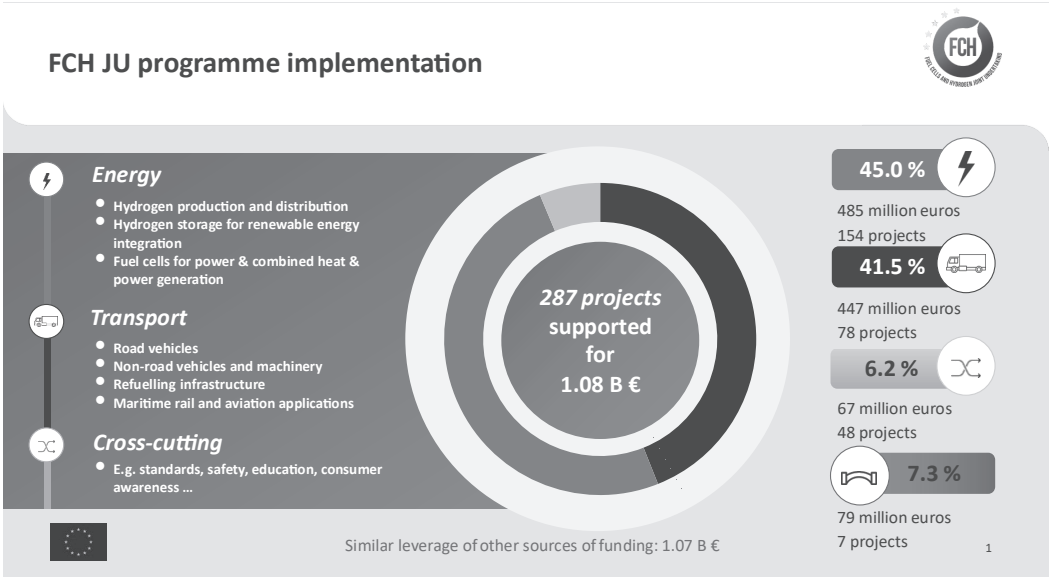
The Energy Pillar supports projects in four areas:

- Hydrogen production for energy storage and grid balancing from renewable electricity
- Hydrogen production from other renewable resources
- Fuel cell systems for Combined Heat and Power (CHP) and Power only
- Hydrogen storage, handling and distribution

The Transport Pillar encompasses all aspects of hydrogen utilisation in transportation:

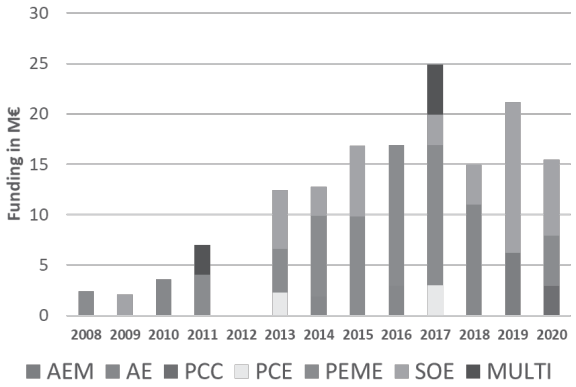
- Fuel Cell Electric Vehicles
- Non-road transportation (train, maritime and aviation applications)
- Hydrogen Refuelling Station infrastructure (HRS) More details can be found in FCH 2 JU Multi Annual Work Programme and its addendum. (1)

FIGURE 1
FCH PROGRAME IMPLEMENTATION



Source: Author

FIGURE 2
FCH JU FUNDING PER TECHNOLOGY



Source: Author

FCH JU SUCCESS STORIES

Electrolysers

Europe is world-leader in electrolysis technologies, especially in low temperature electrolysis. This is also sustained by the most patents and publications in comparison with other parts of the world. FCH JU has contributed significantly to this achievement, having funded 42 electrolyser projects for a total of EUR 150.5 million. The supported projects have been increasing in scale and are showing continuous improvement in their technical performance indicators and characteristics. In addition, a number of ongoing projects support the field demonstration of electrolysers for green hydrogen production to decarbonise heavy industries.

Most funding has been directed towards PEM electrolysers whilst considerable funding has been directed at alkaline and solid oxide electrolysers. Funding has also been provided for two projects regarding breakthrough technology on Proton Ceramic Electrolysers. The figure above shows the cumulative level of EU funding from the FCH JU contributed towards projects related to the different electrolyser technologies: (see figure 2)

- PEME: Proton Exchange Membrane electrolyser
- AE: Alkaline electrolyser
- SOE: Solid Oxide electrolyser
- AEM: Anion Exchange Membrane
- PCE: Proton ceramic electrolysers

Examples of recent projects (see figure 3)

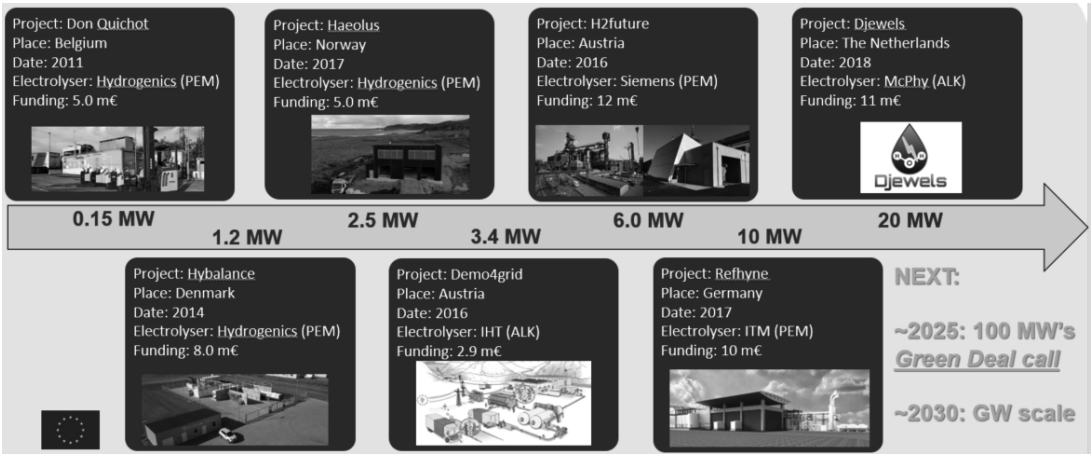
- REFHYNE (2)

  The Europe's largest PEM hydrogen electrolysis plant in operation. The electrolyser has a peak capacity of 10 MW and will be able to produce approximately 1,300 tonnes of hydrogen per year. REFHYNE will use renewable electricity to produce green hydrogen at Shell's Rheinland Refinery in Wesseling, Germany.

- H2Future (3)

  H2FUTURE is operating a 6 MW PEM electrolyser from Siemens at the Voestalpine Linz steel plant

FIGURE 3
EXAMPLES OF RECENT PROJECTS



Source: Author

in Austria since October 2020. The hydrogen produced replaces fossil fuel based steelmaking technology, as part of a stepwise decarbonisation approach to steel production proposed by the steel manufacturer. In the future, the direct reduction of iron ore by hydrogen will lower the footprint of steelmaking significantly.

- Djewels (4)

  The DJEWELS project is deploying a 20 MW electrolyser for the production of renewable methanol (e-fuels production). The electrolyser design foresees a system efficiency of 75%. The project is currently in the engineering phase.

Road Transport FCEV Deployment and Technology Improvements

Europe is leading the way in developing the breakthrough technologies needed to realise hydrogen's energy potential. With hydrogen-powered buses and taxis supported by FCH JU and used across major cities, FCH has demonstrated that the technology can be used on a large scale.

Looking specifically at FC Buses, where significant advancement has been realised, more EU manufacturers are launching fuel cell bus products and interest is growing at a European level. The scaling up has proven to have an important impact on the costs. The first hydrogen bus in 2010 had a price of 1.8 million euros. Today, the JIVE consortium has set the goal of reducing that figure to 650,000 euros.

Cars and buses large-scale demonstration:

- To date, 1390 (5) FCEVs have been funded through FCH JU, out of which 895 are currently in operation and 495 planned or in development phase (mainly via H2ME, H2ME2 projects and ZEFER project).
- 119 FC buses have been demonstrated until today through FCH JU and 247 are planned or in development phase. 315 buses have been demonstrated or planned through the JIVE and JIVE 2 projects (including all buses currently under development).

Hydrogen Refuelling Infrastructure (HRS):

- 159 HRS are demonstrated in Europe, out of which 72 funded via FCH JU (mainly via H2ME and H2ME2 projects). A chart displaying key data on the number and type of hydrogen refuelling stations built in Europe, including location and capacity can be found here or here.

Examples of recent projects

- H2ME & H2ME 2 (6)

  Hydrogen Mobility Europe (H2ME) brings together action in 8 European countries to address the innovations required to make the hydrogen mobility sector truly ready for market. The project performs a large-scale market test of hydrogen refuelling infrastructure, passenger and commercial fuel cell electric vehicles operated in real-world customer applications and demonstrate the system benefits generated by using electrolytic hydrogen solutions in grid operations.

  H2ME and H2ME2 are the largest European demonstration initiatives to date for hydrogen mobility, planning to deploy more than 1200 vehicles in 8 countries and 49 HRS in 5 countries. H2ME has finished in 2020 and H2ME2 will continue until 2022, having already demonstrated in total 687 vehicles and 38 HRS.

- JIVE & JIVE 2 (7)

  The first step in upscaling fuel cell (FC) buses is underway through the JIVE project, which began in January 2017. JIVE 2 is its successor and is Europe's most ambitious FC buses project to date. JIVE 2 involves regions with experience of the technology scaling up FC bus fleets (e.g. Cologne), and those seeking to build their knowledge and experience by demonstrating FC buses in small fleets for the first time (e.g. Auxerre, Gävleborg). All demonstration locations in JIVE 2 share an ambition to increase the size of their FC bus fleets following successful initial demonstrations, hence the participating cities/ regions will be natural locations for larger scale roll-out of the technology in the 2020s.

  Combined JIVE and JIVE 2 will demonstrate nearly 300 FC buses in 22 cities across Europe. The local fleets range from 5 to 50 buses, typically 10 to 20. As of 2020, JIVE has ordered all of the 142 planned buses and 59 are in operation, while JIVE 2 has ordered 110 buses out of the 152 planned, has 5 buses in operation and expects to have half of the committed fleet in operation by the end of 2021.

Hydrogen Valleys. Enabling sectorial integration/ sector coupling

Since 2014, FCH JU has pursued the concept of hydrogen territories (in particular through its continuous work with regions and cities – see below), which have evolved into the most recent concept of Hydrogen Valleys. A Hydrogen Valley is a defined geographical area, city, region or industrial area where several hydrogen applications are combined together and integrated within an FCH ecosystem. The emphasis is not on the technology development of an application but to demonstrate interoperability and synergies between the three pillars (production, storage & distribution and end use applications), to identify the best business-cases and showcase how all the different parts of the use of hydrogen as an energy vector fit together in an integrated system approach.

Hydrogen Valleys combine the entire supply chain from production of hydrogen all the way to its use in different applications and enable 'sector coupling' and large integration of variable renewable energy sources. This concept has gained momentum and is now one of the main priorities of industry and the EC for scaling-up hydrogen deployments and creating interconnected hydrogen ecosystems across Europe.

Examples of recent projects

- HEAVENN (8)

  HEAVENN is a large-scale demonstration project bringing together the core elements of a hydrogen valley: production, distribution, storage and local end-use of H2 into a fully-integrated and functioning «H2 valley» (H2V), that can serve as a blueprint for replication across Europe and beyond. The proposed concept is based on the deployment & integration of existing & planned project clusters across 6 locations in the Northern Netherlands, with a total initial investment of 88 M EUR, including regional funding.

  The first vehicles have been procured, including garbage trucks, and the HRS will open soon. A 4 MW electrolyser, for which the concept design has been completed, will be soon installed. A hydrogen pipeline will be designed to enable a future connection to the hydrogen backbone. Activities for a salt cavern hydrogen storage have commenced with first test set-ups.

- Green Hysland (9)

  Green Hysland is the first Hydrogen Valley in a European Island and will showcase the ability of hydrogen to decarbonise islands at an unprecedented scale. The project requires a total investment of around 50 million EUR, including renewable electricity generation and equipment for green hydrogen production and energy and transport end uses.

  Green Hysland will generate, distribute and use at least 300 tonnes of renewable hydrogen locally per year, produced from solar energy on the island of Mallorca. Green hydrogen will have multiple applications on the island, including the fuel supply to a fleet of fuel cell buses and fuel cell rental vehicles, the generation of heat and power for commercial and public buildings, the supply of auxiliary power for ferries and port operations and the creation of a hydrogen refuelling station.

  The estimated duration for the Green Hysland project will be from 2021 to 2025 and will aim to reduce the CO2 emissions of Mallorca up to 20,700 tonnes per year by the end of the project.

FCH JU Regions Initiative

In 2017, FCH JU launched an initiative to help European regions and cities harness hydrogen and fuel cells to realise their energy transitions. Within this context, the JU finalised a study (10) on the development of business cases for a wide range of fuel cells and hydrogen applications in regions and cities. Building on the conclusions of the study, the FCH JU further developed the cooperation in a number of different ways, including:

- Project Development Assistance (PDA) – Launch of a PDA facility in 2019 to help develop detailed project planning in at least 10 regions and cities with a lower maturity level and a special attention to Central and Eastern Europe. The aim was to work on project concepts and move them from their current stages to implementation.

- Smart Specialisation Platform – Leveraging on the existing network and capacity building generated under the FCH Regions initiative, the FCH 2 JU has facilitated and supported a group of leading Regions to set up a new thematic interregional partnership on Fuel Cells and Hydrogen within the Industrial Modernisation Smart Specialisation Strategies (S3) Platform. Despite only launched in May 2019, the so-called European Hydrogen Valleys Partnership is already the largest and widest thematic interregional partnership implemented so far.

CONCLUSSIONS

The Fuel Cells and Hydrogen Joint Undertaking (FCH JU) was set up in 2008 as an Institutionalised Public-Private partnership and since then has delivered clear impact on implementing optimal research and innovation activities on hydrogen, to the point of market readiness. To reach this target the FCH JU brought together resources under a cohesive public-private partnership to ensure commercial focus, to match RTD activities to industry's needs and expectations and to scale-up and intensify links between the Industry and the Research Communities. Thanks to this partnership between leading research organisations and industrial companies, FCH 2 JU activities cover all stages of product development from low technology readiness level (TRL) research to large demonstration projects.

During these past 12 years, FCH JU has supported 285 projects with an EU funding of 1.07 billion EUR (complemented by at least the same amount of contributions from the private members) and leveraging additional private investments of more than another billion EUR. More than 1,000 beneficiaries/organisations from 40 countries have benefited from this support, covering whole EU states and going beyond with activities at international level.

These projects were addressing development of hydrogen technologies from production (mainly electrolysers but also different other routes of renewable hydrogen production) to distribution and storage technologies (mainly compressed hydrogen but also lately liquid hydrogen and admixtures in the natural gas grid), and ultimately to the end-uses in transportation (cars, buses and related infrastructure, and lately opening markets to heavy-duty transport applications such as trucks, maritime or aviation) but also in stationary applications. In supporting all these technology developments, additional support was provided to cross-cutting issues such as pre-normative research for standards, safety aspects but also education and training.

NOTAS

[1] https://www.fch.europa.eu/page/multi-annual-work-plan

[2] https://refhyne.eu/
[3] https://www.h2future-project.eu/
[4] https://djewels.eu/
[5] Latest status 25/10/2021, including non-commercial vehicles
[6] https://h2me.eu/
[7] https://www.fuelcellbuses.eu/projects/jive
[8] https://heavenn.org/
[9] https://greenhysland.eu/
[10] https://www.fch.europa.eu/publications/fuel-cells-and-hydrogen-green-energy-european-cities-and-regions